Chapter 8: Conservation of Other Species Associated With Older Forest Conditions

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Introduction

This chapter presents information on expectations and outcomes for species closely associated with older (late-successional and old-growth) forests (hereafter referred to as LSOG species), other than fish (see chapter 9) and northern spotted owls (see appendix for scientific names) and marbled murrelets (see chapter 7), that were considered as part of the Northwest Forest Plan (the Plan). Many of the LSOG species are rare and little known, and include fungi, lichens, bryophytes (mosses and liverworts), vascular plants, invertebrates (mostly mollusks, and selected species groups of arthropods), and a few vertebrates. We also review the Survey and Manage (SM) program established under the Plan to provide for rare and poorly known LSOG species.

In this chapter we discuss species outcomes and program outcomes pertaining to what was expected under the Plan, what occurred, and if there were differences between expectations and observations; the extent to which differences were caused by the Plan; and if the Plan assumptions are still valid. We summarize lessons to learn both in terms of conservation concepts and program activities over the last decade.

Biodiversity Was the Umbrella; Species Became the Focus

The Plan was instituted as an ecosystem management plan to attend, in part, to biological diversity. To this end, the Plan was expected to provide for functional LSOG forest ecosystems, including all associated species and all components of biodiversity. Biodiversity is generally defined (for example, DeLong 1996, Raven 1994) as the variety of life and its processes, and includes structure, composition, and function of multiple levels of biological organization ranging from genes through population, species, functional groups, communities, and ecosystems (Noss 1990). Under the Plan, however, the focus on biodiversity narrowed to addressing mainly the composition, amount, dispersion, and dynamics of old forest vegetation communities (see chapter 6) and the presence and persistence of specific species, namely salmonids, spotted owls, marbled murrelets, and a set of other LSOG-associated species.

In this chapter we mostly trace the recent history of species-level conservation and associated programs of work under the Plan. In the next sections we review the recent history of LSOG species assessments and the Plan provisions for conservation of LSOG species. However, at the end of the chapter we will return to the broader vision of biodiversity conservation, where we review recent trends in conservation biology and how they may pertain to lessons learned under the past decade of the Plan.

A Brief History of LSOG Species Assessments Under FEMAT and the Northwest Forest Plan

To help set the stage for much of the rest of this chapter, following is a brief summary of the rather complicated history of the assessments and administrative programs under the Plan pertaining to management of LSOG-associated species (fig. 8-1).

The Forest Ecosystem Management Assessment Team (FEMAT 1993) initially evaluated a list of 1,120 LSOG-associated species under option 9; this option, with some changes, became the basis for the Northwest Forest Plan under the 1994 final supplemental environmental impact statement (FSEIS) (USDA and USDI 1994a). The 1994 FSEIS then identified 4 sets of criteria (“screens”) by which the 1,120 LSOG species were further evaluated to determine

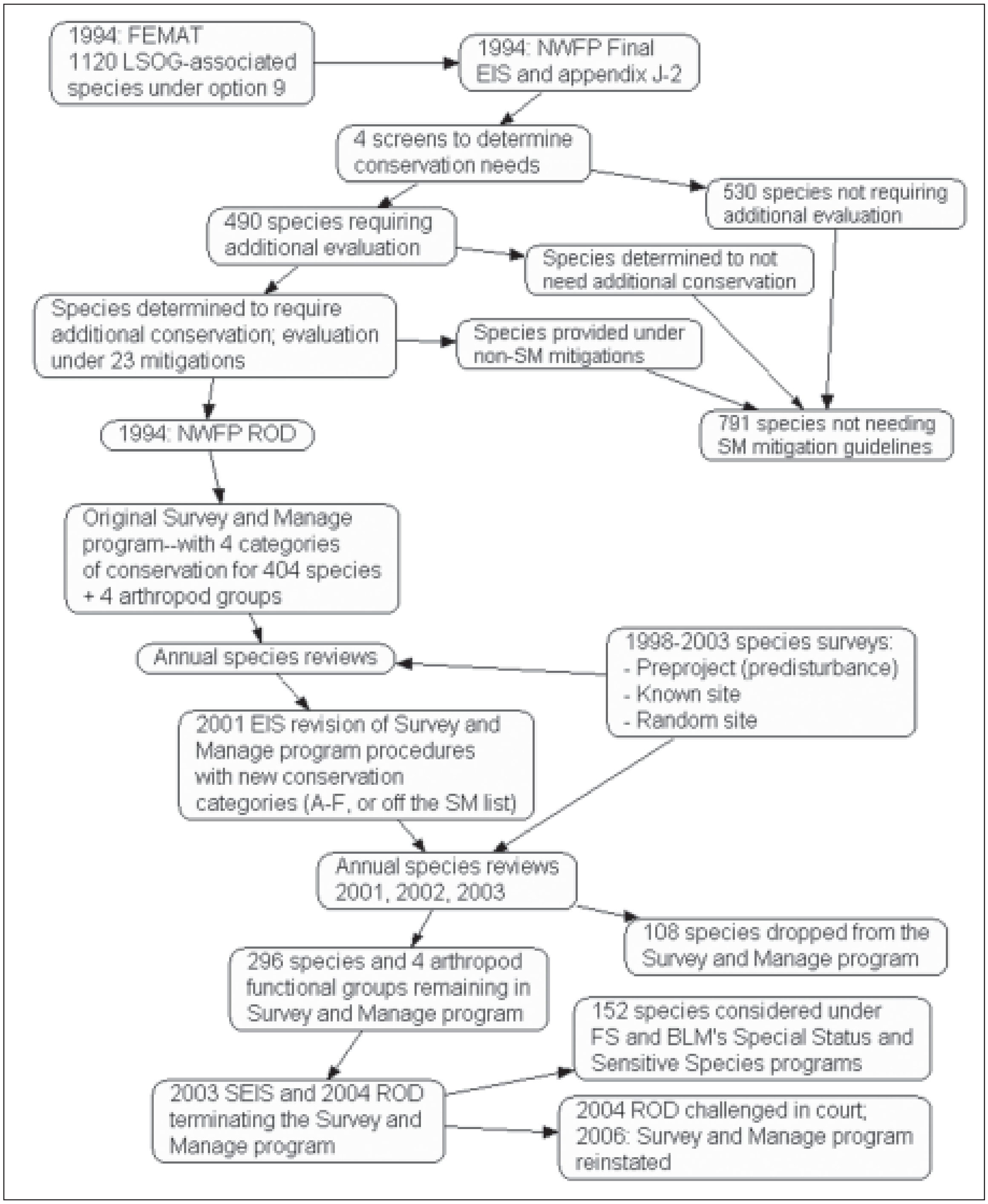


Figure 8-1—Lineage of administrative programs and National Environmental Policy Act environmental impact statement (EIS) and record of decision (ROD) documents under the Forest Ecosystem Management Assessment Team (FEMAT), the Plan (NWFP), and the Plan's Survey and Manage program (SM), addressing species associated with late-successional and old-growth (LSOG) forests on Forest Service (FS) and Bureau of Land Management (BLM) administered lands.

their appropriate conservation categories. The screens resulted in 791 of these species not being carried forward under mitigation for their conservation in addition to the Plan provisions, whereas the remainder of the species were determined to entail additional conservation and evaluation under further mitigation.

A set of 23 mitigations was evaluated in the 1994 SEIS (USDA and USDI 1994a) and 8 of these were adopted in the record decision (ROD) (USDA and USDI 1994b). One of the mitigations was the original SM species mitigation, which categorized each of 404[1] individual species and 4 arthropod species groups[2] according to four conservation classes, each class having a set of mitigation standards and guidelines. Standards and guidelines consisted of employing a variety of survey approaches (preproject or predisturbance, extensive, and general regional surveys) along with guidelines to protect (manage) known sites and to select high-priority sites for management. New information gained from surveys would address the uncertainty regarding species persistence concerns and would inform decisions.

In 2000 and 2001, a new FSEIS and ROD were issued (USDA and USDI 2000, 2001) to revise the SM species program procedures to specify greater details on conducting annual species reviews (ASRs), species management requirements, the use of strategic surveys, and an expanded classification of six species conservation categories. Subsequent ASRs held 2001-2003 used the new (2001) survey guidelines and evaluation procedures, and resulted in 108 SM species being dropped from the SM program because of the new data and evaluations. This left 296 individual species and 4 arthropod species groups remaining in the SM program. The SM program was removed after issuance of an FSEIS and its associated ROD in 2004 (USDA and USDI 2004a, 2004b[3]), which moved 152 of the remaining 296 SM species to the USDA Forest Service (FS) Sensitive Species Program and the USDI Bureau of Land Management (BLM) Special Status Species Program. In January, 2006, the court ruled that the SM program be reinstated according to the 2001 ROD.

[1] In actuality, there were only 403 species, as the name of one species was inadvertently included twice (Holmes 2005). For the sake of consistency with the 1994 ROD, however, we will use the 404 figure here.

[2] The four arthropod species groups are canopy herbivores (south range of Plan area), coarse wood chewers (south range), litter- and soil-dwelling species (south range), and understory forest gap herbivores (USDA and USDI 1994b: C-1).

A Summary of Northwest Forest Plan Provisions for LSOG Species

The Plan, as guided by the 1994 (and later, supplemented to 2001) ROD, contained several provisions for conservation of LSOG species. These included the delineation of late-successional reserves (LSRs) designed to accommodate populations of northern spotted owls, marbled murrelets, LSOG species, and other objectives; the delineation and protection of known sites of SM species found outside the LSRs in "mini" reserves (dubbed LSR3s in the Plan); delineation and protection of high-priority sites of selected SM species; and the expectation that some LSOG species locations and habitats would be provided for by other measures to protect older forest components such as the Aquatic Conservation Strategy and riparian reserves. In general, the major land allocations under the Plan were expected to provide habitat in appropriate amounts and distribution to support most LSOG-associated species.

What Was Expected Under The Northwest Forest Plan?

Expectations of Species Outcomes

Persistence of LSOG species and biodiversity—
Under the Plan, the management guidelines and land allocations, particularly the LSRs, were expected to provide for persistence of most native LSOG-associated species

Although abandoned in 2004 through a SEIS and new ROD, the Survey and Manage program was reinstated in 2005 by court order following lawsuits brought by environmental groups. A new SEIS is currently in progress.

(and all other elements of LSOG biodiversity). This specifically included the 791 species not requiring mitigations of the SM program but that were expected to be provided for by the LSRs and other mitigations specified in the 1994 ROD (USDA and USDI 1994b), and the 404 individual rare and little-known species and 4 arthropod species groups that would require additional consideration and protection under the SM program. The Plan did not specifically define either "rare" or "little-known" in identifying these lists of species. As necessary, species- or taxon-specific assessments would be conducted to help determine where and what additional management guidelines would pertain to ensuring persistence of species and biodiversity elements not otherwise provided for.

Reduction of uncertainty and avoidance of listing—
For the 404 individual species and 4 arthropod species groups, it was generally expected that knowledge gained from SM program surveys, together with immediate protection of known sites, would help reduce scientific uncertainty, reduce risk of their extirpation, and increase overall chances for their persistence within the Plan area. Such mitigation activities under the SM program would be expected to stave off potential federal listing of LSOG-associated species.

Expectations of Program Outcomes

Adaptive management framework—
Expectations under the 1994 ROD (USDA and USDI 1994b) included that the SM program would provide an adaptive management framework for collecting new information on the 404 species and 4 arthropod species groups, for the purpose of evaluating and revising their conservation management status as deemed appropriate to ensure their persistence; and that the SM program would be a practical and economically efficient means to this end, with adequate resources to accomplish its objectives. It was also expected that sites would be protected for those species of high persistence concern, and that management recommendations would be developed to guide site management, which would entail protection on the order of tens of acres (with some exceptions) and some management treatments (for example, prescribed fire for some vascular plants). The agencies would develop an interagency geographic information system (GIS) database to house the information for analysis.

Survey protocols and species surveys—
It was further expected that effective survey protocols would be developed. The 1994 ROD (USDA and USDI 1994b) required surveys for amphibians and the red tree vole to begin by 1997 and for all other "strategy 2" species (species for which predisturbance surveys were to be conducted) by 1999, and that protocols would be prioritized based on species risk level.

Predisturbance surveys would be conducted to avoid loss of sites for some species. Such surveys would start at the watershed analysis level to identify likely species based on habitat. For species for which predisturbance surveys were not required, likely sites would be identified at the individual project scale based on likely range and habitats. Multispecies surveys would be used as possible, and survey protocols and site management would be incorporated into interagency conservation strategies as part of ongoing planning efforts. This would include identifying high-priority sites for protection. Broad-scale (general regional) surveys would be implemented by 1996 and completed within 10 years, and major areas of scientific uncertainty on most species resolved during that period. The 2001 ROD noted that statistically-based "strategic surveys" (Molina and others 2003), together with other approaches including research and habitat modeling, would replace the previous extensive and general regional surveys, to provide more reliable scientific data on species rarity and habitat associations.

Changes in activities and no adverse effect on probable sale quantity—
It was also expected that changes of management activities under the SM program would include evaluating and

potentially altering schedules for conducting surveys, moving species from one category to another, and dropping the SM mitigation for any species whose status is determined to be more secure than originally projected. The SM program would be expected to not adversely affect probable timber sale quantity (PSQ) beyond levels noted in the FSEIS (USDA and USDI 1994a).

Annual species reviews—
As summarized above (also see fig. 8-1), the 2000 FSEIS and 2001 ROD (USDA and USDI 2000, 2001) instituted a revised SM program, which was expected to provide clarity to ASRs as an adaptive evaluation process. It was expected that the data-gathering and ASR procedures would likely result in removing some species from the SM species list, and that National Environmental Policy Act documentation would not be made for decisions made under the ASR process. The ASRs would apply criteria for species' persistence, rarity, and association with LSOG forests and reserves to judge the category of SM mitigation for each species. The 2000 FSEIS and 2001 ROD also provided criteria for potentially adding species to the SM list.

Biodiversity and rare species monitoring—
The 1994 ROD (USDA and USDI 1994b: E-6, E-8–E-11) explicitly called for effectiveness and validation monitoring of biodiversity and rare species. The 1994 ROD defined effectiveness monitoring as "evaluating if application of the management plan achieved the desired goals, and if the objectives of these standards and guidelines were met." It specified that "Success may be measured against the standard of desired future condition… Effectiveness monitoring will be undertaken at a variety of reference sites in geographically and ecologically similar areas. These sites will be located on a number of different scales…" (USDA and USDI 1994b: E-6).

The 1994 ROD specified effectiveness monitoring of biological diversity and late-successional and old-growth forest ecosystems including "forest processes as well as forest species." One evaluation question was stated in the 1994 ROD as: "Are habitat conditions for late-successional forest associated species maintained where adequate, and restored where inadequate?" The 1994 ROD stated that indicators for "assessing the condition and trends" include "seral development and shifts of forest plant communities," and that "key monitoring items" included "abundance and diversity of species associated with late-successional forest communities" and "species presence (to calculate species richness, that is, numbers and diversity" (E-8–E-9).

The 1994 ROD also called for validation monitoring, which it defined as determining "if a cause and effect relationship exists between management activities and the indicators or resource being managed." The 1994 ROD stated that validation monitoring asks "are the underlying management assumptions correct? Do the maintained or restored habitat conditions support stable and well-distributed populations of late-successional associated species?" The 1994 ROD also noted that key items to monitor include "rare and declining species" of plants or animals, including those federally or state listed, proposed, or candidate threatened or endangered, or listed by FS or BLM as sensitive or special status, or "infrequently encountered species not considered by any agency or group as endangered or threatened and classified in the FEMAT Report as rare." This validation monitoring would focus on "the type, number, size and condition of special habitats over time" to "provide a good indication of the potential health of the special habitat-dependent species" (p. E-10–E-11).

The 1994 ROD acknowledged that habitat requirements of species can vary with age, size, or life cycle of the species, and with season, and also that although stable habitats are "not proof that a special habitat-dependent species population is stable, a decrease in a special habitat type does indicate increased risk to that species population." The 1994 ROD also stated that "a monitoring program for rare and declining species will help to identify perceived present and future threats, increase future possibilities of discovering new locations, track their status and trends over time, and ensure that, in times of limited agency resources, priority attention will be given to species most at risk" (p. E-11).

The 2001 ROD (USDA and USDI 2001) stated that monitoring, including biological diversity effectiveness monitoring, should continue as specified in the original 1994 ROD. The 2001 ROD also specified that the strategic surveys and the ASRs would contribute toward the validation monitoring phase.

What Has Occurred and Were There Differences Between Expectations and Observations?

Species Outcomes

Focus on LSOG species—
The Plan was implemented as a set of guidelines for land management allocations, along with additional mitigation guidelines for the evaluation and disposition of LSOG species under the SM program. Implementation of the Plan for LSOG species focused on species and their habitat relationships, and not on other biodiversity parameters such as other levels of biological organization, ecosystem processes, and organisms' ecological functions. There has been no evaluation (including monitoring) of the degree to which the Plan has provided for these other aspects of biodiversity.

Evaluation of species rarity and persistence—
Under the ASRs, new data were collected on selected SM species and the species were reevaluated in an adaptive management framework to confirm or alter their conservation categories under the Plan. Although the term "rare" was never specifically defined by FEMAT or in the Plan, general criteria for determining species rarity were presented in the 2000 FSEIS and 2001 ROD (USDA and USDI 2000, 2001) that revised the SM program with new conservation categories. These criteria included consideration for total number of locations, habitat and population trends, habitat fragmentation and population isolation, ecological amplitude of the species, distribution limitations, dispersal capability, and other factors (table 8-1). None of the criteria, however, was quantified. Also, different and potentially conflicting sets of criteria were presented in the 2000 FSEIS and 2001 ROD for "rare" versus "uncommon" status of the SM species. Also, no specific criteria or procedures were presented for determining overall viability of the SM species (see later discussion on viability issues).

Results of forest vegetation monitoring (Spies, chapter 6 this volume) suggest a net increase in the total area of what is classified as late-successional and old-growth forest vegetation cover over the decade of 1994-2004. However, it is not known the degree to which this "in-growth" of the old-forest vegetation age class provides specific sites or microhabitat conditions used and selected by the individual species addressed in this chapter, nor if forests lost to fire and other causes over this same period eliminated any such sites and microhabitats.

Surveys of rare species conducted—
The original assumption that many of the LSOG-associated species are rare has been partially borne out by surveys conducted over the past decade under the Plan. Data collected over the last decade on number of locations of 399 SM species suggest that many of the species are known only from very few sites. About 42 percent of all species have been found from 10 or fewer sites (accounting for 6 percent of total sites in the database) (table 8-2). On the other end of the abundance spectrum, about 5 percent of the species account for most (two/thirds) of the sites and likely are not rare; these patterns held among all taxonomic groups (figs. 8-2 and 8-3).

The four arthropod functional groups were included in the Plan because of concern that catastrophic disturbance, particularly wildfire, in southern Oregon and northern California could jeopardize their persistence. Given the impractical nature of surveying for potentially tens of thousands of arthropods in the four functional groups (at least some of which are likely to be unnamed species), the arthropod team instead chose a research strategy with three components: (1) examine the effects of experimental thinning and burning on select functional groups in a long-term

Table 8-1—Surrogate measures of population persistence and disposition under the Plan, as specified in the guidelines for the annual species review of nonfish LSOG-associated species other than northern spotted owls and marbled murrelets

Parameter	Surrogates
Geographic range	Occurrence of species within or close to the Plan area Occurrence of suitable habitat within the Plan area
LSOG association	Abundance in LSOG Association with LSOG components Known association with LSOG forests Suspected by experts to be LSOG associated BLM or Forest Service special status species Listed by states as species of concern Federally listed by U.S. Fish and Wildlife Service as threatened or endangered U.S. Fish and Wildlife Service candidate species Adequacy of field data to determine LSOG association
Population persistence provided by the Plan	Likely extant known sites occurring in part or all of its range Total number of individuals Number of individuals at most sites or in most population centers[a] Estimated total number of sites[a b] Limitation of geographic range to the Plan area Distribution of habitat within the Plan area Distribution of individuals within the overall range of the species Proportion of sites and known habitats in reserves Proportion or amount of potential habitat within reserves Probability that habitat in reserves is occupied Whether all other guidelines of the Plan provide for population persistence
Data sufficiency	Sufficiency of information for evaluating basic criteria for including on SM species list Sufficiency of information for determining management for a reasonable assurance of persistence
Practicality of surveys	Predictability of the occurrence of the organism Visibility of the organism Limitation of expertise for identifying the organism Ease of identification of the organism Concerns for safety of surveyors Risk to the species from collection for surveys Surveyable in two field seasons Survey methods can be developed within 1 year

Table 8-1—Surrogate measures of population persistence and disposition under the Plan, as specified in the guidelines for the annual species review of nonfish LSOG-associated species other than northern spotted owls and marbled murrelets (continued)

Parameter	Surrogates
Species rarity	To determine if the species is "rare:" Limited distribution Distribution within its range Distribution within its habitat Dispersal capability on federal land Reproductive characteristics that could limit population growth rate Number of likely extant sites on federal lands Number of individuals per site[a] Population trend declining or not Number of sites in reserves Likelihood of sites or habitats in reserves Ecological amplitude Habitat trend declining or not Habitat fragmentation lending to genetic isolation Availability of microsite habitats Factors beyond the Plan affecting rarity
	To determine if the species is "uncommon:" Number of extant sites Number of individuals per site Restriction of distribution within range or habitat Ecological amplitude Likelihood of sites in reserves Population or habitat stability

Note: LSOG = late-successional and old-growth forests.

[a] Information derived from the random grid surveys (see text for explanation).

[b] Not explicitly included as a guideline in the 2001 ROD but added as a criterion to the annual species review.

Source: USDA and USDI 2001.

Table 8-2—Number of Survey and Manage program species and their total locations within range categories of known locations

Number of known locations per species	Number of species	Percentage of total number of species	Total locations
0	22	6	0
1	26	7	26
2-5	72	18	237
6-10	48	12	401
11-20	48	12	711
21-50	60	15	2,059
51-100	36	9	2,793
101-300	51	13	8,306
301-500	9	2	3,383
501-1,000	9	2	5,989
>1,000	18	5	44,347
Total	399	100	68,252

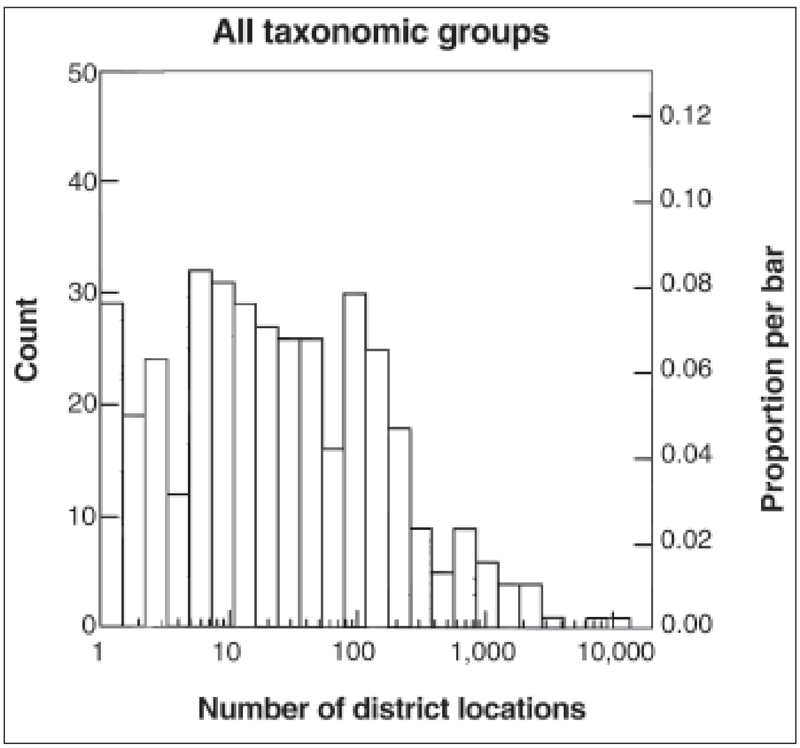


Figure 8-2—Species abundance distribution of number of distinct locations of Survey and Manage species (sites located through various surveys) within the Plan area, combined over all taxonomic groups. Note $\log_{10}$ scale on x-axis. Note that most species are rare, (known from very few sites), but some species are apparently more abundant.

Red Tree Vole

Red tree vole (*Arborimus longicaudus*) was a good example of a Survey and Manage (SM) species for which a great deal of work was done on developing survey protocols, conducting both strategic and predisturbance surveys for nests, and mapping nest locations to determine discrete population distributions for use in the annual species reviews.

One unique contribution to understanding and mapping distribution of this species came from Eric Forsman's research on northern spotted owls. The owl uses the vole as a primary prey item in a portion of the owl's range. Forsman was able to map the vole's distribution as a function of the appearance of the vole in owl pellets (Forsman and others 2004).

Other efforts on red tree voles included developing habitat prediction models and identifying high-priority sites. These tasks proved more involved and difficult than first envisioned because interpretation of the wide variety in the kinds of data available–including interpreting historical sites, potential nest sites, and active nest sites in terms of size and distribution of potential and active colonies—proved to be a challenge.

The red tree vole became one of the more problematic SM species because numerous nest sites were found through predisturbance surveys in the heart of its range in southwest Oregon on matrix land allocations. A large portion of timber harvest was planned for this area, and the presence of red tree vole nests interfered with that harvest, frustrating the management agencies. In the final 2003 annual species review, however, data from all of the combined survey, research, and modeling efforts provided the needed information for managers to decide to remove the red tree vole from the SM list, except for a small population in the northwest Oregon Coast Range. That population was later moved to the agencies' sensitive and special status species program in the 2004 record of decision.

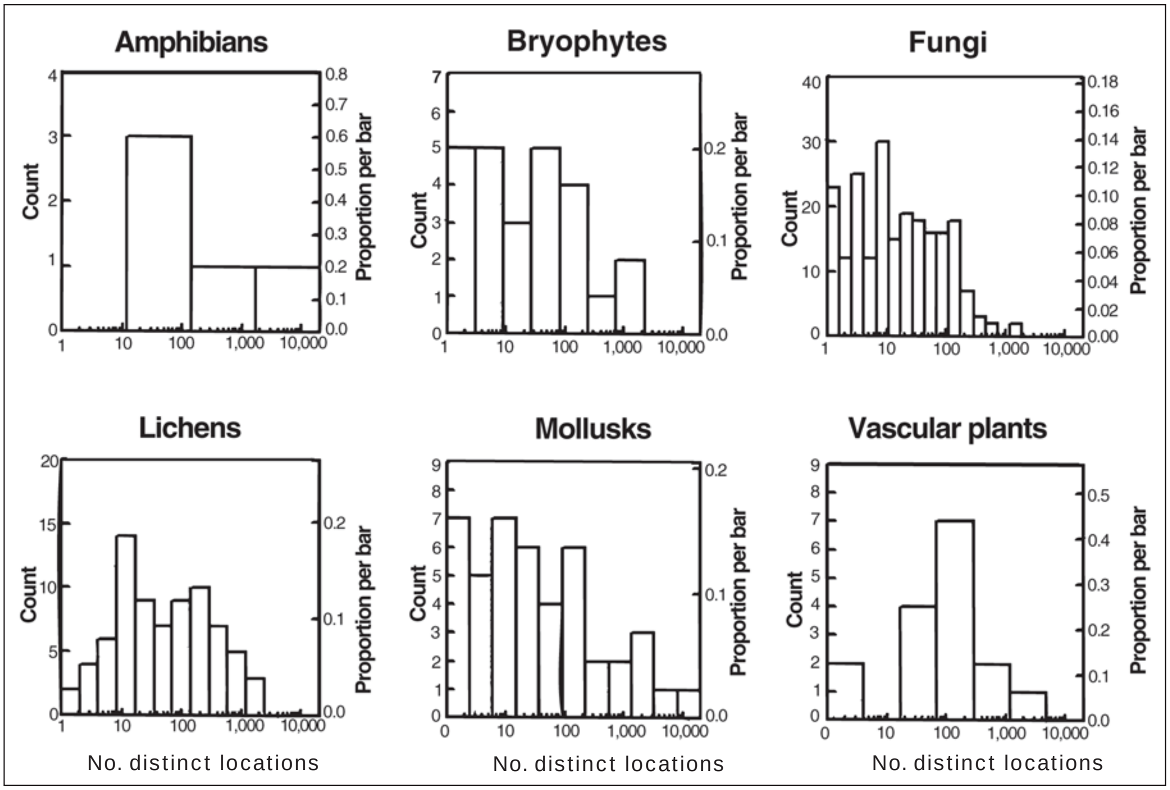


Figure 8-3—Species abundance distributions of number of distinct locations of Survey and Manage species (sites located through various surveys) within the Plan area, by taxonomic group. Note $\log_{10}$ scale on x-axis.

ecological research site in northern California and identify indicator species, (2) conduct retrospective studies of resilience and recovery of the functional groups in areas with different fire histories in southern Oregon, and (3) conduct extensive literature reviews of insects in the region to identify potential treats to persistence. These were multi-year studies funded at about $200,000 to $300,000 per year for 3 to 4 years, resulting in a set of publications and reports answering the basic three research components (for example, Niwa and Peck 2002).

Assumptions of persistence of some species—
The general assumption under the Plan that the 791 LSOG species not originally included in the SM mitigation are indeed viable and persistent (and thus not requiring SM mitigation) remains formally untested, although these species might have benefited from increases in LSOG and the reduced harvests over the past decade. No specific monitoring was established on these species under the Plan. Ancillary information may be available on some of these species under other research studies or agency programs (for example, the Demonstration of Ecosystem Management Options [DEMO] project, research studies of riparian-associated species, effects of retention, and effects of silviculture on suites of species), but this has not been compiled and analyzed.

Identification and protection of LSOG species habitats and locations—
The expectation that the Plan would protect suitable locations or environments for many of the LSOG-associated species is partially borne out by results of the surveys that suggest that many species locations occur within Plan reserves (fig.8-4). Many of the locations of fungi, lichens, bryophytes, and mollusks occurred outside

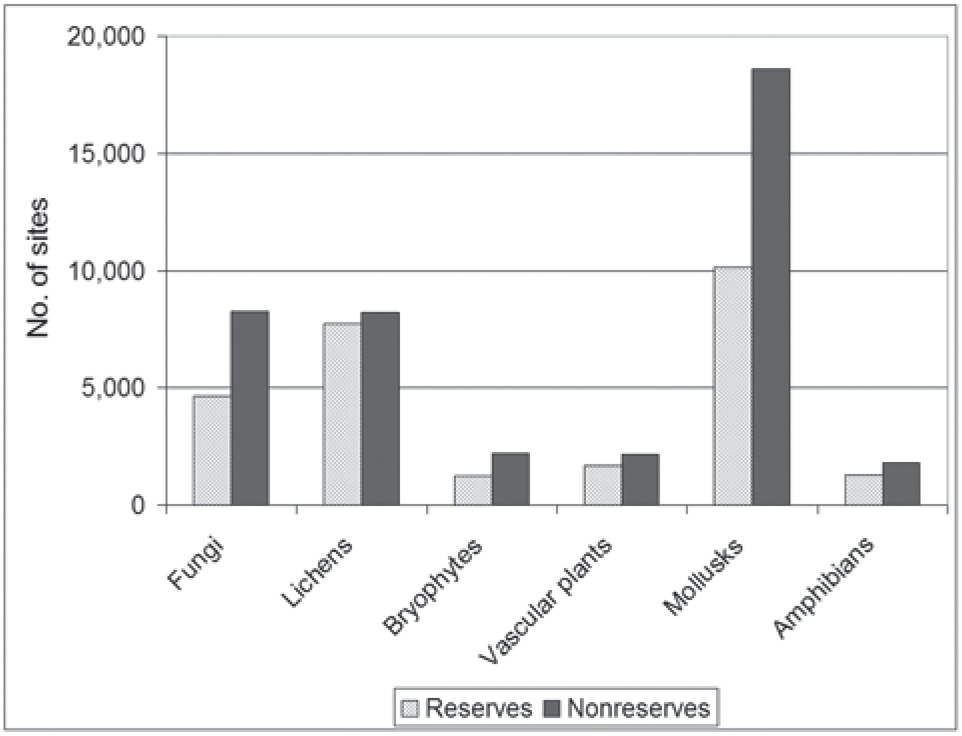


Figure 8-4—Number of known sites of species closely associated with late-successional and old-growth forests, located through various surveys, by reserve and nonreserve land allocations on Bureau of Land Management and Forest Service lands within the Plan area. Reserves include adaptive management areas, administratively or congressionally withdrawn areas, and late-successional reserves; nonreserve lands include riparian reserves (not separable in the database) and matrix lands.

Plan reserves. Survey and Manage species could occur within the Plan reserves, and within LSOG in those reserves, in part by chance. Some SM species likely occur in reserves and matrix sites in non-LSOG vegetation stands having some LSOG components, such as large standing or down wood legacies.

Regardless, the degree to which locations within the Plan reserves would suffice to provide for long-term viability of the other 791 LSOG species was not determined. Additionally, no monitoring per se was instituted for either the original set of 404 SM species and 4 arthropod species groups or for other aspects of LSOG biodiversity. Only various surveys have been conducted, mostly for predisturbance evaluation.

A total of 67,891 locations are known within the area of the Plan on all originally listed 404 SM species of all taxonomic groups, among all types of surveys (predisturbance, random grid, and other). Of this total, 26,676 locations (39 percent) are in reserves. Among taxonomic groups, the proportion of all locations from reserves ranges from 35 percent (10,125 of 28,730 locations) for mollusks to 49 percent (7,742 of 15,942 locations) for lichens. These results are likely biased toward locations outside reserves (viz., in matrix lands) where predisturbance surveys were conducted. Of the total surveys conducted, 79 percent are predisturbance surveys. Protecting SM species sites in matrix lands had a far greater perceived impact on PSQ than expected. This was primarily due to the 5 percent of the species noted previously that turned out not to be rare and were found with predisturbance surveys at nearly 40,000 sites, mostly in matrix lands (see lessons learned for further discussion on implications of the predisturbance survey approach).

Turley (2004) estimated that 67 percent of the federal land base of the Plan area consists of reserves, which include administratively and congressionally withdrawn areas, late-successional reserves, and managed LSRs. The remaining 33 percent consists of matrix lands, which here include timber management matrix lands, adaptive management areas, and riparian reserves designated under the Aquatic Conservation Strategy of the Plan. Not all LSOG forest occurs in reserves, and not all reserve lands are LSOG forest; USDA and USDI (1994a) estimated that 86 percent of existing late-successional forests are in reserves, so 14 percent are in matrix lands.[4]

Program Outcomes

Adaptive management approach and annual species reviews—

In general, the SM program did provide a useful adaptive learning framework by which new inventory and scientific information on the SM species was collected and analyzed, such as on number of locations from predisturbance surveys (figs. 8-5a, 8-5b) and other survey and information gathering efforts. The new information was used in the ASR procedures to reevaluate the conservation management status of each SM species, leading to the removal of some hundred species (about 25 percent) from the SM list during the overall SM program (fig. 8-6). This was a significant achievement, based on an unprecedented, massive database on species locations.

The ASRs also served to reassign some species to different conservation categories as a function of new scientific information mostly on their distribution and habitat associations. For example, the 2003 ASR evaluations resulted in removing from the SM program 29 (16 percent) of the 181 species evaluated that year, based on new scientific information. The 2003 ASR also reassigned 65 (36 percent) of the species to a more conservative category, kept 75 (41 percent) of the species in the same conservation category, and moved 41 (23 percent) of the species to a less conservative category, with no voting bias detected among the ASR panelists (Marcot 2003, Marcot and Turley 2003). These changes–again, part of the adaptive management approach–were scientifically supported by findings from the vast inventories conducted through the SM program.

Effective survey protocols and species surveys—

Many expectations for the SM program were met, particularly for developing and instituting effective species survey protocols, conducting predisturbance and strategic (including random-grid) surveys (Molina and others 2003), accreting new data on species locations, developing databases and GIS information bases (with about 68,000 records), synthesizing science information for individual species into management recommendations and applying those recommendations to project plans, and identifying sites for which protection outside LSRs would be provided. Multispecies, probabilistic regionwide surveys called for in the 2001 FSEIS were developed and implemented that provided opportunities to examine regional species distributions in reserves and their rarity.

Development of species evaluation tools—

Also, useful tools, such as decision models based on the 2001 ROD evaluation criteria, were developed and successfully used to aid decisionmaking during the ASR process (Marcot and others, n.d.). Other models (viz., potential natural vegetation GIS models, for example,

[4] The riparian reserves have not been fully mapped, so there is no individual estimate of their areal extent nor the percentage of LSOG forest therein. However, USDA and USDI (2004b: 11) noted that "matrix and adaptive management area" land allocations constitute 19 percent of the Plan area. Presuming that "matrix" lands here do not constitute riparian reserves, one could estimate that riparian reserves might constitute 33 - 19 = 14 percent of the Plan area. Added to the other reserve lands, this totals 67 + 14 = 81 percent of the Plan land area in reserves including riparian reserves. There is no mapped information, however, on the extent of LSOG forest in riparian reserves.

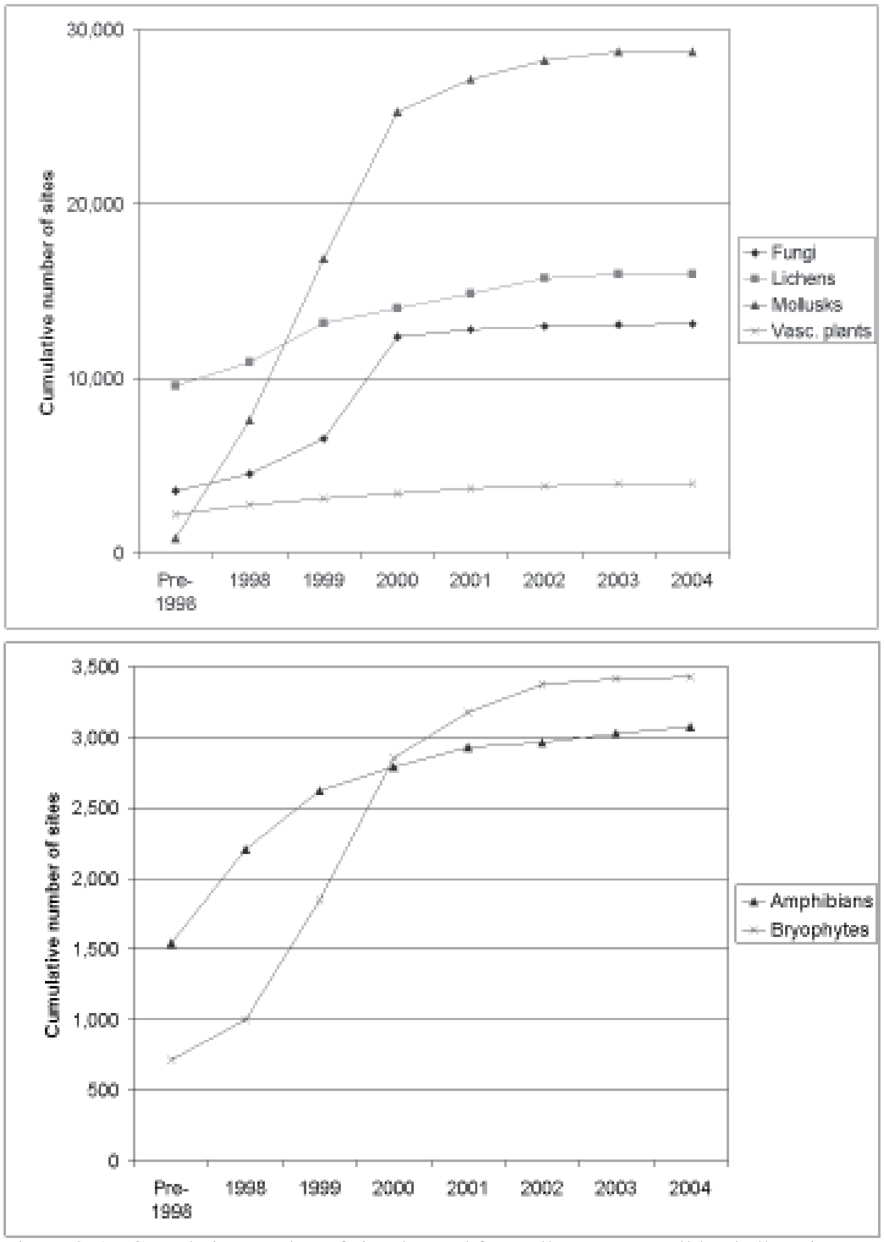
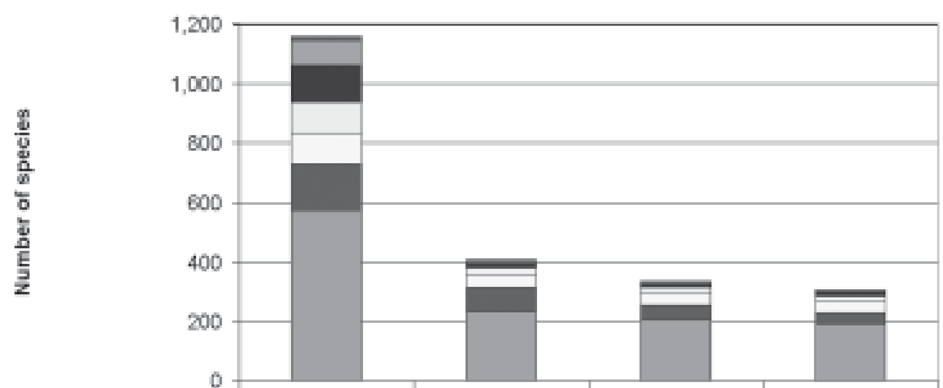


Figure 8-5—Cumulative number of sites located from all surveys on all land allocations (reserves and matrix lands), by taxonomic group and year. Substantial progress was made in locating sites particularly between 1998 and 2000.



	FEMAT analysis	Original guidelines	Revised guidelines	Current
Arthropod groups	15	4	4	4
Vertebrates	82	6	6	5
Vascular plants	124	17	12	12
Bryophytes	106	23	17	15
Mollusks	102	43	43	39
Lichens	157	81	48	43
Fungi	572	234	208	189

Figure 8-6—Number of species assumed closely associated with late-successional and old-growth forests as listed by the Forest Ecosystem Management Assessment Team (FEMAT) in 1994, in original guidelines of the 1994 Environmental Impact Statement (FSEIS) and Record of Decision (ROD) that instituted the Survey and Manage (SM) program under the Northwest Forest Plan, in the revised guidelines of the 2001 FSEIS and ROD that revised the SM program and its annual species review process, and "current" in 2004 at the termination of the SM program. The decline in number of species was because of new information used in the adaptive management process of the annual species reviews.

