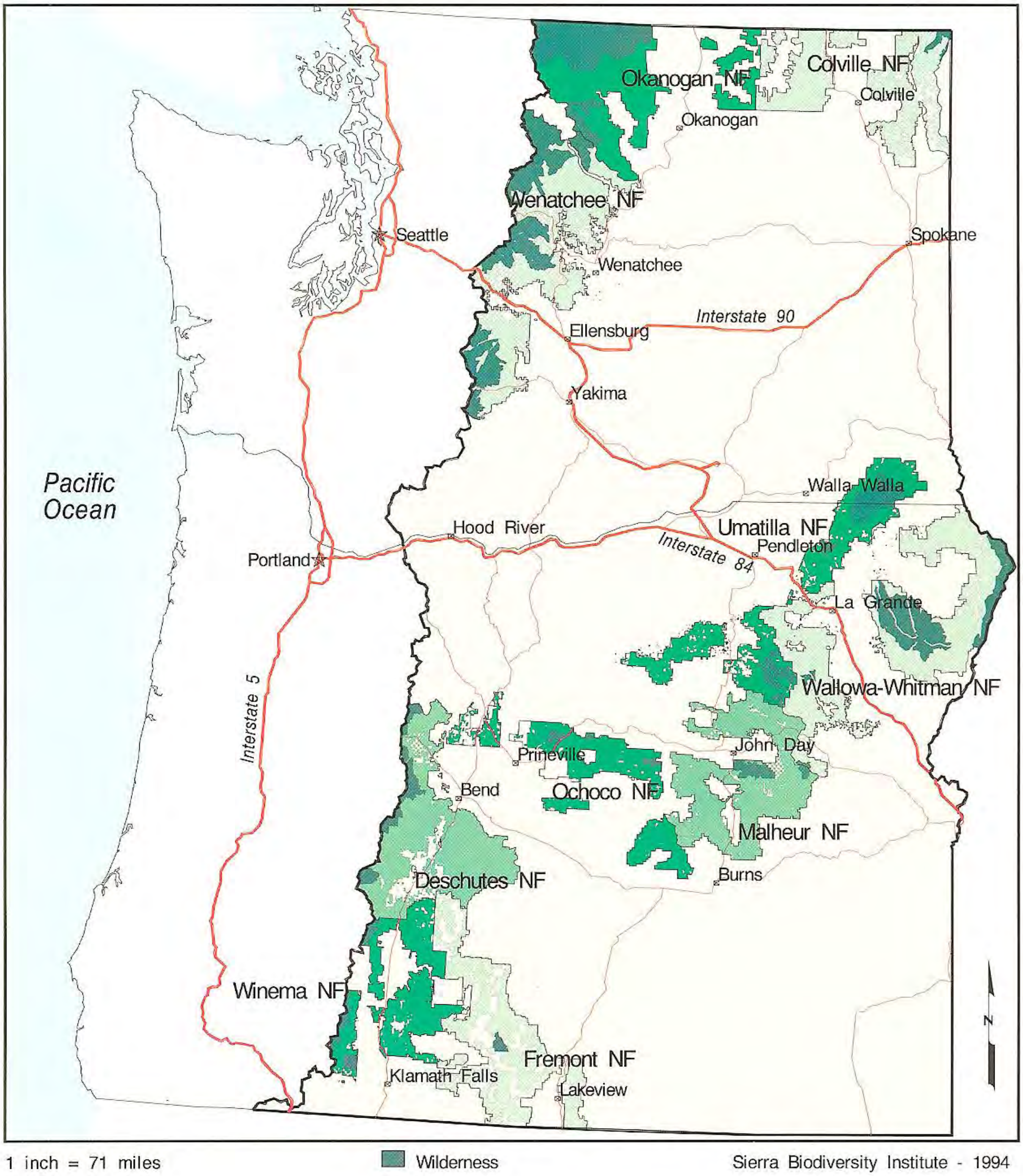
Interim Protection for Late-Successional Forests, Fisheries, and Watersheds