Lesher 2005; and Bayesian belief network models, Marcot, n.d.) for evaluating likelihood of habitat suitability for specific SM species had been developed but were only partially integrated into the program.

Some shortcomings in surveys—

Some expectations for the SM program were not met, however, including the following. The SM program, particularly the predisturbance surveys and ASR procedures, proved to be far more expensive and administratively complex than initially expected. Except for a few species, high-priority sites were not identified for protection, as called for in both the 1994 and 2001 RODs. Data on absence (lack of presence) of species from field surveys, particularly from predisturbance surveys, were not recorded, which was a major loss of otherwise useful information to build and test prediction models of species-habitat associations. Little habitat or species abundance data were collected in predisturbance surveys, similarly impeding the ability to construct habitat models or incorporate population attributes into conservation plans.

What Was the Extent to Which Differences Were Caused by the Northwest Forest Plan?

Species Outcomes

Conservation of LSOG species—

Many or most of the 1,120 LSOG-associated species originally identified by FEMAT are likely far better conserved owing to the Plan, simply by dint of conservation of LSOG forests and forest elements in LSRs, riparian reserves, and matrix management guidelines providing for protection of known locations of some LSOG species. Much information has been collected on the number of sites that were protected for each species. Although that information does not translate to population outcomes, it is nevertheless a significant finding. However, the specific population outcomes, especially of the rarest of SM species, are largely still unknown.

Little information on species persistence—
Much of the implementation of the Plan for other species has focused on procedures for identifying and, where appropriate, protecting locations of rare and little-known, LSOG-associated species, and gathering new information on their associations with land allocations and habitat conditions. Little work has been done on species trend monitoring, and on validation monitoring of the expectations that the Plan has provided for their long-term persistence and viability.

Thus, it is difficult to conclude whether the Plan has indeed provided for the long-term persistence and viability of these species, although (1) protection was afforded to specific matrix land locations when identified through predisturbance surveys and (2) much of the managed landscape occurs as reserves in which a significant amount of LSOG forest remains and LSOG species locations occur. The assumption that the Plan has provided for viability—or conversely, that it has not adequately provided for some species—is still a hypothesis to be tested, at least by monitoring trends in species' locations over time, although we have some incremental, useful insights on locations and number of occurrences of some species from the various surveys.

Much uncertainty remains on whether the Plan has indeed provided for the long-term persistence and viability of a number of the LSOG-associated species and their ecosystem functions, particularly for the more rare of the SM species. A number of the less rare SM species, however, were removed from the SM species list by the annual species reviews, and these species were deemed to be secure under the Plan.

Some major reductions in uncertainty—
Although much remains to be learned about life histories and ecological functions of most LOSG species, knowledge gained on specific distribution and abundance of many of these species has helped greatly reduce scientific uncertainty. In turn, as used in the ASR process, this information helped reduce management uncertainty and increased reliability of management decisions on the conservation requirements of these species. This has not been a trivial accomplishment.

Still, some scientific and management uncertainty remains, including on SM species that were "downgraded" in conservation status under the SM species program, because only indirect, surrogate measures were used to judge the species' persistence. For some species, better data were gathered by use of random grid (strategic) surveys, species-habitat modeling, and other efforts. For these species, some of the uncertainty in their projected persistence was greatly reduced.

Program Outcomes

Perceived impact on timber PSQ—
The predisturbance surveys and their results impacted matrix land management and were viewed as being largely responsible for a far greater impact on PSQ than initially expected (see lessons learned for more details).

Organizational complexity—
Working across agencies to evaluate the entire federal land base (BLM + National Forest System) created a layer of organizational complexity that (adversely) affected timeliness in getting work done, and also in running a regional program that had a large component independently implemented by field staff. We discuss organizational issues further under lessons learned.

Avoiding federal species listings—
The expectation that the Plan would help stave off federal listing of LSOG-associated species has been largely borne out, although listing petitions have been advanced for a few species including lynx and fisher. It is unclear, however, whether the lack of listing petitions for other LSOG-associated species was directly a result of the Plan, although the Plan likely contributed to this outcome.

Are the Northwest Forest Plan Assumptions Still Valid?

Species Outcomes

Most LSOG species protected—
The initial projection that the main elements of the Plan would provide LSOG environments for most, but not necessarily all, species is still valid. Population persistence of the 404 SM species and 4 arthropod species groups–as well as the 791 species deemed to be effectively cared for under the Plan–is still untested.

Protection of some of the rarest species provided, others still uncertain—
The expectation that some species might garner additional conservation attention beyond the main elements of the Plan (Aquatic Conservation Strategy, riparian reserves, LSRs, matrix guidelines) was validated by the work of the annual species reviews. That is, based on the outcome of the ASRs, the late-successional and riparian reserves might **not** suffice to fully ensure protection and persistence of all LSOG species. Additional, species-specific assessments and considerations, as were conducted under the SM program and ASRs, likely are part of meeting this goal. This is particularly true for the rarest species (that is, those known from <20 sites) that had known locations outside of reserves. Thomas and others (1993) provided a detailed example of increased levels of protection granted to species with the addition of each new layer of a multilayered plan such as the Plan. One of the successes of the SM program was identification of known sites for protection of the rarest species outside reserves.

Program Outcomes

Disposition of the SM program—
Final consideration of the validity of Plan assumptions for the SM program is problematic because the SM standards and guidelines were removed from the Plan in 2004 (USDA and USDI 2004b). The SM program was controversial since its inception, resulting in litigations with different publics and eventual development of two SM FSEIS analyses and RODs to deal with implementation issues. Some of those issues were noted above, particularly the adverse impact on PSQ of management decisions not to continue projects (for example, timber harvest) in numerous matrix sites where SM species were detected through predisturbance surveys. The 2001 ROD (USDA and USDI 2001) also documented the adverse impact of SM mitigation activities on ability to conduct healthy forest and fire reduction projects in much of the Plan area.

In response to a 2001 lawsuit brought by the timber industry (Douglas Timber Operation, and others v. Secretary of Agriculture. Civil No. 01-6378 – AA), the administration settled and agreed to conduct a new EIS on the SM program wherein one alternative would consider movement of SM species to the agencies' special status and sensitive species programs (SSSSP). In the resulting 2004 SM FSEIS (USDA and UDSI 2004a), the agencies described their many frustrations in implementing the SM program mitigation and overall adverse impact it had on meeting other important Plan objectives (for example, PSQ, healthy forest restoration, and other management projects) and the high cost of the program. They selected a preferred alternative that removed the SM standards and guidelines developed in the 1994 and 2001 RODs (USDA and USDI 1994b, 2001) and moved 152 of the remaining 296 species into the BLM and FS SSSSP; 57 species not added to the SSSSP were projected to have insufficient habitat for persistence under this preferred alternative compared to a projection of sufficient habitat under the 2001 SM ROD (USDA and USDI 2001). The 2004 FSEIS and ROD clearly described the risks to species extirpation and management risk tolerance in making these decisions. The agencies emphasized the probable contributions of the Plan area in LSRs (80 percent of the Plan area), the risks to rare species persistence inherent in dynamic landscapes, and the stated desire to balance the uncertain nature of conserving these rare and little-known species with meeting other critical Plan objectives (see USDA and USDI 2004b: 9-13, for more details). Costs and benefits of the SM program were also given detailed analyses.

The 2003 FSEIS and 2004 ROD provided detailed effects analyses on the risk of extirpation of SM species under the three alternatives based on available data and expert opinion. The overall objectives of the SSSSP differ from the SM program, and SSSSP coordinators and field managers face many of the same challenges that SM staff did in conserving these species; many of the SM taxa such as fungi have not previously been included in the SSSSP. Therefore, the SSSSP could take advantage of the known site database, distribution maps, science documents, management guidelines, survey protocols, and conservation strategies pioneered and developed by the SM program. In approving the 2004 ROD, the regional executives apparently clearly understood the challenges and impact of moving 152 SM species to the SSSSP in Oregon and Washington, and have supported this transfer of knowledge gained from SM. They also have increased resources (funding and permanent regional staff) to accomplish the increased workload for these and other tasks. A section that follows on information gained and lessons learned from the SM program further supports the potential value of transferring key findings. The 2004 ROD was challenged by environmental groups, and in January 2006, the court ruled that the SM program be reinstated according to the 2001 ROD. It remains uncertain how the agencies will restart and continue the SM program and how a new FSEIS now underway will modify the program.

Information Gained and Lessons Learned

Information Gained on Rare and Little-Known Species

One of the underlying challenges, and indeed an underpinning for the adaptive approach of SM, was lack of fundamental information on species presence, distribution, abundance, biology, ecology, and conservation status: How rare are they? How are they distributed throughout the Plan area? How abundant are their populations? What are their primary habitat requirements? What factors are influencing their risk of extirpation? Answers to these questions are fundamental to discovering how well the Plan provides habitat for maintaining well-distributed, viable populations (that is, meeting the original mission objective for LSOG-associated species) and how to best manage, protect, or restore habitat to meet that original objective. The collection of nearly 68,000 known site records for all SM species over 10 years of Plan implementation provided the basis for unraveling some of this uncertainty for many species and allowed for informed science-based management decisions on their conservation.

Given new information on rarity, distribution in reserves, degree of LSOG-association, and persistence concerns, over 100 species were removed from the SM list because they no longer qualified for the SM mitigation. Many of these species were removed because they were not as rare as originally believed. The removal of these less rare species was an important adaptive decision because they accounted for many thousands of sites in the matrix; once removed from SM, these sites were released to meet other forest harvest and management objectives.

Known site data also showed that most SM species were rare; 54 percent of the species were known from 20 or fewer sites, 42 percent from 10 or fewer sites, and 31 percent from 5 or fewer sites. The SM database includes sites from both federal and nonfederal forests. When nonfederal sites are removed from consideration, the percentage of actual sites protected under the Plan was smaller. Given the high percentage of species that showed such rarity, these data support the assumption made during

Del Norte Salamander

At the initial implementation of the Plan, the del norte salamander (*Plethodon elongatus*) was thought to be a rare species endemic to southwest Oregon and northwest California. Predisturbance surveys were required for the del norte salamander starting in 1996, and by 1999 approximately 882 sites were located, 36 percent occurring on matrix land allocations (Nauman and Olson 1999). The number of sites increased to 1,000-1,500 over the next few years. Considerable reserve land also occurred within the range of the del norte salamander, but the reserve land had received little survey effort. It remained unknown how well the reserves were contributing to the persistence of the species. In 2000, a strategic survey was conducted in the region to examine del norte salamander distribution in reserves. Approximately one-third of all surveys conducted in the reserves yielded presence of the salamander. This new information on potential distribution in reserves, together with the high number of known sites (that is, less concern about rarity) provided support for removing the salamander from the SM list during the 2001 annual species review. This adaptive decision released many hundreds of sites in matrix lands for subsequent timber harvest and other management activities. This exemplified the ability of targeted, strategic surveys to supplement the typically biased records from predisturbance surveys and provide the underpinning for making better science-based decisions on species persistence and management needs.

FEMAT and the 1994 FSEIS (USDA and USDI 1994a) that application of a fine-filter strategy, in this case protection of known sites, would be an important strategy to maintain their viability. The discovery of many of these rare sightings outside of reserve land allocations further supported the protection of the few known sites to meet the objective of helping ensure conservation of these species.

Although the nearly 68,000 records allowed for better informed decisions, the data had shortfalls that limited their utility for answering the many questions noted previously. Lessons learned emerge from understanding the usefulness or limitations of the data. The vast majority of records are simply site locations with little or no information on habitat characteristics or species abundance. Thus, even though distribution maps could be generated, they could not be used directly to analyze population trends and dynamics, nor to predict potential habitat or its distribution. Collecting information on species abundance or habitat characters represents a significant expense compared to noting only presence.

It is important to carefully weigh what information helps to meet conservation objectives and the cost and benefit of obtaining that information in future inventory or monitoring surveys. If surrogate metrics are used to gauge species persistence and to reduce survey cost (for example, using rarity alone without species abundance data), the science panel evaluations of the SM program's annual species reviews taught the importance of knowing the limitations of the data and integrating its uncertainty into management decisions (see later discussion on use of surrogates in species viability analyses).

There was also significant bias in the nearly 68,000 records because most were from predisturbance surveys conducted primarily in matrix land allocations. This bias would be considered when addressing questions of how well the Plan, particularly the reserves, provided habitat for well-distributed, viable populations. The course change documented in the 2001 SM ROD toward more reliance on strategic (including random-site) surveys than on pre-disturbance surveys was directed at resolving this issue.

Regardless of these shortcomings, on a regional scale, the nearly 68,000-record database is one of the largest and richest of its kind for poorly known taxa such as fungi, lichens, bryophytes, and mollusks. It could serve not only as a valuable resource for the SSSSP of Oregon and Washington, but the rigorous procedures for inventory and amassing survey data could help in developing conservation strategies for rare and little-known taxa in other regions.

Information Gained and Lessons Learned From the SM Program

The SM program ploughed new ground in the science and conservation management of rare and little-known species. Results of the SM program are pertinent not only to the stated objectives of the SSSSP, but also to conservation programs worldwide that are grappling with similar challenges in conservation of rare and little-known species. In identifying the challenges of managing biological diversity in Oregon and Washington as part of the PNW Station's Biodiversity Initiative (Molina 2004), Nelson and others (2006) found that numerous clients from inside and outside federal agencies voiced the desire to summarize and make available results from the SM program. We highlight here some of the major results and accomplishments of the SM program with a focus on lessons learned for potential use in future conservation efforts.

Management recommendations, survey protocols, and field guides—
Developing science-based management recommendations was critical to meeting the assumption that agencies could provide immediate site management for species of high concern. The management recommendations documents served two major functions. First, they summarized the best knowledge available on the biology, ecology, and natural history of the species. Second, they synthesized and integrated this knowledge into flexible guidelines so that managers could manage sites within their overall planning objectives. Recommendations focused on guidelines to maintain suitable habitat for species at the site scale.

Survey protocols identified when and where surveys were to be done, and the sampling procedures, the information to collect, and the survey skills required. Field guides for collection, identification, and processing of fungi and mollusks, two of the more difficult taxa, also were developed (for example, Castellano and others 1999, 2003; Frest and Johannes 1999). All management recommendations, survey protocols, and field guide documents are available on line (www.or.blm.gov/surveyandmanage) and provide the most extensive management guidance to inventory and manage habitat for these taxa. These documents are available for the SSSSP efforts.

Development of an interagency species database—
As directed under the 1994 ROD, the SM program strove to develop an interagency database capable of mapping known locations through GIS procedures to aid analysis of other critical habitat and species attributes.

Development began as a simple "known site" database with much of the information coming from herbaria, museums, and agency data collected as part of the FEMAT and the Plan processes. In 1999, the new database (called the Interagency Species Management System or ISMS) came on line with full-time staff. After extensive training of field staff on ISMS use, new data were entered and analyses conducted as part of the annual species review process. At the conclusion of the SM program nearly 70,000 survey records were housed in the ISMS database. This is the largest known assemblage of site and habitat data for these particular taxa.

The data, resulting maps, and analyses were used in the ASR process and, later, by the Natural Heritage Program to place species into the agencies' SSSSP when the SM program was terminated. The ISMS database has now migrated to the new interagency Geographic Biotic Observations (GeoBOB) database and provides the framework for future GIS analysis and planning for the conservation of species in the SSSSP program and elsewhere.

Predisturbance surveys—

The intent of predisturbance surveys was to avoid the inadvertent loss of sites to maintain species persistence, particularly for rare species found outside reserves in matrix lands. As noted previously, predisturbance surveys became the most costly and controversial part of the SM program.

The 1994 ROD stated that most preproject surveys would begin with a watershed analysis and would identify likely habitat therein that required survey of the SM species. However, because so little was known about the habitat for these species, most surveys were conducted at the project level (that is, nearly all management projects required preproject surveys, often for multiple species). Surveys often were expensive and constrained by lack of trained personnel, and some species survey protocols were difficult and time consuming.

Field managers often stalled or cancelled projects because of the presence of SM species at the project sites. Eventually many of these species that turned out not to be as rare as previously known were removed from the SM program, but not until late in the program. The end result was a major impact on meeting the timber PSQ.

Although the conduct of predisturbance surveys met the expectation of avoiding inadvertent loss of sites, it became an unintended dominant aspect of the program. About 75 percent of all ISMS records were from preproject surveys, and these were only for about 10 percent of all SM species. When survey protocols were developed, data on habitat features and species abundance were not required, so these survey records mostly consisted of only a "known site" location. Nor were negative findings typically recorded from these surveys. The predisturbance survey data did not aid understanding of species' habitat requirements and had limited utility for building habitat models of species' habitat associations by which to predict occurrence on the landscape.

Three valuable lessons emerge from the predisturbance survey effort: (1) Predisturbance surveys can locate new sites and aid in rare species protection, but often provide biased data of limited value in understanding species distribution, habitat selection, persistence, and conservation management. (2) Presence/absence data is of limited value in understanding species viability and conservation management; data on habitat and species abundance are required to better inform decisions on management for species persistence. (3) An adaptive process to quickly review and evaluate the effectiveness and cost/benefit of survey strategies is important to meet long-term goals. The 2001 ROD recognized some of these issues and emphasized that strategic surveys that would focus on reserve lands were required.

Strategic surveys—

Strategic surveys, which were to be conducted on both matrix and reserve lands as well as in LSOG and non-LSOG, were developed as an underpinning for the 2001 SM ROD for three reasons. First, the agencies recognized that predisturbance surveys were not targeting reserve lands because most projects occurred in the matrix. A fundamental uncertainty of the SM mitigation was how well the reserves provide for species persistence. Second, little habitat or abundance data were collected in preproject surveys; this information is vital to understanding habitat association and designating high-priority sites as part of conservation plan development. Third, the SM program was based on an organizing principle and vision tool to work through the priorities of the SM program to bring better balance to meeting species conservation with other Plan objectives such as timber harvest. The strategic survey effort together with the newly defined annual species review process was designed to address these issues.

The strategic survey effort followed the adaptive framework developed by Molina and others (2003). The framework represents an iterative process that identifies specific information gaps, prioritizes species based on biological or management gaps, designs and implements efficient survey approaches, and then analyzes the survey findings as part of the annual species review. A new set of information gaps is identified from these analyses and the planning and implementation process is repeated. The strength of this approach is that it is designed to address specific questions that reflect priority information gaps.

Strategic surveys included a wide variety of approaches to fill information gaps, including research and modeling approaches. This variety of approaches increases flexibility of the overall program and enhances opportunities for partnerships between managers and researchers. Such a flexible "strategic" approach could enhance the effectiveness of the SSSSP, particularly in dealing with species such as fungi where predisturbance surveys largely remain impractical. Landscape-scale surveys, for example, that cross BLM and FS district boundaries and that use a statistically designed sampling scheme, could help field managers to share resources for collecting and analyzing data throughout a significant portion of a species' range. We provide results below from one example of this approach, the random grid survey.

Random grid surveys—

In 1999, regional leadership requested development of a broad-scale survey throughout the Plan area that would provide valuable information on all SM species (that is, use a multiple-species approach) concerning their rarity and distribution in LSOG habitat and reserves. The survey would be statistically designed to allow for use of probabilistic inferences of species' occurrence across the Plan area. Working in consultation with a team of statisticians, a strategic survey workgroup developed what is called the random grid survey (see Cutler and others 2002 and Molina and others 2003 for a discussion of the strengths and weaknesses of this survey approach).

The random grid survey uses permanent points on the landscape (the forest inventory and analysis [FIA] and current vegetation survey [CVS] grid) that contain a wealth of information on stand age, composition, and structure (for example, amount of coarse woody debris and number of snags). Seven hundred fifty randomly selected sampling points were stratified into LSOG vs. non-LSOG (LSOG = forests >80 years) and reserve vs. matrix lands to address the primary questions of LSOG and reserve association of each species. Occurrence estimates of each species were calculated by extrapolation of the number of sites at which the species was found to predict occurrences over the survey area. Implementing this survey for about 300 species was extremely complex and expensive (about $8 million) and took over 2 years to complete. Nearly 240 people were involved in planning, execution, specimen identification, analysis, and reporting. Final results are still in the reporting stage so we can only provide a limited summary at this time.

Overall, it appears that the random grid survey met some of the original expectations and objectives. Approximately 3,000 new records were added on 179 SM species, roughly one third on lichens and another third on fungi. Figure 8-7 shows, however, that most species were found from only 10 or fewer sites each, one third were found from 1 or 2 sites, and 40 percent of the species were not found at all. This is the general result predicted by Cutler and others (2002) who noted that this broad-scale type of survey would likely not detect extremely rare species. Although that was true overall, a few very rare species (that is, known from only a few sites) were detected in the survey.

Results from the random grid survey also helped expand the known overall distribution of several species. However, evaluating the degree of association of the SM species with LSOG or reserve lands proved difficult because these analyses require at least 10 detections for a reasonable amount of certainty. Of the 41 species with 10 or more detections, about 30 showed a statistical association with LSOG and 7 with reserve or matrix land allocations (two with reserves and five with matrix). Regardless of statistically significant results, knowing that species were detected in reserves may be useful because this information was previously lacking in the ISMS database.

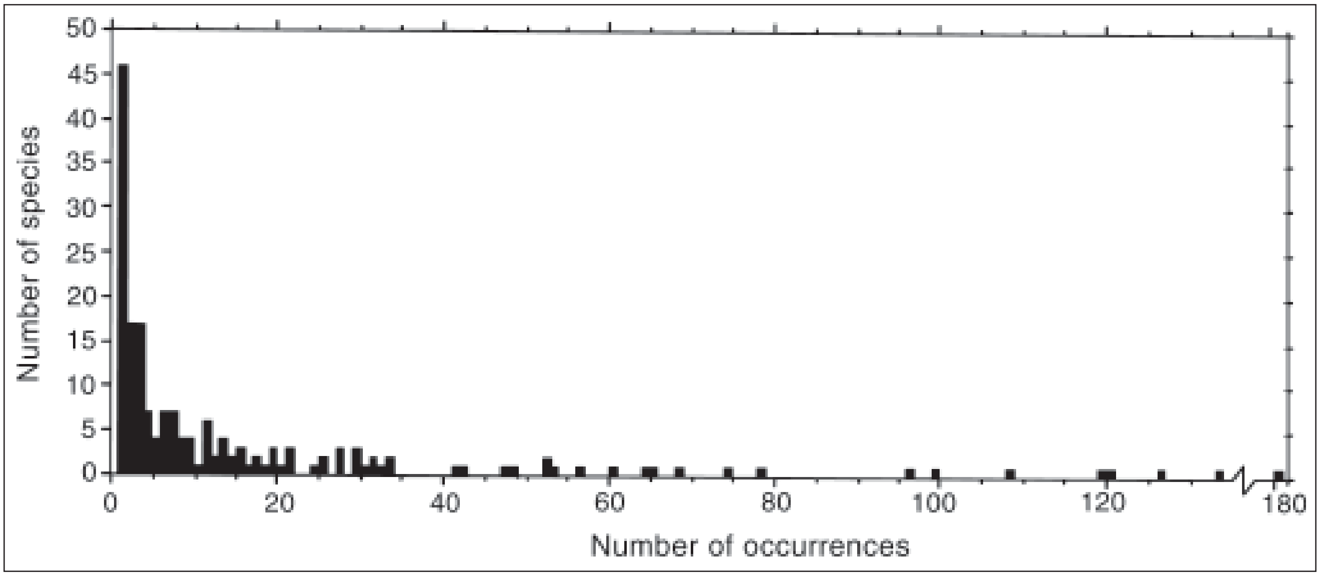


Figure 8-7—Distribution of number of species found at sampled random grid survey points. Data represent a total of 2,985 occurrences found among 179 species of bryophytes, fungi, lichens, and mollusks sampled on 660 grid points throughout the Plan area.

Figure 8-7 also shows that several species were detected frequently on the random grid. Most of these species had already been removed from the SM list or were being viewed in the annual species reviews as not rare.

Although the random grid survey data analyses were not completed prior to the termination of the SM program, preliminary results were used in the annual species review. For example, some species were removed from the SM species list in part because the random grid surveys suggested the species were not rare within the Plan area.

Given the mixed results (few to no locations of very rare species, but useful information on other species on LSOG and reserve association) and great expense of the random grid survey, the SSSSP may wish to carefully review the findings and identify advantages of this survey approach, to help meet program objectives (see Edwards and others 2004 for further discussion).

Annual species reviews—

One of the more successful outcomes of the SM program was the annual species review (ASR), designed as an adaptive decision framework to address uncertainty and provide new information to guide SM species conservation decisions (fig. 8-8). The 2001 ROD revised and expanded the ASR process and provided specific criteria and guidelines by which panels of species experts and evaluators would summarize and interpret ecological attributes of each SM species for reevaluation of the species' conservation status under the Plan.

Bruce G. Marcot

Figure 8-8—Annual species review panel of the Survey and Manage program being led by Russ Holmes. The panels were used in a successful adaptive management process to evaluate species conservation status under the Plan.

Using this process, the agencies removed about one quarter of all SM species from the list, and changed categories of several species to either a more or less conservatory status to reflect mitigation. Decisions to remove some species provided the agencies with the latitude to permit other management activities to proceed on those sites.

The ASR process was not a formal population viability analysis but rather a decision process that used a number of surrogate factors that represented species rarity and persistence. It is unlikely that traditional population viability analyses—which demand data on demography, population genetics, community interactions, and other ecological factors—could be conducted on most of the SM species owing to the species' rarity and to the dearth of quantitative information. Thus, it was vital to ensure that the ASRs served as a rigorous decision analysis procedure. To this end, the 2001 ROD guidelines specifying the criteria for the ASR species evaluations were formalized into a set of decision models (Marcot and others, n.d.). The models were used by the ASR evaluation panels to determine which categories of conservation status, if any, might pertain to each species given the scientific data. The models clearly showed how the surrogate factors were used to judge potential conservation status categories, and the ASR evaluation panel fully documented their use of the data and model outcomes in their recommendations. Thus, the overall ASR process was trackable, rigorously conducted, and fully documented. Many of the processes used in the ASR may prove valuable in assessing SSSSP species status and trends.

Selecting high-priority sites for management—
The 2001 ROD also specified identifying high-priority sites for some of the SM species categories (for uncommon species whose status was not determined). Selecting high-priority sites for management was intended to provide a measure of protection for the species but also allow some sites to be used for other management objectives such as forest stand thinning and timber harvest.

This aspect of the SM program was slow to be implemented, and by the end of the SM program, plans were still in developmental stages for only a few species. This was an unfortunate outcome because developing these plans (that is, selecting high-priority sites for management) was a key process to release known sites in the matrix for other management objectives.

The plans under development used information from watershed analyses to determine where critical sites occurred in relation to nearby reserves with suitable habitat. These plans and the process used to develop them may provide useful tools for the SSSSP, particularly in evaluating the degree to which reserve lands could provide for species and could thereby defer the development of site-specific protection measures.

Program organization and implementation—
Implementing the SM mitigation became a far more complex, expensive, and process-driven program than originally envisioned by the FEMAT and EIS writers (Holthausen 2004). Reasons for this are many and varied. Although some aspects of the SM program were expected to be expensive (tables 8-3 through 8-6), final costs exceeded expectations, particularly in conducting pre-project surveys throughout the region by field units (see USDA and USDI 2001 and 2004a for details on program costs). Available information makes it difficult to compare projected and actual costs.

The 1994 ROD provided little guidance for SM program organization and implementation. None of the original FEMAT or EIS team members who developed the standards and guidelines of the Plan program participated in early development or design of the SM program, so original intentions may have been lost or overlooked. A group of interagency specialists eventually formed a core team to develop the SM program of work. Most of these specialists were assigned only part time to this project, with some members coming and going as details ended. A shortage of taxa expertise within the management agencies surfaced early in SM program implementation and affected the

Noble Polypore


Forest Mycology Team

The noble polypore (*Bridgeoporus nobilissimus*) was unique among the original 234 SM fungal species. It forms large conks or shelf-like fruiting bodies up to a meter across at the base of large trees (it is a heart-rot fungus) that are perennial. Because the fruiting bodies of the noble polypore are always present and easy to detect, the species was listed under the original category 2 conservation status—survey prior to ground-disturbing activities. No other fungal species were placed in this category because of the difficulty in locating them through surveys in any given year.

The noble polypore was only known from six sites at the time of FEMAT, and two of those sites had no protection because they existed outside of reserve land allocations. Those two known sites were given unique protection in the original SM standards and guidelines: “Management areas of all useable habitat up to 600 acres are to be established around those two sites for the protection of those populations until the sites can be thoroughly surveyed and site-specific measures taken” (USDA and USDI 1994b: C-5).

Over the next several years those original sites were surveyed by the survey and manage mycology team and several new records of fruiting conks were noted. More importantly, detailed habitat data were collected at these known sites. A better understanding of required habitat emerged, which allowed for construction of habitat models (Marcot, n.d.) and targeted, purposive surveys into potential habitat in the region. A critical finding, for example, was the specific association of noble polypore conks with large stumps of *Abies procera* Rehd. in the Oregon Coast Range and *Abies amabilis* Dougl. ex Forbes in the Cascade Ranges of Oregon and Washington as well as the Olympic Peninsula. Subsequent surveys by expert mycologists found several new sites, approximately tripling the number of known sites and extending the known range. The species was not located in predisturbance or random grid surveys.

This provides a good example of using expert knowledge to build habitat models to better target regional surveys. The noble polypore was transferred to the agencies’ Sensitive and Special Status Species programs in the 2004 record of decision.

Table 8-3—Projected (anticipated) costs for survey activities over the life of the Survey and Manage program[a]

Survey activity	Projected costs
	Thousand dollars
Bryophyte extensive and general regional surveys	100
Lichen extensive and general regional surveys	500
Vascular plants preproject surveys	330
Known locations for rare, endemic fungi (over 3 years)	1,000
Fungi extensive and general regional surveys (over 10 years)	10,000
Arthropods, 20 watershed surveys	9,000
Total	20,930

[a] Extensive and general regional surveys were expected to take at least 10 years.

Source: USDA and USDI 1994a, Appendix J2. Values do not include regional program implementation costs or predisturbance survey costs.

Table 8-4—Approximate regional expenditures of implementing the Survey and Manage program from 1994 to 1999

Cost element	Cost
	Thousand dollars
Program management	600
Preparation of survey protocols, management recommendations, and field guides	1,905
Training and species identifications	1,566
Extensive and general regional surveys[a]	2,875
Known-site database	610
Interagency Species Management System	1,100
Overhead	1,904
Subtotal regional program costs	10,560
Predisturbance surveys 1994-1998	1,000
Predisturbance surveys 1999	8,500
Total	20,060

[a] Did not begin until 1996.

Source: USDA and USDI 2000: 410-412.

Table 8-5—Annual projected (anticipated) short-term (1 to 5 years) and long-term (6 to 10 years) cost, projected from 2001 onward, to implement the preferred alternative for the Survey and Manage program

Program level	Cost element	Short-term cost	Long-term cost
		Thousand dollars	
Regional	Strategic surveys[a]	7,700	1,000
	Field guides, management recommendations, survey protocols	600	300
	Program management	500	500
	Data management	400	400
	Training, species identification	600	600
	Subtotal	9,800	2,800
Field	Predisturbance surveys for timber	8,200	6,100
	Predisturbance surveys for fire	10,300	7,700
	Predisturbance surveys for other	400	300
	Subtotal	18,900	13,400
	Total	28,700	16,900

[a] Beginning in 2001, strategic surveys replaced the extensive and general regional surveys.

Source: USDA and USDI 2000: 417-419.

Table 8-6—Approximate expenditures of the Survey and Manage program 2001–2004

Fiscal year	Regional program	Predisturbance surveys	Total
		Thousand dollars	
2001	10,400[a]	—[b]	—
2002	8,300[a]	7,700[c]	16,000
2003	6,100[a]	—	—
2004	5,200[d]	—	—
Total	30,000	>7,700	>16,000

[a] Source: 2003 Survey and Manage annual report, p. 8: http://www.or.blm.gov/surveyandmanage/AnnualStatusReport/2003/S_and_M-2003.pdf

[b] Data unavailable in existing documentation.

[c] Source: USDA and USDI 2004a: 215 noted that the level of expenditure for fiscal year 2002 fell short of predicted costs owing to less predisturbance surveys that year and stated that the total spent for the program was $16 million. The 2003 Annual Report shows program costs at $8.3 million, so the predisturbance cost was calculated from the difference between total and regional costs.

[d] Source: Survey and Manage program expenditure spreadsheet. On file with: Forest Service, Pacific Northwest Regional Office, Portland, Oregon 97208.

ability of the SM program to develop science-based products (for example, management recommendations and survey protocols) for over 400 poorly known, taxonomically diverse species. This shortage of expertise was especially critical on some taxa such as mollusks and fungi. Shortage of expertise also affected ability to develop products within deadlines envisioned by original planners. Nevertheless, the early SM organization struggled successfully to develop these essential products and to initiate broad regional surveys.

In 1999, as agencies began the EIS process to redefine the SM mitigation (eventually resulting in the 2001 ROD), a new SM organization was established with permanent staff that was responsible for all aspects of program implementation. Permanent positions included a program manager, strategic survey coordinator, conservation planner, and annual species review coordinator. A team of four agency representatives continued to provide support for many tasks. Approximately 90 specialists from BLM and FS field units (totaling 35 full-time equivalents) worked on taxa teams to develop species-specific products and to conduct species evaluations. An interagency group of intermediate managers provided direct oversight and leadership, thus enabling more efficient policy and management decisions. This new organization and leadership support greatly improved the efficiency and effectiveness of the program.

Much of the complexity and process-laden aspects of the SM program grew from the enormous task of building a science-based approach for conserving 400 poorly known species that required gathering new information over a 24-million-acre planning area. Working across BLM and FS agency boundaries, both organizationally and physically on the landscape, added another layer of complexity. Many SM tasks such as development of management recommendations and protocols, database development and analysis, and species status evaluations, required regional oversight; other tasks such as conduct of preproject surveys and data collection were the responsibility of field units. Successfully implementing these tasks required new ways of communicating between agencies and between regional headquarters and district offices. In the end, the ability of agencies to cross these boundaries and overcome many of the challenges was perhaps one of the more successful aspects of the SM program, particularly after formation of the new SM permanent organization. Six federal agencies shared personnel and resources over several years to accomplish these many difficult tasks, thus meeting one of the primary goals of the Plan in working together to manage resources at a regional scale.

Several important lessons emerge regarding the organization of an effective science-based management conservation program. First, and most important, is having a long-term vision that clearly articulates both short- and long-term objectives for the program. Such a vision was lacking in the early years of SM implementation so it was difficult to pull together the complex tasks into a cohesive framework to measure success. Secondly, permanent expert staff assigned to the program provided continuity and accountability for meeting expectations far more efficiently than did staff temporarily assigned as detailers from other units. The SM program significantly enhanced its productivity and accountability with the development of a recognized program with permanent positions. The recent additions of new positions to the regional SSSSP is an important step in that direction. Third is development of effective communication between regional and field staff to provide timely information sharing of ongoing tasks, deadlines, and accomplishments. The SM Web site (www.or.blm.gov/surveyandmanage), annual reports, data calls, and field training workshops are good examples. Finally, connecting the program to a regional vision to conserve biodiversity would help to place the conservation of rare species in a broader agency mission context.


Bruce G. Marcot

Figure 8-9—This rare Survey and Manage species is Van Dyke's salamander (*Plethodon vandykei*), found mostly in southwest Washington.

Considerations

Efficacy of Large Reserves for Conservation of Rare Species and Biodiversity

A central tenet of the Plan was that the system of late-successional reserves would largely suffice to provide for species and biodiversity components associated with late-successional and old-growth forest ecosystems. We have found that, to an extent, this is likely true. However, the degree to which late-successional reserves–along with the set of other Plan land allocations (for example, riparian reserves in matrix lands)–suffice varies considerably by species and biodiversity component. It also likely varies by the specific locations chosen for the late-successional reserves–such as whether they happen to intersect unknown sites of particular species or communities, and if they happen to contain microenvironmental conditions and specific habitat elements used and selected by those species or communities (figs. 8-9, 8-10).


Bruce G. Marcot

Figure 8-10—Typical streamside habitat of Van Dyke's salamander on Gifford Pinchot National Forest in the southern Washington Cascade Mountains, being studied by research wildlife biologist Charlie Crisafulli.

Initial findings (Turley 2004) of the random-grid survey study on SM species suggest that both Plan reserves and LSOG forests within and outside reserves may play key roles in providing habitat for many species. Out of a total 394 SM species targeted for survey in this study, sufficient data were gathered on 108 species (bryophytes, fungi, lichens, and mollusks) by which to determine degree of association with reserves and with LSOG. Of these 108 species, 41 species had 10 or more detections. These results alone suggest that most of the 394 SM species were seldom if ever encountered during the random grid survey, and thus results of this study pertain largely to the more abundant species. Of the 108 species tested for association with reserves, only 2 species (2 lichens) were significantly or marginally statistically associated with reserves, and 5 species (1 bryophyte, 1 fungus, 3 lichens) with matrix lands; the rest of the species showed no association with either reserve or matrix lands (figs. 8-11, 8-12). Of the 108 species

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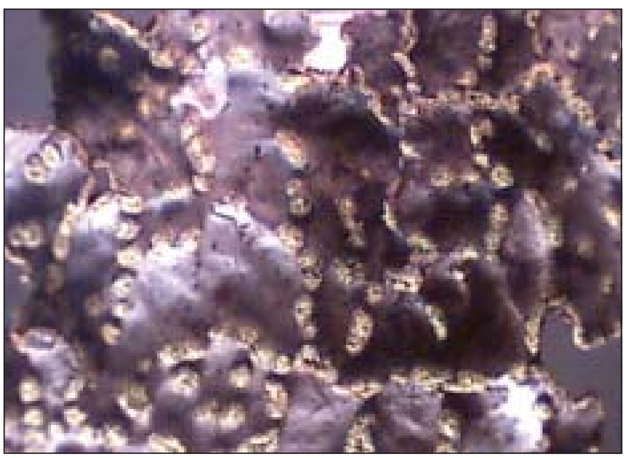
Figure 8-11—A Survey and Manage species of lichen, *Lobaria pulmonaria*, "lungwort" or "lung lichen," so named because it reminded medieval European doctors of lung tissue. It grows on trees, shrubs, and mossy rocks in moist low- to mid-elevation forests mostly in coastal influence zones (McCune and Geiser 1997). It is used in Britain as an indicator species of undisturbed forest ecosystems.



Bruce G. Marcot

Figure 8-12—This Survey and Manage lichen is *Pseudocyphellaria crocata.* The round yellowish edges are structures called soralia, where algae enclosed in fungal threads are produced for asexual reproduction. This lichen grows on bark and wood of hardwoods in low- to mid-elevation forests in the western Cascade Mountains (McCune and Geiser 1997). The species is sensitive to, and can be used to indicate, air pollution.

tested for association with LSOG, 30 species (3 bryophytes, 6 fungi, 20 lichens, 1 mollusk) were significantly or marginally statistically associated with LSOG, and 1 species (1 lichen) with non-LSOG lands; the rest of the species showed no association with either LSOG or non-LSOG.

These results suggest that about one third of all species that could be tested (again, being the more abundant of the SM species) were marginally to closely associated with LSOG, but only one SM species showed such association with reserves. This provides evidence that LSOG is important for at least 30 SM species–which is useful information not available before the study. However, no information is available on most (73 percent) of the more rare SM species (286 species), which were not found or which were undersampled for statistical analysis.

For all SM species combined, reserves per se were not specifically selected for; over all species detections from this study, 81 percent were found in reserves, compared to 80 percent of the land base sampled being in reserves. Still, the data on 10 species selecting for reserves was new and significant information. Also, lack of association with reserves should not necessarily be construed as reserves not providing important habitat for species persistence, particularly for those species that do show association with LSOG. Late-successional and old-growth occurs in both reserve and matrix lands, and over time if LSOG regrows within reserves and is reduced in matrix lands, such a study as this could detect greater association with reserves per se.

In general, to maintain a large component of late-successional forest species and biodiversity elements, a reserve system may be viewed as a major "coarse filter" component, although additional "fine filter" evaluations and guidelines for some species and biodiversity elements also may be included (see below).

Recent Trends in Conservation of Biodiversity

Alternative approaches to biodiversity conservation and their efficacy for rare species conservation—
In the past decade, much has been written on methods and approaches to biodiversity conservation. A main focus has been on species conservation, with emphasis on maintaining or restoring viability of rare, declining, or listed species, although other dimensions of biodiversity besides individual species also have been addressed.

One example is the concept of coarse and fine filters in biodiversity conservation (Armstrong and others 2003, Reyers and others 2001). These terms have been used in a wide range of contexts but, in general, coarse filter refers to management of overall ecosystems and habitats and fine filter refers to management of specific habitats or sites for selected individual species. In a sense, the Plan follows this approach where the overall LSRs, riparian reserves, and guidelines for old-forest conservation and restoration constitute the coarse filter, and the SM program's focus on selected habitats and sites of rare species constituted the fine filter. The literature generally concurs that a combination of both coarse and fine filter elements better ensure conservation of a fuller array of species and biodiversity elements (Dobson and others 2001, Kintsch and Urban 2002). That is, applying just coarse-filter management of general ecosystems and habitats alone would not suffice to ensure conservation of all biodiversity elements including rare species associated with uncommon microhabitats and environmental conditions (Lawler and others 2003).

Another approach to biodiversity conservation has been delineation of hot spots of high species richness or of locations of endemic or at-risk species, and use of "gap analysis" to determine where such hot spots fail to coincide with conservation-oriented land allocations (Flather and others 1997, Root and others 2003). Reliability of hot spot locations and gap analyses depend on the accuracy of underlying species distribution maps. Some studies suggest that the hot spot approach alone does not necessarily ensure protection of rare species and that focus on a diverse set of species representative of a range of variation within ecological communities may be a more effective approach (Chase and others 2000).

Other recent approaches to biodiversity conservation have been devised to use many forms of surrogate species, such as umbrella species, management and ecological indicator species, flagship species, species functional groups, ecosystem functioning (for example, Hooper and others 2005), and others. Few of these approaches alone have proven fully reliable for ensuring conservation of rare species.

The conclusion is that, unless specifically targeted to address conservation requirements of rare species, alternative approaches to biodiversity conservation generally do not suffice to fully ensure persistence and protection of all rare species.

Monitoring of biodiversity—
The original ROD (USDA and USDI 1994b) called for effectiveness monitoring of biological diversity and late-successional and old-growth forest ecosystems. Beyond the species-specific owl and murrelet population studies and the surveys conducted of SM species, little information has been gathered on the ecology of these species. Even at the species level, little information has been gathered on ecosystem functions of rare and little-known LSOG species, including SM species, especially in terms of their contribution to overall ecosystem processes. However, such information would be very difficult to gather. Any effort to monitor biodiversity would do well to consider the specific utility of such information in guiding forest management, and selection of surrogate measures for difficult parameters used for adaptive forest planning.

Considerations in Developing Species Conservation Programs

Although the Plan was considered a science-based plan, there remained significant uncertainties and untested assumptions after implementation. This was particularly true for the SM program because this mitigation grew out of the uncertainty surrounding the viability of the species and how well the overall Plan (especially the reserve systems) provided for species persistence. Furthermore, most of the taxa listed for protection were rare or little known, so available science was meager on how best to conserve these species. These issues point to the benefits from partnering with research agencies and universities in developing the science basis for conservation programs. Indeed, some of the conservation issues may call for specific research approaches to develop new knowledge on specific areas of concern (for example, from understanding individual species ecology to developing landscape sampling designs). From experience gained we offer the following considerations:

Research partnerships—

- Consider including research partners in initial program design.
- Consider clearly defining the role of research in adaptive management and decision processes.
- Consider identifying specific information gaps and developing appropriate research studies to fill those gaps.

Coarse- vs. fine-filter approaches—

- Consider carefully defining what is meant by coarse and fine filter (that is, what elements these represent).
- Consider clearly laying out in your conservation program the contributions expected from these two approaches (for example, role of reserves and protecting specific sites).

Species viability and persistence—

- If these represent species management goals, consider clearly defining the terms and how you will measure obtaining that goal.

Value of metrics—

- Consider clearly designing metrics to meet specific objectives.
- Consider the limitations of surrogates (for example, indicator or focal species) for meeting broad conservation objectives.
- Consider validating the use of surrogates in meeting conservation objectives.

Database—

- Consider designing an effective database for data storage and analysis that will meet both short- and long-term objectives.
- Consider developing a robust database that is easy for diverse users to query.
- Consider the types of analyses that are required from the data.
- Consider adequately staffing this function to provide for quality stewardship and timely analyses.

Survey design—

- Consider developing a framework and process to strategically focus resources on key information gaps.
- Consider exploring a variety of survey approaches and analyze these for efficiencies in terms of cost and information gained.
- Consider the value that certain types of surveys provide or do not provide (for example, predisturbance surveys typically provide biased data on species distribution and abundance).
- Consider looking for efficiencies by designing surveys to include multiple species.
- Consider collecting information that is critical to meeting specific conservation objectives (for example, habitat information for modeling, species abundances for population considerations).
- Consider using statistically designed surveys when possible that allow for extrapolation of results to larger landscapes.

Habitat modeling—

- Consider exploring different habitat modeling approaches to meet specific conservation objectives.
- Consider the limitations of habitat modeling.

Decision support—

- Consider developing decision-support models that integrate relevant information.

Monitoring—

- Consider developing a monitoring framework that will enable you to measure how well you meet specific objectives (for example, species persistence, minimizing management effects, evaluating trends, etc.).

The Future

The Plan has been a remarkably ambitious effort designed, in part, to conserve a wide array of rare and little-known species across multiple taxonomic and ecological groups. Although the charge for the conservation of most species now falls into another program (SSSSP), lessons learned from the Plan on species responses and program implementation can help guide successful outcomes.

The broader expectations for demonstrating conservation of forest biodiversity elements beyond rare species, and the direction in the Plan to address biodiversity issues through effectiveness monitoring (Ringold and others 1999), however, still remain as mostly unmet challenges.

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Chapter 9: The Aquatic Conservation Strategy of the Northwest Forest Plan: An Assessment After 10 Years

Gordon H. Reeves

Introduction

The Aquatic Conservation Strategy (ACS) of the Northwest Forest Plan (the Plan) is a regional strategy designed to restore and maintain the processes that create and maintain conditions in aquatic ecosystems over time across the area inhabited by the northern spotted owl (see appendix for species names). It seeks to prevent further degradation of aquatic ecosystems and to restore habitat and the ecological processes responsible for creating of habitat over broad landscapes, as opposed to individual projects or small watersheds (USDA and USDI 1994). The foundation of the ACS is a refinement of earlier strategies, "The Gang of Four" (Johnson and others 1991), PacFISH (USDA 1992), and the Scientific Assessment Team (Thomas and others 1993). Its primary objectives are to maintain and restore:

- The distribution, diversity, and complexity of watershed and landscape-scale features to ensure protection of the aquatic ecosystems to which species, populations, and communities are uniquely adapted.
- The spatial and temporal connectivity within and between watersheds.
- The physical integrity of aquatic ecosystems, including shorelines, banks, and bottom configurations.
- Water quality necessary to support healthy riparian, aquatic, and wetland ecosystems.
- The sediment regime under which the aquatic ecosystem evolved.
- Instream flows sufficient to create and sustain riparian, aquatic, and wetland habitats and to retain patterns of sediment, nutrient, and wood routing.
- The timing, variability, and duration of flood plain inundation and water table elevation in meadows and wetlands.
- The species composition and structural diversity of plant communities in riparian zones and wetlands.
- Habitat to support well-distributed populations of native plant, vertebrate, and invertebrate riparian-dependent species.

In the short term (10 to 20 years), the ACS was designed to protect watersheds that currently had good habitat and fish populations (FEMAT 1993). The long-term goal (100 years) was to develop a network of functioning watersheds that supported populations of fish and other aquatic and riparian-dependent organisms across the Plan area (USDA and USDI 1994).

The ACS contains four components to meet these goals and objectives:

- Watershed analysis: Watershed analysis is an analytical process to characterize watersheds and identify potential actions for addressing problems and concerns and to identify possible management options. It assembles information necessary to determining the ecological characteristics and behavior of the watershed and to develop options to guide management in the watershed, including adjusting riparian reserve boundaries.
- Riparian reserves: Riparian reserves define the outer boundaries of the riparian ecosystem. They are the portions of the watershed most tightly coupled with streams and rivers. They provide the ecological functions and processes necessary to create and maintain habitat for aquatic- and riparian-dependent organisms over time, provide

dispersal corridors for terrestrial organisms, and to provide connectivity in a watershed. The boundaries were interim until a watershed analysis was completed, at which time they could be modified depending on suggestions made in the watershed analyses.

- Key watersheds: Key watersheds are intended to serve as refugia for aquatic organisms, particularly in the short term for at-risk fish populations, to have the greatest potential for restoration, or to provide sources of high-quality water. Tier 1 key watersheds currently have good populations or habitat, a high restoration potential, or both. Tier 2 key watersheds provide sources of high-quality water.
- Watershed restoration: Watershed restoration is designed to recover degraded habitat. Restoration activities focus on restoring the key ecological processes required to create and maintain favorable environmental conditions for aquatic and riparian-dependent organisms.

The ACS also includes standards and guidelines that apply to management activities in riparian reserves and key watersheds.

The primary objective of this chapter is to identify the expectations for the ACS in the first 10 years of implementation and to assess how well the ACS has met the expectations. Additionally, I will review the original scientific basis for the ACS and the relevant science produced since then.

Expectations and Results

Potential Listing of Fish Species and Evolutionarily Significant Units Under the Endangered Species Act

A primary motivation for developing the ACS was the anticipated listing of distinct population segments of various species of Pacific salmon, called evolutionarily significant units (ESUs), and other fish species under the Endangered Species Act (ESA 1973). When the Plan was developed in 1993, only the Sacramento winter chinook salmon, the shortnose sucker, and the Lost River sucker were listed. Since then, 23 ESUs of Pacific salmon and 3 population segments of bull trout found in the Plan area have been listed. Twenty units of salmon and all bull trout population segments are found on federal lands managed under the Plan (table 9-1). Additionally, the Oregon chub was listed after the Plan was implemented and coho salmon in the Oregon coast is currently a candidate for listing (table 9-1).

A coho salmon in Bell Creek, in the coastal lakes watershed (Oregon Coast Range) on the Siuslaw National Forest near Florence, Oregon.

The Plan was expected to contribute to the recovery of the ESA-listed fish, particularly the anadromous salmon and trout (that is, fish that spend their early life in freshwater, move to the ocean to mature, and then return to freshwater to reproduce), by increasing the quantity and quality of freshwater habitat (FEMAT 1993). It was not expected to prevent the listing of any species or distinct population segment. The primary reason for this expectation was that the federal land management agencies are responsible only for the habitat they manage; state agencies are responsible for populations on all lands and for the regulation of activities that affect populations and habitats on other ownerships. Factors outside the responsibility of federal land managers contribute to the declines of these populations and will strongly influence their recovery. These

Table 9-1—Evolutionarily significant units (ESUs) of Pacific salmon and trout (*Oncorhynchus* spp.), distinct populations segments (DPSs) of bull trout (*Salvelinus confluentus*), and fish species listed and candidates for listing (*) under the Endangered Species Act that occur in the area covered by the Plan

Species	ESU/DPS	National forests (NF) and Bureau of Land Management (BLM) districts where species occur
Coho salmon	Lower Columbia/southwest Washington	Gifford Pinchot NF, Mount Hood NF
	Oregon coast*	Siuslaw NF, Umpqua NF, Siskiyou NF, Eugene BLM, Coos Bay BLM, Medford BLM, Roseberg BLM, Salem BLM
	Southern Oregon/ northern California	Rogue River-Siskiyou NF, Six Rivers NF, Shasta-Trinity NF, Klamath NF, Mendocino NF, Arcata BLM, Kings Range National Conserva-ion Area (NCA), Redding BLM, Medford BLM, Coos Bay BLM
	Central California coast	Ukiah BLM
Chinook salmon	Puget Sound	Mount Baker-Snoqualmie NF, Olympic NF, Gifford Pinchot NF
	Lower Columbia	Gifford Pinchot NF, Mount Hood NF, Salem BLM
	Upper Columbia	Okanogan NF, Wenatchee NF
	Upper Willamette	Mount Hood NF, Willamette NF, Eugene BLM, Salem BLM
	California coastal	Six Rivers NF, Mendocino NF, Arcata BLM, Kings Range NCA, Ukiah BLM
	Sacramento River winter run	Mendocino BLM
	Central Valley spring run	Shasta-Trinity NF, Mendocino BLM, Redding BLM
	Central Valley winter run	Redding BLM
Chum salmon	Hood Canal summer	Olympic NF
	Columbia River	Salem BLM
Steelhead	Lower Columbia	Gifford Pinchot NF, Mount Hood NF, Salem BLM
	Mid-Columbia	Gifford Pinchot NF, Mount Hood NF, Wenatchee NF
	Upper Columbia	Wenatchee NF, Okanagon NF
	Upper Willamette	Willamette NF, Salem BLM, Eugene BLM
	Northern California	Six Rivers NF, Mendocino BLM, Arcata BLM, Ukiah BLM, Kings Range NCA
	Central California coast	Arcata BLM, Kings Range NCA
	Central Valley, California	Shasta-Trinity NF, Mendocino BLM
Coastal cutthroat trout	Southwest Washington/ Columbia River	Gifford Pinchot NF

Table 9-1—Evolutionarily significant units (ESUs) of Pacific salmon and trout (*Oncorhynchus* spp.), distinct populations segments (DPSs) of bull trout (*Salvelinus confluentus*), and fish species listed and candidates for listing (*) under the Endangered Species Act that occur in the area covered by the Plan (continued)

Species	ESU/DPS	National forests (NF) and Bureau of Land Management (BLM) districts where species occur
Bull trout	Klamath River	Winema NF
	Columbia River	Deschutes NF, Gifford Pinchot NF, Mount Hood NF, Wenatchee NF, Okanongon NF, Willamette NF, Eugene BLM
	Coastal-Puget Sound	Gifford Pinchot NF, Mount Baker-Snoqualmie NF, Olympic NF
Oregon chub		Willamettte NF, Umpqua NF
Lost River sucker		Winema NF
Shortnose sucker		Winema NF

include (National Research Council 1996):

- Degradation and loss of freshwater and estuarine habitats.
- Excessive harvest in commercial and recreational fisheries.
- Migratory impediments, such as dams.
- Loss of genetic integrity from the effects of hatchery practices and introductions.

Ocean productivity also strongly influences population numbers of anadromous salmonids. Conditions in the marine environment in the Plan area are highly variable over time. The oceanic boundary between cool, nutrient-rich northern currents and warm, nutrient-poor southern currents is off the coast of Washington, Oregon, and northern California (Fulton and LaBrasseur 1985) (fig. 9-1). The location of this boundary is influenced by the Pacific Decadal Oscillation (PDO), which is climatically driven and results in an oscillation between positive and negative phases every 20 to 30 years. This oscillation results in alternating regimes of salmon production between the Pacific Northwest and more northerly areas along the Pacific coast of North America (Mantua and others 1997). During periods of high productivity, zooplankton biomass—a critical food for salmonids when they first enter the ocean—is greater in the productive zone than in the less productive region. Early ocean survival of anadromous salmonids and the number of adults returning to freshwater are greater during the positive phases (Mantua and others 1997). The last period of high productivity was from the late 1940s to 1977 (Mantua and others 1997). The Plan area is currently in another positive production phase, but how long the current phase that began in 2001 will last is unknown.

Population numbers of many ESA-listed salmon and trout in the Plan area, and other parts of the Pacific Northwest, have increased since the Plan was implemented. However it is not possible to discern how much the Plan has contributed to this increase. Conditions of freshwater habitats on federal lands have improved moderately under the Plan (see later discussion for more details) but not to an extent that could account for the current increases in the numbers of returning adults. Populations in areas outside of the Plan area have shown similar, and even larger, changes.

The real contribution of freshwater habitats to the persistence and recovery of anadromous salmon and trout in the region covered by the Plan will be measured when the PDO moves into a less productive phase and the persistence of andromous salmon and trout populations will depend to a larger degree on freshwater habitat (Lawson 1993) (fig. 9-2). Improvements in the quantity and quality of

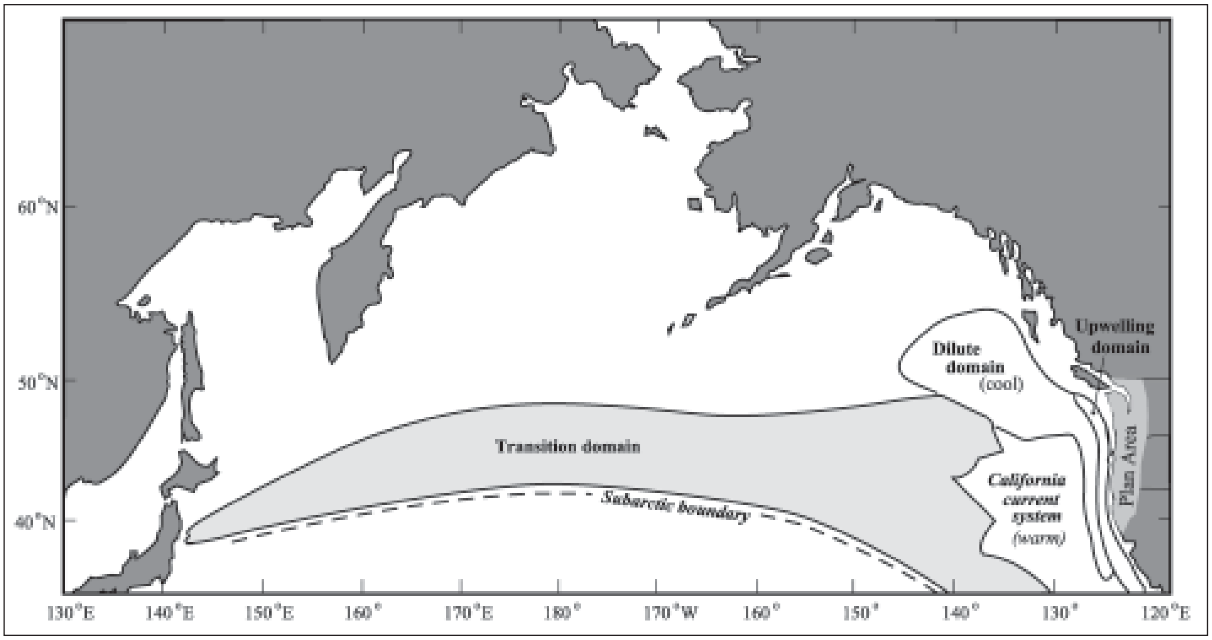

Figure 9-1—Boundaries of eastern north Pacific Ocean currents. Source: Fulton and LaBrasseur 1985.

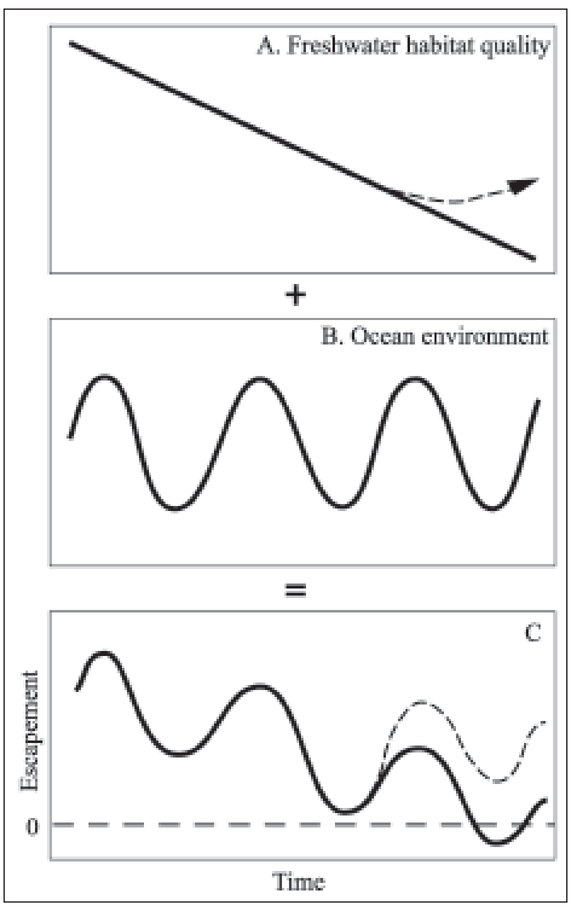

Figure 9-2—Conceptual relation between the quality of freshwater habitat, variable ocean conditions, and the persistence of populations of anadromous salmonids. "A" is the trajectory of habitat quality over time. Dotted line represents possible effects of improvement in habitat quality. "B" is the generalized time series of ocean productivity over time. "C" is the sum of the interaction of A and B. Source: Modified from: Lawson 1993.

freshwater habitat should result in greater numbers of fish entering the ocean, thus increasing the likelihood of persistence of many populations during periods of low productivity.

Changes in Watershed Condition

The ACS was designed to improve the ecological condition of watersheds in the Plan area over an extended time (that is, several years to decades). It is based on preserving key ecological processes and recognizes that periodic disturbances may be required to maintain ecological productivity. As a result, the ACS does not expect that all watersheds will be in good condition at any point in time, nor does it expect that any particular watershed will be in a certain condition through time. If the ACS and the Plan are effective, the proportion of watersheds in better condition is expected to remain the same or increase over time (Reeves and others 2004). However, the ACS does not identify a particular desired or acceptable distribution of watershed condition. It does, however, recognize that significant results from the ACS were not expected for several years or decades because it will take extended time for the condition of watersheds that were extensively degraded from past management activities to improve (FEMAT 1993).

The ACS attempts to improve watershed conditions by preserving key ecological processes.

Large improvements in the condition of individual watersheds or changes in the distribution of conditions were not expected in the short term (10 to 20 years) because this was too short a time for many watersheds to improve, and the impact of restoration efforts would not be extensive enough across the Plan area to result in discernable changes in the distribution of watershed conditions. At best, it was expected that the pattern of degradation would be slowed or halted, and there may be some minor to moderate improvements in watershed condition as a result of the implementation of the ACS.

A monitoring program to determine the effectiveness of the ACS was expected to be developed and implemented within a short time of the record of decision (ROD) (USDA and USDI 1994), but the Aquatic and Riparian Effectiveness Monitoring Program (AREMP) did not begin until 2000. This delay resulted from the difficulty that the relevant agencies (USDA Forest Service [FS], USDI Bureau of Land Management [BLM], the Environmental Protection Agency [EPA], and National Oceanic and Atmospheric Administration [NOAA] Fisheries) had with agreeing on an approach, much less an actual program. Before 2000, two attempts were made to develop an effectiveness monitoring plan that all agencies could support. Both attempts failed because the involved parties could not agree on a common vision for the plan, a common approach to the problem, or methodology. The need for three attempts to develop an effectiveness monitoring plan illustrates the struggle over the ACS because of differences in operating and thinking among the involved agencies. The AREMP was approved by the regional executives in 2000, and pilot testing began that year. Components of AREMP and the rationale for them are described in Reeves and others 2004.

The AREMP attempts to characterize the ecological condition of watersheds by integrating a set of biological and physical indicators, and it tracks the trend in condition of the population of watersheds over time. The condition of watersheds is evaluated with decision-support models by using fuzzy logic (Reeves and others 2004). The relations between the selected parameters and the watershed condition used in these models were based on empirical evidence and the professional judgment of aquatic specialists from the national forests, BLM districts, management and regulatory agencies involved with the Plan, and state fish management agencies. The models were built at the province and subprovince scales to account for ecological variability.

The condition of a watershed was defined as "good" if the physical attributes were adequate to maintain or improve biological integrity, primarily for native and desired fish species (Reeves and others 2004). Also, the systems that were in good condition were expected to be able to recover to desired conditions when disturbed by a natural event or land-management activities. Scores for watershed conditions ranged from 1 to -1: 1 if absolutely true (based on the assumptions in the decision-support model) that the watershed was in good condition, and -1 if absolutely false that it was in good condition. Reeves and others (2004) emphasized the need to recognize that condition of any watershed may vary widely naturally. For that reason, it was recognized that watersheds with little or no human activity were not necessarily in good condition at any point in time.

The focus of AREMP is not on individual watersheds but rather on the statistical distribution of watershed conditions across the Plan area. Two hundred fifty 6^{th}-field watersheds (10,000 to 40,000 acres) were randomly selected from throughout the Plan area to be sampled over a 5-year cycle (Reeves and others 2004). The full range of management from roadless and wilderness to intensive timber harvest and livestock grazing were found in these watersheds.

Pilot testing in AREMP to evaluate sampling protocols and to determine funding and staff requirements occurred in 2000 and 2001. Actual monitoring began in 2002, with about half of the estimated funding needed to fully implement AREMP. Monitoring continued at reduced levels in 2003 and 2004. A total of 55 (of an expected 100) watersheds were sampled in 2002 and 2003 (Gallo and others 2005). No watersheds have been resampled to permit direct estimates of change in watershed condition.

The parameters necessary to estimate watershed condition—in-channel, upslope, and vegetation—were only available for 55 watersheds, and as mentioned above, none of these have been resampled (Gallo and others 2005). Lacking the ability to assess the total changes in watershed conditions in the Plan area, Gallo and others (2005) examined changes associated with riparian vegetation and the amount of roads in the 250 watersheds selected for sampling by AREMP. They calculated partial changes in watershed condition scores based on these parameters for two periods, roughly 1994 and 2003 (fig. 9-3). The distribution of these scores did not change to a statistically significant degree during this time (Gallo and others 2005). This result is not surprising given the relatively short period in which the ACS has been in place and that condition scores only represented a partial change.

The proportion of watersheds (of those that exhibited a change) that had a higher condition in 2003 than in 1994 compared to those with lower scores was greater than expected by chance alone ($P < 0.01$, Wilcoxon signed-rank test [Sokal and Rohlf 1969]). The changes in condition scores for individual watersheds are shown in figure 9-3. The condition scores of about 18 of the 250 remained the same, 161 improved, and 71 decreased between 1994 and 2003 (fig. 9-3). The average changes in scores were relatively small, 0.09 (SD 0.19) for those that increased and 0.14 (SD 0.3) for those that decreased. The decreases in watershed condition scores were not simply related to management activities; the four watersheds that exhibited the largest decline had 30 to 60 percent of the watershed area burned.

The observed changes suggest some progress owing to the ACS. The ecological significance of this progress is not known, however. An understanding of the relation between changes in watershed scores is not established as yet. Also, because there are multiple factors influencing watershed condition, a change in score can occur from a combination of changes in the factors. This is certainly an area that lacks research.

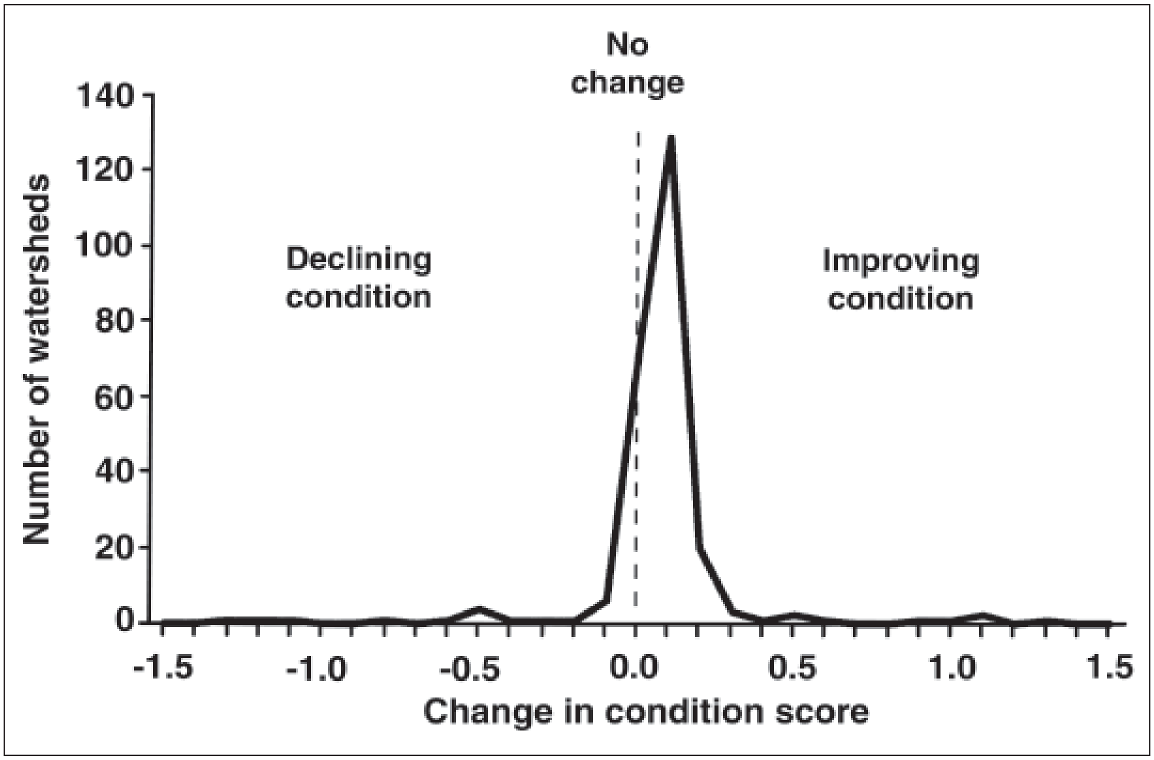

Figure 9-3—Changes in condition scores for 250 watersheds sampled as part of the aquatic and riparian effectiveness monitoring program of the Plan. Source: Gallo and others 2005.

The change in watershed condition scores during the first decade of the Plan was attributable primarily to changes in riparian vegetation and, more specifically, an increase in the number of large trees in riparian areas. The type, size, and distribution of vegetation in riparian and upslope areas influence the condition of aquatic ecosystems (Burnett 2001); generally, the bigger and more numerous the conifers the better the condition of the watershed. Gallo and others (2005) compared the number of trees >20 inches diameter at breast height (d.b.h.) in riparian (defined in the ACS as 150 feet on both sides of the stream on the west side of the Plan area and 90 feet on the east side) and upslope areas in the 250 watersheds in 1996 shortly after the Plan was implemented and in 2002. They used the geographic information system (GIS) layers developed by the Interagency Vegetation Mapping Project (IVMP) for Oregon and Washington and CalVeg for California, which were used to assess changes in late-successional and old-growth habitat (Moeur and others 2005). The number of large trees increased an estimated 2 to 4 percent during this time, most likely the result of tree growth into the >20-inch d.b.h. category (Gallo and others 2005). Concurrently, the amount of riparian area subjected to clearcutting on federal lands in Oregon and Washington in the Plan area was one-seventh the level of harvest in 1988-91 and even less compared to earlier periods (Gallo and others 2005). Projections of tree size on federally managed lands in the central and northern Oregon Coast range suggest that the number of large trees will continue to increase by 15 to 20 percent over the next 100 years under the current policy (Burnett and others, in press; Spies and others, in press).

Roads, permanent and temporary, can significantly affect aquatic ecosystems. They can result in increased rates of erosion (Furniss and others 1991, Potondy and others 1991), which, in turn, may affect populations of fish and other aquatic organisms (Quigley and Arbelbide 1997, Young and others 1991) and their habitats (Buffington and others 2002, Megahan and Kidd 1972). They can also form barriers to movements and can reduce interactions within and among populations of fish, amphibians, and other aquatic organisms (Trombulak and Frissell 1999).

The condition scores of watersheds as influenced by roads generally did not change significantly since the Plan was implemented (Gallo and others 2005). Three of the watersheds that had the largest increase in condition scores had the most extensive road decommissioning efforts (Gallo and others 2005). It is likely in the other cases that the amounts of road removed from any given watershed may have been relatively small and insufficient to change the watershed condition. There were 3,324 miles of road (3.6 percent of the total road mileage) decommissioned from 1995 to 2002 on FS and BLM lands (Baker and others, in press). An estimated 354 miles of new roads were constructed during the same time (Baker and others, in press). The effect of roads on aquatic ecosystems is also a function of road location; valley bottom roads affect aquatic ecosystems more than those on ridgetops (Wemple and others 2001). The provincial and subprovincial models that evaluate watershed condition differed widely in how they considered road location; some consider location, whereas others only consider the density of roads. Modification of those that currently do not consider road location may increase their sensitivity to restoration activities.

Several miles of roads have been "improved"—that is, actions were taken to reduce sediment delivery and improve stability or to allow more natural functioning of streams and flood plains, which includes improvements in drainage, stabilization, and relocation (Baker and others, in press). However, the watershed condition models currently do not take this into account because road improvement data are currently not available in the federal agencies' corporate databases.

Assessment of the ecological condition of an individual watershed was done on the basis of the entire landscape, which resulted, in many instances, in considering conditions on nonfederal lands. In many of the watersheds sampled by AREMP, there were a number of different owners, each with objectives and practices that differed from those of the Plan. Watersheds with more nonfederal ownership had the lowest changes in watershed condition scores (Gallo and others 2005). This influences the potential amount of change that can be expected in some watersheds and could be considered in future assessments of the effectiveness of the ACS.

One clear success of the ACS is a change in the general expectation of trends in aquatic conditions across the Plan area. There is general recognition that aquatic conditions deteriorated during the pre-Plan periods of intensive federal timber harvest and road building, and these declines were predicted to continue under many of the forest plans that the Plan amended. Several forest plans that were to be implemented before the Plan acknowledged that aquatic habitat would decline (for example, the Siuslaw National Forest [NF]) or have a high probability of declining (Umpqua NF, Siskiyou NF). Many of the activities that could have had negative effects on aquatic ecosystems, however, have decreased under the Plan. As cited earlier, the amount of timber harvest in riparian areas decreased substantially (Gallo and others 2005). Implementing the ACS appears also to have influenced the rate at which roads were built in the Plan area. The amount of roads decommissioned was 10 times the amount built between 1995 and 2002, the reverse of the trend before the Plan (Baker and others, in press). The ACS and the Plan appear to have prevented further degradation of watersheds that was likely under previous forest plans.

Riparian Reserves

The riparian reserve network established by the ACS encompasses an estimated 2.6 million acres (Baker and others, in press) and was one of the major changes from previous forest plans. Before the ACS, the riparian ecosystem was generally defined as 100 feet on either side of fish-bearing streams and some areas with high landslide risk. The riparian reserve network of the ACS was based on an "ecological functional" approach that identified zones of influence rather than set distances and included the entire stream network, not just fish-bearing streams. Consequently,

Example of how riparian habitat extends from the edge of a stream.

the riparian zone along streams was expanded to the height of two site-potential trees (or 300 feet) along fish-bearing streams and one tree height (or 150 feet) along permanently flowing and intermittent non-fish-bearing streams (USDA and USDI 1994). The latter undoubtedly contributed the greatest to the increased amount of area considered as the riparian reserve. More than 800 of the more than 1,100 organisms considered in FEMAT (1993) were found to be associated with the riparian reserve network. It was also suggested in FEMAT (1993) that the width of the riparian reserve on each side of headwater streams be equal to one-half the height of a site-potential tree, but it was changed to a full tree height in the ROD (USDA and USDI 1994) to increase the likelihood of persistence of habitat for aquatic and riparian-dependent organisms.

The initial riparian reserve network was expected to be interim, and activities within them were very restricted until a watershed analysis was completed. It appears, however, that the interim boundaries of the riparian reserves remained intact in the vast majority of watersheds (Baker and others, in press). The primary reasons offered for the relatively low harvest in the riparian reserve were that it was difficult to justify changing the interim boundaries or that there was no compelling justification for changing the interim boundaries. (It should be noted that harvest from the riparian reserve was not part of the estimates of potential timber harvest.) Baker and others (in press) found that agency personnel thought that "burden of proof [for changing interim boundaries] was too high." No explicit criteria for changing the boundaries were offered by the Forest Ecosystem Management Assessment Team (FEMAT 1993) or the ROD (USDA and USDI 1994), but tools are available now that can help identify the more ecologically important parts of the riparian and stream network from an aquatic perspective (such as Benda and others, n.d.). Because watershed analysis is an interdisciplinary endeavor, however, changes in the riparian reserve boundaries need to consider non-aquatic factors such as terrestrial and social concerns. Only a few watershed analyses considered these factors (such as Cissel and others 1998). The effect of the extent of the riparian reserves is probably most likely in the steeper more highly dissected landscapes, where the riparian reserves network is most extensive (FEMAT 1993).

Timber production, primarily in precommercial thinning, has occurred on an estimated 48,000 acres (1.8 percent of the estimated total area) of the riparian reserve (table 9-2). The volume of timber harvested is not known because agencies do not track it. Timber harvest was expected to occur in riparian reserves, but no level was specified by FEMAT (1993) or the ROD (USDA and USDI 1994). Harvest from the riparian reserve was not part of the estimated potential sale quantity of the Plan. Agency personnel thought that one of the primary reasons for the limited timber harvest in the riparian reserve was the difficulty in changing boundaries and in determining that there would be no adverse affects from the activities (Baker and others, in press).

Watershed Restoration

Watershed restoration efforts were expected to be a catalyst for initiating ecological recovery (FEMAT 1993). It was expected that restoration efforts would be comprehensive, addressing both protection of existing functioning aspects of a watershed and restoration of degraded or compromised aspects. It was recognized that it may not be possible for restoration efforts to restore every watershed or that some

Table 9-2—Estimated area of riparian reserve in which silvicultural activities have occurred during the first 10 years of the Plan

Administrative unit	Period	Treatment: Precommerical thin	Treatment: Regeneration harvest	Total
		Acres		
USDA Forest Service				
Region 6				
Mount Baker-Snoqualamie	1994-2000	1,100	0	1,100
Okanogan-Wenatchee	1994-2000	875	300	1,175
Gifford-Pinchot	1994-2004	600	0	600
Olympic	1994-2004	1,100	1,100	2,200
Mount Hood	1998-2004			1,200[a]
Deschutes	1997-2004	700	0	700
Willamette	1994-2004	6,600	125	6,725
Siuslaw	1994-2004	1,285	12,570	13,855
Umpqua	1994-2004	2,200	300	2,500
Siskiyou-Rogue River	2000-2004	1,902	0	1,902
Fremont-Winema	2003	0	0	400[b]
Estimated total		16,362	14,395	32,357
Region 5				
Klamath	1994-2004	4,598	781	5,379
Shasta-Trinity	1994-2004	1,701	515	2,216
Six Rivers	1994-2004	3,288	516	3,804
Mendocino	1994-2004	0	0	0
Estimated total		9,587	1,812	11,399
Bureau of Land Management				
Oregon-Washington				
Salem	1995-2003			797[b]
Coos Bay	1995-2003			1,326[b]
Eugene	1995-2003			520[b]
Roseburg	1995-2003			827[b]
Medford	1995-2003			663[b]
Estimated total				4,133
California				
Arcata	1995-2004	84	0	84
Ukiah	1995-2004	0	0	0
Estimated total		84		84
Estimated total				47,973

[a] Estimate was of 100 to 200 acres per year with no breakdown of treatment type.
[b] No breakdown of treatment type provided.

would only have limited success because of the extensive level of degradation. The impact of restoration efforts was not expected to be large or to be immediately visible. At the watershed scale, it may take an extended time to observe the effect of the restoration effort. The aggregate effect of watershed restoration effort, particularly those done during the initial phases of the ACS, may not be observable at the regional scale. Although it may appear that relatively large amounts of area have been restored, the reality is that this represents a small part of the total area that is degraded.

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A restoration project on Fiddle Creek (Siuslaw National Forest) where a portable yarder was used to pull logs into the creek from surrounding mature Douglas-fir stands to enhance spawning and rearing habitat for coho salmon.

It is not possible to accurately assess the regional effect of the numerous restoration efforts undertaken as part of the ACS. Gallo and others (2005) highlighted several watershed restoration efforts that were successful, but their impact cannot be discerned at the regional scale. The length of streams restored or made assessable to fish is also a relatively small fraction of the totals. However, the watersheds that had the largest improvement in condition scores were three that had relatively extensive road restoration programs (Gallo and others 2005). Similarly, Baker and others (in press) reported that almost 69,000 acres of riparian reserve were restored, primarily in Washington and Oregon, between 1998 and 2003. The total amount of area in riparian reserve in this area is not known, but the 69,000 acres represents a relatively small part (estimated at about 2.6 percent) of total area occupied by the riparian reserve. It is expected that as time passes, the effect of these restoration efforts that have been implemented already and those that may occur in the future will be more discernable.

Key Watersheds

Key watersheds (1) are intended to serve as refugia for aquatic organisms, particularly in the short term for at-risk fish populations; (2) have the greatest potential for restoration; or (3) provide sources of high-quality water (USDA and USDI 1994). Tier 1 key watersheds serve one of the first two purposes. These include 141 watersheds covering 8.1 million acres. Tier 2 key watersheds provide sources of high-quality water and include 23 watersheds covering about 1 million acres. Key watersheds were aligned with late-successional reserves as closely as possible to maximize ecological efficiency (USDA and USDI 1994) and to minimize the amount of area in which timber harvest activities were restricted.

A primary objective for the Tier 1 key watersheds was to aid in the recovery of ESA-listed fish, particularly in the short term (FEMAT 1993). Refugia that are areas of high-quality habitat and contain remnant populations are a cornerstone of conservation strategies. Past attempts to recover fish populations were generally unsuccessful because the focus was on fragmented areas of good habitat in stream reaches and not on a watershed perspective (Moyle and Sato 1991, Naiman and others 1992, Williams and others 1989). Tier 1 key watersheds currently in good condition were assumed to serve as anchors for potential recovery of depressed populations. Tier 1 key watersheds that had degraded conditions were judged to have the greatest potential for restoration and therefore become future sources of good habitat.

Key watersheds had greater increases in condition scores than did non-key watersheds (Gallo and others 2005). More than 70 percent of the key watersheds improved, whereas less than 50 percent of the non-key watersheds improved. The primary reason was that more than twice as many miles of roads were decommissioned in key watersheds compared to non-key watersheds. This result suggests that land management agencies appear to have treated key watersheds as priority areas for restoration, as stated in the ROD (USDA and USDI 1994).

Key watersheds were originally selected based on the professional judgment of fish biologists from the national forests and BLM districts covered by the Plan. No formal evaluation of the potential effectiveness of the network was conducted when the Plan was developed or since it was implemented. Fish populations in need of attention are clearly identified now, and it would be useful to see if the current system is beneficial to those fish in terms of the overall distribution as well as the suitability of individual watersheds.

New techniques are now available to aid in this assessment. For example, Burnett and others (2003) have developed a process to identify the potential of a watershed or stream reach to provide habitat for coho salmon and steelhead based on topographic features. In an analysis of a portion of the northern Oregon Coast Range, areas with the highest potential to provide habitat for coho salmon, an ESA candidate species, were primarily on private lands and for steelhead, which is not a listed species, on public lands. Analysis of Oregon State, BLM, and FS Pacific Northwest Region (R6) Forest Service Lands in the Oregon Coast Range (Peets and Doelker 2005) found that about 10 percent (155 miles) of the area with the best potential to provide habitat for coho salmon was on federally managed lands. A relatively small proportion of this habitat is found in key watersheds. Similar analyses in other areas could help determine the current effectiveness of the key watersheds.

Watershed Analyses

Watershed analysis was intended to provide the context for management activities in a particular watershed. It was to serve as the basis for developing project-specific proposals and determining restoration needs. It was envisioned in the ROD (USDA and USDI 1994) as analysis to involve individuals from the appropriate disciplines but not a decision-making process. The management agencies were expected to complete a watershed analysis before activities (except minor ones) were started in key watersheds and riparian reserves (USDA and USDI 1994b). The version of watershed analysis advocated in the Plan differed from the versions of watershed analyses that were used at the time (such as the Washington Forest Practices Board 1993) in that it involved disciplines and issues other than aquatic ones. Since the ROD (USDA and USDI 1994), several publications have examined the watershed analysis process and framework (Montgomery and others 1995, Reid 1998), but these analyses have been primarily from an aquatic perspective. A more comprehensive review and evaluation of watershed analyses could help improve processes and likely reduce costs while increasing the usefulness of the product.