National Forests East of the Cascade Crest, Oregon, and Washington

Eastside Forests Scientific Society Panel



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Interim Protection for Late-Successional Forests, Fisheries, and Watersheds

National Forests East of the Cascade Crest, Oregon and Washington

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edited by
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A Report to the Congress and President of the United States
Eastside Forests Scientific Society Panel

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Preface

The forests east of the crest of the Cascade Range in Oregon and Washington States have undergone dramatic changes during the last 50 years. Legislated increases in timber harvests and an expanding network of roads have fragmented forests across the landscape. Other human activities, including grazing, fire control, and mining, have seriously degraded watersheds and riparian areas, and, among other things, led to disease and pest outbreaks. The result is declining habitat quality for a variety of biological resources and lengthening lists of endangered, threatened, and sensitive fish and wildlife species.

Eastside forests comprise mostly pine, Douglas fir, and true fir; they grow on the relatively dry eastern slopes of the Cascades; in the cold, dry Okanogan Highlands near the Canadian border; and in the Blue Mountains rising from the deserts of eastern Oregon. Recently, much public attention has focused on the need to protect these resources. Unfortunately, no comprehensive review exists of the status of eastside forests or their associated resources; thus the federal government has yet to consider eastside forests in legislation or administrative proposals affecting Pacific Northwest forestlands.

To begin to fill this void, a bipartisan group of seven members of the US House of Representatives approached several scientific societies to form the Eastside Forests Scientific Society Panel to "initiate a review and report on the Eastside Forests of Oregon and Washington."

In their April 1992 letter (Appendix I) to the societies, House members requested that this panel delineate "remaining old-growth ecosystems, forests associated with old growth, riparian and watershed management areas, habitats necessary for the protection of wildlife, and fisheries dependent on old growth." House members also requested "recommendations for any interim management guidelines that might be appropriate to implement on a short-term basis to preserve options while a longer term study [is undertaken]." The overall purpose of this study is to help the US House of Representatives "enact scientifically sound legislation which ensures that old-growth ecosystems, including the species dependent upon those systems, will survive into the future."

The Eastside Forests Scientific Society Panel includes members from the American Fisheries Society, American Ornithologists' Union, Ecological Society of America, Society for Conservation Biology, and The Wildlife Society. Staff of the Sierra Biodiversity Institute participated in all phases of the panel's efforts, especially management and analysis of digital data sets. The panel compiled existing information to define conditions and review trends in forest and associated resources in the national forests east of the Cascade Crest in Oregon and Washington.

This report presents our findings in several forms. In it we summarize technical data available for each forest and synthesize current conditions across eastside forests. We also review the technical literature to account for the trends we observe, including their association with specific human actions. Finally, we offer interim recommendations for preventing further degradation of remaining resources until more comprehensive data are gathered and a long-term protection and restoration plan can be implemented.

We emphasize that these are *interim* recommendations; they do not eliminate the need for a thorough, long-term monitoring program and management plan.

Acknowledgments

This report was made possible by the support, dedication and hard work of many people. Funding was provided by generous grants from the W. Alton Jones Foundation, Pew Charitable Trusts, and Bullitt Foundation. We extend our appreciation to the staff members of these foundations, in particular, Debra J. Callahan of the W. Alton Jones Foundation; Cecily C. Kihn of the Pew Charitable Trusts; and Kathy Becker of the Bullitt Foundation, who came through with supplemental funding for report publication when it was needed.

Thomas Franklin, Wildlife Policy Director of the Wildlife Society, administered grants, organized formation of the Eastside Scientific Society Panel, and facilitated communications among the scientific societies and government officials. Special thanks go to Washington, DC, representatives of the participating scientific societies: David Blockstein, American Ornithologists' Union; Paul Brouha, American Fisheries Society; Marjorie Holland, Ecological Society of America; and Mark Shaffer, Society for Conservation Biology. Charles Cisco, on the staff of Congressman Jim Jontz, helped initiate the project.