Baker and others (in press) estimated that 89 percent of the watersheds (of a total of 550 watersheds) in the Plan area had completed watershed analyses by 2003 and that some unknown proportion of them had been revised at least once. This percentage seems high, given budget and personnel constraints that the land management agencies have faced. No formal assessment of watershed analyses has been done, but their quality and effectiveness likely differ widely. There is also the opportunity to reexamine the watershed analyses process to see if it can be conducted more efficiently and include not just a focus on the watershed of interest and what happens there but the context of the watershed in the basin. The latter is particularly relevant for the Plan to be implemented at a landscape scale.

Relevant New Science Information

Landscapes and Dynamic Ecosystems

The ACS was based on the best science available at the time. Much scientific literature on aquatic ecosystems, on the effects of human activities on them, and on conservation strategies for fish and other aquatic and riparian organisms has been produced since the Plan was implemented in 1994. Key science findings on the ecosystem and landscape dynamics and the historical range of variation (HRV) and on the ecological role of headwater streams are summarized here. These topics relate to ACS components and are particularly relevant to assessing the validity of the ACS components and other parts of the Plan and for considering future modifications. Not all of the relevant scientific literature is summarized or reviewed here. Documents that provide excellent reviews and synthesis on these and other relevant topics include Spence and others (1996), Naiman and Bilby (1998), National Research Council (1996), Gresswell (1999), and Everest and Reeves (in press.).

The ACS combined ecosystem and landscape perspectives to forge a management strategy that could be applied over broad heterogeneous areas. Before the ACS was developed, much of the management and research focus for fish ecology and conservation was on relatively small spatial scales, such as habitat units (Bisson and others 1982, Nickelson and others 1992) and reaches (Murphy and Koski 1989). At these scales, the needs of individual fish or communities are the primary interest. Williams and others (1989) found that no fish species listed under the ESA was ever recovered after listing and attributed this failure to the general focus of recovery efforts on habitat attributes rather than on restoring and conserving ecosystems. Thus, the developers of the ACS believed that shifting the focus to larger scales was necessary to aid in the recovery of freshwater habitats of listed and declining populations of anadromous salmon and trout and other fish in the range of the northern spotted owl. Since the ROD was approved (USDA and USDI 1994), a variety of sources, including interested citizens, interest groups, scientific review and evaluation groups (such as the Independent Multidisciplinary Scientific Team 1999, National Research Council 1996), regulatory agencies, and policy- and decisionmakers have called for developing policies and practices to manage the freshwater habitats of at-risk fish at ecosystem and landscape scales.

Understanding the differences and relation between scale and ecological organization is critical to implementing and evaluating the ACS. Allen and Hoekstra (1992) proposed a framework that emphasizes the role of the observer in choosing a scale of observation and deciding how to conceptually organize the parts and processes. By **scale**, they mean spatial or temporal extent. In contrast, **organization** is a subjective or definitional construct that invokes implicit, user-defined criteria. Ecological organization, such as ecosystem, landscape, or population, has meaning without any reference to a particular scale. For real-world management issues, both scale and organization should be made explicit. The intersection of the two creates a clear conceptual boundary that allows discourse and management to proceed.

Ecosystems and landscapes are levels of organization that are especially important within the ACS. Of the two, landscapes are the most tangible in that spatial proximity is the organizing principle (Allen and Hoekstra 1992), and the components of the landscape (such as forest stands, streams, clearings, roads, and so on) are readily apparent to human observers. From an aquatic perspective, the landscape of interest can be quite large and include multiple watersheds (Reeves and others 2002, 2004) but spatial patterns (that is, landscape attributes) can also be important at smaller scales. In contrast to landscapes, ecosystems are organized around the interaction between physical and biological components. The processes and material flows that are the substance of the ecosystem organization may be difficult to observe. Reeves and others (2002, 2004) used the directional flow of water to define aquatic ecosystems, and bounded their spatial extent by using watersheds, defined by FEMAT (1993) as subbasins of 20 to 200 square miles.

In conventional terms, ecosystem management often refers to managing large geographic areas, which has contributed to the confusion between ecosystems and scale. Lugo and others (1999) reiterated the major paradigms of ecosystem management, including:

- Ecosystems are not steady state but are constantly changing through time.
- Ecosystems should be managed from the perspective of resilience, as opposed to stability.
- Disturbance is an integral part of any ecosystem and is required to maintain ecosystems.

Clearly, these principles are not tied to a particular scale and would apply equally well to a single watershed and to a region.

Ecologists and managers recognize the dynamic nature of terrestrial ecosystems and how the associated biota and physical characteristics change through time. They are also aware that the range of conditions an ecosystem experiences is determined to a large extent by the disturbance it experiences (such as wildfire, hurricane, and timber harvest and associated activities). Natural disturbances can increase biological diversity, be crucial for the persistence of some organisms and the habitat that support them, and express and maintain key ecological processes (Turner and others 1994). Disturbances invariably involve a disruption in existing connections among ecosystem components, which leads to the release of nutrients and other materials and the potential for reorganization (Holling 1992). Resilience is the ability of an ecosystem to recover after a disturbance (Lugo and others 1999). An ecosystem demonstrates resilience after a disturbance when the environmental conditions after the disturbance are within the range of conditions that the system exhibited before the disturbance. Reduced resilience may result in both the extirpation of some species and increases in species favored by available habitats (Hansen and Urban 1992, Harrison and Quinn 1989, Levin 1974).

Given the role of disturbance in ecosystem dynamics, it is reasonable to expect ecosystems to be most resilient to the types of disturbance under which an ecosystem developed. Thus, one approach to minimizing management impacts is to make the combination of management actions and natural disturbance resemble the natural disturbance regime as closely as possible (Lindenmayer and Franklin 2002). Factors considered in developing ecosystem management plans and policies include the frequency, magnitude (Hobbs and Huenneke 1992, White and Pickett 1985), and legacy (that is, the conditions and materials that exist immediately following the disturbance) (Lindenmayer and Franklin 2002, Reeves and others 1995) of disturbance regimes in managed ecosystems. The effects of land management on the ecosystem depend on how closely the management disturbance regime resembles the natural disturbance regime with regard to these factors. Everest and Reeves (in press) reported they found little evidence or studies in the peer-reviewed literature of fish populations or habitat responding positively to or remaining unchanged as a result of intensive land management activities.

Landscape management strives to maintain a variety of ecological states in some desired spatial and temporal distribution. Management at that scale addresses the dynamics of individual ecosystems, the external factors that influence the ecosystems that compose the landscape, and the dynamics of the aggregate of ecosystems (Concannon and others 1999). To do this, landscape management could consider developing a variety of conditions or states in individual ecosystems within the landscape and the pattern resulting from the range of ecological conditions that are present (Gosz and others 1999). The specific features of the ecological states and their temporal and spatial distribution will vary with the objectives for a given landscape.

Scientists and managers have worked in concert to try to develop tools and techniques to facilitate landscape management. One such approach relies on HRV, which is conditions that a level of organization experiences naturally over an extended time, from several decades to centuries. The term is often used for individual components of an ecosystem, such as the number of pieces of large wood or number of pools, or for ecological states. The usual manner for establishing the HRV for a component of interest is to

Streams with the greatest diversity of juvenile salmonids can be in midsuccessional forests.

measure the parameter in pristine systems (systems with little or no history of effects from human activities). The HRV is represented by the distribution of these values. This range is well established for terrestrial systems (early-, mid-, and late-successional) (for example, Wimberly and others 2000), but it is not incorporated into aquatic ecology.

Spatial scale is an important, but not well recognized, element of the HRV. The HRV is generally inversely related to spatial scale (Wimberly and others 2000) because it represents the range of average condition for the area. The smaller the spatial scale, the larger is the HRV and, conversely, the larger the scale, the smaller the HRV. Hierarchy theory provides the rationale for this relation and is an appropriate framework for considering ecosystem issues at and between different spatial scales (Overton 1977). Each level in the hierarchy of an ecosystem has unique properties and behaviors that are expressed over time. The properties of lower levels of organization are "averaged, filtered, and smoothed" as they are aggregated at higher levels of organization (O'Neill and others 1986). Consequently, the range and variability in the properties and conditions of the system are relatively wide at lower levels of organization compared to higher levels (Wimberly and others 2000). A recent paper on the concept of HRV (Landres and others 1999), and another estimating HRVs (Keane and others 2002) did not consider the effect of spatial scales.

Wimberly and others (2000) illustrated the HRV of successional vegetative stages in the Oregon Coast Range at multiple spatial scales. They estimated (based on a model of fire frequency and intensity and vegetation response over 3,000 years) that, at the scale of a late-successional reserve (100,000 acres), the range in the amount of old growth was from 0 to 100 percent. For an area roughly the size of a national forest (750,000 acres), the HRV for old-growth was from about 10 to 75 percent. The HRV for the Coast Range (5,600,000 acres) was 30 to 55 percent. The large, infrequent disturbance events generally affect relatively small portions of the landscape at any one time. Thus, having the entire area affected by a disturbance event at the same time is highly unlikely. The asynchronous nature of the disturbance events results in a series of patches of vegetation of different ages. This narrows the HRV because of the reduced likelihood of finding the entire area either with no or all old-growth at any particular time. The HRV is further reduced at larger spatial scales because disturbance events are even more desynchronized. Consequently, the range and variability in the properties and conditions of the system are relatively wide at lower levels of organization compared to higher levels (Wimberly and others 2000).

Spatial scale and implementation problems—
The developers of the Aquatic Conservation Strategy (FEMAT 1993) and the ROD (USDA and USDI 1994) did not fully recognize the implications of shifts to the landscape scale of the Plan and the ACS and its objectives, which has led to much confusion with the ACS objectives. The land management and regulatory agencies initially attempted to meet all of the ACS objectives for any action, which led to many problems and was the impetus for the final environmental impact statement (FSEIS) that clarified the intent of the ACS (USDA and USDI 2003). The objectives provide a framework for managing aquatic ecosystems at multiple spatial scales, but they became a checklist to evaluate the acceptability of any proposed action at the site scale. The objectives were not intended to be a hard set of criteria that could be applied equally at

each spatial scale of concern. This application was technically impossible because the objectives include a range of spatial scales, and the relation among scales was not considered. For example, objectives 1, 2, and 9 (listed on page 1) deal with landscape and regional objectives. The others deal with ecosystems. Determining consistency with the ACS at the site or small watershed scale is not as simple as assuming that all sites or small watersheds need to be in "good" condition at all times and that any actions that "degrade" a site or small watershed violates the ACS objectives. Conditions at the small scale range widely over time. The overriding objective is to have a mix of conditions at the broader scale, which requires that individual sites each exhibit a range of conditions over time.

Consistency at the small scale (site or subwatershed) is determined by the range of variability established at the larger scales (watershed or basin). The range of variability at the larger scales is the frequency distribution of conditions at the smaller scale that support acceptable amounts of habitat for populations of fish and other aquatic organisms. Watershed analysis was expected to establish the range of variability at the different scales, which was to be used to determine if proposed actions were consistent with the ACS. The focus of watershed analyses, however, has been primarily on the watershed; they fail to provide the context of the watershed in the larger landscape.

The recent supplemental FSEIS that clarifies the original intent of the ACS (USDA and USDI 2003) discusses the importance of considering multiple scales. Dealing with this issue is important if the ACS is to succeed.

Dynamics and aquatic ecosystems—
The perspective that aquatic systems are dynamic, particularly at the ecosystem and landscape scales, was not widely recognized, and no time was left to work out the implications when the ACS was developed. Before it was developed, a small number of researchers recognized that biotic (Resh and others 1988) and physical (Swanson and others 1988) components of aquatic systems, particularly at the smaller spatial scales, were influenced by relatively infrequent events, such as floods. One reason for the absence of the recognition of dynamics of aquatic ecosystems is that the major paradigms that shape our thinking about aquatic systems, such as the River Continuum Concept (Vannote and others 1980), do not consider time or its influence. Similarly, classification schemes such as that of Rosgen (1994) identify a single set of conditions for a given stream or reach type; how these conditions may vary over time is not considered. The physical and biological relations were assumed to be fixed in time and to be unchanging. From this perspective, watershed processes were assumed to be continuous and predictable, implying that the biophysical changes along the riverine network were easily predictable and modeled (for example, Newbold and others 1982, Vannote and others 1980).

Frissell and others (1986) described the hierarchical organization of aquatic ecosystems and identified a temporal component associated with each spatial scale; the finer the scale, the shorter the response period. However, they did not consider how features of a given level in the hierarchy respond over time. A more recent examination of the hierarchical organization of streams by Fausch and others (2002) also recognized that time is a critical factor to consider when examining aquatic ecosystems. They did not integrate time into their description of stream systems, however. The failure to incorporate time into consideration of aquatic systems, especially at higher levels of organization, has led to an implied expectation that stream ecosystems experience a limited, if not a single, set of conditions and that this condition is relatively stable through time.

The foundation for the ACS focus on ecological processes and dynamics came from Naiman and others (1992). They hypothesized that different parts of a watershed (headwaters, middle portion, and lower portion) had different disturbance regimes, based on the frequency and magnitude of disturbance. They also believed that the landscape would have watersheds with a range of conditions because of the asynchronous nature of large and infrequent disturbance events, such as wildfire and flooding. More recent studies have proposed that stream systems are complex networks with branched shapes rather than linear systems, which provides a better understanding of the ecological processes that link riparian and aquatic ecosystems (Benda and others 2004, Fisher 1997). This perspective implies that aquatic ecosystems are not steady state; rather, streams are invariably dynamic, and their conditions vary in space and time because of periodic events such as wildfire and large storms and subsequent floods, hillslope failures, landslides, and debris flows. The signatures of these events are most visible at tributary junctions, which also are sites of high biological diversity (Benda and others 2004).

Since the Plan was implemented, several studies examined the dynamics of aquatic ecosystems in space and time. Reeves and others (1995) described the range of conditions of watershed in the Tyee sandstones of the central Oregon coast in response to wildfire. They found a range of conditions from less productive to more productive. The most complex habitat and biologically diverse fish assemblage was found in a stream that was about 160 to 180 years from the last major wildfire disturbance. Simplified habitat conditions and less diverse fish assemblages were found in streams that were more recently disturbed (80 to 100 years) and that had not been disturbed for a longer period (300+ years). This pattern appears to have resulted from the change in amounts of wood and sediment over time. Immediately after a wildfire, channels are filled with sediments and, as result, much of the wood is buried. The amount of sediment decreases over time because it is eroded and exported from the system faster than it is being delivered to the channel from hillslopes stabilized by forest recovery. Habitat conditions improve as the amount of sediment declines and wood increases either from recruitment or excavation. After extended times, however, sediment declines to amounts that do not support development of pools.

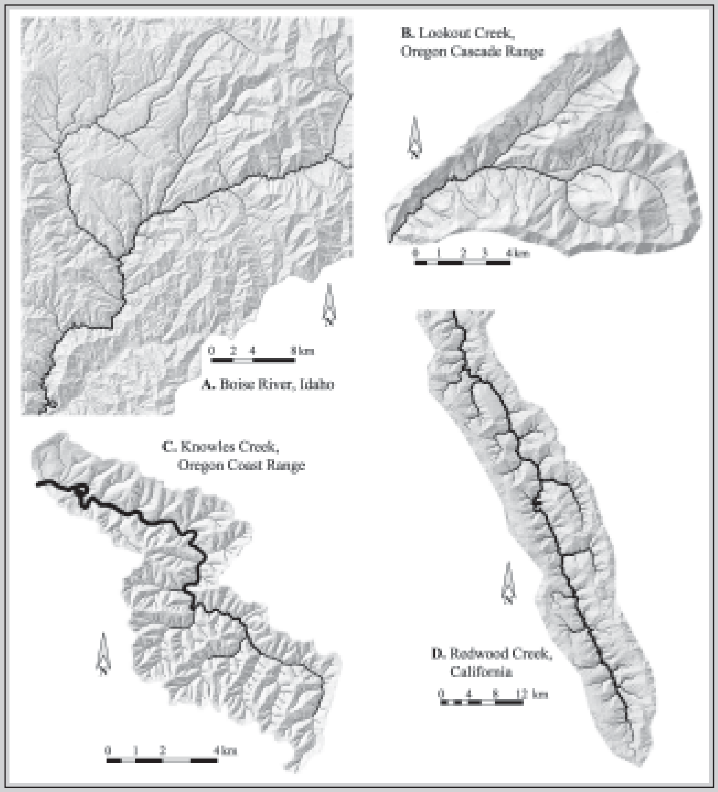
Headwater streams in the same region studied by Reeves and others (1995) exhibited a different pattern of variation in conditions over time (May and Gresswell 2004). Channels that had not been disturbed for several decades were filled with gravel and wood. Recently disturbed channels were devoid of sediment and wood and were scoured to bedrock. Benda and Dunne (1997a, 1997b) and Benda and others (1998) described a similar distribution of in-channel sediment conditions in watersheds over time. Benda and others (2003b) examined the effects of landslides after wildfires on aquatic ecosystems in the Boise River, Idaho. The landslides significantly affected the channel, creating complex channels and delivering large amounts of wood to the channel. As was observed in the Oregon Coast Range (Reeves and others 1995), channel conditions are expected to vary widely over time. See box on next page for further discussion on the variation among watersheds in the response to large disturbance events.

Several factors influenced the responses of these studies. The physical legacy of the disturbances was important; wood in headwater channels accumulated gravel and began the refilling process. Wood and sediment delivered to fish-bearing streams from headwater channels facilitated development of conditions favorable to fish over time. Refugia can be areas that afford protection to individuals during the disturbance event and in the affected area or in nearby areas that are not affected and provide sources of individuals to reestablish populations in affected areas (Roghair and others 2002, Sedell and others 1990). The life history (Dolloff and others 1994) and habitat requirements (Reeves and others 1993, 2002) can also influence the immediate and long-term responses of a population to disturbance events.

Implications—

The dynamic view of aquatic ecosystems and landscapes just described is at odds with the experience and perspectives of some in the research, management, and regulatory agencies and the public. Montgomery and others (2003) questioned the role that dynamics play under natural conditions. They contend that the role of disturbances such as debris flows in old-growth forests is limited. They believe that models of disturbance ecology for salmonids, such as that presented by Reeves and others (1995), need to recognize differences in the disturbance dynamics of old-growth and industrial forests to “provide credible avenues

Variation in Susceptibility to and Response of Watersheds in the Northwest Forest Plan Area to Natural Disturbances



Figures from L.E. Benda. 2005. Geomorphologist, Earth Systems Institute, Mount Shasta, CA.

The recognition that dynamic processes, such as periodic large disturbances, have strong impacts on aquatic ecosystems represents a relatively new perspective (for example, Naiman and others 1992, Resh and others 1988). Moderate to large-scale fluctuations in the movement and storage of sediment and wood during these events can create habitats and features that have long-term implications for system productivity (Benda and others 2003b). There is wide variation in the response of aquatic ecosystems to given disturbance events depending on the frequency and magnitude of the disturbance event and a watershed's local topography, channel type (Montgomery and Buffington 1993), shape and configuration of the stream network (Benda and others 2004), and soil and rock type. The four watersheds shown here illustrate some of this variation. The North Fork of the Boise River (A) is outside the Plan area but is representative of parts of the dryer portions of the Plan area. In these steeper systems, periodic disturbances are relatively frequent because of wildfires, but the disturbances have moderate impacts on the channel, and the system is relatively resilient. Postfire sedimentation can lead to large-scale channel changes in small streams and local changes in large channels at tributary confluences (Benda and others 2003a).

Lookout Creek (B) is on the west side of the Cascade Mountains. It is in an area of hard rock and has a relatively limited stream network. Additionally, the channel gradient is relatively steep. Wildfires and floods, the primary natural disturbances, are relatively infrequent but large. The channel is generally resilient to disturbances, except at some lower gradients spots within the network. The range of conditions observed within the channel is relatively limited.

Knowles Creek (C) is in the soft rock Tyee sandstones of the central Oregon coast, similar to the streams studies by Reeves and others (1995). The primary natural disturbances are infrequent, but large, floods and wildfires. The watershed is characterized by relatively steep tributaries and a lower gradient main channel. The latter results in the deposition of large amounts of wood and sediment in the channel, which experiences a wide range of conditions over time as a result of disturbances events.

Redwood Creek (D) is in northern California. The basin is long and narrow and has a large natural sediment load. The upper portion of the basin is relatively narrow so material moves through it relatively quickly; as a result, inchannel conditions are relatively stable. The lower end is lower gradient and, as a result, is a depositional area. Consequently, there can be a wide variation in habitat conditions over time.

for determining risk associated with land management in steep forested terrain" (Montgomery and others 2003). They believe that "management recommendations based on evolutionary interpretations that are themselves based on a disturbance model primarily applicable to industrial forests may prove misleading" (Montgomery and others 2003).

Clearly, obstacles remain in the path toward a fully implemented ACS that is consistent with the vision articulated in FEMAT (1993) and the ROD (USDA and USDI 1994). Experience has shown that the ACS accommodates a management model that is an alternative to site-specific standards and guidelines. Reeves and others (1995, 1998, 2002) presented an example for the Oregon Coast Range. Another example was for the central Oregon Cascade Mountains (Cissel and others 1998). Progress could be facilitated by attention to several pressing issues.

Focusing policies for and management of aquatic ecosystems at the landscape scale presents challenges to policymakers, managers, and regulators (Reeves and others 2002). A fuller exposition of the HRV would provide a richer understanding of how the conditions of aquatic ecosystems vary through time at all spatial scales and the ecological, social, and economic implications of this variation. Currently, the historical range of the conditions of aquatic ecosystems is assumed to be small and, generally, to be good for habitat. Many managers, regulators, and interested citizens expect aquatic conditions to be relatively constant through time and to be good in all systems at the same time. More realistic expectations would aid both implementing and assessing the ACS.

The interaction of multiple processes operating at multiple spatial and temporal scales is difficult to understand, and even more difficult to incorporate into a coherent management strategy. Understanding the relation among different spatial scales is necessary to successfully assess the effects of management policies and activities on aquatic ecosystems in the future. The challenge is to develop a process that not only looks at current aquatic conditions but also:

- Looks broadly to determine the large context.
- Looks historically to assess past trajectories of the systems and natural history.
- Looks ahead to identify potential threats and expectations.

This perspective would allow for a more integrated response to basic questions such as Where are we, where do we want to go, and how do we get there? Watershed assessment is a logical forum to explore these questions.

The failure to recognize the landscape focus of the ACS has precluded consideration of potential options for different management practices and policies. Some practices and policies for managing aquatic ecosystems under the Plan are in many ways similar to those before the Plan. For example, cumulative effects are still determined at the 6^{th}- to 7^{th}-field watershed scale. Thus, management activities are dispersed among watersheds to avoid potential negative effects (fig. 9-4a). But this approach is not necessarily consistent with the landscape focus of the ACS. A potential alternative option was offered by Reeves and others (1995). They suggested that management activities be concentrated in a given watershed for an extended period (fig. 9-4b), rather than dispersed over wider areas. Grant (1990) modeled both scenarios to determine their effects on the pattern of peak flows and found little difference between the two. Concentrating rather than dispersing activities may also confer benefits to terrestrial organisms that require late-successional forests (Franklin and Formann 1987).

Specifying the spatial scale is important when range of natural variation and cumulative effects are discussed or evaluated. At small scales, the HRV is very large, so, except for the most extreme impacts, no cumulative effects may result from management actions. Most assessments of the effects of human activities are made at relatively small scales. Failure to recognize the relation between space and HRV undoubtedly contributed to the current confusion about the ACS and the scales at which it is applied and how compliance is measured.

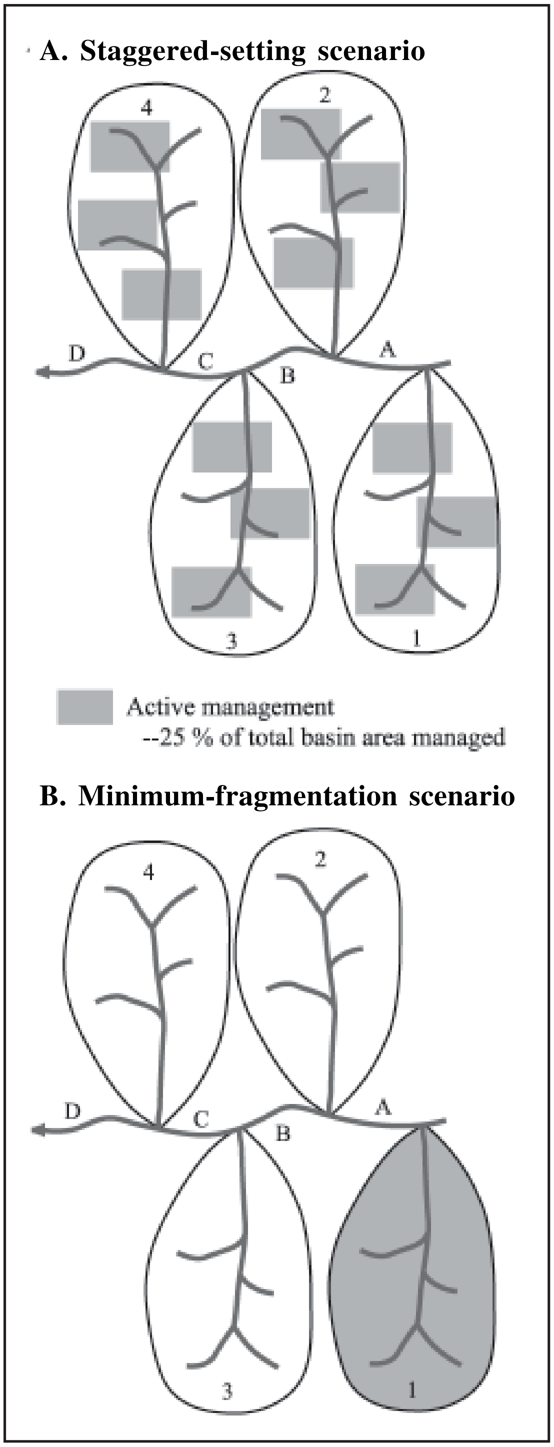


Figure 9-4—Potential approaches to watershed (A) and landscape (B) management. Source: Grant 1990.

The view of aquatic ecosystems as dynamic entities has implications for the network of key watersheds and the potential long-term success of the ACS. First, an underlying assumption about key watersheds was that streams in old-growth forests contained the best habitats for fish. Many of the key watersheds in option 9 of FEMAT (1993) were associated with late-successional reserves. Reeves and others (1995) suggested that streams in mid-successional forests were more productive than those in old-growth forests in the Oregon Coast Range. Whether this pattern is found in other areas is not known at present and could be a future research emphasis. The second implication of treating aquatic ecosystems as dynamic entities deals with the expectations for reserves in dynamic landscapes. Reserves in such a setting cannot be expected to persist for long periods. How future key watersheds will develop and where in the landscape they will occur are key questions for managers, regulators, and researchers to consider.

Riparian Reserves

Ecological functions and distance—
The generalized curves (fig. 9-5) developed in FEMAT (1993) were developed by examining the available scientific literature about key ecological processes in riparian ecosystems. The effects of riparian vegetation decreased with an increasing distance from the streambank (FEMAT 1993). Generally, most ecological processes occurred within 100 feet (about two-thirds the height of a site-potential tree) (fig. 9-5).

An exception was large wood (fig. 9-5a). Large wood provides a crucial ecological function (see Bilby and Bisson 1998, Spence and others 1996) in aquatic ecosystems in the Plan area and is readily acknowledged by land management and regulatory agencies. In developing the generalized curve for wood sources, trees were assumed to reach a stream from a slope distance equal to the height of the tree (FEMAT 1993). Implicit in this assumption, but unstated by FEMAT (1993), was that trees in the riparian zone farthest from the channel would not immediately be

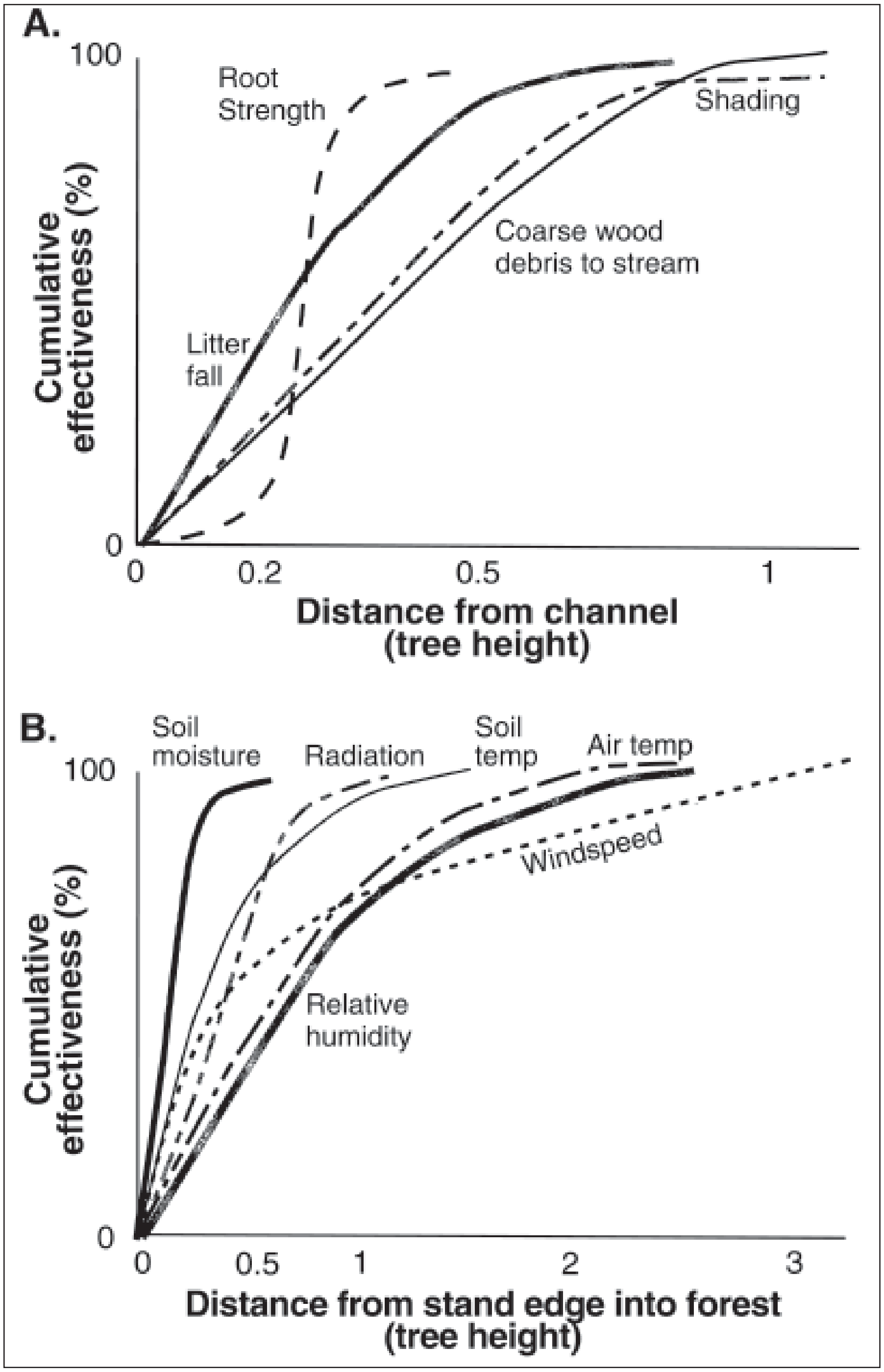


Figure 9-5—Generalized ecological functions in riparian zones as a distance from the stream. Source: FEMAT 1993.

in the current stream channel. These trees could either be recruited over time to the channel or, with wide valley floors, the channel would migrate over time and such pieces could then be in the channel. Bilby and Bisson (1998) noted that the latter process may be an important source of wood for streams in some areas.

Recognition of the role and importance of down wood in riparian areas has increased since the ACS was implemented. Down wood, particularly larger pieces, provides required high-moisture microhabitats for many riparian-associated amphibians (Pilliod and others 2003). It also provides habitat for several species of birds and small mammals found in riparian areas (Kelsey and West 1998). And down wood may collect and impede the movement of finer sediment into streams, preventing fine sediment from reaching streams where it can affect habitat conditions and biota (see references in McIver and Starr 2001, Wondzell and King 2003). This effect may be particularly important in areas where chronic overland erosional processes dominate, which are very rare in the Plan area except after intense fire or severe management disturbance. Trees in the riparian area farthest from the channel are sources of this down wood.

Pete Bisson

Carcasses of salmon and trout provide nutrients for riparian vegetation and a number of aquatic and terrestrial organisms.

Microclimate conditions in riparian areas was another ecological function in addition to wood sources that occurred beyond 100 feet (a distance of about two-thirds of the height of a site potential tree) (fig. 9-5b). Based on the work of Chen (1991), the developers of the ACS (FEMAT 1993) argued wider buffers may be needed to maintain interior microclimatic conditions. Subsequent work by Brosofske and others (1997) supported this contention. Maintaining favorable microhabitat conditions in riparian areas is also important for wildlife species (Kelsey and West 1998).

Headwater streams—

The riparian reserve was one of the cornerstones of the ACS. The riparian reserve network included fish-bearing streams, which had been the focus of management of aquatic ecosystems before FEMAT, as well as small, fishless headwater streams. The latter generally make up 70 percent or more of the stream network (Gomi and others 2002). Before the ACS, these streams were not widely recognized as part of the aquatic ecosystem, but knowledge about and recognition of the ecological importance of headwater streams has increased since then. They are sources of sediment (Benda and Dunne 1997a, 1997b; Zimmerman and Church 2001) and wood (Reeves and others 2003) for fish-bearing streams. They provide habitat for several species of native amphibians (Kelsey and West 1998) and macroinvertebrates (Meyer and Wallace 2001), including recently discovered species (Dieterich and Anderson 2000), and may be important sources of food for fish (Wipfli and Gregovich 2002). Small streams are also storage and processing sites of nutrients and organic matter, important components of the energy base for organisms used by fish for food (Kiffney and others 2000, Wallace and others 1995, Webster and others 1999, Wipfli and Gregovich 2002).

Headwater streams are among the most dynamic portions of the aquatic ecosystems (Naiman and others 1992). Tributary junctions between headwater streams and larger channels are important nodes for regulating material flows in a watershed (Benda and others 2004, Gomi and others 2002) and are the locations where site-scale effects from management activities are often observed. These locations have unique hydrologic, geomorphic, and biological attributes. The movement of sediment, wood, and other materials through these locations results in sites of high biodiversity (Johnson and others 1995, Minshall and others 1985). Habitat in these sites may also range from simple to complex, depending on time from the disturbance (such as landslides and debris flows) and the types and amount of materials delivered to the channel.

Large wood is an important element of stream and river ecosystems. It forms and influences the size and frequency of habitat units for fish and other organisms that depend on aquatic and riparian habitats (Bilby and Bisson 1998, Bilby and Ward 1989, Wallace and others 1995). The size of pieces and amount of wood in the channel also influences the abundance, biomass, and movement of fish (Fausch and Northcote 1992, Harvey and Nakamoto 1998, Harvey and others 1999, Murphy and others 1985, Roni and Quinn 2001). Wood enters streams via chronic and episodic processes (Bisson and others 1987). Chronic processes, such as tree mortality and bank undercutting (Bilby and Bisson 1998, Grette 1985, Murphy and Koski 1989), generally introduce single pieces or relatively small numbers of trees at frequent intervals. Episodic processes usually add large amounts of wood to streams in big but infrequent events, such as windthrow (Harmon and others 1986), wildfire (Agee 1993), severe floods, and landslides and debris flows (Keller and Swanson 1979, May 2002, Reeves and others 2003).

Examinations of wood sources in streams (such as McDade and others 1990, Murphy and Koski 1989, Robison and Beschta 1990) have focused until recently on chronic input from the immediately adjacent riparian zone. Such studies concluded that most of the wood found in streams was derived from within a distance of about 100 feet. Riparian management in forest plans developed before the Plan was based primarily on these cited studies and assumed that most of the wood found in streams came from within 100 feet of the stream. The studies on which this assumption was made, however, either did not consider episodic sources of wood (such as Van Sickle and Gregory 1990) or did not sample study reaches influenced by upslope sources (such as McDade and others 1990). The assumption that all wood came from within 100 feet of the channel based in the cited studies is incorrect, and the potential effectiveness of plans and policies based on it are questionable.

In steep terrain, which is found on much of the Plan area, landslides and debris flows are potentially important mechanisms for delivering sediment and wood from hillslopes and small headwater channels to valley-bottom streams. Reeves and others (2003) found that an estimated 65 percent of the number of pieces and 46 percent of the total volume of wood in a pristine watershed in coastal Oregon came from outside the riparian zone immediately adjacent to the fish-bearing stream. More than 80 percent of the total number of pieces of wood in a western Washington stream (Benda and others 2003b) and a northern California stream (Benda and others 2002) were from upslope sources. Other studies, such as May (2002) and Benda and others (2003a), found large amounts of wood from upslope sources in streams in the Oregon Coast Range and Idaho, respectively.

Pieces of large wood delivered from upslope areas are generally smaller than those originating from the riparian zones along fish-bearing streams. Reeves and others (2003) found that the mean volume of a piece of large wood from upslope areas was one-third the mean size of pieces from stream-adjacent riparian areas in a coastal Oregon stream. Difference in mean size is likely attributable to fire history and other stand-resetting events. Hillslopes are more susceptible to fire and burn more frequently than streamside riparian zones (Agee 1993). Thus, trees in the streamside riparian zone may be disturbed less frequently and achieve larger sizes than upslope trees.

Geomorphic features of a watershed influence the potential contribution of upslope wood sources. Steeper, more highly dissected watersheds will likely have a greater proportion of wood coming from upslope sources than will watersheds with lower gradients. Murphy and Koski (1989) and Martin and Benda (2001) found that upslope sources of wood composed a relatively small proportion of the total wood in streams that they examined in Alaska. The watershed studied by Martin and Benda (2001) had a wide valley floor, so wood was deposited along valley floors away from the main channel. In contrast, Benda and others (2003a) found that wood delivered in landslides after wildfires was deposited in wide valley reaches in the Boise River, Idaho. In a central Oregon coast stream, Reeves and others (2003) found that the amount of upslope-derived wood was greatest in reaches with narrow valley floors.

Even in watersheds where the potential contribution from upslope sources of wood is high, the ability of individual upslope sources to contribute wood to fish-bearing streams can differ widely. Benda and Cundy (1990) identified the features of first-and second-order channels with the greatest potential to deliver sediment and wood to fish-bearing streams in the central Oregon coast. The primary features were gradients of 8 to 10 percent with tributary junction angles $<45^{o}$. These features can be identified from Digital Elevation Models (DEMs) and topographic maps. Benda and others (N.d.) have developed a process that uses information from DEMs to develop basin-specific information for stratifying landscapes for varying intensity of resource management, identifying ecologically significant terrain for conservation, and prioritizing watershed and instream restoration and monitoring activities.

The presence of large wood from headwater streams influences the behavior of landslides and debris flows and the response of the channel to such events. Large wood in debris flows and landslides influences the runout length of these events (Lancaster and others 2003). Debris flows without wood move faster and longer distances than those with wood, and they are less likely to stop high in the stream network and to reach fish-bearing channels. A debris flow without wood is likely to be primarily a concentrated slurry of sediments of varying sizes that can move at relatively high speeds over long distances scouring substrate and wood from the affected channels. These types of flows are more likely to negatively affect fish-bearing channels rather than have potential favorable effects that result from the presence of wood. They can further delay or impede the development of favorable conditions for fish and other aquatic organisms.

Over time, headwater depressions and channels are filled with material from the surrounding hillslopes, including large wood that falls into these channels, forming obstructions behind which sediments accumulate (Benda and Cundy 1990, May and Gresswell 2004). These areas are evacuated following a landslide or debris flow. This cycle of filling and emptying results in a punctuated movement of sediment and wood to larger, fish-bearing streams (Benda and others 1998), which is—at least, in part—responsible for the long-term productivity of many aquatic ecosystems (Benda and others 2003a, Hogan and others 1998, Reeves and others 1995). The absence of wood to replenish the refilling process may result in a chronic movement of sediment to larger channels, which could lead to those channels developing different characteristics than those that occurred before forest management. Such conditions could be outside the range of watershed conditions to which native biota are adapted (Beschta and others 2004).

Fire and riparian and aquatic ecosystems—
The issue of fire and aquatic ecosystems was given little consideration by the Aquatic Conservation Plan's developers (FEMAT 1993), primarily because the potential threat of fire to aquatic ecosystems was not widely recognized at that time. Since then, numerous studies have examined the effect of fire on upland ecosystems, but relatively few examined aquatic and riparian ecosystems. Those studies that considered riparian areas generally focused on perennial streams, and the specific results differ with geographic location. In general, the frequency and

magnitude (following the definitions of Agee 1993) of fires in riparian areas is less than in adjacent upslope areas. Differences between fire effects on riparian and upland areas are less in regions with more frequent and less severe fires compared to locations where the fire return interval is larger and the fires are more severe. Fire in riparian areas along intermittent streams has not been studied, most likely because the inclusion of these areas as part of the riparian systems is only recently beginning to be recognized. Assuming that the effects of fire on the riparian zones of ephemeral and intermittent streams are similar to fire effects on upland plant communities is probably safe; however, I acknowledge that much additional research is needed.

Wildfire can profoundly affect watersheds and streams and associated aquatic organisms. The immediate effects of severe fires that burn through riparian areas and across small streams may include high mortality or emigration of fishes and other organisms caused by direct heating and changes in water chemistry (Minshall and others 1997, Rieman and Clayton 1997, Spencer and others 2003). Subsequent effects associated with the loss of vegetation and infiltration capacity of soils may include increased erosion, changes in the timing and amount of runoff, elevated stream temperatures and changes in the structure of stream channels (Benda and others 2003a, Wondzell and King 2003). The nature of these changes depends on the extent, continuity, and severity of the fire, and on lithology, landform, and local climate (Luce, in press; Rieman and Clayton 1997; Swanson and others 1988). A severe fire burning through dense fuels can produce extensive areas of hydrophobic soils (DeBano and others 1998). If a large storm follows in steep, highly dissected terrain, the result can be massive erosion and debris or hyper-concentrated flows that completely reorganize entire segments of mountain streams and deposit large volumes of sediment in lower gradient reaches (Benda and others 2003a).