We extend our thanks to Region 6 of the US Forest Service for permitting free access to numerous data sets and providing digital copies of those data; we appreciate the cooperation of all Forest Service staff including field technicians and the regional forester. The compilation and release of US Forest Service digital data sets were coordinated by John Steffenson, USFS Region 6, who was extraordinarily helpful. We also thank Tom Nygren and Tim Rogan of the

Region 6 regional office and Regional Forester John Lowe for release of essential digital information. Special thanks to Regional Ecologist Bill Hopkins, Regional Soil Scientist Bob Meurisse, and the ecosystem management teams of the Ochoco and Deschutes National Forests.

Summaries of nineteenth-century survey notes were provided by the Ochoco National Forest ecosystem management planning team. Determining the extent of late-successional/old-growth forests would have been impossible without the work of the National Audubon Society's Adopt-a-Forest project, carried out in cooperation with the US Forest Service. In particular, we thank Judith Johnson, Adopt-a-Forest coordinator, and Kevin Scribner (Umatilla); Mark Gaffney (Fremont, Winema, and Deschutes); Duncan Cox (all Oregon forests); Kim Moriyama (Fremont); Maureen Quinn (Malheur, Fremont, and Ochoco); John Talberth (Deschutes; Winema), Betty Carter, Jo Broadwell, Liam O'Callaghan, Kathey Sterbenz, Susan Carter, and Bruce Honeyman (Wallowa-Whitman); Dave Kliegman and Gerldine Payton (Okanogan); Sue Coleman, Tim Coleman, Mike Peterson, Mike Erving, and Susan Himpleman (Colville); Liz Tanke, Deborah Seyler, Cara Nelson, and Marvin Hoover (Wenatchee); David Werntz (Wenatchee, Ochoco and Winema); Mark Lear (Ochoco and Deschutes); Bill Marlette, Penny Allen, and Paul Dewly (Deschutes); Tanya Wolf-Payne (Ochoco); Tim Lillebo (all Oregon forests), Karen Coulter and Charles Swanson (Umatilla); Skayler Rickbaugh, Linda Driskal, Gerald Ebeltoft, Margaret Carey, and Frazier Nichol (Malheur); Ellen Santasiero (Winema); and others for their meticulous LS/OG mapping and accuracy assessment.

Forest Service personnel essential to cooperative mapping included Ralph Perkins and Rod Johnson (Walla Walla Ranger District, Umatilla National Forest); Karen Kronner and Lew Wallenmier (North Fork Ranger District, Umatilla); Dick Haines and Carl Corey (Malheur); Don Gay (Lake Ranger District, Fremont); Dave Zilanardo (Ochoco); Bernie Carter (Ochoco); Randy Ghormley (Unity Ranger District, Wallowa-Whitman); Ralph Anderson (Wallowa Valley Ranger District, Wallowa-Whitman); Elaine Zieroth (Tonasket Ranger District, Okanogan); Mary C. Hunt (Chemult Ranger District, Winema); Rick Hardey (Klamath Ranger District, Winema); Heather Murphy (Lake Wenatchee Ranger District, Wenatchee); and many others.

Susan Balikov and Peter Morrison of the Wilderness Society responded promptly to our request for comprehensive digital map information. Morrison provided forest condition GIS data for Wenatchee and Okanogan National Forests and assisted in the analyses for those forests. We likewise thank the Oregon State Service Center and the Washington and Oregon Departments of Fish and Wildlife for digital data on rare, threatened, and endangered species; essential map information; and other generous support.

Charles Convis of the Environmental Systems Research Institute was invaluable in coordinating scans of several million acres of LS/OG maps, often returning digital files within three days of receiving them. We are grateful to the Oregon chapter of The Wildlife Society; its president, Mike Wisdom; and the Oregon chapter of the American Fisheries Society for their generous contributions toward a printer.

Project Lighthawk pilot and flight instructor Margaret Puckette of Corvallis, Oregon, took us on an invaluable air tour of the eastern Blue Mountain national forests.

For helpful comments on early drafts of the sections on aquatic systems, we thank Dave Buchanan and Kirk Schroeder of the Oregon Department of Fish and Wildlife, Jon Rhodes of the Columbia River Intertribal Fish Commission, and James Lichatowich of Alder Fort Consulting.