Whether fire is viewed as ecologically catastrophic, however, is a matter of context and scale. Following the Boise fire in central Idaho, most fish populations rebounded quickly, in part through dispersal from unburned stream refugia (Rieman and Clayton 1997). Roughly 10 years after the disturbance, little evidence remains to suggest that the distribution and abundance of fishes in these streams are fundamentally different from similar-sized unburned streams. Beneficial effects of fire, such as increased primary productivity and invertebrate abundances, may offer mechanisms for individual fish to cope with potentially stressful conditions (such as high temperatures) in disturbed streams. Further, on timescales of decades to millennia, large disturbances have been common in these landscapes. Fishes and other species probably evolved mechanisms such as dispersal and plasticity in life history that allow them to recover (Dunham and others 2003, Reeves and others 1995).

Additionally, physical complexity in a stream may increase after a wildfire. Recent work has shown that fire and subsequent hydrologic events can contribute wood and coarse sediment necessary to create and maintain productive instream habitats (Bisson and others 2003, Reeves and others 1995). Benda and others (2003a), for example, have shown how mass erosion and deposition at tributary junctions can produce important heterogeneity in channel structure. Natural disturbances interacting with complex terrain has been linked to a changing mosaic of habitat conditions in both terrestrial and aquatic systems (Bisson and others 2003, Miller and others 2003, Reeves and others 1995). This variation of conditions in space and time may be the key to evolving and maintaining biological diversity and, ultimately, the resilience and productivity of many aquatic populations and communities (Bisson and others 2003, Dunham and others 2003, Poff and Ward 1990).

Land managers may view salvage logging after wildfire as a potential restoration technique by which they can respond to the perceived adverse effects of fire (McIver and Starr 2001). Research on the effects of postfire salvage logging on terrestrial organisms has shown mixed results; some organisms showed no effect, others increased (such as, Blake 1982, Haim and Izhaki 1994), and others declined

(Saab and Dudley 1998). Studies on the potential effects of fire and postfire logging of riparian systems and associated biota are lacking, however. Reeves and others (2006) argue that salvage logging in riparian zones may, among other things, reduce the amount and size of wood delivered to stream channels. This reduction may have immediate and long-term ecological consequences for trophic inputs and physical habitats of streams. Activities associated with salvage logging, including building new roads or opening old ones, may further exacerbate the effects of salvage logging by increasing erosion and fragmentation of the stream network. Although, in some circumstances, concerns about human safety justify salvage logging in a riparian zone, there is presently a paucity of evidence of scientific support for salvage logging in riparian zones (Reeves and others 2006). This certainly is an area worthy of future research.

"Cultural shifts" within the land management agencies—
Implementation of the Plan and ACS bought major changes to the way the affected agencies viewed and managed aquatic resources and watersheds. It is difficult to accurately describe or to quantify these changes, but conversations with agency personnel reveal that the vast majority believe that these changes were the most important effect of the Plan and ACS. The ACS replaced local plans that contained a variety of management directions and objectives with a common framework for managing aquatic and riparian resources on public lands. Additionally, it required a more comprehensive approach to the management of aquatic and riparian resources and much more interaction among disciplines that previously had little interaction. Table 9-3 summarizes these changes in agency culture, analysis, and analytical basis of management. In the view of many of the people responsible for the implementation of the ACS, these changes clearly are the primary successes of the Plan.

In a survey authorized by the Forest Plan Revision Board of Directors of FS Pacific Northwest Region (Region 6), personnel involved with the implementation of the ACS (forest and district fish biologists, hydrologists, and wildlife biologists) believed that ACS was appropriate and that it has led to improved and proactive management of aquatic resources (Heller and others 2004). The respondents also believed that there was a need to develop a single unified regional ACS, and this was accepted by the Board of Directors. A single framework is currently being developed for FS Region 6 with the Plan ACS as its cornerstone.

Summary and Considerations

Producing a quantitative assessment of the ACS of the Plan continues to be challenged by issues of data availability and quality. First, the accuracy and quality of data on some activities is questionable. For example, Baker and others (in press) report in their summary that the FS and BLM reported decommissioning 295 miles of road. When they examined 89 watershed assessments done between 1999 and 2003, they found that road mileage in those watersheds was reduced by 1,179 miles. Data on important indicators of effectiveness, such as miles of streams with water quality problems (that is 303d-listed streams) on federally managed lands and volume of timber harvested in riparian reserves, are not available. Watersheds degraded by management activities before the Plan was implemented were expected to take several years or decades to recover (FEMAT 1993). Thus, it is not too late to assemble credible data on activities and actions done under the auspices of the ACS. Field units are improving watershed conditions by removing and improving roads, in-channel restoration projects, improving riparian areas, and so forth, in addition to providing some timber volume from the riparian reserve network. The land management agencies could consider requiring field units to report uniformly on selected key activities and have the data assembled and accessible in a central location. The availability of such data would allow for at least a more defensible qualitative assessment of the effectiveness of the ACS.

Table 9-3—Changes in paradigms for managing aquatic and riparian resources that occurred as result of the implementation of the Plan and Aquatic Conservation Strategy

Old	New
Management activities can occur unless unacceptable adverse impacts can be shown likely to occur.	Management activities should contribute to, or not retard, attainment of ACS objectives.
There is a variety of individual approaches for the protection and restoration of aquatic and riparian-dependent resources. These are often different between administrative units for no apparent reason.	There is a consistent strategic approach for the protection restoration of aquatic and riparian-dependent resources across the entire Plan area.
Focus is on the condition of individual streams or stream segments or sites. Attention is focused primarily on public land.	Management focus is on process and function of whole watersheds. Special efforts are made to consider and coordinate activities on all ownerships.
Effectiveness monitoring is highly variable between administrative units. Protocols are inconsistent and preclude summarization and analysis across the Plan area.	There is a formal program, with consistent protocols, to monitor effectiveness of the strategy across the Plan area. Data can be summarized and analyzed for the Plan area.
Federal agencies generally work independently. Coordination is often infrequent and driven by "problems." Efforts to involve all stakeholders occur but are not the norm.	The emphasis is to coordinate the activities of federal agencies in the implementation and evaluation of the Plan. Special efforts are made to include all stakeholders.
Proposed actions came from "target" generally unrelated to ecosystem characteristics. Analysis is generally single disciplinary, single scale, and noncollaborative.	There is a multiscale analysis of ecosystem form and function prior to formulating proposed actions.

Source: Heller 2002.

The ACS met its expectation that watershed condition would begin to improve in the first decade of the Plan. The conditions of watersheds in the Plan appear to have improved slightly since the Plan was implemented. The proportion of watersheds whose conditions improved was significantly greater than those that declined. A primary reason for this improvement was an increase in the number of large trees in riparian areas and a decrease in the extent of clearcut harvesting in riparian zones. This general trend of improvement should be expected to continue, and may actually accelerate in the future, if the ACS is implemented in its current form. It is highly likely that these trends would have been the reverse under many of the forest plans that were in place before the ACS.

Science information developed since the Plan was implemented supports the framework and components of the ACS, particularly for the ecological importance of smaller, headwater streams. Also, a growing body of science about the dynamics of aquatic and riparian ecosystems could provide a foundation for developing new management approaches and policies. Scientifically based tools for aiding watershed analysis are also available and could be considered for use by the various agencies.

One of the main topics that could be examined and considered in more detail is that of the relation between spatial scales that are considered by the Plan and the ACS. The Plan and ACS changed the focus of the land management agencies from small spatial scales (i.e., watersheds) to larger scales (that is, landscapes). It appears that the implications of doing this have not been fully recognized or appreciated by the land management or regulatory agencies, and it has created confusion with the public and policymakers. This has precluded the consideration of new options and approaches to management. A rigorous examination of this issue would certainly be worthwhile.

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Chapter 10: Adaptive Management and Regional Monitoring

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Introduction

We have cast a broad net in evaluating adaptive management in the Northwest Forest Plan's (the Plan) first decade. We include the experiences with adaptive management areas, adaptive management outside of those areas, the regional interagency monitoring program, and some aspects of public-participation policy. Because the Plan tried an ambitious form of adaptive management, meeting all of its expectations would be an unparalleled achievement—this approach at this scale was never tried before the Plan. Adaptive management was seen as a cornerstone of the Plan, in response to clearly articulated uncertainties about how the chosen approach would play out. About 1.5 million acres (6 percent of the Plan area) was set aside into a land-use designation called adaptive management areas (see fig. 1-1), which were given a special mandate for learning. Regional monitoring grew out of directives specific to owls from the Dwyer injunction and subsequent rulings into specific requirements in the Plan (USDA and USDI 1994). Although adaptive management and monitoring were implemented largely independently, we consider them together now because they are both central to the general process of adaptive management, also mandated by the Plan. We also evaluate how the concepts, presentation, and, perhaps, the goals of adaptive management continued to evolve during the Plan's first decade.

The Plan was designed to manage environmental risk by applying the precautionary principle, and to actively seek to reduce uncertainty with adaptive management and monitoring. The designers and implementers of the Plan recognized that uncertainty and risk are inherent in natural resource management and public policy (chapter 3). In social and ecological systems as large and complex as the Pacific Northwest, myriad interacting factors ensure that people's best-made plans or intentions are disrupted by unexpected human and natural events and, in retrospect, many rational predictions look more like guesses. Uncertainty arises in two major forms: natural variability of processes and lack of knowledge. With variability, the process involved is understood, but the realized values can only be predicted within a range (for example, population growth rates or timber prices). In contrast, lack of knowledge includes both what is thought to be true (or false) but is not, and what is true but not thought about (such as unknown natural processes). When uncertainty intersects with objects or services of value, then loss can happen; the probability of lost value is known as risk.

The precautionary principle, as applied when the Plan was implemented, dictated that activities with risks of environmental degradation, such as harvest in riparian reserves or salvage, were halted or could proceed only if net ecological benefits of the action could be demonstrated. Thus, the Plan created a burden of proof that favored passive protective measures over active management. The Plan, as perhaps is not widely appreciated, also recognized the limits to this approach. Recognizing the benefits of active management in some instances, and the uncertainty in both action and inaction, Plan designers looked to adaptive management as a way to address uncertainty. The adaptive management concepts of Holling (1978), Walters (1986), and Lee (1993) were added as the primary mechanism for using management activities as experiments, and thus encouraging managers to learn by doing. Through time, such learning would reduce uncertainty and be incorporated into Plan direction.

Conflict can arise when the precautionary principle is invoked without formal risk assessment. With a consensus that possible negative outcomes are large relative to possible positive outcomes, little debate would happen regardless of different opinions or exact probabilities. For example, if a thunderstorm is approaching, few would question a decision to move children from a playground to

The Precautionary Principle

The precautionary principle has become increasingly prominent in environmental management. Simply stated, it rejects inaction as a response to uncertainty. A widely quoted definition from the 1992 Rio Declaration,* states:

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The basic idea behind the precautionary principle is common to human experience; where a possible but uncertain threat to life or property exists, precaution calls for reasonable effort at avoidance. Sometimes avoidance calls for active measures (such as security screening in public buildings) and, at other times, stopping activities that might otherwise take place (such as prohibiting use of cell phones on airplanes).

Note that the precautionary principle does not advocate avoiding all actions with possible negative consequences, nor does it suggest avoiding environmental degradation at all cost. As defined in the Rio Declaration, the precautionary principle is fully consistent with formal methods of risk assessment and risk management that have been developed as models of rational behavior. In quantitative risk assessments, a range of plausible outcomes is identified and probabilities are associated with each outcome. Expected loss, or risk, is calculated by summing the probability of each outcome multiplied by its associated loss or gain in value. Decisions that result in high expected loss are viewed as undesirable. The precautionary principle logically follows when negative outcomes are highly probable, or when the magnitude of the potential loss is very high relative to possible gains, regardless of probabilities. In either case, attempting to reduce the chance of loss is prudent.

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* Drafted at the 1992 United Nations Conference on Environment and Development, also known as Agenda 21.

a protected area. But many environmental decisions are not so obvious. Often the probabilities are not well understood, and assigning value to the range of possible outcomes is highly subjective. In disagreements among values, invoking the precautionary principle invariably favors one set of values over another. Similar conflicts can arise if different groups share the same values, but differ in assessing probabilities because of competing worldviews or, perhaps, lack of trust. Formal risk assessment methods share the same shortcomings, but they have the advantage of explicitly revealing people’s value judgments and probabilities.

Because the Plan language about adaptive management was somewhat vague and lacked performance standards, our assessment of intent is unavoidably subjective. Clearly, expectations were suggested in the Plan, and we use them where appropriate. We mainly use standards for an active form of adaptive management as described by Stankey and others (2003):

- Applying elements of the scientific method (specifying hypotheses, highlighting uncertainties, and structuring actions to expose hypotheses to field tests).
- Collecting, processing, and evaluating results.
- Adjusting subsequent actions in light of those results.

Evidence of Changed Direction

Evidence that these expectations were or were not met comes from the status and trends reports and various internal and external reviews, including an agency-funded review (Stankey and others 2003). We later place the Plan experience in the broader context of how well adaptive management has been applied in other places. Because regional interagency monitoring is such an integral part of adaptive management, we look in detail at the regional monitoring program and its dual role of measuring progress and advancing learning.

The primary goal of adaptive management under the Plan was to gain improved understanding to influence Plan changes through time. Clearly, the need for purposeful, systematic learning inside and outside adaptive management areas and in the monitoring program was envisioned. Standards for determining when something has been learned were not developed, however. For example, how much time is needed to produce evidence of sufficient weight to alter the Plan was not discussed, nor does this question have a simple answer. How long depends on the nature of the issue, the inherent rates and dynamics of the processes, and the pace of learning. Much time and effort are needed to learn about complex forests, and perhaps 10 years is insufficient to form many concrete conclusions. Although some uncertainties might be resolved enough to allow quick changes in direction, others could require many decades. Another ambiguity was whether adaptive management was intended to evaluate the Plan approaches simply by monitoring them or to contrast them to alternative strategies, such as disturbance-ecology-based approaches, on the adaptive management areas.

Evidence of a well-coordinated, systematic approach to learning contributing directly to Plan changes is, so far, limited. Stankey and others (2003) interviewed adaptive management area participants who found the new approaches innovative, but candidly recognized the many barriers (internal and external, operational and systemic). An agency committee review[1] found that managers in charge of adaptive management areas came to the same conclusion. They also reported that most studies were funded by the Pacific Northwest Research Station (about 30 studies: 4 that directly tested standards and guidelines and 7 that were in adaptive management areas). These areas were valuable in many ways, but they did not become a learning institution as envisioned by many of the people who proposed the idea.

Regional monitoring and various change mechanisms integral to the Plan do offer evidence of institutionalized learning and adapting. Local successes notwithstanding, evidence of a well-coordinated, systematic approach to adaptive management, including both adaptive management areas and monitoring, are harder to find.

Monitoring was well institutionalized—with multiple agencies working together—to measure Plan success and to provide new knowledge at a regional scale as a basis for decisions. Clearly, new knowledge was produced, and efforts (including this report) are underway to consider whether changes are needed. By itself, regional monitoring is a very passive form of adaptive management that does not compare alternative approaches and is slower than more active forms of adaptive management (Bormann and others 1999). Evidence that a broad systematic approach was implemented in the Plan is also weak. For example, few links were made between regional monitoring and local monitoring or other adaptive management activities.

Several deliberate mechanisms of change in the Plan were successfully implemented. Required monitoring for marbled murrelets (see app. for species names) in matrix lands led to half-mile-radius, late-successional reserves being created when murrelets were found. In response, the Siuslaw National Forest abandoned matrix management partly because they had previously found murrelets in

[1] Intergovernmental Advisory Committee, adaptive management area subcommittee report, March 10, 2004. http://www.reo.gov/library/iac/letters/1910iac3.htm.

about 90 percent of their surveys.[2] The Survey and Manage program was designed to deliberately change survey schedules, individual species categories, and mitigation requirements in response to new information; such changes were made (chapter 8). The decision in 2004 (USDA and USDI 2004) to change from Survey and Manage to a sensitive species program was based on several factors, including cost. This change was viewed by some as passive adaptive management—a new approach was tried, evaluated, and then changed (whether the program was evaluated long enough is still debated). In contrast to changes induced by murrelet and other species surveys, evidence of adjustments in riparian buffers was uncommon (chapter 9).

The decision to thin plantations in late-successional reserves also provides some evidence that an adaptive management process was used. Various stand and landscape research and management studies and experiments—some sponsored by adaptive management areas of the Plan—presented initial evidence that thinning could speed developing late-successional characteristics in plantations in the late-successional reserves (chapter 6). These thinnings were not considered a major source of timber to meet timber production objectives in the Plan, and initially they were not included in the probable sale quantity. In the later years of the Plan's first decade, however, thinnings in late-successional reserves became a major source of timber, benefiting the economy of some local communities (Charnley and others 2006), as well as appearing to move stands toward late-successional conditions. Other changes as the Plan was implemented were precipitated by courts, civil disobedience, or threats thereof, and some were precipitated to avoid contested projects. These types of unstructured reactions to immediate stimuli, appropriate or otherwise, are not widely viewed as adaptive management (Bormann and others 1999, Gunderson 1999a, Walters 1997).

Bruce G. Marcot

Variable-density thinning of an older plantation in a late-successional reserve on Olympic National Forest, Washington. The goals of such thinning are to grow larger diameter trees faster and to create more spatial variability, thereby promoting some characteristics of old-growth forests.

Reflections on Adaptive Management

Any interpretation of adaptive management needs to consider ongoing processes that are producing understanding yet to be adopted (where the adaptive management loop is yet to close). Perhaps the most promising activity is the monitoring program and its 10-year interpretive report, to which this synthesis belongs. Here, we discuss problems and successes in the context of experiences with adaptive management outside of the Plan.

One difficulty in implementing and evaluating adaptive management is ambiguity in its definition. At one end of the spectrum are those who view any reaction to new stimuli as adaptive management. At the opposite end are those who invoke a more rigorous experimental framework characteristic of scientific research. Problems in the Plan seem to have started when no single definition of adaptive management was established. The Plan's most commonly implemented expression of adaptive management appears to be a very passive form, where a single approach was chosen (for example, on the reserves, with the preserve-and-protect tenets

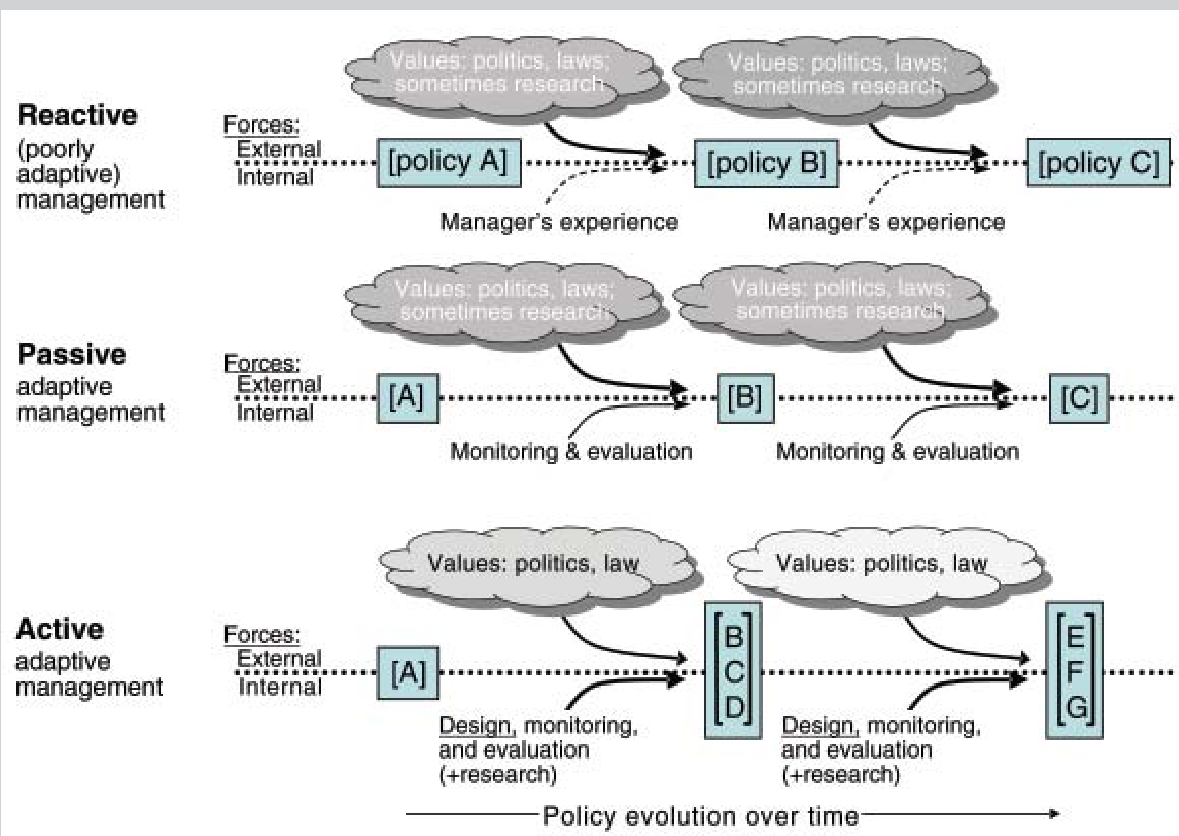
[2] Linares, Jose. 2005. Personal communication, Forest Supervisor, Siuslaw National Forest, 4077 Research Way, Corvallis, OR 97333.

Forms of Adaptive Management

The literature describes three main forms of adaptive management: reactive, passive, and active (figure below). The forms differ in the degree that external factors (such as legislators, courts, and civil disobedience) drive policy evolution more than learning activities internal to the management system, and in how fast policies can evolve given the lengthy evaluation period needed.

- **Reactive management** is not thought to be very adaptive when policies change A to B to C without much influence from what was learned on the ground.
- **Passive adaptive management** adds a specific monitoring and evaluation step to increase the influence of internal knowledge, potentially improving the subsequent policy but perhaps with little effect on the rate of policy evolution.
- **Active adaptive management** adds a design step, seeking to speed policy evolution and make research more of an internal force. Designed "management experiments" speed learning by trying a set of policies simultaneously within scientifically defensible experimental designs (usually subject to rigorous peer review).

Learning is a function of the strength of monitored comparisons; comparing multiple policies simultaneously with replication is far more powerful than trying one at a time. Active adaptive management should not be confused with research—although management experiments use an experimental design, they are developed, implemented, and monitored by managers, with only consultative help from researchers.



of conventional conservation biology), with regional monitoring as the primary feedback and learning mechanism. Most management experiments on adaptive management areas closely resembled traditional research experiments, with tightly constrained treatments on uniform small areas. With a few exceptions, published concepts of active adaptive management (including the interagency implementation report, Bormann and others 1994) were not widely adopted (Pipkin 1998, Salwasser 2004, Stankey and others 2003).

Implementing elements of a broader adaptive management strategy in the Plan area was piecemeal. Multiple interagency implementation teams, with both scientists and managers, were convened after the record of decision, and released in five separate reports (adaptive management areas, adaptive management process [Bormann and others 1994], monitoring, information technology, and planning). Not surprisingly, implementation that followed was compartmentalized (for example, adaptive management areas in provinces, monitoring in the interagency monitoring program). Except for some of their local field personnel, regulatory agencies did not participate in designing learning activities, and many people concluded that their interpretation of adaptive management did not include activities that deviated from the standards and guidelines (Stankey and Shindler 1997, Stankey and others 2003). An initial decision to allow adaptive management to develop without regional oversight was supported by scientists who argued against creating a cookbook for adaptive management (Bormann and others 1994). The lack of direction, coordination, and motivational support from either regional or local decisionmakers, in retrospect, appeared to hinder adaptive management efforts. The perceived lack of progress slowed research and then management funding in adaptive management areas after 1998.

These results are fully consistent with experience in other places, where successful implementing of adaptive management remains rare (Walters 1997). Many of the obstacles that were observed with the Plan are shared by other efforts. Four main obstacles hindered the Plan.


Bernard Bormann

Looking across the heavily managed, structurally diverse landscape of Five Rivers (Siuslaw National Forest), where a landscape-scale, adaptive-management experiment is underway in an area first harvested in 1952.

First, perceived or real latitude to try different approaches on adaptive management areas was limited. Many of the Forest Ecosystem Management Assessment Team (FEMAT) scientists thought that the areas would have wide latitude to test approaches that substantially differed from Plan approaches applied in the late-successional and riparian reserves. This need for experiments was clearly recognized as a way to respond to the large uncertainties in the Plan directions. The rules for adaptive management areas changed as the Plan was written, and most of the latitude was eliminated—for example, riparian reserve standards and guidelines were applied to all and late-successional standards and guidelines to some of the adaptive management areas, and both took precedence over adaptive management standards and guidelines. After much debate, the Regional Ecosystem Office sent a letter clarifying the possibilities and needs for modifying standards and guidelines in the adaptive management areas (REO 2000). The letter created a mechanism to differ from standards and guidelines but was not widely adopted as other barriers appeared to come into play.

Second, some people saw adaptive management as a public participation process only. Specific collaborative goals were included in the Plan (in part because of the success of the pioneering community collaborative efforts in the Applegate Valley, Oregon), as a means for planning and accomplishing projects. Many of the adaptive management areas created new partnerships working through the new provincial advisory committees established by the Plan. The organized dialogue between managers of different agencies, regulators, and different constituencies improved communication and understanding between these players. Expectations of reaching consensus or implementing consensus ideas on the ground were not often met, however. Many of the partnerships have lost momentum in the last few years (Stankey and others 2003). Note that multiple efforts involving the public were undertaken outside of the adaptive management areas as well.

Third, precaution trumped adaptation. In contrast to the precautionary principle, adaptive management embraces risk and uncertainty as opportunities for building understanding that might ultimately reduce potential risks (Stankey and others 2003). Withholding action until more is known is a rational response to uncertainty in many instances, but undue concerns with avoiding risk and uncertainty can suppress the experimental policies and actions needed to increase understanding. When minimizing the possibility of failure dominates policy and management processes, uncertainty is traded for a "spurious certitude" that provides a comforting, but illusionary, sense of predictability and control (Gunderson 1999a, Wildavsky 1988). Although the Plan's precautionary strategy might be assumed to be the most viable approach to long-term protection of declining species, another perspective is to treat this assumption as a "question masquerading as an answer" (Gunderson 1999b).

Finally, regardless of good intentions, sufficient resources were not available to implement adaptive management as envisioned by FEMAT scientists or by the implementation team (Bormann and others 1994). Causes of inadequate funding are complex. Various Plan requirements, such as watershed analyses and the Survey and Manage program, consumed many of the available resources early on. Writing complex decision documents, responding to continuing lawsuits, and regulatory consultations also consumed time of agency specialists. Decreased timber harvests reduced receipts that might have been used for monitoring projects on adaptive management areas on USDA Forest Service (FS) lands. The most powerful evidence to consider is the decline in FS positions—a loss of more than 70 percent of the full-time employees on some Plan forests since 1990 (chapter 3). Reduced budgets made centralization attractive, and several forests and numerous ranger district offices were combined. Workforce motivation in this environment, especially to meet needs perceived as additional—like adaptive management—would be difficult for any organization. This context suggests that the agencies' decision to allocate substantial resources to the regional monitoring reflected a serious commitment to at least one aspect of adaptive management.

Examples of unfolding, potential successes of active adaptive management (as envisioned by researchers and some managers) can be found, despite all the problems. For example, the Blue River landscape management project, currently being implemented in the Central Cascades Adaptive Management Area, helped develop a landscape prescription for matrix lands based on a disturbance ecology approach with deviations from standard and guidelines (Cissel and others 1999). The Five Rivers landscape experiment on the Siuslaw National Forest began a 12,000-acre, replicated management experiment testing alternatives to growing late-successional habitat (Bormann and Kiester 2004). The Blue River study continued work that began on the H.J. Andrews experimental forest before the Plan included the forest in an adaptive management area. After gridlock prevented implementing its predecessor in the North Coast Adaptive Management Area, the Five Rivers project was applied outside the adaptive management area (Bormann and Kiester 2004). The Little Horse Peak project in the Goosenest Adaptive Management Area was established to determine the extent to which different combinations of silvicultural treatments (especially tree harvesting and prescribed fire) can accelerate development of late-successional forest attributes in mixed stands of ponderosa pine and white fir; the project is examining responses of many forest attributes, including vegetation, insects, and wildlife. These successes demonstrate that adaptive management can be possible outside of formal adaptive management areas if management-agency leadership and research participation are adequate. As such, they present models for future consideration.

Reflections on Regional Monitoring

Monitoring Observations

A framework for Plan monitoring (Mulder and others 1999) helped shape plans for monitoring a range of resources (Hemstrom and others 1998, Lint and others 1999, Madsen and others 1999, Reeves and others 2004). The interagency monitoring program coordinated all of these regional efforts and took charge of the 10-year interpretive report (5-year reports were mandated by the Plan), consisting of five status and trend (module) reports and this science synthesis. The monitoring program reported on trends in the Plan region over a decade or more in forest vegetation (older forests), implementation, and northern spotted owl modules, and some aspects of socioeconomics and aquatic systems. In parts of other modules, the time series were much shorter; they are considered initial inventories or baselines for now. All monitoring modules have produced results that allow at least preliminary examination of underlying assumptions, conceptual models, analytical tools, development of descriptive or predictive models, and efficiency of protocols used in Plan monitoring.

We briefly express our interpretations of how well the regional monitoring program worked in its first decade. We then present an adaptive-management-oriented conceptual model for monitoring, as a way to look forward to improving monitoring in support of future interpretive 5-year reports. A thorough assessment of the monitoring program is beyond the scope of this chapter, but such an assessment would provide substantial useful information for future decisions. Our retrospective interpretations are:

- Monitoring was the activity making greatest progress in meeting the regional expectations of adaptive management established in the Plan. Monitoring took the first step in moving from opinion toward evidence-based decisions (opinion will always be involved). Monitoring provided the opportunity for using feedback to make midcourse corrections. Adaptive management cannot be done without monitoring; monitoring without adaptive management is just data.
- The Plan helped institutionalize adaptive management at a regional scale through the monitoring program and 10-year interpretive report. This report brought strong focus on what has been learned, improved communication, and raised the chances that knowledge will be incorporated in future planning, implementing, and monitoring, which meet the criteria of McLain and Lee (1996).
- Plan monitoring provided our first estimates of measurement error and underlying variance of key Plan indicators. Sampling strategies can be evaluated for the first time and fine-tuned to become more efficient now that we have an understanding of this variability. Such data are valuable even where significant trends have yet to be observed.
- The regional monitoring program demonstrated that agencies can work together effectively.
- Monitoring was expensive—about $50 million over 12 years (about 17¢ per acre per year). Most resources were focused on continuing owl demographic monitoring (about $25 million).
- The compartmentalizing of monitoring into implementation, effectiveness, and validation monitoring—and then a dominating focus on effectiveness—probably limited learning. Because people believed being “effective” was more important than creating records of activities that

could be assembled for regional analysis or more important than questioning the many assumptions, effectiveness was monitored while record keeping and skepticism waned. Two legs of the monitoring stool were quite weak (implementation monitoring and research efforts notwithstanding).

Monitoring Concepts

We propose a conceptual model for monitoring consistent with evolving ideas about adaptive management, with some minor changes in emphasis from Mulder and others (1999). The most important premise of this model is that the monitoring questions reflect crucial management decisions. The primary purpose of monitoring is to inform future decisions and meet legal obligations, not to do research or public relations. Once the questions are chosen, then the emphasis is on applying the best available technical approaches for data collection and compilation. When technical issues are addressed rigorously, most large-scale ecosystem monitoring will be expensive. Thus, we propose that the ideal set of monitoring questions will:

- Be chosen by accountable decisionmakers (with input from others).
- Be focused on a limited range of possible future decisions.
- Be as durable as possible, so results are still useful when they are finally produced.
- Have quantified expectations laid out in advance, so monitored deviations from expected outcomes can serve to make clear conclusions about changes.
- Reflect a broad spectrum of public opinion.
- Be linked to potential management changes by laying out in advance explicit assumptions and potential management responses.

Monitoring results complete an adaptive management cycle when they influence management decisions. Formal methods for linking decisions to monitoring can facilitate this process. A monitoring program is a proactive strategy for managers to inform and counter external forces driving policy shifts with more internal knowledge. Other, less tangible benefits from monitoring could be considered as well, such as building public trust, cross-checking assumptions, learning about emerging questions, and institutionalizing adaptive management.

Our monitoring model has technical aspects to consider, such as: Do chosen variables answer the question posed? Is monitoring efficient? Is monitoring information effectively summarized and communicated? These questions are addressed briefly before preliminary recommendations are presented.

Do Chosen Variables Answer the Question Posed?

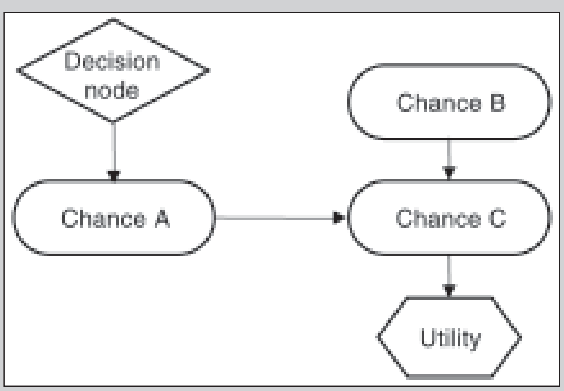
Fundamental to monitoring a large, complex ecosystem is choosing the variables or metrics most appropriate to the questions posed and their scale. Because of spatial and temporal complexity, simply choosing what to measure is not enough; when and where are also important. The Plan embodies conservation goals and implementation standards across 22 million acres of federal land in the Northwest. At the finest resolution, the Plan is implemented with management decisions affecting as little as a few acres or restricted stream segments. The challenge is how to most effectively meet information needs at multiple scales. Ideally, aggregating monitoring information up from local scales would help higher in the hierarchy, and monitoring at large scales would provide valuable context for more localized questions (Busch and Trexler 2003, Morrison and Marcot 1995). Choosing where to measure requires understanding the primary scales of interest to decisionmakers and how inferences change across scales. Clarity about the acceptability of developing stronger inferences where data and analyses can be aggregated to a regional scale, together with acceptance of weaker inferences at smaller scales, would be helpful. Initial monitoring results showed how information on nonfederal lands can serve a more complete ecosystem analysis, which has so far been accomplished only with inventory and remote-sensing data. Because potential responses may play out quickly or slowly, determining if the intensity of data collection can detect

Decision Models

Decision models take various forms. One framework for linking decisions to monitoring (see Lee and Bradshaw, n.d.) involves the use of influence diagrams (Clemen 1996, Howard and Matheson 1981). An influence diagram is intended to represent the decision process in a way that explicitly recognizes the uncertainty in consequences or outcomes of the decision. Influence diagrams consist of nodes or variables connected by directed arrows (below). Three kinds of nodes exist: decision nodes represent alternative actions that might be taken; chance nodes represent events or variables affected by the decision or other chance variables; and value or utility nodes represent variables summarizing the final outcome of a decision. In business decisions, value nodes are often expressed in monetary units. For other kinds of outcomes, the relative benefit offered by a particular outcome is summarized by its utility, a nondimensional metric that allows comparing dissimilar elements (such as, fish versus timber). Relations between outcomes and utility are expressed as utility or preference functions; such functions reflect both comparative value and attitudes about risk (Keeney and Raiffa 1976). Although decisions can be analyzed without explicitly assigning values or utilities to outcomes, the act of choosing one outcome or the other as preferable implicitly reveals a preference function.

An influence diagram is more than simply a schematic representation of the interaction of decisions and chance variables. Well-established statistical methods are used to quantify the strength of causal dependencies by using conditional probability matrices that link chance nodes to decisions or to other chance nodes. Influences are propagated mathematically through the network such that conditional changes in probability at each node are calculated based on the decision option and various input variables. The mathematical framework underlying influence diagrams provides a strong conceptual link to statistics, and a rigorous means of using experimental results or monitoring data to update or verify the diagrams.

Influence diagrams are commonly used to identify the decision option with the highest expected utility given the information in hand, but they have other uses. One purpose they serve is to allow calculating the value of information; that is, they rigorously calculate the change in expected utility given a reduction in uncertainty about a particular chance node. Many businesses use this type of analysis to decide whether investing in additional information gathering or research before making a decision is cost effective. Sensitivity analyses are also easily accommodated, in which the variables most critical to making an optimal decision are identified.



Decision model: a simple influence diagram with one decision node, three chance nodes, and one utility node. Arrows indicate causal dependencies or effects; that is, the decision has a direct influence on chance node A, chance nodes A and B affect C, and utility is derived from C.

projected trends is also important. Monitoring some variables on a nearly continuous basis and others less frequently may also be reasonable.

Is Monitoring Efficient?

The efficiency of monitoring under the conceptual model we use lies with how useful the results were per unit of monitoring effort. Measuring this kind of efficiency is complicated by the time lags between collecting data and considering findings in decisions, and by the various intangibles of decisionmaking. Most effort is therefore usually focused on other forms of efficiency. Several mechanisms were incorporated into the Plan's monitoring program design, with the prospect of making the program operate efficiently, and to become more efficient over time (Mulder and others 1999). Many of the efficiency issues address aspects of the sampling designs.

One tradeoff is between using statistically rigorous sample design compared to scientific consensus. Both were used, and reasons may be found to adjust monitoring program elements toward one approach or the other. Another tradeoff lies between sampling and spatial resolution. For example, study sites were randomly selected, so inferences drawn from the data monitored in the watershed-module applied to the entire Plan region—at the cost of limited spatial and temporal resolution. Risks and benefits of such approaches in all monitoring modules are reasonably well known, so a determination about the desired course for the program as a whole (either change or continuity) should be possible.

Another issue is whether new information about dynamic ecosystems has been incorporated into monitoring design, and if the information needed about disturbance is at odds with monitoring of the Plan's land-use designations. Monitoring programs have not been oriented toward detecting the effects of environmental disturbance or how dynamic environments interact with land-use designations. Despite their focus, some sampling designs may be able to detect change caused by disturbance. Monitoring based on interpreted satellite imagery with complete coverage or based on probabilistic sampling approaches are best suited to conducting analyses on disturbances detected by the monitoring protocols. Sample-size limitations can, however, constrain inferences about types of disturbance at multiple scales (for example, effects of slope failure in key and nonkey watersheds or effects of fire in late-successional reserves versus matrix).

The relative value of monitoring wildlife populations or their habitat is also important. The Plan stressed the role of the FS and USDI Bureau of Land Management (BLM) in managing habitat to provide for viable populations of desired species. Monitoring plans adopted a strategy where habitat models would complement or partially replace some direct monitoring of populations. In addition, watershed monitoring included a strategy where watershed models would obviate the need for extensive instream measurements. The hope was to gain efficiency by using robust databases on both habitat and populations, and by developing models for projecting populations based on habitat condition. At this point, the proportion of the variation in spotted owl population vital rates that can be explained by habitat variables is too small to make reliable predictions about demographic characteristics and, thus, population trend. Some indications suggest that monitoring vegetation may be more reliable in predicting owl and murrelet presence than in predicting populations. Although some differences in watershed condition were apparent across different Plan land-use designations, whether subtle trends in condition will be discernable over time is unclear. Even less certain is that watershed condition will have much predictive value in describing instream factors or aquatic populations. Although better data and better models are unlikely ever to permit complete conversion to habitat-based monitoring, strategic development of models is an important research tool with potential for helping to make predictions and develop cause-and-effect relations.

Another key issue is continuity in the face of changing technology. Recognizing the value of continuity when considering changes to the monitoring program is important. Variables with a longer record or a record that can be retrospectively assessed may be more useful than those of short duration, all else being equal. Changing course in midstream can come at a high price. Wall-to-wall remote-sensing approaches used in the first decade, however, may be at a point for change. The Thematic Mapper satellite is failing. We suggest that some form of three-dimensional measures of forest structure (light detection and ranging [LIDAR] and interferometric synthetic-aperture radar [IFSAR]) linked with digital aerial photography will present the most value for the next decade. This approach can produce positional (x, y, z) data that do not require additional interpretation, at a scale of individual trees.

To ensure long-term success of the Plan, increased emphasis on monitoring that can improve understanding of causes and effects is important. Agency and university researchers attempted to analyze some of the Plan's underlying assumptions, but the process was largely ad hoc. Some cause-and-effect links are possible at regional scales; for example, a stand-replacing disturbance can be compared to management history. Many links are not possible; for example, smaller disturbances cannot be detected with current remote sensing. Confounding factors will always limit cause-effect links; the only way to reduce confounding is through more structured learning (rigorous comparisons in designed management experiments). Few midscale management experiments envisioned for adaptive management areas were designed or implemented (with some notable exceptions). These efforts could be considered part of a system of adaptive management and monitoring in the next decade.

Is Monitoring Information Effectively Summarized and Communicated?

We discussed how change in management direction could be used as evidence of adaptive management. Change in management direction could also be used as evidence of how effectively monitoring information is summarized and communicated. To be fair, judging success or failure now is too early—the status and trend reports and our own synthesis were just released. Nonetheless, we think some opportunities to improve how monitoring is summarized and communicated are available.

Models can help to summarize and characterize understanding, but they are only as good as the data and assumptions they use. Models can help identify and estimate causal relations, quantify strength of evidence for alternative hypotheses, and be used to make (or update) projections for objects of interest. New information accumulated since Plan inception might provide a basis for adjusting models underlying the regional monitoring program. Clearly, some influential factors were less understood before, such as potential barred owl effects on spotted owl populations. Other factors may affect all systems monitored, but they may be thought of as exerting their influences less directly, such as global climate change or forest-marine ecosystem links. Increasing social awareness of issues such as fire and invasive species and activities by managers to address these questions also argue for potential model revisions. Given the above, incorporation of "new" factors in revised models could be considered before changing monitoring protocols. Without this step, discussions of prospective change might not provide sufficient rationale for change, or could be viewed as unjustifiably producing winners and losers in terms of the subsystems monitored.

Lastly, the monitoring program sometimes suffers from a lack of clearly articulated expectations or goals. Information now exists to rectify this shortcoming. For example, the monitoring program has yielded important information on the amount and distribution of old forests under various definitions, on the distribution and abundance of marbled murrelets, on demographic parameters for owls, on watershed condition, and on social and economic conditions throughout the Plan area. Data can now help clarify baselines and targets with greater accuracy than was possible at the beginning of the Plan. Because targets are based on social values and agency policies, decisionmakers need to help articulate them.