We thank the following colleagues for reviewing the entire manuscript: David Blockstein of the National Institute for the Environment; Leonard Carpenter of the Colorado Division of Wildlife, Denver; Gordon Haugen, Columbia River Basin–PACFISH coordinator; Robert Hughes of Corvallis, Oregon; Lynn R. Irby of Montana State University, Bozeman; Hiram Li of Oregon State University, Corvallis; Michael Morrison of the University of Arizona; Peter Morrison, formerly with The Wilderness Society and now with the Sierra Biodiversity Institute; Henry A. Pearson of Booneville, Arkansas; and Jon Rhodes of the Columbia River Intertribal Fish Commission.

Any errors that remain are ours alone. The views and recommendations are also ours and do not necessarily reflect the position of any of the scientific societies to which we belong or imply endorsement of this report by any of these societies.

Chapter 1

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

For the past decade, the national forests of western Washington and Oregon have received national as well as regional attention because of their central role in the economic and ecological health of the Pacific Northwest. The national forests east of the Cascade crest[1] are no less important and, like the western forests addressed by the 1993 Northwest Forest Conference and resulting Forest Plan, are also receiving national attention. Yet despite the importance of these eastside forests, no synthesis of scientific information about their status and the status of their associated biological resources is available.

To begin to fill this void, a bipartisan group of seven members of the US House of Representatives approached several scientific societies in 1992 to form the Eastside Forests Scientific Society Panel to "initiate a review and report on the eastside forests of Washington and Oregon." The House members hoped to make "every effort to include the eastside forests in whatever ancient forest legislation is considered by the Congress." The panel's mandate was to review the status of all eastside forests and their associated resources—a broader mandate than that of the Forest Health Assessment Team (the Everett Panel). The Everett Panel focused largely on forest health and covered only six river basins; their report is described as "general in nature" (USFS 1993a).

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[1] Ten national forests (Colville, Deschutes, Fremont, Malheur, Ochoco, Okanogan, Umatilla, Wallowa-Whitman, Wenatchee, and Winema) occupy lands between the Cascade crest and the eastern boundaries of Washington and Oregon States. We excluded Mt. Hood and Gifford Pinchot National Forests from our analysis because only small areas of those forests lie east of the Cascades.

The geographical extent of old-growth forest ecosystems in eastside national forests has shrunk dramatically during the twentieth century. Continued logging of old growth outside current reserves will jeopardize unknown numbers of native species. Forest harvest and other human actions have also changed the character of many other components of eastside landscapes, including rivers and their populations of resident and migratory salmonids. Many ecologists believe that the combined effects of logging old growth and fire prevention have significantly increased the vulnerability of eastside landscapes to catastrophic disturbances, further threatening what are already severely reduced and degraded habitats.

Based on our synthesis of existing information, this report defines current conditions and offers *interim* recommendations for protecting the resources remaining on the Eastside until a long-term plan for protection and restoration can be formulated.

THE DATA SETS

Our analysis of late-successional/old-growth forest (LS/OG)[2] is based on (1) the National Audubon Society's Adopt-a-Forest project, carried out in cooperation with the US Forest Service (USFS), and (2) in-house USFS old-growth inventories. Both projects involved interpretation of aerial photography and validation by ranger district staff and, sometimes, field reconnaissance. USFS personnel also furnished many additional details about the national forests of the Eastside. The Oregon chapter of the American Fisheries Society defined aquatic diversity areas for Oregon. Critical watersheds in Washington were identified by a team of fisheries biologists associated with the North Pacific International chapter of the American Fisheries Society. All available geographical data were assembled in a geographic information system (GIS) by the Sierra Biodiversity Institute.