The Costs and Benefits of Regional Monitoring

We consider the value of what was a unique experience with regional-scale, interagency monitoring linked directly with land management. The costs of regional monitoring under the Plan were substantial (table 10-1 [by agency] and table 10-2 [by monitoring modules]). Although the total amount ($50 million) is large, the per-acre cost for 12 years was about $2 per acre, or less than 17¢ per acre per year. For the last 4 years, costs have averaged about $6 million per year. The costs are not shared equally across the various modules, however; owl monitoring accounts for half of the total costs. Watershed conditions and marbled murrelet monitoring were the next two most costly. These costs before fiscal year 1999 are underestimated because contributed staff time spent developing monitoring protocols was not accounted for. At the Pacific Northwest Research Station in the early parts of the decade (1994 to 1998), support for developing monitoring protocols and initial monitoring was two to three times what is shown in table 10-2 (see app. 5 in Haynes and Perez 2001). After monitoring began in earnest, this support was reduced as efforts shifted from research to the monitoring program.

To put the costs in perspective, regional monitoring was about 12 percent of the cost of implementing the Plan and about half of what was spent on the Survey and Manage program when it was at its peak. Regional monitoring may also have reduced the costs of local monitoring. The costs are offset by many benefits, especially when monitoring is seen as a vital cog in an adaptive management strategy. Monitoring cannot be judged in isolation but by how well its interpretation is integrated with knowledge from available sources and facilitated decisions on whether course corrections are needed. Although room for improvement clearly exists, we conclude that regional monitoring and its interpretation:

- Complied with specific legal mandates.
- Provided information about progress at a regional scale to help identify when changes should be considered, thereby completing a loop in the adaptive management cycle.
- Provided a venue where managers and researchers can consider recent research findings holistically and in the context of the complex societal and legal environment.
- Began to substitute opinion with data-based evidence, where possible.
- Institutionalized part of an adaptive management system, and—perhaps more important—convinced managers that adaptive management is an integral part of management.
- Provided an opportunity for increased trust between agencies and among constituents by better communicating progress toward achieving broad goals.

Considerations for Future Progress in Adaptive Management and Regional Monitoring

We present some initial ideas to improve the regional monitoring program, as we were asked to do by the regional agency executives. Because regional monitoring is only part of a systematic approach to adaptive management, we then offer ideas on ways to improve adaptive management more generally.

Improving the Monitoring Program's Second Decade

Ways to improve the monitoring program:

- Consider committing to interpreting regional monitoring and research every 10 years, if not more often, to gain the most value from the monitoring effort.
- Consider developing a list of corporate questions to set up the next interpretive report and defining priorities in this list based on decisionmakers' understanding of emerging issues, their vision of future societal goals, and the cost and feasibility of obtaining quality monitoring data.
- Consider developing a new adaptive-management-oriented monitoring framework that includes new monitoring plans with quantitative expectations from experts and others and potential management responses to deviations from expectations (without clear expectations, clear changes cannot be measured or interpreted).

Table 10-1—Plan monitoring expenditures by agency[a] by fiscal year (Oct. 1)

Agency	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
	Thousand dollars												
BLM	549	549	636	625	318	1,272	889	1,313	1,249	1,306	1,294	1,218	11,218
R5	193	193	234	234	209	354	322	774	839	885	995	973	6,205
R6	549	549	635	625	494	1,631	1,332	2,050	2,212	2,326	2,263	2,425	17,091
NPS					68	105	140	190	190	140	140	115	1,088
FWS			20		20	724	481	396	411	416	435	435	3,338
PNW	549	549	549	508	415	876	476	602	630	452	520	607	6,733
PSW						90	270	179	200	200	135	135	1,209
USGS					302	365	234	234	231	226	185	67	1,844
EPA						60	103	90	90	90	120	110	663
NOAA-F						45	0	100	170	170	170	90	745
Total	1,840	1,840	2,074	1,992	1,826	5,522	4,247	5,928	6,222	6,211	6,257	6,175	50,134

[a] Contributing agencies

BLM–OR/WA Bureau of Land Management
R5–USDA FS, Pacific Southwest Region
R6–USDA FS, Pacific Northwest Region
NPS–National Park Service
FWS–US Fish & Wildlife Service Western Region
PNW–USDA FS, Pacific Northwest Research Station
PSW–USDA FS, Pacific Southwest Research Station
USGS–US Geological Survey
EPA–Environmental Protection Agency
NOAA-F–National Oceanic & Atmospheric Administration–Marine Fisheries

Table 10-2—Plan monitoring expenditures by monitoring module

Module	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
	Thousand dollars												
Spotted owl	1,840	1,840	1,840	1,740	1,626	2,291	2,117	2,363	2,553	2,369	2,548	2,612	25,739
Marbled murrelet						1,490	854	1,139	987	767	814	738	6,789
Older forests						752	446	411	486	777	551	433	3,856
Watersheds						422	450	1,426	1,053	1,007	1,252	1,223	6,833
Implementation			234	252	200	250	200	239	263	280	225	216	2,359
Socioeconomics						17	25	140	200	383	400	395	1,560
Biodiversity						75	75	35	58	47	47	27	364
Tribal issues								10	40	58	105	76	289
Program management						225	80	165	582	523	315	455	2,345
Total	1,840	1,840	2,074	1,992	1,826	5,522	4,247	5,928	6,222	6,211	6,257	6,175	50,134

- Consider focusing more effort on agency record keeping, vital to any future interpretive analysis. Our team was not able to assemble existing local activities records, such as thinning and prescribed fire, into a regional analysis, in part because no mechanism to do so existed. We have also seen evidence that previous FS record-keeping systems have been replaced with ad hoc local record keeping.
- Consider ways to overcome obstacles to coordinating monitoring at different scales and from different sources, including projects, management experiments, assessments, inventory, and other federal and state agencies (Busch and Trexler 2003, Morrison and Marcot 1995).
- Consider reallocating some resources to testing assumptions and learning about mechanisms that explain management effects or population trends, in management experiments and mechanism-oriented research; also considering supporting retrospective monitoring by using old agency records.
- Consider promoting multiple methods of quantitatively interpreting monitoring data. Using traditional Neyman-Pearson statistics, Bayesian statistics, and exploratory data analysis helps to strengthen evidence.
- Consider continuing to make data and interpretations widely available.

Changing the Course of Adaptive Management

Whenever scientists and managers get together to discuss large-scale resource management issues, two common refrains are heard. Managers complain that risk-averse policies and regulations limit their ability to manage effectively. Scientists complain insufficient attention is paid to uncertainty, monitoring is underfunded, and rigorous learning from management experience is not valued by risk-averse decisionmakers. Unfortunately, considerable truth lies in both complaints, yet neither perspective is entirely accurate or easily addressed. The precautionary principle is clearly in play in the Plan, and the burden of proof required of managers before they act is perceived as very high, but some avenues for action are clearly permitted in the Plan. Similarly, regional agency executives have made major investments in monitoring and evaluating the Plan's success—for example, this report is a result of the agencies' commitment to a periodic evaluation of what has been learned as a basis for possible change in direction. The path to reduced uncertainty and manageable risk, however, is not the exclusive purview of regional executives, analysts, or science teams.

We suggest several potential adjustments that might further the broad aims of adaptive management, which ultimately is to improve management to meet societal needs. These suggestions augment the various observations made throughout this report. The experience in the Plan's first decade suggests that the effectiveness of adaptive management can be increased by bringing together the wide array of learning and adapting activities into a more coordinated, directed, and institutionalized system designed to be more than the sum of its parts. Many elements started in the first Plan decade need only to be better coordinated in an adaptive system (fig. 10-1). Developing this system will likely require staff work, key decisions, and continual support and nurturing by managers, regulators, and researchers.

Implementing management experiments—
One of the most important, least developed elements of a systematic approach to adaptive management (fig. 10-1) is management experiments (on or off the adaptive management areas). Active adaptive management compares alternate management pathways in management experiments applied, not as research projects, but as well-designed, agency-led administrative studies undertaken as an integral part of management itself. These experiments, conducted on or off adaptive management areas at the normal scale of management, would include alternative strategies or "pathways" to achieve specified goals of the Plan. Management experiments are extensive in that they will not require intensive monitoring as typically required

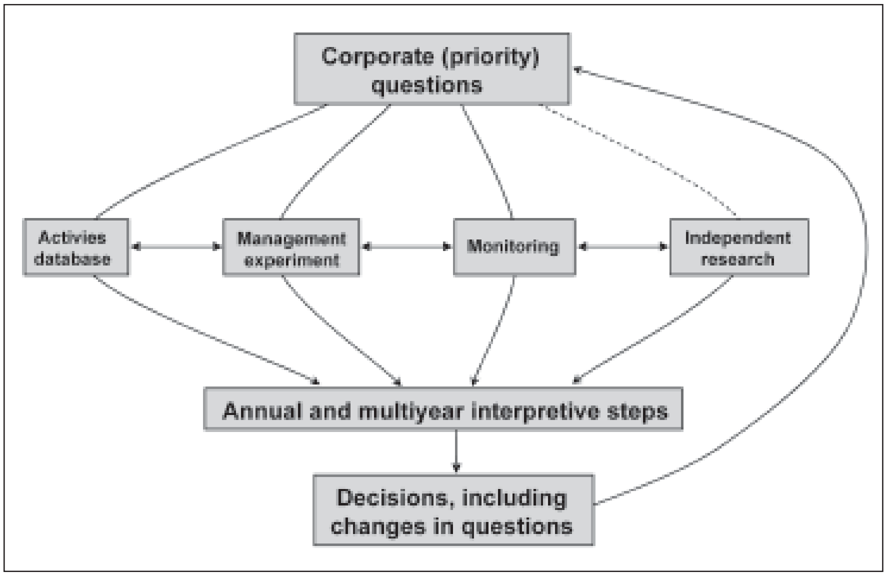


Figure 10-1—A conceptual model for more systematic learning, where corporate questions drive various learning activities that feed into interpretive steps facilitating decisions on whether course changes are needed, as well as on whether to revise the questions.

in research experiments; monitoring will be more in line with project monitoring (such as stand exams, surveys, photointerpretation, and remote sensing). Management experiments offer an opportunity to provide increased understanding of how management causes observed effects. Regional monitoring and even limited-scope research cannot shed much light on these complex cause-effect relations.What can be learned by comparing practical approaches in these trials strongly complements status and trends emerging in regional monitoring and understanding of new mechanisms in research. Comparing alternative pathways also meets the adaptive-management intent of the Plan, to accelerate learning while managing as a way to respond to the high uncertainties associated with implementing approaches never tried before.

Large-scale experiments may be viewed by some people as risky or in violation of the precautionary principle. Management experiments often make more sense at a scale large enough to reflect the complexity of the landscape and the management strategy. Aggressive learning comes from management actions that challenge underlying assumptions and provide sufficient strength of evidence in a timely manner to distinguish between competing hypotheses. Where management experiments need to include treatments that exceed regional standards and guidelines to provide enough contrast, regulatory and court actions may be needed for this flexibility. Not all management experiments need to violate standards and guidelines; they simply contrast alternative approaches to achieving an objective, as in the Siuslaw National Forest's Five Rivers project. The challenges are clear.

Other important ways to learn—
Not all learning will be gained through monitoring or management experiments. Other important opportunities to gain information may lead to management changes as well. First are the opportunities to exploit retrospective observations. The forests we manage today are a legacy of past actions. What can we observe from the various actions and the associated trajectories that forests have followed over the last 50 years through agency records and aerial photography? Second, we could try to explore the considerable knowledge and experience of active management gained on private timberlands. Other insights from indigenous and local communities may also spark important creative leaps in both questions and approaches. Changing the cultures of federal, industry, and private land managers, and also researchers to equally value this observed or existing knowledge will be a challenge.

A More Systematic Approach to Adaptive Management

Key system elements—many of these elements were started in the first Plan decade and need only to be coordinated in a systematic approach (see fig. 3-4):

- **A periodic, formal interpretive step.** This step is needed to integrate and synthesize disparate information from monitoring and other sources over a sufficient period so that decisionmakers can more fully understand the context for truly adaptive course adjustments. In the Plan, 10 years of monitoring and research worked well to fuel the 10-year interpretive step. More frequent interpretive workshops may prove useful as well.
- **A prioritized list of corporate questions and learning objectives.** Because of time lags in monitoring, research, and evaluation, defining questions now for the next interpretation step is critical. Corporate questions are needed to drive multiagency regional monitoring, and subregional learning objectives are needed to direct management experiments.
- **Linkage and balance among corporate learning activities.** Activities need to be linked through the questions and learning objectives. Resources from management and regulatory agencies need to be balanced among the three main activities:
    - **Agency record keeping** clearly describing what management happened that can be assembled for regional analysis in the next interpretive step (including old records).
    - **Regional monitoring** focused on documenting outcomes for a diverse subset of key outputs and conditions (avoiding indicators, if possible), and also yielding information on unexpected changes and uncertainty, and taking advantage of monitoring by others. Publishing quantitative expectations is also essential to interpreting subsequent outcomes.
    - **Management experiments** (on or off adaptive management areas) designed to produce evidence of links between management direction and changes in outputs and conditions and to evaluate alternative pathways (preferably with pathways linked to different constituents).
- **Research explicitly linked to this system.** Research explicitly linked to questions and learning objectives is also an important learning activity (note, unlinked research is also important because it may produce unexpected results of considerable importance and relevance to future decisions). Researchers are well suited to:
    - Help **frame questions, design monitoring, and design management experiments** to guide learning for the next interpretive step.
    - Lead periodic **interpretive steps** to synthesize and integrate available evidence from monitoring and research in a broader, longer term framework.
    - Conduct **retrospective studies** of past management to uncover temporal uncertainties and causes and effects of past management as a basis for looking forward.
    - Conduct **research experiments** that can address more-focused elements of the corporate questions, or to evaluate effects of specific practices.
- **Upward links.** Links are needed to the planning regulations, the environmental management system, and to the national budget-allocation debate (learning is a legitimate agency output).
- **A financial and institutional commitment to producing evidence** of sufficient weight and relevance to counterbalance some of the external forces driving policy change. Consider a fixed percentage of total financial resources (perhaps 15 percent) and developing more administrative processes to make learning and adapting a part of core business (including training, rewarding, and so on).

Obstacles to learning are not easily overcome, as the experience in the Plan thus far attests. We offer the following principles for effective adaptive management and monitoring:

- **Engage multiagency regional executives in guiding learning.** Agency executives and their staffs bring a perspective and authority that is essential to defining the most important questions to be answered in the next decades and to managing regional experimentation and monitoring. Engagement also increases the chance that what is learned will be incorporated in future decisions.
- **Involve regulatory agencies.** Collaboration with regulatory agencies is especially important in facilitating and learning from more controversial management experiments. For example, if management experiments are properly structured and explained, they can be seen as a way to improve environmental conditions or sensitive species' habitat, not as risks to them.
- **Accommodate reasonable disagreements**. Where uncertainty is high and competing social values and constituencies are connected to different bodies of knowledge and experience, consensus on a single management strategy may be an unreasonable goal. Disagreement can be used to develop different strategies for testing, and it can even help to connect back to multiple constituents.
- **Commit to quality record keeping.** A regionally compatible system with a quality matching the current BLM or the old FS total resource inventory system would document land management activities so they can be compiled across the entire region. Securing, properly archiving, and making accessible old records are also vital to learning. Many of these records are disintegrating, and some have been lost. Retrospective studies of long-term processes require these records.
- **Recognize and address local knowledge needs.** Spatial and temporal complexities in the Pacific Northwest region, in subregional landscapes, and even in smaller areas dictate that local evidence and knowledge are important to land management decisions. Local experts and the public are best positioned to identify information needs, and help design site-specific, midscale management experiments to address them. Engaging and supporting community research efforts have the added benefit of building broad-based support for a regional adaptive management program.
- **Organize around a regional monitoring program.** The regional monitoring program has reduced uncertainty and helped agencies apply adaptive management. Other adaptive management activities, such as midscale monitoring and regional and local management experiments, could be coordinated through the regional monitoring program. Linking regional monitoring to record keeping, monitoring at other scales, or by other agencies and research will remain a difficult proposition, requiring significant attention.
- **Build institutional capacity through employee training.** The complexity of planning adaptive management linked to both local and regional monitoring, designing and implementing management experiments, and interpreting monitoring results demands a significant investment in training that crosses scales and agency boundaries. A new within-agency certification system (perhaps building on the silviculture institute concept) might be considered. Boundary spanning assignments might become part of such a system, where field specialists and researchers would work together on relevant research and management experiments.

- **Value continuing partnerships between researchers and managers.** A sustained partnership (more than periodic regional assessments or evaluations) would aid in overcoming traditional barriers between researchers and managers. Learning from management in a scientifically credible way may meet resource objectives and advance science at the same time. In one approach pioneered at Five Rivers, researchers provided advice on designing management experiments and rigorous monitoring techniques and helped with interpretation of data, managers provided leadership and implemented landscape experiments and monitoring, and researchers are providing knowledge from retrospective research on past management and disturbance through peer-reviewed literature (Bormann and Kiester 2004).
- **Develop long-term funding strategies.** Funding will likely remain a major limiting factor for learning (Stankey and others 2003). A rate of investment in learning commensurate with the value of the information obtained is easily justified, but long-term benefits will have to compete against problems of the day. Regional management-agency staff could learn how to better justify adaptive management expenses to their national offices where funding allocations between regions are made. An alternative approach would be to invest a fixed percentage of incoming receipts (from timber sales, recreation passes, and other sources) in increasing the quality of managing the forest. The Coquille Forest Plan proposed a fixed allocation of 15 percent of timber receipts for monitoring. Some constituents have argued that when agencies are allowed to use timber receipts, an incentive is set to perpetually increase timber harvest and benefits to corporations. Such challenges can be countered only by describing the long-term benefits of learning to society and to the forest itself.
- **Reshape the burden of proof and the precautionary principle.** Managers, regulators, and others are not "embracing uncertainty" (Lee 1993) when they place a heavy burden of proof on those who either wish to protect nontimber resources (as in the past) or on those who wish to actively manage forests (as the Plan was implemented). With uncertainties of the magnitude we see, and because chosen approaches have never been tried before, demonstrating proof of either kind is not possible or reasonable. We have also learned in the past decade that doing nothing—by applying the precautionary principle as a regional standard or legal directive—is a choice that has much uncertainty as well, and some potential for highly undesirable outcomes. A different set of burdens could be articulated. (Whether some constituencies and courts can be convinced remains to be seen).
- **Diversify practices.** Uncertainty leads us to try multiple approaches to meet a goal so that all of our eggs are not in one basket. Beyond simple diversification, we have much to learn about more elaborate hedging strategies (chapter 3).
- **Structure learning.** Uncertainty about management outcomes can be reduced through formal methods of learning, applied most effectively not as small-scale research studies but as management itself (in representative areas).
- **Maintain critical mass.** Enough technical expertise (across multiple disciplines) is needed locally to understand local limits to general knowledge and apply complex multiscale management scenarios.
- **Promote social tolerance.** Perhaps the most important method to embrace uncertainty is to create more pluralistic, multiconstituency agencies by simultaneously applying approaches promoted by different constituencies—so that each constituency can see their ideas reflected in at least part of the landscape.

Finally, the Plan's requirement of an interpretive report is an important success that could be continued and considered in the design of other monitoring programs. The report is important because it brings a periodic focus on what was learned, improves communication of what was learned, improves integration of science disciplines and science and management, and raises the chances that knowledge will be incorporated in future planning, implementing, and monitoring. Here is where the agencies have a good chance to meet the criteria of McLain and Lee (1996): producing new understanding, incorporating that knowledge into subsequent actions, and creating venues in which understanding can be communicated.

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Part III

Chapter 11: Key Management Implications of the Northwest Forest Plan

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Introduction

Part III of this volume was prepared to assist the Northwest Forest Plan (Plan) agencies[1] in responding to the monitoring and science information that was recently compiled to examine the effectiveness of the Plan in its first 10 years of implementation. To set the stage for their response to the new information, the Regional Interagency Executive Committee (RIEC) commissioned the authors to review material from the 10-year status and trend monitoring reports along with Parts I and II of this volume, and suggest implications[2] and potential future actions. The purpose was to help the agencies develop an organized, meaningful, and documented response to the new information, and to facilitate the accomplishment of the "adjust" phase of the **adaptive management**[3] sequence of "plan-act-monitor-adjust."

Given the broad scope and scale of the Plan, it is no small task to ascertain the implications of the recently compiled information and to determine how to best move forward on the basis of knowledge gained. This report describes some of the likely implications of the new information and potential responses on key issues. It is not intended to represent an exhaustive catalog of possible actions, nor does it reflect any particular agency position or policy. The goal of this report is simply to provide an initial framework for discussing possible responses, and to facilitate the development of adjustments and improvements.

There are many factors the agencies must address in responding to the recent information. First and foremost, laws (see box 1) and regulations must be followed. For example, the majority of the USDI Bureau of Land Management (BLM) lands within the Plan area are managed under the Oregon and California (O&C) Lands Act, which directed that these lands be managed primarily for timber production under the principles of sustained yield. Management of federal lands is also guided by provisions of the Endangered Species and Clean Water Acts (ESA and CWA), which call for protection of federally listed threatened or endangered species and water resources, respectively. In addition, congressional and administration priorities, and human and financial resources, all have significant influences on policy and management direction for public lands.

The preparers of the Plan were charged by President Clinton to "achieve a balanced and comprehensive policy that recognizes the importance of the forests and timber to the economy and jobs in this region" and to "preserve our precious old-growth forests, which are part of our national heritage and that, once destroyed, can never be replaced" (USDA and USDI 1994). The President set forth five principles to guide interagency development of a management strategy to protect old-growth-related species and produce a sustainable level of timber (see box 2). The basic components of the Plan (see box 3) were intended to provide for long-term habitat conditions for old-forest species (including two ESA-listed species, the northern spotted owl

[1] The federal agencies responsible for the Northwest Forest Plan are USDA Forest Service, USDI Bureau of Land Management, and USDI National Park Service (land management agencies); USDI Fish and Wildlife Service, USDC NOAA/National Marine Fisheries Service, and the Environmental Protection Agency (EPA) (consulting/regulatory agencies); and USDA Forest Service Pacific Northwest and Pacific Southwest Research Stations, USDI Geological Survey/Western Research Region, and EPA/Western Ecological Research Division (research agencies). Supporting agencies include USDA Natural Resources Conservation Service, Army Corps of Engineers, and USDI Bureau of Indian Affairs.

[2] In this report, "implications" refers to the potential significance of information to agency policies or actions, or what the information suggests may be needed in the future in order to meet the Plan's objectives.

[3] Definitions of bold text can be found in the Glossary.

Box 1—Significant Laws Governing Federal Lands Within the Northwest Forest Plan Area

Clean Air Act Amendments (1990)—Establishes standards for the amount of point and nonpoint pollution that can be released into the atmosphere.

Endangered Species Act [ESA] (1988)—Sets federal procedures for identifying and protecting threatened and endangered plant and animal species.

Federal Lands Policy and Management Act [FLPMA] (1976)—Authorizes the BLM to inventory and manage its public lands in accordance with the principle of multiple use and sustained yield, and requires BLM to complete management plans every 10 years.

Multiple-Use Sustained Yield Act [MUSY] (1960)—Clarifies the Forest Service's broad mission to manage the national forests for recreation, range, timber, water, wildlife, and fish in a combination that will best meet the needs of the American people.

National Environmental Policy Act [NEPA] (1969)—Requires that environmental impact statements accompany all proposed major federal actions significantly affecting the quality of the human environment.

National Forest Management Act [NFMA] (1976)—Requires the Forest Service to prepare management plans for each national forest that meet the requirements of the MUSY to address such matters as nondeclining even flow of timber, biological diversity, land suitability for timber production, and social and economic factors in decisionmaking.

Oregon and California Lands Act [O&C] (1937)—Mandates that the former Oregon and California Railroad Co. lands be managed by the General Land Office (later, the BLM) for sustainable timber production, water quality, and recreation to promote community stability.

Clean Water Act [CWA] (1987)—Establishes standards for the amount of point and nonpoint pollution that is released into the Nation's waters.

Source: Tuchmann and others 1996.


Kath Collier

Northwest Forest Plan Intergovernmental Advisory Committee reviewing a dam removal project on the Olympic National Park.

Box 2—President Clinton's Five Principles for the FEMAT Process

"First, we must never forget the human and the economic dimensions of these problems. Where sound management policies can preserve the health of forest lands, [timber] sales should go forward. Where this requirement cannot be met, we need to do our best to offer new economic opportunities for year-round, high-wage, high-skill jobs.

Second, as we craft a plan, we need to protect the long-term health of our forests, our wildlife, and our waterways. They are...a gift from God; and we hold them in trust for future generations.

Third, our efforts must be, insofar as we are wise enough to know it, scientifically sound, ecological credible, and legally responsible.

Fourth, the plan should produce a predictable and sustainable level of timber sales and nontimber resources that will not degrade or destroy the environment.

Fifth, to achieve these goals, we will do our best, as I said, to make the federal government work together and work for you. We may make mistakes but we will try to end the gridlock within the federal government, and we will insist on collaboration, not confrontation."

Source: FEMAT 1993.

Box 3—Plan Components

Basic Land Allocation–24,877,949* acres (note: there is overlap between some categories):

Congressionally-Reserved Areas-7,291,246* acres. Areas set aside by Congress, such as wildernesses, national wildlife refuges, etc.

Administrative Withdrawals–1,532,605* acres. Areas set aside by local national forest or BLM district plans, such as backcountry recreation or visual areas.

Late-Successional Reserves (LSRs)–7,155,280* acres. Areas reserved to provide a functional, interactive ecosystem of late-successional and old-growth forest. Stand management to enhance or accelerate older forest attributes is allowed up to age 80.

Riparian Reserves–not mapped; estimated in 1994 record of decision (ROD) to be 2,627,500 acres. Zones adjacent to streams, water bodies, and wetlands, where conservation of aquatic and riparian resources is paramount. The width of the zone and the management direction within it may differ.

***Adaptive Management Areas (*AMAs)**–1,493,579* acres. Ten areas designated for testing new management approaches and enhanced community involvement.

Matrix–4,043,059* acres (includes small administratively withdrawn areas). Lands where most timber production would occur; includes areas outside of reserves, withdrawals, and AMAs. Includes management direction for retention of smaller fragments of old growth, and also live "leave trees" in harvested areas.

Key Watersheds–10,121,100 acres. Watersheds with special management emphasis for at-risk fish or high-water quality. Key watersheds are a component of the Aquatic Conservation Strategy that overlays the land allocations listed above.

Other Components:

Aquatic Conservation Strategy (ACS)–In addition to the riparian reserve and key watershed land allocations described above, ACS provided for watershed analysis, a procedure to develop information on the ecological function of watersheds. That information is used to refine riparian reserve boundaries, guide land management activities, and prioritize restoration opportunities.

Survey and Manage Guidelines–Guidelines for the inventory and conservation of over 400 rare or uncommon species associated with older forests but not listed under the Endangered Species Act, including amphibians, lichens, bryophytes, fungi, vascular plants, vertebrates, and arthropods. The original provisions have been amended (USDA and USDI 2001, 2004).

Box 3—Plan Components (continued)

Northwest Economic Adjustment Initiative–An effort to provide more than $1 billion of federal funding over 5 years to rural communities to assist them in adjusting to the lower timber harvest levels under the Plan. The funds were provided for infrastructure development, technical and financial assistance to businesses, retraining, and creation of new jobs.

Regional Monitoring–A program of monitoring across the Plan area to evaluate the implementation and efficacy of the Plan.

*Source: "Net Change in Acres by Plan Land Use Allocation Category," 2002 data report at www.reo.gov/gis/data/gisdata/final_lua/LUA_acreage.htm. Matrix acreage was calculated by subtracting the 1994 ROD estimate for riparian reserves from the "other" category.

and the marbled murrelet; see appendix for scientific names), a connected late-successional and old-growth forest ecosystem, and habitats for anadromous and other fish species of concern. The Plan is also focused on goals for sustained production of timber and other commodities in order to accommodate a wide variety of public uses and support jobs and the social well-being of communities within the region over the long term. For a more complete discussion of the goals, components, and implementation of the Plan, see chapter 1 in this volume.

The Plan was constructed with the principle of adaptive management in mind (Bormann and others 1994, USDA and USDI 1994). Any large-scale plan contains considerable uncertainty, and there are unavoidable risks associated with making decisions (including decisions *not* to act) when information is lacking. During development of the Plan, measures were taken to limit risk and reduce uncertainty. For example, the precautionary principle[4] is implicit in the Forest Ecosystem Management Assessment Team (FEMAT) report, resulting in options ranging from a medium to a very high probability of ensuring the viability of species. In addition, the Plan provided a mechanism to conduct monitoring and research that would help evaluate the goals and assumptions underlying the Plan, and reduce uncertainty for future decisions.

The Plan is a long-term strategy, with some goals likely only achievable over 100 years or more (for example, development of old-growth conditions in younger parts of late-successional reserves [LSRs]). The information collected since 1994 represents only the first decade of that timespan. Some of the available information represents just a few years of study within that first decade, and therefore may not be "ripe" for application through an adaptive process at this time. Some tendencies and trends are beginning to emerge, but for many issues, it is too early to tell what the long-term results of the Plan will be. The agencies do have a better picture of information gaps (for example, the need to better understand the influence of barred owls on northern spotted owl population trends) that will help improve the ability of future monitoring and research to support land management policies and decisions. And the agencies now have a better ability to prepare for the next decadal cycle of Plan implementation and adjustment.

[4] There are various articulations of the "precautionary principle." The Rio Declaration of 1992 (United Nations Conference on Environment and Development) states: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

The Plan agencies have a variety of options to consider as they continue to implement the Plan (see box 4). These options would likely be combined to produce a mix of complementary actions. The intent of this part of the synthesis is to provide a foundation from which to begin framing subsequent actions within the realities of agency goals, resources, and capabilities.

Overview of Implications

One of the primary objectives of the 10-year status and trend monitoring reports and synthesis was to determine to what extent the assumptions and components of the Plan had actually contributed to meeting the goals identified in the Plan. Another key objective was to determine what changes might be needed to better achieve the Plan's goals. After 10 years, the information suggests that some parts of the Plan are producing the desired results, some are not, and for some, it is too early to tell. In many cases, external factors (for example, the consequences of the rapid increase in the regional population over the last 10 years) have made it difficult to separate the effects of the Plan from other influences.

The need to sort out subregional variation (at a range of scales from provinces to watersheds) while maintaining resonance with the overall regional strategy is one of the key general implications of the 10-year monitoring and science synthesis reports. In particular, the "fire-prone" provinces and riparian areas have been singled out as places where management direction deserves a second look. Human communities may also differ in their response to the Plan and other influences on a subregional basis.

Although the monitoring and new science information reveals considerable success in meeting Plan goals related to environmental protection and conservation, it

Box 4—Categories of Agency Options for Responding to Management Implications of Monitoring and New Science Information

Option category	Description
Regional policy	Policy decisions made by federal agencies
Program direction	Agency direction for individual programs, administrative actions, budget priorities, best management practices, etc.
Land management planning	Establishment of desired future conditions, objectives, management areas, standards/guidelines, suitability, monitoring, etc. through land management planning processes. "The Northwest Forest Plan," although sanctioned as a term by the Regional Interagency Executive Committee and commonly understood as the regional strategy that guides the management of Forest Service and Bureau of Land Management (BLM) lands within the range of the northern spotted owl, was actually legally embedded and continues its life in the various land management plans for national forests and BLM districts under NEPA. Significant changes to "the Plan" involve amending these plans either collectively or individually.
Research	Development of science-based knowledge
Assessments	Compilation of information and analysis to support decisions or develop options

NEPA = National Environmental Policy Act.

also indicates that many of the social and economic goals, such as timber outputs, were not met. In addition, it indicates a clear need for improvements in some areas, such as risk reduction in fire-prone areas. One challenge for the agencies after 10 years of implementing the Plan is finding the balance between retention of the aspects of the Plan that currently appear successful, and making improvements on the basis of new information. Because the Plan was intended to be adjusted as uncertainty is reduced or as new issues emerge, the agencies are (and will continue to be) considering how to improve implementation through agency plan amendment and revision processes.

Implications for the Scope of the Plan[5]

The Complementary Roles of Federal and Nonfederal Lands

For many Plan goals, consideration of what federal lands can provide reveals only part of the picture. Examples of issues that occur across multiple ownerships include conservation of anadromous salmonids, timber production, and invasive species. Questions have been raised about whether these issues can actually be resolved through a plan that addresses only federal policies and practices. Information accumulated in the last 10 years indicates that state and private management of nonfederal lands significantly contributes to achievement of Plan goals for old-growth forests, endangered species, biodiversity, watershed conditions, and socioeconomic factors.

A better understanding of the role of federal forests within the broader context of all forest lands in the region could help federal managers refine their objectives within the greater regional picture (fig. 11-1). A broad spectrum of forest owners, managers, and policymakers could be engaged to craft a vision of how to collectively meet management goals, or even to craft new goals. Such an effort would provide the opportunity for a different public dialogue about the purpose and roles of the various entities (state and federal agencies with varying mandates, industrial lands, and small private forests) of forest ownership on the Pacific Northwest. Specific questions might include: What are the likely ecological and socioeconomic impacts of changes to the Plan on nonfederal lands? And, how do land management and land-use changes on nonfederal lands affect conditions within the federal forest lands? Such discussions could help inform management decisions across the landscape.

New tools are available to facilitate an improved understanding of broad-scale issues, such as spatially explicit landscape models that simulate the effects of alternative policy scenarios through time on various resources, that facilitate modeling the outcomes of change through time across broad areas, and that project consequences of unpredictable events like disturbances. These tools could help clarify the ability of federal forests to contribute to

Box 5—Plan Scope and Scale Findings

- Many of the ecological, social, and economic goals of the Plan cannot be met on federal forest lands alone.
- Exclusive focus on older forests in the Plan has not achieved a comprehensive strategy for federal forest ecosystems, and leaves unanswered questions about the fate of important landscape components such as mid- and early-seral vegetation, hardwoods, and nonforest plant communities.
- Mitigations for emerging threats, including those from global climate cycles and invasive species, were not built into the Plan, which could significantly affect the long-term ability to meet management goals.

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[5] Findings for this section are from various chapters in parts I and II, this volume.

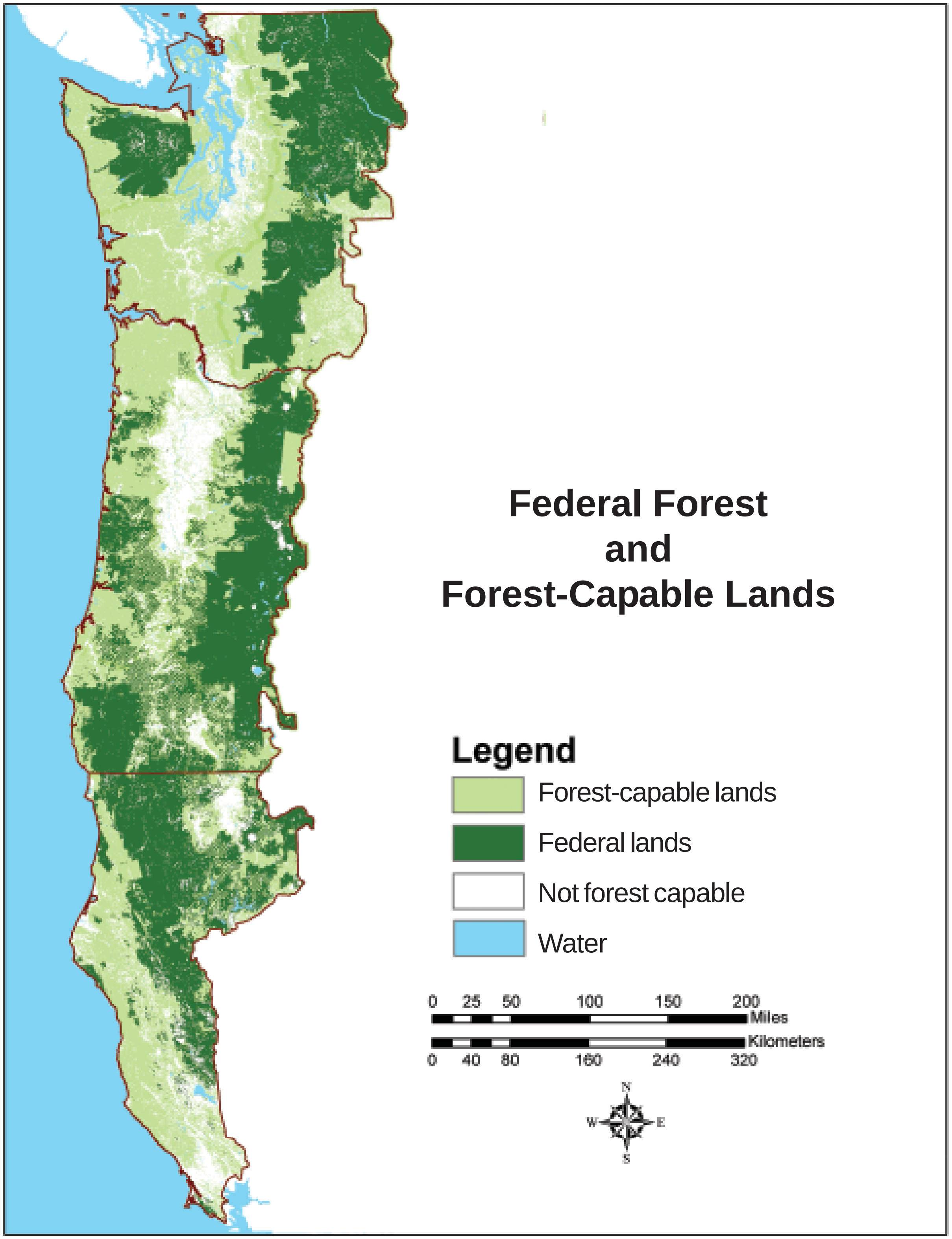


Figure 11-1—Federal forest lands within the Northwest Forest Plan Area. Note that 48 percent of the forested lands are federally managed.

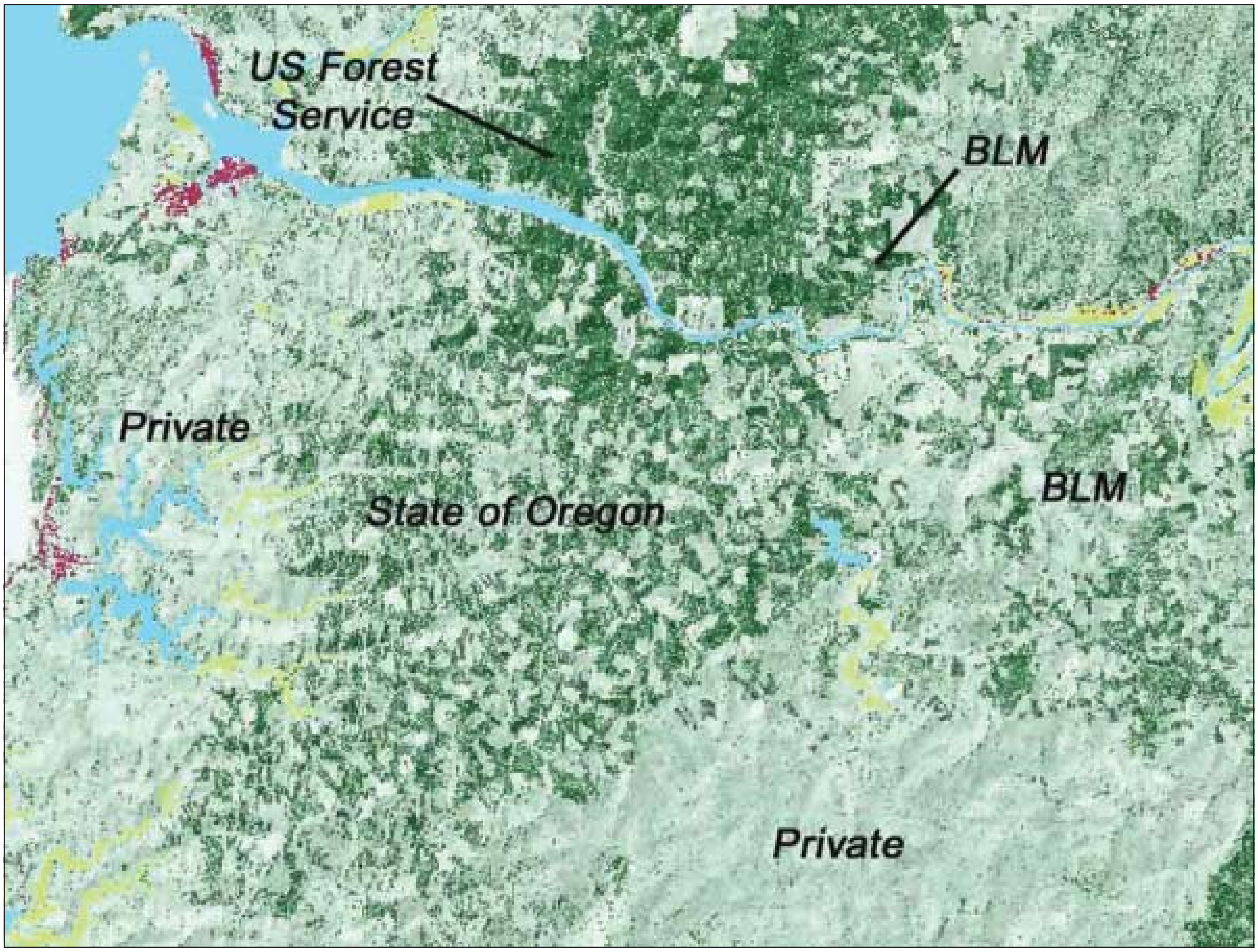


Figure 11-2—Darker green shows area of large trees near Reedsport Oregon. Light green shows area with small trees. The contrast between federal and private management has become greater since 1994.

ecological and economic goals within subregions of the Plan area, and to identify mutual influences among landowners and managers. Some of these tools present challenges in terms of data requirements, cost effectiveness, and clarity.

Beyond Old Growth?

New information about the importance of different forest age classes and nonforest vegetation types suggests that a comprehensive, integrated strategy for managing forest ecosystems should not focus exclusively on older forests. Examples of new findings include the emerging picture of the implications of "bifurcated" forest conditions (only older or young forest) caused by differences between federal and nonfederal policies and land management (fig. 11-2), the increasing threat of invasive species, and growing appreciation of the ecological roles of hardwood and nonforest vegetation types. Limiting the focus to older forests, and ignoring either the earlier developmental vegetation stages that lead up to it or the overall landscape complexity that provides its context, potentially leaves large gaps in the ability to plan and predict future landscape conditions.

Although the FEMAT science assessment that preceded development of the Plan focused primarily on conservation of older forests and associated species, timber harvest, and water resource protection, the USDA Forest Service (FS) and the BLM address a broad spectrum of other resources and forest uses, (recreation, grazing, and mining, for example) in their land and resource management plans. In the process of revising these plans, the agencies could reconsider how to address the full range of forest management issues in light of new findings about broad landscape objectives.

Emerging Threats

Since the FEMAT science assessment was completed in the early 1990s, awareness of the threats of climate change and invasive species to Pacific Northwest forest ecosystems have increased. These emerging threats were acknowledged as a source of uncertainty during development of the Plan, and remain so. The most likely departures from expected future outcomes caused by climate change would be in the drier forests and at higher elevations. New information has shed some light on invasive species; for example, barred owls, sudden oak death, and avian flu virus have been identified as emerging or potential threats to the northern spotted owl.

Climate change and invasive species could have broad-scale and long-term resource management consequences. Additional review of their potential effects on the ability to achieve Plan goals could help inform agency planning processes as science information becomes available that reduces uncertainty in these areas. The nature, extent, timing, and specific effects of emerging threats are still uncertain, and the reports do not specify the level of urgency, or the kinds of actions that could be taken in response. Both the BLM and the FS have programs for managing invasive species, pathogens, and other biological invaders. All of these programs have data available that could be used to assess current and future problems that are likely to affect the ability to meet the Plan goals.

Implications About Plan Components and Issues

Social and Economic Implications[6]

The economic and social context of federal forest lands in the Pacific Northwest has clearly changed in the last decade. In the socioeconomic arena, there were significant differences between Plan expectations and what actually occurred as a consequence of the Plan and other factors. The more striking departures were related to federal timber harvest, the regional timber economy, and communities considered dependent on federal timber production. Much of the information (see box 6) about the social and economic implications of the Plan contained in the *Socioeconomic Monitoring Results* (Charnley and others 2006) and synthesis (chapter 5, this volume) reflects this, challenging earlier notions about the relationship between federal land management, the regional economy, and communities near federal forest lands. A greater understanding of the variety of economic benefits from federal forest lands (besides timber products) would help to improve forecasting of economic impacts. This includes service industries supporting recreation (for example, outfitters/guides, the ski industry, etc.), municipal water supplies, and grazing, among others.

An important part of the agencies' efforts to position themselves for the future will be to find ways to factor this evolving picture of the economic and social role of federal lands and resources into policies, plans, and decisions. This includes more explicitly differentiating between factors that are and are not within the influence of federal land managers. Future planning and implementation efforts would also benefit from inclusion of new information about community resilience and adaptability, and about what being "forest based" actually means for individual communities. There currently are significant gaps in this information for specific communities.

[6] Findings in this section are from Charnley and others 2006, and chapter 5 in this volume.

Box 6—Socioeconomic Findings

- Federal timber harvest in the last decade was lower than expected, averaging 54 percent of the probable sale quantity over the first decade, owing in part to increasing costs and litigation.
- The effect of the reduced timber harvest under the Plan on rural communities was mitigated to some extent by changes in the regional economy. The overall regional economy grew, but at the same time, some individuals and communities experienced significant negative impacts.
- Local communities were found to be generally more dynamic and varied than was expected, and were influenced by a broader set of factors (including nonfederal contributions to the economy), and are influenced by a wider range of forest uses (in addition to timber harvest) than was originally expected. The concept of "forest-dependent communities" is evolving to include economic ties to forests that are based on recreation and other amenities in addition to wood products, and to reflect local living traditions and the sense of place held by many communities.
- Changes in socioeconomic well-being of rural communities varied during the first decade of the Plan. In one-third of the 1,314 non-metropolitan communities in the Plan area, socioeconomic well-being scores improved, one-third declined, and one-third stayed the same. For communities located within 5 miles of federal forests, socioeconomic well-being scores decreased for 40 percent, increased for 37 percent, and stayed the same for 23 percent.
- The prevailing social paradigm for forest management has evolved. At the onset of the Plan, it was transitioning from "sustained yield" to "ecosystem management," and now seems to be moving more toward "sustainability." In addition, societal values about the importance of old growth have changed, and the viewpoint of "no harvest of old growth" is apparently becoming increasingly acceptable to a larger segment of society.
- There have been significant changes in the timber industry over the life of the Plan, including changes in the infrastructure. The strong link between the timber production infrastructure and communities adjacent to federal forest lands no longer exists as it did in previous decades; for example, a higher proportion of mills is now located near major transportation routes, rather than near forest lands.

Source: Charnley and others 2006; chapter 5, this volume.

Box 7—Components of Community Well-Being Index

The following indicators were combined into an index used to assess the relative well-being of forest-based communities in the Plan area:

- Diversity of employment by industry (the variety of industries that employ people from a particular community)
- Percentage of population 25 years and older having a bachelor's degree or higher
- Percentage of the population unemployed
- Percentage of persons living below the poverty level
- Household income inequality (a measure of the disparity between high- and low-income households)
- Average travel time to work

Source: Charnley and others 2006.

Population has increased by 20 percent in the past 10 years, mostly in urban areas. But many of these areas are close to federal forest.

Susan Charnley

The population and socioeconomic well-being of about 40 percent of small towns near federal forest lands declined over the past 10 years.

Progress on the Plan goal of protecting the environment and creating jobs by investing in locally based restoration, research, and stewardship was less than was hoped for. Improvements could be made by identifying and addressing the institutional barriers that make it hard for agencies to create forest-based jobs that local community members can obtain and by strengthening the links between the Plan's biophysical and socioeconomic goals, to increase community engagement in forest management.

Implications for the Management of Late-Successional and Old-Growth Forest Structure[7]

What is old growth?—

One finding of the research synthesis is that the terms "old-growth," "late-successional forest," "older forest," etc. do not have the same meaning for everyone who uses them. As more members of the public become interested in conserving old forests, the definitions have taken on additional

[7] Findings in this section are from Moeur and others 2005, and chapter 6, this volume.

Box 8—Findings About Older Forests

The current network of late-successional reserves (LSRs) appears effective at protecting the best large, most connected blocks of remaining older forest.

- A significant amount of high-quality, smaller fragments of old forest exists in matrix lands.
- The structure, composition, and dynamics of older forests differ across the Plan area.
- Current management of older forest and LSRs in "fire-prone" areas is not in line with the current understanding of ecosystem conditions and processes.
- At the current rate of thinning, a large proportion of stands in LSRs needing density reduction for fire risk and habitat improvements will move beyond the 80-year window before they are treated.
- Measures to reduce fire risk may also locally reduce the quality of habitat for owls and other species associated with dense forests.
- The effects of postfire management (including salvage logging) in LSRs are not well-understood.
- There is lack of clarity and consensus regarding the definitions of "late successional" and "old growth." This results in different maps and analysis outputs, depending on whose definition is used.

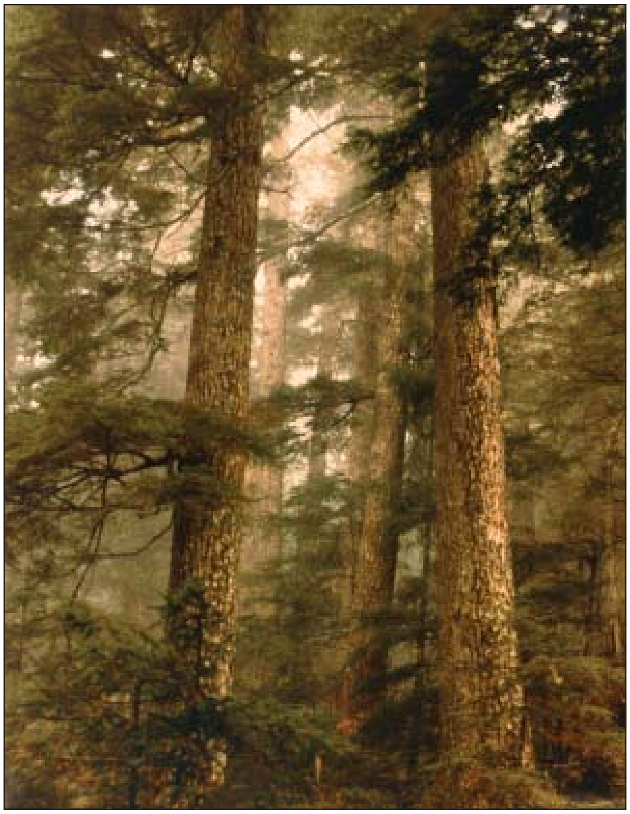
Source: Moeur and others 2005; chapter 6, this volume.

social and political meanings, besides the strictly ecological ones. From an implementation point of view, the Plan does provide clear direction through standards and guidelines. There is, however, disagreement (as evidenced by litigation) regarding how much should be conserved. New knowledge about the considerable complexity and variability of older forests across the region only makes the situation more complicated. Furthermore, the challenging question of how to define old growth in forest types that have been altered by fire exclusion, or are subject to frequent disturbances, remains.

A joint effort by scientists and others to reach a common understanding of the diverse meanings of these terms, and of the diverse forest conditions they represent, could help sort out some of the confusion and imprecision. Ways to represent the social values of older forests may be found during such a process. There is a pressing need for those engaged in federal land planning processes to be aware of which definitions are being used by the various parties, and for the Plan agencies to seek common ground among those involved in developing and implementing plans for the future.

Older forest conservation and management—
As indicated by FEMAT (1993) and Moeur and others (2005), older forests in the Pacific Northwest have been significantly reduced and fragmented by settlement, fires, and pre-Plan logging, and federal lands contain most of the remaining high-quality late-successional and old-growth forest in the region. Conservation of older forests remains both an important societal goal and a necessary element of meeting the ecological objectives of federal land management.

The Plan's strategy of reserves (LSRs in conjunction with congressionally and administratively reserved areas) and management direction for matrix lands appears to be having the intended effect of protecting older forests. But there is both sufficient uncertainty about long-term outcomes, and evidence of problems in the fire-prone provinces, to suggest a need to continue to selectively test and compare alternative approaches at the appropriate scale and with due attention to the risks. The new science findings suggest that active management is likely needed in both young and mature stands in LSRs where stand densities greatly exceed that which would have occurred naturally, to restore ecological conditions and reduce the



Jon R. Martin

Old-growth western hemlock forest.

Steve Lanigan

Aquatic monitoring crew measuring down wood in an old growth forest.

Dave Baker

Stakeholders discuss late-successional reserve management.

potential for loss to catastrophic fires. A dual framework of improving on the Plan's existing reserve component and testing alternative approaches would be one way for the agencies to determine what kinds of (and also where) active management activities would be appropriate. Several alternative approaches for conservation of older forests have been proposed (for example see chapter 6, this volume), but most are largely untested. Options differ in the degree of risk to older forest values and tradeoffs with commodity production.

Approaches such as structure-based management or temporary reserves that result in a "shifting mosaic" of forest age classes (and that may include the use of long **rotations**) could be considered where stronger emphasis on timber production is indicated. These and other alternative approaches could be considered as part of a disturbance ecology strategy to manage for the natural range of conditions at a provincial or watershed scale, and could yield significant new information that would be useful in adjusting management direction. Consideration of information on local ecology and local conditions is an important element of these approaches.

In addition, further consideration of the variation and complexity of older forests across provinces or watersheds


Tom Kogut

Young stand marked for commercial thinning to enhance large tree growth, Gifford Pinchot National Forest.


Tom Kogut

Areas that has been commercially thinned to enhance growth of large trees, Gifford Pinchot National Forest.

could improve the overall late-successional, old-growth forest management component of the Plan. This could result in guidelines for adjusting LSR boundaries where appropriate, and in solving some of the problems associated with current LSR management in fire-prone areas. A new look at the 80-year threshold for LSR stand treatments in areas where later thinnings might still have beneficial effects to stand structure (for habitats) is also ripe for consideration.

It bears noting that there has been significantly less harvest of older forests in matrix lands than was anticipated by the Plan, largely because of litigation. Some have suggested that more emphasis on thinning in younger stands would in part make up for the loss of the timber harvest that was expected and help mitigate the economic effects. Although this might be a short-term solution, longer term economic and harvest projections indicate that the supply of timber appropriate for thinning is limited and will not sustain the targeted levels currently expected under the Plan over the long term.

The problem of the "fire-prone" provinces—
A key question in the management of older forests in the fire-prone provinces is how to simultaneously, across the landscape, provide dense old-forest habitat for species like the northern spotted owl, while minimizing the risk of loss from wildfire. Some of the new information suggests that in northern California and southwest Oregon, low-intensity fire may actually enhance habitat for old-growth species like the northern spotted owl if it creates a favorable mix of successional stages (Franklin and others 2002). There is a significant amount of recent information on older forest ecology to support a new look at how conservation goals could be better achieved in light of the significant risk of loss from wildfire without compromising the integrity of the overall Plan. A provincial- or watershed-scale look at management of older forests (especially an evaluation of LSRs and matrix guidelines) is needed for the fire-prone provinces, that is (1) geared to reducing fire risk at a landscape level; (2) reflective of local environmental conditions, forest structure/composition, and ecological processes; and (3) realistic in regard to what is actually ecologically sustainable in these landscapes. Such an effort could address:

- Areas where there is a need for active management to restore old-forest conditions.
- Guidelines to address the conflict between protecting habitat for species that require more dense, multistoried forests, and the risk of loss to fires.
- Habitats for special-status species that require a long time to recolonize after a disturbance in order to persist (for example, some lichen species).

Note forest ranger in this 1920s photo from the Gotchen Area on the dry, east side of the Gifford Pinchot National Forest.

Today, fir trees have encroached on pine stands in the Gotchen Area of the Gifford Pinchot National Forest.

- Risks of various management activities to other resources and property.

The agencies are already making significant efforts to address these issues.

Postfire timber harvest in LSRs—

Current information shows that there can be considerable ecological value in leaving down wood and snags and minimizing ground disturbance after a fire. At the same time, there can also be economic and fuels reduction benefits from conducting well-designed fire salvage operations that retain appropriate levels of down wood and snags. There is variation in likely results of salvage logging across the Plan area, depending on postfire conditions and other factors. There are substantial gaps in our understanding of the effects of salvage logging and other postfire activities and few opportunities to implement rigorous studies. A partnership between the science and management agencies (such as those that developed following the Timbered Rock and Biscuit Fires) to identify and answer key questions about the effectiveness and consequences of various postfire activities and about the balance between the ecological and economic values of down wood and snags could provide scientific information needed to reduce uncertainty and support future policy development. Litigation experience suggests that postfire salvage is particularly controversial in LSRs, and in those areas, some people's underlying concerns may go beyond the issues of the ecological or economic values of down wood.

Implications for the Conservation of Species Associated With Older Forests[8]

ESA-listed species: northern spotted owls and marbled murrelets—

The protections put into place by the Plan for late-successional and old-growth-related species appear to be succeeding at reducing the rate of habitat loss of federal forest lands. In addition to the Plan's measures, there have been less timber harvest and fewer stand-replacing fires than anticipated. Thus, federal lands are producing older forest habitat at or above expectations, and it has increased over the first decade. Recent science information has raised new questions about what constitutes old-forest habitat for different species (for example, in northern California, habitat heterogeneity appears to be more important for

[8] Findings in this section are from Lint 2005; Huff and others 2006, and chapters 7 and 8, this volume.


Dave Baker

Deciding on the best forest management treatment following wildfire is a challenge.

Box 9—Species Conservation Findings

The reserve system is succeeding at conserving and restoring habitat for spotted owls and marbled murrelets.

- In southwest Oregon and northern California, a mix of forest age classes appears to be important for spotted owls, probably owing to greater abundance of prey in more open areas.
- Spotted owl populations were shown to be level to declining for the decade in different parts of the region, and there is uncertainty about both the causes and the long-term consequences of the trends.
- Fire remains a risk to older forest habitats, and there has been a small amount of fuel reduction treatments relative to the need.
- There are uncertainties about the inland geographic distribution of the marbled murrelet, and some areas classified as murrelet habitat may actually be outside the range.
- The population trends observed over the last 10 years for spotted owls and murrelets may not continue into the future.
- New science information on substitutes for a fine-filter conservation approach (for example, use of surrogates or indicators; protection of biodiversity “hot spots”) revealed some problems, including uncertainty about the ability to make inferences for other species.
- Continuing a combined coarse- and fine-filter approach seems called for given the remaining uncertainty about the status of nonlisted rare and uncommon older forest species.

Source: Lint 2005; Huff and others 2006; chapters 7 and 8, this volume.

northern spotted owl populations than in other parts of the Plan area), and there are new concerns about the ability to mitigate fire risk.

Discerning long-term population trends for the northern spotted owl and marbled murrelet after only 10 years is difficult, and the causes of the observed 10-year findings are unclear. In spite of the observed habitat increases, some populations of the northern spotted owl are declining, with different trends in demographic performance among the provinces. Although the agencies anticipated a decline of northern spotted owl populations during the short term, it was thought likely that the species would begin to recover over longer periods as old forest habitat increased. What was actually found through monitoring (Lint 2005) was greater than expected northern spotted owl population decline in Washington and northern portions of Oregon, and essentially a level trend in southern Oregon and northern California. No attempt has yet been made to predict the longer term outcomes based on these trends.

In addition, the reports were not able to make a direct correlation between habitat conditions and changes in northern spotted owl populations, and they were inconclusive as to the cause of the declines. Lag effects from prior harvest of suitable habitat, competition with barred owls, and habitat loss from wildfire somewhat confounded the ability to draw tight relationships between the Plan's results and northern spotted owl population trends. The reports did not include recommendations regarding potential changes to the basic conservation strategy underlying the Plan, but did identify opportunities for further study.

Similarly, nonhabitat factors appear to be affecting marbled murrelet population trends. Marbled murrelet populations seem to be stable for now, but with only 3 years of monitoring data, more time is needed to be confident in the estimated trends. As with owls (and other species), murrelets respond to cumulative effects of many interacting factors, such as oil spills, nest predators, and oceanic conditions, in addition to land management actions such as timber harvest that affect their habitat. There are also uncertainties about reproductive success, habitat/population relationships, and predation.


Joe Kulig

Northern spotted owl.


Tom Kogut

Barred owl.

In spite of these complex issues, the current Plan's reserve-based habitat conservation strategy appears to make an important contribution toward meeting goals for these species at this time. There may be other habitat conservation strategies that would also be effective in this regard, and that could be explored and analyzed through agency planning processes. In addition, answering the following questions helps assess the likelihood of success over the long term:

- What factors contribute to the observed trends in populations, especially the declines measured for the northern spotted owl in Washington?
- Do species-habitat relationships differ across the range of environments in the region?
- How can the agencies reduce fire risk and at the same time meet species' needs for dense old-forest habitats?
- How do non-stand-replacing events (low-intensity fires, insect outbreaks, thinnings, etc.) affect species and habitats?
- What are the likely future scenarios with regard to emerging nonhabitat concerns, like barred owls, etc.?
- What is the actual distribution of marbled murrelets in the inland (zone 2) portion of the current range?

An important part of answering these questions will be to overcome the significant challenges presented by the limitations of current remote-sensing technology that make it difficult to efficiently and consistently portray fine-scale habitat changes (for example, from partial timber harvest or non-stand-replacing fires).

Strategies for managing both the northern spotted owls and marbled murrelets on nonfederal lands (such as habitat conservation plans) have been devised with the Plan in mind, but an overall assessment of the relative roles of federal and nonfederal lands in the species' conservation efforts is lacking. This issue is particularly important to conservation planning for the murrelet, which has large amounts of habitat on nonfederal lands. This is a good example of the need for greater understanding of the federal land context, as discussed above. Recovery planning processes for these species could help address these issues.

Other rare and uncommon old-forest-related species— The Plan's ecosystem-based strategy for biodiversity conservation still appears to be a valid approach. At the same time, uncertainty remains about the extent to which the reserve system provides for the persistence of all late-successional and old-growth forest species, especially those that are very rare.


Tom Kogut

Larch Mountain salamander is one of many Survey and Manage species.

Information collected through the Survey and Manage program revealed that for some old-forest species, the reserve system likely does contribute to their persistence, whereas others (mostly the rarest species) appear to warrant continued protection of known sites outside reserves. Further interpretation of this and other information will be helpful in refining species conservation approaches. In addition, information gleaned from these efforts could be useful in improving the statistical design and efficiency of future data collection efforts. Fine-filter conservation approaches are important to maintaining persistence of extremely rare species. Reducing uncertainty through accumulation of additional information on rare and uncommon old-forest-related species would likely lessen the amount of work required on the fine-filter side, focusing fine-filter efforts on those species that are most at risk or rare.[9] The high cost of acquiring this type of data requires the agencies to seriously consider the tradeoffs, given limited resources.

Implications for Aquatic and Riparian Conservation[10]

Because the aquatic and riparian monitoring program was not initiated until well into the first decade, and also because watershed conditions change slowly, it is too early to tell for certain whether Plan assumptions about the Aquatic Conservation Strategy (ACS) relative to riparian reserves and restoration are validated. Early results indicate conditions have improved in many watersheds since the inception of the Plan. Future monitoring results will allow more rigorous assessment of effects of reduced timber harvest and road construction on federal land under the Plan, as compared to the previous decade.

Riparian reserves—

In the case of the riparian reserve system, FEMAT assumed that adjustments to interim reserve boundaries would result in a reserve network more tailored to local conditions and processes. Under the Plan standards and guidelines, an analytical process was developed by the agencies to assess and document adjustments to the interim boundaries. As it turned out, many managers and their staffs felt that the burden of proof for interim boundary adjustment was too high, and the procedural requirements outweighed the benefits of boundary changes (which in many cases were viewed as marginal from an operational perspective). As a result, few interim boundaries were adjusted (one example is in Cissel and others 1999), and an extensive network of fixed-width riparian reserves on virtually all water bodies resulted (although forest stands in some of the reserves were thinned). This illustrates the need to ensure that the procedures developed from Plan direction that are intended to foster flexibility and site specificity are practical, efficient, and cost effective.

An aquatic and watershed conservation strategy focused on permanent, unmanaged, and fixed-width buffers

Box 10–Aquatic/Riparian Findings

The monitoring timeframe (2 to 3 years) was too short to produce statistically significant results, but the monitoring did suggest that the combination of restoration activities and reduction in practices that typically degrade riparian areas and watersheds (timber harvest along streams, high road densities) was sufficient to produce improved watershed condition scores in many cases.

- There were fewer adjustments to interim riparian reserve boundaries and management guidelines than anticipated by Forest Ecosystem Management Assessment Team.
- Given the dynamic nature of riparian areas, permanent, unmanaged forest stream buffers may not be sustainable over the long term. Other approaches may be needed to enhance riparian conditions and aquatic habitats.
- New fish population and habitat information (including findings from the Oregon Coast Range that midseral forests may provide better habitat for fish in some cases than does old growth) suggests that revising the key watershed network be considered.

Source: Gallo and others 2005; chapter 9, this volume.

[9] In the original Plan record of decision, over 400 rare and uncommon species believed to be associated with older forests were provided special inventory and conservation measures through the survey and manage standards and guidelines. Some species were removed from the survey and manage list as information came to light regarding their abundance or lack of association with older forests. In 2004, a supplemental environmnetal impact statement that amended BLM and FS plans ended the Survey and Manage provisions, and 152 species were transferred to the inter-agency special status species program. Litigation of this action continues as of this writing.

[10] Findings in this section are from Gallo and others 2005, and chapter 9 of this volume.

Terry Lawson

Project designer and contractor discuss log placement to improve aquatic habitat, Trout Creek, Gifford Pinchot National Forest.

on all streams was not originally intended by FEMAT as a long-term approach, and appears inconsistent with the current body of science findings. Chapter 9 of this volume highlights the dynamic nature of Pacific Northwest watersheds, the variability of riparian geomorphology and habitat from site to site, and the complexities of how changes occur across landscapes over time. Current science clearly indicates that aquatic ecosystems do not exist in a steady state, and that a range of conditions occurring through time and space is normal. Furthermore, because the processes that influence riparian and aquatic functions (like fires, storms, landslides, floods, etc.) are asynchronous, and differ in intensity, extent, and effects from one watershed to another, management approaches appropriate to one watershed may not be appropriate in another.

The new information constitutes an important resource for the design of more effective approaches to the conservation and management of riparian systems, especially development of indepth understanding of the functional relationships in particular watersheds, and data-derived target conditions specific to particular watersheds and streams. Much of the new information addresses the importance of smaller headwater streams, landforms, tributary junctions, large wood, routing of debris flow materials, upslope conditions, terrestrial wildlife habitat needs, and disturbance processes. Tools are now available that could help (1) identify the "hot spots" in watersheds that most contribute to or affect the overall function, (2) address the spatial and temporal distribution of ecological conditions in a watershed, and (3) set criteria for refining riparian reserve boundaries and management guidance within them. The challenge will be to revise the current processes or develop a new process that provides for appropriate consideration of this information in a cost-effective framework.

Road removal in Cummins Creek, Siuslaw National Forest to restore valuable riparian and flood-plain processes.

Key watersheds—
Key watersheds were intended to serve as refugia for aquatic species, especially to aid in recovery of ESA-listed fish, as well as to focus on water quality for municipal supplies. They were originally selected based on professional judgment, and relied in part on the assumption that streams in old-growth forests contained the best fish habitat (an assumption that has since been shown to be questionable for some sites in the Oregon Coast Range, see Reeves and others 1995). No attempt has subsequently been made to update the network or test its effectiveness, even though new information on fish populations and habitats has been compiled. As federal agencies review the key watersheds component of the ACS (using National Oceanic and Atmosphere Administration [NOAA]—Fisheries recovery plans as a foundation), incorporation of new information on fish populations would help clarify (1) whether, and what kind of, management direction for key watersheds is appropriate; (2) whether the existing network is meeting the intended goals of the key watershed Plan component; and (3) whether watershed restoration priorities should be reconsidered.

A watershed analysis team getting started.

Watershed Analysis

No comprehensive assessment of the effectiveness of watershed analysis has been developed. However, there seems to be agreement that:

- Under the current interagency federal guide for watershed analysis, a diverse set of approaches and products resulted. An assessment of the utility and cost of various processes and products could provide helpful insights to inform future iterations.
- In general, watershed analysis was not commonly used to provide a basis for adjustment of the interim riparian reserve boundaries, as had been envisioned by FEMAT.
- For the future, watershed analysis provides a logical vehicle for "stepping down" Plan goals to a watershed scale, for doing midscale assessments, and for providing a framework for prioritization of management activities. Some watershed analyses actually did this by "localizing" the Plan's desired future conditions and establishing projects to achieve them.
- Watershed analyses that used a multidisciplinary (rather than interdisciplinary) approach often included conflicting recommendations from staff specialists. This has surfaced as a concern during litigation. It would be helpful to review and address the topic to inform future guidance relative to watershed analyses.

Implications for How the Plan Is Implemented[11]

Adaptive Management

What constitutes "adaptive management"?—
Whether efforts to achieve "adaptive management" under the Plan are considered successful or not depends to some extent on the definition adopted. The term "adaptive management" has been applied to a wide range of activities that involve learning from experience. At the more

[11] Findings in this section are from various chapters in parts I and II of this volume.

Box 11— Adaptive Management Findings

- Plan expectations about adaptive management were only partially fulfilled, in part because of different views on the definition of "adaptive management," and in part because of a perceived or real lack of flexibility to test strategies that departed from Plan management direction (standards and guidelines).
- Alternative approaches to landscape management may need to be considered in the fire-prone parts of the Plan area in order for the goals for older forest ecosystem conservation to be achieved.
- Tools are available to help decisionmakers identify and organize information about uncertainties, and to systematically describe the risks associated with alternative courses of action and the causes of those risks.

Source: Chapter 10, this volume.

Box 12—Suggestions for Improving Adaptive Management

- Incorporate "learning" as an objective in various plans and activities.
- Identify places with a specific objective of testing and learning (like adaptive management areas), where new management approaches could be evaluated.
- Determine how to make testing new approaches easier to accomplish. This could include assessment of existing avenues to engage in management experiments (for example, experimental forests, cooperative research projects with other landowners, etc.) and assessment of perceived or real barriers in existing Plan direction and other policies, funding mechanisms, appropriation rules, etc.
- Give greater weight to long-term benefits of increased knowledge vs. short-term ecological impacts, and assess the risks associated with **not** taking action.
- For specific projects or initiatives, involve partners and stakeholders.
- Consider adoption of an integrated "adaptive management system":
    - Regular compilation, synthesis, and integration of new information.
    - A prioritized list of questions and learning objectives that drive the collection and development of data and information.
    - Connections among:
        - Agency record-keeping activities
        - Regional monitoring
        - Designed management experiments
        - Long-term financial and institutional commitment to (1) develop and use information to support policy formulation and (2) update information

Source: Chapter 10, this volume.

rigorous end of the spectrum, scientifically designed management experiments can be effectively employed to test various strategies and their effects. In a less formal mode, simply tracking and communicating the results of management activities on the ground in an organized way can lead to significant learning and adaptation. No matter where they occur in this spectrum, successful attempts to manage public lands adaptively will likely have the following attributes: (1) development of projects with an explicit intent to learn; (2) wide communication of knowledge gained; (3) future decisions made on the basis of what was learned; and (4) active collaboration by research, management, and regulatory agencies along with other stakeholders. Communication about lessons learned is fundamental to adaptive management, a fact reflected in the large number of workshops and reports that have been produced by the agencies on Plan-related topics over the last decade.

Adaptive management in the Plan—
Besides being in a general sense a primary component of ecosystem management, adaptive management was incorporated into the Plan in part to balance the implicit use of the precautionary principle to address uncertainty. A particular design of reserves and other land allocations was incorporated into the Plan with the expectation that adaptive management would result in adjustments as the growing body of information helped reduce uncertainty. Under the Plan, continued use of the precautionary principle appears to have limited application of adaptive management and resulted in a higher burden of proof regarding benefits of management actions to ecosystems and species than was intended. Passive protective measures have been favored over active management, even when the benefits of active management are quite apparent (for example, use of thinning to reduce fire risk in fire-prone areas or to accelerate the development of late-successional features in younger forest stands). The balance that adaptive management was expected to provide has not been achieved to the degree that was hoped for.

There were many successes with regard to adaptive management, including the implementation of regional monitoring, and the 10-year status and trend reports and science synthesis (this volume). The shortfalls in applying the concept center around the quantity and quality of experimental treatments, documentation of results, and institutionalizing change based on what was learned. Perceived lack of flexibility in Plan direction (including similar application of standards and guidelines inside and outside adaptive management areas [AMA]) and limitations in budget and staff are often given as reasons for the less-than-optimal application of adaptive management. Given the strained fiscal and organizational resources, agencies must focus on testing approaches that are likely to work and that maximize relevant lessons for managers pressured to show tangible results on the ground.

The "plan," "act," and "monitor" phases of adaptive management have been applied under the Plan, but the "adjust" phase remains problematic.[12] One contributing reason is the lack of institutionally structured means for documenting and communicating when and why adjustments occur. Others are the lengthy time needed to accumulate enough information to support adjustments, and lack of agreement regarding how much information is needed to do so. There is significant controversy and expense associated with making changes, especially at larger scales where formal Plan amendments or revisions might be needed. Several regional adjustments have already been made to the Plan (for example, changes made to the Survey and Manage program; see USDA and USDI 2001, 2004). An exploration of the balance between the Plan's prescriptive nature and the flexibility it was intended to provide could yield useful insights for making adaptations. For example, a plan that

[12] The problem with the "adjust" phase of adaptive management is not unique to the Plan. In Oregon, the state agencies responsible for implementing monitoring under the Oregon Plan for Salmon and Watersheds have experienced similar difficulties (IMST 1999, 2001).

prescribes leaving six to eight green trees per acre provides little flexibility, whereas a plan that describes an objective of leaving large snags of a specific decay class to support a population of cavity nesters provides more room for adaptation. Plan flexibility involves uncertainty and risk. Some tolerance of risk is intrinsic to successful adaptive management, which requires acknowledgment that learning in order to improve for the future may mean accepting risks today.

Adaptive management areas—

The 10 AMAs partially fulfilled their intended role. Many AMAs were successful at providing opportunities for learning, and several highly relevant research projects were established. But many of the successes and lessons learned were not communicated widely, and large-scale experimentation was generally lacking. There were many reasons for this, including perceived or actual lack of flexibility to test alternative approaches, difficulty in reaching consensus among collaborators, and limited funding, staffing, and management emphasis. Extensive litigation and varying interpretations of the Plan, particularly regarding the extent to which activities in AMAs may deviate from the standards and guidelines, certainly played a role in making it difficult for the federal agencies to test new practices and take risks.

Some large-scale experimental treatments, involving different configurations of reserves, rotation lengths, and harvest patterns, actually have been installed in areas inside (for example, the Blue River Landscape study in the Central Cascades AMA on the Willamette National Forest) and outside (for example, the Five Rivers Projects on the Siuslaw National Forest) of AMAs. As results are monitored and evaluated, these kinds of studies will significantly contribute to the knowledge base, reduce uncertainty, and support Plan adjustments based on what is learned.

The AMA experience leaves some questions the agencies will need to grapple with if success is to be achieved: Is the specific land allocation of “AMA” really needed to accomplish adaptive management (for example, by providing areas for watershed-scale experiments)? If so, what will make AMAs different from other land allocations and successful in leading to adjustments that improve land management? If AMAs are continued as a defined management area, they need flexibility and commitment of resources to fulfill their intended role. Consideration of other approaches to allowing experimentation and structured learning (especially at larger scales) without the creation of special land allocations may be useful as well.

Development and Testing of New Landscape-Scale Approaches

One of the primary reasons for considering new landscape management approaches (see box 13) is that given the significant ecological, social, and economic variation across the Plan area, the goals could probably be better met if management direction were more tailored to local conditions. In addition, the agencies could gain significant new knowledge to support future improvements by testing alternative landscape approaches, with due attention to designing and implementing activities in such a way that inferences across broader areas can be made.

Modeling, retrospective studies, and compilation of traditional knowledge from Native American tribes are examples of avenues for developing and analyzing alternative landscape strategies in addition to actual management experiments. Another option is development of cooperative partnerships between federal and nonfederal landowners and agencies, to test approaches that may not be implementable on federal lands. In this scenario, federal lands could be used as controls, or to test approaches with a conservation emphasis and less manipulation of forest vegetation, while other alternatives could be tested on lands with fewer restrictions.

Rigorous comparison of various landscape approaches (including the Plan) could help provide a basis for clarifying goals, articulating knowledge gaps, and strengthening future decisions.

Risk and uncertainty—

FEMAT recognized that uncertainty in managing the forests of the Plan area would always exist, and tried to create

Box 13—Landscape-Scale Approaches to Consider for Testing in the Plan Area

- Structure-based management (Oliver 1992): a landscape approach that prescribes proportions of the landscape in different structural classes (regeneration, closed single canopy, understory reinitiation, multilayered, and older forest), which are then achieved through active management that also meets commodity goals.
- Temporary reserves that revert to matrix status after loss from natural disturbances, at which time new reserves would presumably be established.
- Hybrid of disturbance-based management and fixed reserves, for example, Blue River Landscape study (Cissel and others 1999). The details would be specific to particular watersheds.
- Reserve all remaining old growth. Commodity goals would be met from young and middle-aged forests.
- Landscape restoration (more appropriate in the fire-prone provinces). Would likely involve designating certain lands as owl habitat, and then crafting a large-scale fuel treatment plan to achieve both habitat and risk-reduction goals.

Source: Chapter 6, this volume.

a framework of adaptation whereby uncertainty would be reduced over time and the Plan adjusted accordingly. However, benefits could be attained from more explicitly exploring and disclosing risk and uncertainty in decision-making processes than is currently the case. Keys to being successful in this situation include having clear goals, establishing explicit desired future conditions and benchmarks, and rigorously documenting the logic behind decisions when uncertainty exists. New decision-support tools are available to help managers more visibly and systematically factor information about uncertainties into decisions, and to describe the risks associated with alternative courses of action. Better organization and documentation of decisionmaking could be achieved through employment of such tools, and application of adaptive management could provide a structured framework to continually update the tools and make them work more successfully. Use of such an approach for certain types of decisions seems clearly called for. Moving forward in this direction will require acknowledgement that uncertainty and risk *do* exist, whether management activities occur or not.

The idea of "diversified approaches" (comparison of multiple approaches to accomplish the same objective) is described in chapter 10 of this volume as a tool for dealing with uncertainty in land management. Use of diversified approaches makes sense where there is significant uncertainty or risk, to avoid "putting all the eggs in one basket," and is helpful when there are questions about which approach among a group of alternatives will best meet objectives. The use of diverse approaches as a tool for developing new techniques for managing older forests in fire-prone areas may prove a good way to accelerate the development of needed improvements discussed elsewhere in this report.

Monitoring

The utility of a regional monitoring program has been verified, and a program has been established for selected Plan components. In addition to resource questions that it was designed to answer, the regional monitoring program significantly added new knowledge about how to design and implement a multiagency, scientifically rigorous monitoring program. In large part, the successes of the monitoring program arose from the strong commitment of resources by the agencies, and the establishment of a permanent full-time team to accomplish the work. An examination of how broad-scale interagency monitoring is accomplished

Box 14—Monitoring Findings

The regional monitoring program is in many respects functioning as expected, producing information about status and trends, and also producing significant information that will be useful for making improvements.

- Changing issues, new threats, and new information suggests that the monitoring questions should be reevaluated.
- In some cases, more quantitative targets should be established against which to evaluate the information obtained by monitoring. Examples include trends in populations of species of concern and watershed condition scores.
- Habitat models can be helpful in developing hypotheses, understanding relationships, and stratifying sample designs, but do not provide a surrogate for population monitoring.
- The Plan expectations for overall biodiversity monitoring have not been implemented, although much inventory information on rare and little-known older forest species was collected through the survey and manage effort and continues under the interagency special status species program.
- Incorporating fish population monitoring information from other agencies would significantly complement the aquatic/riparian monitoring that is occurring under the regional monitoring program.

Source: Chapter 10, this volume.

Ted Sedell

Stream monitoring crew taking measurements

Steve Lanigan

Fisheries biologists monitoring stream insects.

Steve Lanigan

Stream monitoring crew measuring stream width and depth.

within agency financial structures, including an assessment of institutional barriers, could yield important information to help ensure an effective monitoring program in the future.

There are significant improvements that could be made. New information suggests a revisit of the monitoring questions is needed, including a review of their applicability to Plan goals, and establishing more specific or different targets or benchmarks for monitored items. The information could significantly help future interpretations of status and trend information and ensure its relevance. A review would also provide information that could set new directions for continued Plan monitoring.

Scale and data resolution are key considerations in developing monitoring questions. Regional-scale monitoring is appropriate where (1) issues operate at that scale, (2) economies of scale can be captured, or (3) consistency of approach is essential. But regional-scale monitoring often lacks the resolution needed to answer finer scale questions. Ideally, fine-scale monitoring should contribute to addressing larger scale questions (for example, to help reduce overall costs), but often this requires a rigorous design to accommodate making inferences to larger areas, and there are few examples where this has been done successfully.

Besides asking the right questions and accumulating information at the right scale and resolution, expectations of a monitoring program need to match the resources available. The identification of information needs and the actual monitoring questions themselves need to continue to take into account the capacity of funding sources over the long term. Integrating monitoring information from multiple data sources has potential to reduce costs. Development and maintenance of common database systems and greater integration between modeling and monitoring (for example, to stratify sample design) also help make monitoring programs more efficient.

Under the Plan, interagency monitoring of older forests, northern spotted owls, and marbled murrelets, as well as surveys for old-forest-associated species conducted under the Survey and Manage program (and subsequently the special-status species program), have significantly increased knowledge of species about which little was known. Agencies invested a huge amount of effort and funding to achieve this outcome. The allocation of resources among specific monitoring priorities, and among activities and programs necessary to achieve the full range of intended Plan outcomes, warrants examination.

In spite of the significant investments for monitoring and surveys, it remains hard to say with certainty what the future trends of species persistence (a primary goal of the Plan) are likely to be, for all species believed to be associated with older forests. Although biodiversity monitoring was mandated by the Plan, it proved difficult to design an effective and affordable comprehensive approach for the large numbers of species involved. In the 10 years since the Plan was initiated, there have been many new developments in the field of biodiversity characterization and monitoring. In addition, the agencies already collect a large amount of information in existing regional inventories that could provide information on biodiversity without the expense of a special effort or creation of a formal "module." Consideration of a new look at this subject in relation to biodiversity goals would likely be productive, especially if it is focused on answering questions at larger scales, integrates the coarse- and fine-filter dimensions of biodiversity conservation, and addresses both habitat and population questions. In the absence of the resources to undertake a huge effort that addresses all of the biodiversity questions, greater reliance on modeling may be a productive avenue for gaining information and forming hypotheses about how to provide protection for some species. In addition, some type of population and habitat monitoring and focused research would be valuable to assess species/habitat relationships, cause-and-effect relationships between management activities and species viability, and effectiveness of management direction to provide for species conservation. In the special-status species program, the agencies are currently emphasizing working with field offices on the identification of local and regional conservation needs, and on directing money and effort toward meeting those needs.

In addition to monitoring the effectiveness of the various components of the Plan, implementation monitoring was established to track overall compliance with the

California Coast Provincial Advisory Committee evaluating project compliance with plan standards and guidelines.

Plan's standards and guidelines (Baker and others 2005). The effort used a statistically based design to sample land management projects (mainly timber sales, but also restoration projects and other silvicultural treatments), and relied heavily on participation by advisory groups to accomplish the work and achieve an independent assessment. In general, the results showed high compliance (less than 7 percent of the projects surveyed were less than 90 percent compliant), with recurring (but few) problems in the areas of snag retention, management of coarse woody debris, and riparian reserve management guidelines.[13] The high overall compliance rate suggests an opportunity to adjust the implementation monitoring program. Potential responses to the monitoring data include lengthening the monitoring interval or focusing on specific areas of concern. This adaptive management step would ensure that implementation monitoring questions are addressed cost effectively and could result in the availability of funds to meet other higher monitoring priorities. The potential for this type of monitoring to provide a foundation for future adjustments to the Plan is great. The program's move into more watershed-scale implementation monitoring in recent years could provide an opportunity for further assessment of progress toward meeting Plan goals, especially by providing additional context for interpretation of results from the other monitoring modules.

Integration Among Scales

Implementation of the Plan started with a broad regional strategy, but is being carried out through assessments, plans, and activities at a whole host of different scales. For the Plan to succeed on the ground, there must be resonance and feedback across the various scales with regard to goals, strategies, plans, and monitoring. In the absence of such integration, it is difficult for local managers to develop program workplans and prioritize projects to accomplish the broader goals, because there is so little ability to tell how their individual project or set of activities does or does not contribute to the overall regional picture. In addition, it becomes very problematic to "roll up" individual actions and assess their collective effects on meeting goals.

One major task is that of identifying which scales are most appropriate to address particular resource issues or monitoring needs. Many issues are most appropriately addressed at some scale between the region and the project area, for example, prioritization of restoration efforts in watersheds. Another essential task is that of crafting a spatially explicit representation of target conditions (a "map" of the future forest patterns and conditions) at intermediate (i.e., watershed) scales against which to compare the projected cumulative effects of various combinations of fine-scale activities.

Management of older forests under the Plan is a good illustration of the need for integration across scales. The LSR network was designed at a *regional* scale to accomplish particular objectives, which drove the location, size, and connectivity among LSRs. The FEMAT team envisioned that there would be a finer scale look at individual

[13] Many of the observed departures from Plan standards and guidelines were due to overriding concerns, such as safety. For example, in some cases, snag densities fell below desired levels because of requirements to reduce hazardous trees in campgrounds or along roads.

or groups of LSRs, to ensure that management objectives and treatments are consistent with the *subregional* variation in ecological capability. At the *stand* scale, there are younger stands within LSRs for which treatments tailored to local conditions are needed to accomplish LSR structural and compositional objectives. Some way of connecting these different themes among scales is necessary to ensure the individual efforts are all actually achieving the desired goal.

Solving the dilemma of multiscale integration will likely involve:

- Determining the appropriate scales to address particular issues, to describe target landscape conditions, and Plan activities and outcomes.
- Developing means for feedback among and between scales by linking goals, plans, strategies, assessments, and monitoring across scales.
- Establishing priorities that address the greatest need in relation to available resources.
- Considering interrelations between actions on federal and nonfederal lands.

Organization and Function of Agency Groups and Stakeholders

Collaboration—
The complexity of overlapping goals, authorities, and interests in the Plan area has created a need for the various entities to coordinate their Plan implementation activities, requiring a highly collaborative model of management and decisionmaking. Even though the successes have not always been easy, inexpensive, or quick in coming, in the 10 years of Plan implementation, significant progress toward interagency collaboration has been made, including new organizational structures, improved relationships, shared expectations for success, and cooperative approaches to funding and staffing.

Plan implementation has also produced several good examples of improved involvement of nonagency stakeholders, including positive changes in the relationships between federal agencies and Native American tribes. Other improvements have occurred through the establishment of formal and informal committees and organizations, including many intergovernmental committees and work groups (for example, the RIEC, Intergovernmental Advisory Committee, Provincial Advisory Committees, watershed councils, etc.).

Some collaborative processes did not meet expectations (for example, those for some AMAs). And many field office employees and community members feel that the Plan moved the locus of decisionmaking to the regional level, reducing their ability to participate effectively.

In the face of declining budgets and staff, the roles of partnerships, volunteers, concessionaires, and joint forest stewardship activities have increased in importance as a way of helping federal agencies complete their work, including restoration activities, infrastructure maintenance, and interacting with the public. The capacity of local communities to engage in these activities is important to success and enhances the ability of agency field offices to participate.

Collaboration will likely remain a necessary feature of regional and local land management and decisionmaking,

Box 15—Opportunities to Improve Collaboration

Renewed commitment to collaboration in the adaptive management areas.

- Learning from the existing models of successful agency-citizen collaboration in joint forest stewardship.
- Adequate planning for the time and financial resources collaboration consumes and planning accordingly.
- Facilitation of local-level decisionmaking so that there is a reason for communities to become engaged.

Source: Charnley and others 2006.


David Burns

Karuk Tribe of California operating equipment to decommission the Steinacher road. Collaboration between the Karuk Tribe, Klamath and Six Rivers National Forests made this possible.

building on the foundation that has already been laid. The lessons learned thus far will be important as policies and relationships evolve to take into account the changing role of federal forests, and the ways in which management on federal and nonfederal lands affect or complement each other. The ability to "walk the talk" is essential to building trust, and creating realistic expectations about what actually can be accomplished is important as engagement of all forest landowners in conservation and development of strategies grows in the future.

Interagency program management and adaptation— Interagency management of the Survey and Manage and regional monitoring programs has yielded useful "lessons learned" to achieve greater efficiency, enhanced credibility, and reduced long-term costs. Some examples of interagency program features that enhanced success are:

- Active participation of researchers, resource staff, and managers in program design, data collection and analysis, and development and application of decision-support tools that integrate relevant information.
- Shared specific goals and objectives, expectations, and evaluation criteria.
- A permanent staff with necessary expertise (for example, in taxa biology/ecology, biometrics, etc.), effective organizational communication links, and clear connection to program goals.
- A monitoring and research framework to strategically focus resources on key information needs, and a plan for appropriate measures to fill those gaps.
- An effective information management infrastructure for data storage and analysis easily accessed and used by diverse users that will meet both short- and long-term information needs.
- Data collection efforts that achieve consistency and economies of scale, by being designed to address multiple species or resource issues and that allow for extrapolation of results to larger landscapes (that is, are probabilistic in design).
- A structured adaptive management process of accumulating new information and then rigorously evaluating that information through use of decision-support models and other means to identify potential adjustments.

The partnership between science and management— From the beginning, the Plan has entailed a close working relationship among the federal research organizations (USDA Forest Service Pacific Northwest and Pacific Southwest Research Stations; USDI Geological Survey, Western Research Region; and Environmental Protection Agency-Western Ecological Research Division) and the other agencies in the Plan area. At its best, this collaboration resulted in joint identification of research needs, pooling of resources to accomplish the necessary work, and shared interpretation of the implications of results. The AMAs provided a forum for exploring how this collaboration could play out on a very localized scale. The partnership has at times been challenging, given the differing roles, policy frameworks, jargon, reward systems, and organizational cultures between the two kinds of agencies.

In the latter half of the Plan's first decade, resources targeted at Plan research needs declined significantly. At the same time, new avenues for scientists to support Plan implementation have emerged, such as this volume. Clearly, the need for strong science underpinnings for the Plan continues. With the development of new issues and new tools for addressing them, a fresh look at science needs, along with the role science and scientists can play in the Plan, is timely.

Information Management

A separate report (Palmer and others 2005) on the management of the wealth of information accumulated as part of the regional monitoring effort was prepared by the Plan agencies. The report outlines the challenges and lessons learned, and also discusses the effect that information management problems had on the ability of the regional monitoring team to produce their reports. Some of this information is summarized in box 16.

Accessible, relevant, accurate data is the foundation of any effort to fill gaps in knowledge. The information management issues identified by the monitoring team may seem rather unexciting when compared to old-growth management issues in fire-prone ecosystems, or the causes of northern spotted owl population trends. But virtually all of what has been learned about the effects of policies and practices on lands and resources is shaped by the quality and nature of the information. Support of the information management function within the regional monitoring program, and integrating it into the larger data management processes of the individual agencies, will be essential if the agencies are to continue to benefit from and use the large amount of data that is being gathered. A key step in accomplishing this will be to prioritize information-gathering and management efforts in light of agency resources and funding.

Box 16–Problems Encountered in Regional Monitoring Information Management

- Some critical data do not exist, could not be found, or were not in a usable format.
- Some databases are not easily accessible outside agency firewalls.
- There are significant inconsistencies in data standards and formats within and among agencies, especially with stream and road data.
- Much information exists but has not been compiled across the analysis area.
- Data are seldom archived, updated, or maintained.
- There are significant gaps in documentation of data.
- Topics where improvements are most needed:
  - Ground-disturbing activities (timber harvest, road building)
  - Restoration activities
  - Riparian reserve boundaries
  - Streams (hydrography)
  - Land allocations and ownership
  - Roads
  - Vegetation
  - Fish passage/barriers
  - Potential natural vegetation
  - Contracting data for projects

Source: Palmer and others 2005.

Conclusions

At this 10-year anniversary of the Plan, the monitoring and new science information suggests both that the overall framework of the Plan is working, and that certain improvements are needed in order to meet the goals. The following suggestions summarize the major implications of the series of 10-year monitoring and research reports:

Plan Scope:

- Reconsider the management goals for federal lands, giving greater attention to the overall context of land ownerships and the contributions of other lands and policies to meeting the goals envisioned by the Plan.
- Incorporate new information on emerging threats (climate change, invasive species) into management direction, and take steps to address the uncertainties.

Plan Components*:*

- Consider revisions to late-successional and old-growth forest management in areas with a natural history of frequent, low-intensity fires.
- Using new science information, create analysis guidelines for adjustment of riparian reserve boundaries and management direction.
- Revisit the key watershed concept and network.

Plan Implementation:

- Adapt the regional monitoring program by
  - Revisiting the monitoring questions (including the desired scale and resolution of data) to ensure the next decade's issues are addressed.
  - Establishing more specific goals and benchmarks.
  - Seeking a better balance among costs, benefits, and expectations.
- Find ways to increase support for taking measured risks in efforts to be successful at adaptive management.
- Continue to improve interagency and stakeholder collaboration; streamline processes and build trust.
- Develop, communicate, and use (in policies and decisions) a clearer understanding of new knowledge about the contribution of federal lands and resources to the regional economy and to communities near federal lands.
- Continue the productive partnership between research, consulting, and land management agencies to identify and fill significant knowledge gaps with needed research and assessments, to provide the basis for future Plan adjustments.
- Make improvements in the management of information, especially accessibility and consistency. Focus on critical data needs.
- Continue to seek ways to help achieve the balance of environmental and economic outcomes envisioned in the Plan.

The extent to which the Plan agencies are able to move forward on these findings will be largely dependent on the priorities set by the RIEC within the considerable constraints on financial and personnel resources that exist, as well as the sideboards set by the laws, policies, and regulations under which the public forest lands and resources are managed.

As far as we know, the series of reports associated with the 10-year review of the Plan constitutes a unique example of adaptive management, in terms of the breadth of topics covered, the sheer size and diversity of the area covered by the Plan, the large number of agency partners and other collaborators, and, perhaps most importantly, in the transparency of the process of sharing new information and developing future policies and actions. The reports for the next decade will no doubt be vastly streamlined and improved, but clearly this decade's effort has established that adaptive management can work at the Plan scale, and provides a good framework for establishing a basis upon which sustainable policies and decisions can be made.

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches	2.54	Centimeters
Feet	.3048	Meters
Cubic feet	.0283	Cubic meters
Miles	1.609	Kilometers
Acres	.405	Hectares
Board feet, log scale	.0045	Cubic meters, log
Board feet, full sawn lumber scale	.0024	Cubic meters, lumber

Glossary

This glossary has evolved from the Forest Ecosystem Management Assessment Team report (FEMAT 1993).

adaptive management—The process of implementing policy decisions as scientifically driven management experiments that test predictions and assumptions in management plans, and using the resulting information to improve the plans.

adaptive management areas—Landscape units designated for development and testing of technical and social approaches to achieving desired ecological, economic, and other social objectives.

age class—A management classification using the age of a stand of trees.

alluvial—Originated through the transport by and deposition from running water.

aquatic ecosystem—Any body of water, such as a stream, lake, or estuary, and all organisms and nonliving components within it, functioning as a natural system.

aquatic habitat—Habitat that occurs in free water.

associated species—A species found to be numerically more abundant in a particular forest successional stage or type compared to other areas.

baseline—The starting point for analysis of environmental consequences. This may be the conditions at a point in time (for example, when inventory data are collected) or may be the average of a set of data collected over a specified period).

biological diversity—Various life forms and processes, including a complexity of species, communities, gene pools, and ecological functions.

biomass—The total quantity (at any given time) of living organisms of one or more species per unit of space (species biomass), or of all the species in a biotic community (community biomass).

blowdown—Trees felled by high winds.

board foot—Lumber or timber measurement term. The amount of wood contained in an unfinished board 1 inch thick, 12 inches long, and 12 inches wide.

breast height—A standard height from ground level for recording diameter, girth, or basal area of a tree, generally 4.5 feet.

Bureau of Land Management—A division within the U.S. Department of the Interior.

canopy—A layer of foliage in a forest stand. This most often refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried stand.

clearcut—A harvest in which all or almost all of the trees are removed in one cutting.

coarse woody debris—Portion of a tree that has fallen or been cut and left in the woods. Usually refers to pieces at least 20 inches in diameter.

colonization—The establishment of a species in an area not currently occupied by that species. Colonization often involves dispersal across an area of unsuitable habitat.

community—(1) Pertaining to human associations based on social interactions, shared interests, norms, or values, or geography, (2) Pertaining to plant or animal species living in close association and interacting as a unit.

conifer—A tree belonging to the order Gymnospermae, comprising a wide range of trees that are mostly evergreens. Conifers bear cones (hence, coniferous) and have needle-shaped or scalelike leaves.

connectivity—A measure of the extent to which conditions among late-successional and old-growth forest areas (LSOG) provide habitat for breeding, feeding, dispersal, and movement of LSOG-associated wildlife and fish species (see LSOG habitat).

conservation—The process or means of achieving recovery of viable populations.

conservation strategy—A management plan for a species, group of species, or ecosystem that prescribes standards and guidelines that, if implemented, provide a high likelihood that the species, groups of species, or ecosystem, with its full complement of species and processes, will continue to exist well distributed throughout a planning area; that is, a viable population.

corridor—A defined tract of land, usually linear, through which a species must travel to reach habitat suitable for reproduction and other life-sustaining needs.

cover—Vegetation used by wildlife for protection from predators, or to mitigate weather conditions, or to reproduce. May also refer to the protection of the soil and the shading provided to herbs and forbs by vegetation.

cumulative effects—Those effects on the environment that result from the incremental effect of the action when added to the past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period.

debris flow (debris torrent)—A rapid-moving mass of rock fragments, soil, and mud, with more than half of the particles being larger than sand.

demography—The quantitative analysis of population structure and trends; population dynamics.

desired future condition—An explicit description of the physical and biological characteristics of aquatic and riparian environments believed necessary to meet fish, aquatic ecosystem, and riparian ecosystem objectives.

diameter at breast height—The diameter of a tree 4.5 feet above the ground on the uphill side of the tree.

dispersal—The movement, usually one way and on any time scale, of plants or animals from their point of origin to another location where they subsequently produce offspring.

distribution (of a species)—The spatial arrangement of a species within its range.

disturbance—A force that causes significant change in structure and composition through natural events such as fire, flood, wind, or earthquake, mortality caused by insect or disease outbreaks, or by human activities, for example, the harvest of forest products.

diversity—The variety, distribution, and abundance of different communities or species within an area (see biological diversity).

down log—Portion of a tree that has fallen or been cut and left in the woods. Particularly important as habitat for some late-successional and old-growth-associated species.

draft environmental impact statement (DEIS)—The draft statement of environmental effects that is required for major federal action under Section 102 of the National Environment Policy Act, and released to the public and other agencies for comment and review.

drainage—An area (basin) mostly bounded by ridges or other similar topographic features, encompassing part, most, or all of a watershed and enclosing some 5,000 acres.

ecosystem—A unit comprising interacting organisms considered together with their environment (for example, marsh, watershed, and lake ecosystems).

ecosystem diversity—Various species and ecological processes that occur in different physical settings.

ecosystem management—A strategy or plan to manage ecosystems to provide for all associated organisms, as opposed to a strategy or plan for managing individual species.

edge—Where plant communities meet or where successional stages or vegetative conditions of plant communities come together.

endangered species—Any species of plant or animal defined through the Endangered Species Act as being in danger of extinction throughout all or a significant portion of its range, and published in the Federal Register.

environmental assessment—A systematic analysis of site-specific activities used to determine whether such activities have a significant effect on the quality of the human environment and whether a formal environmental impact statement is required; also to aid an agency's compliance with the National Environmental Policy Act when no environmental impact statement is necessary.

environmental impact—The positive or negative effect of any action on a given area or resource.

environmental impact statement (EIS)—A formal document to be filed with the Environmental Protection Agency that considers significant environmental impacts expected from implementation of a major federal action.

Environmental Protection Agency—An independent agency of the U.S. Government.

ephemeral streams—Streams that contain running water only sporadically, such as during and following storm events.

even-age silviculture—Manipulation of a forest stand to achieve a condition in which trees have less than a 20-year age difference. Regeneration in a particular stand is obtained during a short period at or near the time that a stand has reached the desired age or size for harvesting. Clearcut, shelterwood, or seed-tree cutting methods result in even-aged stands.

experimental forests—Forest tracts, generally on national forests, designated as areas where research and experiments involving forestry, wildlife, and related disciplines can be conducted.

extirpation—The elimination of a species from a particular area.

filter—Coarse filter management refers to management of overall ecosystems and habitats.

Fine filter management refers to management of specific habitats or sites for selected individual species.

final environmental impact statement (FEIS)—The final report of environmental effects of proposed action on an area of land. This is required for major federal actions under Section 102 of the National Environmental Policy Act. It is a revision of the draft environmental impact statement to include public and agency responses to the draft.

Forest Ecosystem Management Assessment Team (FEMAT)—As assigned by President Clinton, the team of scientists, researchers, and technicians from seven federal agencies who created the FEMAT report (1993).

function—The flow of mineral nutrients, water, energy, or species.

geomorphic—Pertaining to the form or shape of those processes that affect the surface of the Earth.

geographic information system—A computer system capable of storing and manipulating spatial (that is, mapped) data.

green-tree retention—A stand management practice in which live trees as well as snags and large down wood are left as biological legacies within harvest units to provide habitat components over the next management cycle.

guideline—A policy statement that is not a mandatory requirement (as opposed to a standard, which is mandatory).

habitat—The place where a plant or animal naturally or normally lives and grows.

habitat diversity—The number of different types of habitat within a given area.

habitat fragmentation—The breaking up of habitat into discrete islands through modification or conversion of habitat by management activities.

impact—A spatial or temporal change in the environment caused by human activity.

Interagency Scientific Committee (ISC)—A committee of scientists that was established by the Forest Service, Bureau of Land Management, Fish and Wildlife Service, and National Park Service to develop a conservation strategy for northern spotted owls.

interdisciplinary team—A group of individuals with varying areas of specialty assembled to solve a problem or perform a task. The team is assembled out of recognition that no one scientific discipline is sufficiently broad enough to adequately analyze the problem and propose action.

intermittent stream—Any nonpermanent flowing drainage feature having a definable channel and evidence of scour or deposition. This includes what are sometimes referred to as ephemeral streams if they meet these two criteria.

issue—A matter of controversy or dispute over resource management activities that is well defined or topically discrete. Addressed in the design of planning alternatives.

key watershed—As defined by National Forest System and Bureau of Land Management district fish biologists, a watershed containing (1) habitat for potentially threatened species or stocks of anadromous salmonids or other potentially threatened fish, or (2) greater than 6 square miles with high-quality water and fish habitat.

land allocation—The specification in forest plans of where activities, including timber harvest, can occur on a National Forest System or Bureau of Land Management district.

landscape—A heterogeneous land area with interacting ecosystems that are repeated in similar form throughout.

large woody debris—Pieces of wood larger than 10 feet long and 6 inches in diameter, in a steam channel.

late-successional old-growth habitat—A forest in its mature or old-growth stages.

late-successional reserve—A forest in its mature or old-growth stages that has been reserved under a management option (see “old-growth forest” and “succession”).

low-level green-tree retention—A regeneration harvest designed to retain only enough green trees and other structural components (snag, coarse woody debris, etc.) to result in the development of stands that meet old-growth definitions within 100 to 120 years after harvest entry, considering overstory mortality.

management activity—An activity undertaken for the purpose of harvesting, traversing, transporting, protecting, changing, replenishing, or otherwise using resources.

marbled murrelet—A small robin-sized seabird (*Brachyramphus marmoratus*) that nests in old-growth forests within 50 miles of marine environments. Listed as a threatened species in California, Oregon, and Washington by the U.S. Fish and Wildlife Service.

marbled murrelet habitat—Primarily late-successional old-growth forest with trees that are large enough and old enough to develop broad crowns and large limbs that provide substrates for nests. Also includes some younger stands in which tree limbs are deformed by dwarf mistletoe, creating broad platforms.

matrix—Federal lands not in reserves, withdrawn areas, or managed late-successional areas.

mature stand—A mappable stand of trees for which the annual net rate of growth has peaked. Stands are generally greater than 80 to 100 years old and less than 180 to 200 years old. Stand age, diameter of dominant trees, and stand structure at maturity differ by forest cover types and local site conditions. Mature stands generally contain trees with a smaller average diameter, less age-class variation, and less structural complexity than old-growth stands of the same forest type. Mature stages of some forest types are suitable habitat for spotted owls. However, mature forests are not always spotted owl habitat, and spotted owl habitat is not always mature forest.

model—An idealized representation of reality developed to describe, analyze, or understand the behavior of some aspect of it; a mathematical representation of the relations under study. The term model is applicable to a broad class of representations, ranging from a relatively simple qualitative description of a system or organization to a highly abstract set of mathematical equations.

monitoring—The process of collecting information to evaluate if objective and anticipated or assumed results of a management plan are being realized or if implementation is proceeding as planned.

monitoring program—The administrative program used for monitoring.

multiple use—Land management strategy often applied on public lands that emphasizes using various resource values in the combination that will best meet the present and future societal needs. It includes the use of some land for only some resources and, overall, provides a combination of balanced and diverse resource uses that takes into account the long-term needs of future generations for renewable and nonrenewable resources, including, but not limited to, recreation, range, timber, minerals, watershed, wildlife and fish, and natural scenic, scientific, and historical values.

multistoried—Forest stands that contain trees of various heights and diameter classes and therefore support foliage at various heights in the vertical profile of the stand.

National Environmental Policy Act—An act passed in 1969 that encourages productive and enjoyable harmony between humankind and the environment, promotes efforts that will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of humanity, enriches the understanding of the ecological systems and natural resources important to the Nation, and establishes a Council on Environmental Quality (The Principal Laws Relating to Forest Service Activities, Agric. Handb. 453. USDA Forest Service 1983).

National Forest Management Act—A law passed in 1976 as an amendment to the Forest and Rangeland Renewable Resources Planning Act, requiring the preparation of forest plans and the preparation of regulations to guide that development.

National Marine Fisheries Service—A division within the U.S. Department of Commerce.

National Park Service—A division within the U.S. Department of the Interior.

northern spotted owl—One (*Strix occidentalis caurina*) of three subspecies of the spotted owl that ranges from southern British Columbia, Canada, through western Washington and Oregon, and into northwestern California. Listed as a threatened species by the U.S. Fish and Wildlife Service.

old growth—This stage constitutes the potential plant community capable of existing on a site given the frequency of natural disturbance events. For forest communities, this stage exists from about age 200 until stand replacement occurs and secondary succession begins again. Depending on fire frequency and intensity, old-growth forests may have different structures, species composition, and age distributions. In forests with longer periods between natural disturbance, the forest structure will be more even-aged at late mature or early old-growth stages.

old-growth forest—A forest stand usually at least 180 to 220 years old with moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; high incidence of large trees, some with broken tops and other indications of old and decaying wood (decadence); many large snags; and heavy accumulations of wood, including large logs on the ground.

old-growth stand—A mappable area of old-growth forest.

overstory—Trees that provide the uppermost layer of foliage in a forest with more than one roughly horizontal layer of foliage.

owl region—The geographic area within the range of the northern spotted owl.

peak flow—The highest amount of stream or river flow occurring in a year or from a single storm event.

perennial stream—A stream that typically has running water on a year-round basis.

physiographic province—A geographic area having a similar set of biophysical characteristics and processes because of the effects of climate and geology that result in patterns of soils and broad-scale plant communities. Habitat patterns, wildlife distributions, and historical land use patterns may differ significantly from those of adjacent provinces.

planning area—All the lands within a federal agency's management boundary addressed in land management plans.

plant association—A plant community type based on land management potential, successional patterns, and species composition.

plant community—An association of plants of various species found growing together in different areas with similar site characteristics.

population—A collection of individual organisms of the same species that potentially interbreed and share a common gene pool. Population density refers to the number of individuals of a species per unit area, population persistence to the capacity of the population to maintain sufficient density to persist, well distributed, over time (see "viable population").

population dynamics—The aggregate of changes that occur during the life of a population. Included are all phases of recruitment and growth, senility, mortality, seasonal fluctuation in biomass, and persistence of each year class and its relative dominance, and the effects that any or all of these factors exert on the population.

population viability—Probability that a population will persist for a specified period across its range despite normal fluctuations in population and environmental conditions.

predator—Any animal that preys on others by hunting, killing, and generally feeding on a succession of hosts, that is, the prey.

prescribed fire—A fire burning under specified conditions that will accomplish certain planned objectives. The fire may result from planned or unplanned ignitions.

process—Change in state of an entity.

range (of a species)—The area or region over which an organism occurs.

record of decision (ROD)—A document separate from but associated with an environmental impact statement that states the management decision, identifies all alternatives including both the environmentally preferable and preferred alternatives, states whether all practicable means to avoid environmental harm from the preferred alternative have been adopted and, if not, why not.

recovery—Action that is necessary to reduce or resolve the threats that caused a species to be listed as threatened or endangered.

reforestation—The natural or artificial restocking of an area with forest trees; most commonly used in reference to artificial stocking.

refugia—Locations and habitats that support populations of organisms that are limited to small fragments of their previous geographic range (that is, endemic populations).

regeneration—The actual seedlings and saplings existing in a stand; or the act of establishing young trees naturally or artificially.

region—A Forest Service administrative unit. For example, the Pacific Northwest Region (Region 6) includes national forests in Oregon and Washington, and the Pacific Southwest Region (Region 5) includes national forests in California.

regional guide—The guide developed to meet the requirements of the Forest and Rangeland Renewable Resources Planning Act of 1974, as amended (National Forest Management Act). Regional guides provide standards and guidelines for addressing major issues and management concerns that need to be considered at the regional level to facilitate national forest planning.

regulation models—For a forest, different ways of controlling stocking, harvests, growth, and yields to meet management objectives.

riparian area—A geographic area containing an aquatic ecosystem and adjacent upland areas that directly affect it. This includes flood plain, woodlands, and all areas within a horizontal distance of about 100 feet from the normal line of high water of a steam channel or from the shoreline of a standing body of water.

riparian reserves—Designated riparian areas found outside the late-successional reserves.

riparian zone—Those terrestrial areas where the vegetation complex and microclimate conditions are products of the combined presence and influence of perennial and intermittent water, associated high water tables, and soils that exhibit some wetness characteristics. Normally used to refer to the zone within which plants grow rooted in the water table of these rivers, streams, lakes, ponds, reservoirs, springs, marshes, seeps, bogs, and wet meadows.

risk analysis—A qualitative assessment of the probability of persistence of wildlife species and ecological systems under various alternatives and management options; generally also accounts for scientific uncertainties.

rotation—The planned number of years between regeneration of a forest stand and its final harvest (regeneration cut or harvest). The age of a forest at final harvest is referred to as rotation age. In the Douglas-fir region, an extended rotation is 120 to 180 years, a long rotation 180 years.

scale—The level of spatial or temporal resolution perceived or considered.

sensitive species—Those species that (1) have appeared in the Federal Register as proposed for classification and are under consideration for official listing as endangered or threatened species or (2) are on an official state list or (3) are recognized by the USDA Forest Service or other management agency as needing special management to prevent their being placed on federal or state lists.

seral stage—See glossary table 1 for three alternative definitions.

shade-tolerant species—Plant species that have evolved to grow well in shade.

silvicultural practices (or treatments or system)—The set of field techniques and general methods used to modify and manage a forest stand over time to meet desired conditions and objectives.

silvicultural prescription—A professional plan for controlling the establishment, composition, constitution, and growth of forests.

silviculture—The science and practice of controlling the establishment, composition, and growth of the vegetation of forest stands. It includes the control or production of stand structures such as snags and down logs in addition to live vegetation.

simulation—The use of a computer or mathematical model to predict effects from a management option given different sets of assumptions about population vital rates.

site productivity—The ability of a geographic area to produce biomass, as determined by conditions (for example, soil type and depth, rainfall, temperature) in that area.

snag—Any standing dead, partially dead, or defective (cull) tree at least 10 inches in diameter at breast height and at least 6 feet tall. A hard snag is composed primarily of sound wood, generally merchantable. A soft snag is composed primarily of wood in advanced stages of decay and deterioration, generally not merchantable.

soil compaction—An increase in bulk density (weight per unit volume) and a decrease in soil porosity resulting from applied loads, vibration, or pressure.

soil productivity—Capacity or suitability of a soil for establishment and growth of a specified crop or plant species, primarily through nutrient availability.

species—(1) A group of individuals that have their major characteristics in common and are potentially interfertile. (2) The Endangered Species Act defines species as including any species or subspecies of plant or animal. Distinct populations of vertebrates also are considered to be species under the act.

species diversity—The number, different kinds, and relative abundance of species.

stand (tree stand)—An aggregation of trees occupying a specific area and sufficiently uniform in composition, age, arrangement, and condition so that it is distinguishable from the forest in adjoining areas.

stand condition—A description of the physical properties of a stand such as crown closure or diameters.

stand-replacing event—A disturbance that is severe enough over a large enough area (for example, 10 acres) to virtually eliminate an existing stand of trees and initiate a new stand.

standards and guidelines—The primary instructions for land managers. Standards address mandatory actions, whereas guidelines are recommended actions necessary to a land management decision.

stochastic—Random, uncertain; involving a random variable.

stocked-stocking—The degree to which an area of land is occupied by trees as measured by basal area or number of trees.

stream order—A hydrologic system of stream classification. Each small unbranched tributary is a first-order stream. Two first-order streams join to make a second-order stream. A third-order stream has only first-and second-order tributaries, and so forth.

stream reach—An individual first-order stream or a segment of another stream that has beginning and ending points at a stream confluence. Reach end points are normally designated where a tributary confluence changes the channel character or order. Although reaches identified by the Bureau of Land Management are variable in length, they normally have a range of 0.5 to 1.5 miles in length unless channel character, confluence distribution, or management considerations require variance.

structure—The various horizontal and vertical physical elements of the forest.

stumpage—The volume or value of standing timber.

succession—A series of dynamic changes by which one group of organisms succeeds another through stages leading to potential natural community or climax. An example is the development of series of plant communities (called seral stages) following a major disturbance.

successional stage—A stage or recognizable condition of a plant community that occurs during its development from bare ground to climax. For example, coniferous forests in the Blue Mountains progress through six recognized stages: grass-forb, shrub-seedling, pole-sapling, young, mature, and old growth.

suppression—The action of extinguishing or confining a fire.

surface erosion—A group of processes whereby soil materials are removed by running water, waves and currents, moving ice, or wind.

sustainable harvest—A harvest volume that can be maintained through time without decline.

take—Under the Endangered Species Act, take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect an animal, or to attempt to engage in any such conduct.

threatened species—Those plant or animal species likely to become endangered species throughout all or a significant portion of their range within the foreseeable future. A plant or animal identified and defined in accordance with the 1973 Endangered Species Act and published in the Federal Register.

timber production—The purposeful growing, tending, harvesting, and regeneration of regulated crops of trees to be cut into logs, bolts, or other round sections for industrial or consumer use other than for fuelwood.

unique ecosystems—Ecosystems embracing special habitat features such as beaches and dunes, talus slopes, meadows, and wetlands.

U.S. Department of Agriculture (USDA)—Federal land management agency whose main mission is multiple use of lands under its jurisdiction.

U.S. Department of the Interior (USDI)—Federal land management agency whose main mission is multiple use of lands under its jurisdiction.

viability—The ability of a wildlife or plant population to maintain sufficient size so that it persists over time in spite of normal fluctuations in numbers; usually expressed as a probability of maintaining a specific population for a specified period.

viable population—A wildlife or plant population that contains an adequate number of reproductive individuals appropriately distributed on the planning area to ensure the long-term existence of the species.

water quality—The chemical, physical, and biological characteristics of water.

watershed—The drainage basin contributing water, organic matter, dissolved nutrients, and sediments to a stream or lake.

watershed analysis—A systematic procedure for characterizing watershed and ecological processes to meet specific management and social objectives. Watershed analysis is a stratum of ecosystem management planning applied to watersheds of about 20 to 200 square miles.

watershed restoration—Improving current conditions of watersheds to restore degraded fish habitat and provide long-term protection to aquatic and riparian resources.

well distributed—A geographic distribution of habitats that maintains a population throughout a planning area and allows for interaction of individuals through periodic interbreeding and colonization of unoccupied habitats.

wetlands—Areas that are inundated by surface water or ground water with a frequency sufficient to support, and that under normal circumstances do or would support, a prevalence of vegetative or aquatic life that require saturated or seasonally saturated soil conditions for growth and reproduction (Executive Order 11990). Wetlands generally include, but are not limited to, swamps, marshes, bogs, and similar areas.

wilderness—Areas designated by congressional action under the 1964 Wilderness Act. Wilderness is defined as undeveloped federal land retaining its primeval character and influence without permanent improvements or human habitation. Wilderness areas are protected and managed to preserve their natural conditions, which generally appear to have been affected primarily by the forces of nature, with the imprint of human activity substantially unnoticeable; have outstanding opportunities for solitude or for a primitive and confined type of recreation; include at least 5,000 acres or are of sufficient size to make practical their preservation, enjoyment, and use in an unimpaired condition; and may contain features of scientific, education, scenic, or historical value as well as ecologic and geologic interest.

wildfire—Any wildland fire that is not a prescribed fire.

windfall—Trees or parts of trees felled by high winds (see also "blowdown" and "windthrow").

windthrow—Synonymous with windfall, blowdown.

young stands—Forest stands not yet mature, generally less than 50 to 80 years old; typically 20 to 40 years old.

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Glossary Table 1—Major classification schemes used to describe forest developmental stages and associated characteristics[a]

Forest development stage	Ecosystem perspective: Ecological structure and process	Ecosystem perspective: Wildlife habitat	Ecosystem perspective: Timber production
First	Reorganization (Bormann and Likens 1979) Stand initiation (Oliver and Larson 1990) Establishment (Spies and Franklin 1991) Ecosystem initiation (Carey and Curtis 1996) Disturbance/legacy creation and cohort establishment (Franklin and others 2002)	Grass/forb-open, grass/forb-closed, shrub/seedling-open, shrub/seedling-closed, sapling/pole-open (O'Neil and others 2001)	Seedling (Haynes 2003) Early seral (FEMAT 1993)
Characteristics	• Pioneer tree cohort established with a range of regeneration densities • Biological legacies present depending on initial disturbance type, intensity and management • Rapid biomass accumulation • Above- and belowground resource availability high • Nutrient transfer from soil to biomass • Possible introduction and spread of exotic/invasive species	• Biodiversity high • Herb and shrub understory may be abundant or persistent • Open canopy conditions important for birds and mammals • Biological legacies retained provide habitat	• Stand age typically 0 to 15 years • Single-species tree cohort densely seeded or planted, typically with genetically altered stock • Competing vegetation controlled or removed • Precommercial • Includes first tree age class of seedlings (average age of 5 years)
Second	Aggradation (Bormann and Likens 1979) Stem (Oliver and Larson 1990) Thinning (Spies and Franklin 1991) Competitive exclusion (Carey and Curtis 1996) Canopy closure (Franklin and others 2002)	Sapling/pole-moderate, sapling/pole-closed (O'Neil and others 2001)	Poles and saplings (Haynes 2003) Mid-seral (FEMAT 1993)
Characteristics	• Taller vegetation becomes dominant • Leaf area and biomass accumulate • Canopies close on some sites—rate depends on regeneration density and site productivity • Few snags and coarse woody debris (CWD) in managed stands • Rapid understory environment changes • Resource availability decline	• Biodiversity declines • Depending on canopy structure, herb and shrub understory abundance declines • Amphibians associated with closed canopies • Minimize stage through precommercial and variable-density thinning	• Stand age typically 15 to 35 years • Conventional precommercial thinning to maintain evenly spaced trees and promote tree growth • Pole- and sapling-sized trees usually not merchantable • Commercial thinning can occur depending on market conditions

Glossary Table 1—Major classification schemes used to describe forest developmental stages and associated characteristics[a] (continued)

Forest development stage	Ecosystem perspective		
	Ecological structure and process	**Wildlife habitat**	**Timber production**
Third	Aggradation (Bormann and Likens 1979) Stem exclusion (Oliver and Larson 1990) Thinning (Spies and Franklin 1991) Competitive exclusion (Carey and Curtis 1996) Biomass accumulation/competitive exclusion (Franklin and others 2002)	Small tree-single story-moderate, small tree-single story-closed, medium tree-single story-moderate, medium tree-single story-closed, large tree-single story-moderate, large tree-single story-closed (O'Neil and others 2001)	Young (Haynes 2003) Late seral (FEMAT 1993)
Characteristics	• Woody biomass development • Tree crown differentiation and lower branch pruning • Low resource availability early, increases later • Density-dependent tree mortality with high stand density • Few snags and CWD • Competitive exclusion of many organisms	• Low biodiversity • Depending on canopy structure, herb and shrub abundance may be low • Amphibians associated with closed canopies • Minimize stage through precommercial and variable-density thinning	• Stand age typically 45 to 75 years • Pioneer tree cohort dominates site • Sawtimber and nonsawtimber-size trees • Conventionally thought of as the culmination of mean annual increment • For many private industrial landowners, may reflect typical rotation lengths and stand developments ends
Fourth	Transition (Bormann and Likens 1979) Understory reinitiation (Oliver and Larson 1990) Mature (Spies and Franklin 1991) Understory reinitiation, developed understory (Carey and Curtis 1996) Maturation (Franklin and others 2002)	Small tree-single story-open, medium tree-single story-open, large tree-single story-open (O'Neil and others 2001)	Mature seral (FEMAT 1993) Mature (Haynes 2003)
Characteristics	• Maximum height and crown spread of pioneer tree cohort • Minimal coarse woody debris • Heterogeneous resource availability • Shift to density-independent mortality • Sub-lethal tree damage produces greater individual tree conditions and niche diversification	• Extended rotations (>80 years) to provide habitat • Reestablishment of understory species, including shade-tolerant conifers • Increase in diversity of fauna, especially with multistored canopies • Increased habitat through commercial thinning and CWD management	• Stand age typically 85 to 135 years • Less common stage on private industrial lands • Composed mostly of sawtimber-size trees • Conventionally thought of as over culmination of mean annual increment

Glossary Table 1—Major classification schemes used to describe forest developmental stages and associated characteristics[a] (continued)

Forest development stage	Ecosystem perspective		
	Ecological structure and process	**Wildlife habitat**	**Timber production**
Fifth	Steady-state (Bormann and Likens 1979) Old-growth (Oliver and Larson 1990) Transition and shifting-gap (Spies and Franklin 1996) Botanically diverse, niche diversification fully functional (managed) and old growth (Carey and Curtis 1996) Vertical diversification, horizontal diversification and pioneer cohort loss (Franklin and others 2002)	Small tree-multistory-open, small tree-multistory-moderate, small tree-multistory-closed, medium tree-multistory-open, medium tree-multistory-moderate, medium tree-multistory-closed, large tree-multistory-open, large tree-multistory-moderate, large tree-multistory-closed, giant tree-multistory (O'Neil and others 2001)	Mature (FEMAT 1993) Old mature stage (Haynes 2003)
Characteristics	• Slow decline in aboveground biomass • Many substages for long-lived species • Development of late-successional and old-growth attributes (Spies and Franklin 1996) • Density-independent mortality increases, large, persistent gaps may form • Accelerated generation of CWD • Highly heterogeneous resource availability • Sublethal tree damage continues • Loss of dominants (800 to 1,300 yrs.)	• Extended rotations to provide habitat • Large trees, multiple stories, snags, CWD, and closed canopies create habitats for numerous species • Faunal diversity, especially birds and mammals is high	• Stand age typically more than 145 years • Uncommon stage on private industrial lands • Conventionally thought of as past the point where net annual growth has peaked

[a] Characteristics are illustrated from various ecosystem perspectives by using a Douglas-fir-dominated sere growing in the western hemlock zone (Franklin and Dyrness 1988). Characteristics will vary widely based on site location, disturbance history, management, and forest type. This table was developed by B. Kerns (see Monserud et al. 2003).

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Appendix

Common and Scientific Names of Species

Common name	Scientific name
Flora:	
Aspen	*Populus* spp.
Fir	*Abies* spp.
Hemlock	*Tsuga* spp.
California black oak	*Quercus kelloggii* Newberry
Douglas-fir	*Pseudotsuga menziesii* (Mirbel) Franco.
Grand fir	*Abies grandis* (Dougl. ex D. Don) Lindl.
Ponderosa pine	*Pinus ponderosa* Dougl. ex Laws.
Tanoak	*Lithocarpus* spp. Blume
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
Western redcedar	*Thuja plicata* Donn ex D. Don
Bear grass	*Xerophyllum* spp. Michx.
Salal	*Gaultheria shallon* Pursh
Trailing blackberry	*Rubus ursinus* Cham. & Schlecht.
Aquatic species:	
Fish—	
Pacific salmon	*Oncorhynchus* spp.
Bull trout	*Salvelinus confluentus*
Coastal cutthroat trout	*Oncorhynchus clarkii clarkii*
Chinook salmon	*Oncorhynchus tshawytscha*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Cutthroat trout	*Oncorhynchus clarkii*
Lost River sucker	*Deltistes luxatus*
Shortnose sucker	*Chasmistes brevirostris*
Steelhead	*Oncorhynchus mykis*
Oregon chub	*Oregonichthys crameri*
Amphibians and reptiles—	
del Norte salamander	*Plethodon elongatus*
Terrestrial species:	
Birds—	
Jay	*Cyanocitta* spp.
Raven	*Corvus* spp.
Crow	*Corvus* spp.
Barred owl	*Strix varia*
Marbled murrelet	*Brachyramphus marmoratus*
Northern spotted owl	*Strix occidentalis caurina*
Pileated woodpecker	*Dryocopus pileatus*
Mammals:	
Wood rat	*Neotoma* spp.
Red tree vole	*Arborimus longicaudus*
Disease:	
Sudden oak death	*Phytophthora ramorum*

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