RESOURCE CONDITIONS

The forest ecosystems east of the Cascade crest differ significantly from those west of the crest. Compared with westside forests, eastside forests grow in a more extreme climate—hotter and drier in summer and colder in winter—and on soils that are often less productive. In general, their structure is more open, with a grassy understory maintained by frequent, light groundfires; the

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[2] In this report, we follow the definition of late-successional/old-growth forest (LS/OG) as stated in Hopkins (1992), Hopkins et al. (1992a,b), and Williams et al. (1992a,b) with two important exceptions: (1) We adopt a minimum patch size for LS/OG of 0.5 acres, as opposed to the 10 to 80 acres in USFS interim guidelines, and (2) an old-growth tree is defined by either size or age, not both (see Chapter 3).

ecological dynamics and key habitat attributes required by fish and wildlife communities also differ.

Late-Successional/Old-Growth Forest

Present levels of late-successional/old-growth forest on the Eastside fall far below historic levels, particularly in lower-elevation forests dominated by ponderosa pine, western larch, and Douglas fir. Only about 20–25% of remaining LS/OG is now protected administratively or by statute (from 8% in Wallowa-Whitman National Forest to 32% in Deschutes National Forest). From 70 to 95% of the LS/OG patches that remain cover less than 100 acres each—too small to provide for the basic needs of many LS/OG-associated species. Three national forests (Colville, Wallowa-Whitman, and Winema) have no LS/OG patches larger than 5000 acres; of the seven LS/OG patches larger than 5000 acres in three national forests (Malheur, Ochoco, and Umatilla), only one is protected.

Many areas set aside in current forest plans as "designated old growth" are not old growth. The overlap of actual and "designated" old growth varies significantly among national forests: in Winema National Forest, only 16% of designated old-growth patches contain more than 70% actual old-growth forest, but in Wallowa-Whitman National Forest, 70% of designated old-growth patches do.

Continued logging of now unprotected LS/OG at 1980s rates would reduce the area occupied by these unique ecosystems to between 7 and 13% of forested lands in the national forests. Further reduction in LS/OG is likely to jeopardize many components of the biological diversity of eastside forests and increase numbers of threatened, endangered, and extinct species, especially among sensitive wildlife such as the American marten, northern goshawk, pileated woodpecker, white-headed woodpecker, and flammulated owl. Ponderosa pine forests have been especially hard hit by logging. Only 3–5% of the original ponderosa climax old growth remains in Deschutes National Forest, 2–8% in Fremont National Forest.

The impact of human actions in eastside forests goes well beyond logging. Road construction, grazing, mining, and fire control also degrade forests and associated resources.

Aquatic Systems

Since Europeans settled the region, the ability of aquatic systems to sustain native animal and plant populations, vertebrates in particular, has been compromised: large numbers of fish and amphibian taxa now face extinction in watersheds throughout the Eastside. Salmon production in the Columbia River has declined to less than five percent of its historic levels. At least 106 major populations of migratory salmon and steelhead trout have been extirpated on the West Coast, many of these east of the Cascades. Several resident species that complete their life cycles within freshwater habitats are also threatened with extinction. In Oregon, 24 of 25 at-risk resident fish species or subspecies occur exclusively in eastside waters; 14 are found in watersheds within the boundaries or immediately downstream of national forests.

Roadless Regions

Because roads crisscross so many forested areas on the Eastside, existing roadless regions have enormous ecological value. Unfortunately, few of these remaining areas are protected; in the Blue Mountains of eastern Oregon and Washington, for example, less than 8% of 722,000 acres of forested, roadless area is administratively protected. Although roads were intended as innocuous corridors to ease the movement of humans and commodities across the landscape, they harm the water, soils, plants, and animals in those landscapes.

Riparian Corridors

Riparian (river, stream, and lake-edge) corridors—which link forest and stream environments, serve as buffer zones protecting water resources, and support a disproportionate share of regional biological diversity—have been damaged by logging, road construction, and grazing throughout the Eastside. This destruction also threatens the flow of high-quality water for use by humans.

Soils

Soils on steep slopes, especially pumice and soils derived from granitics, are vulnerable to erosion when disturbed, leading to siltation and reducing soil fertility. It takes a minimum of 200 years to reestablish old-growth forests on the best, most stable sites after logging; reestablishment could take much longer on fragile sites. In particularly fragile areas, forest cover could be permanently lost.

Elements and Processes

In short, the elements (genetic diversity and richness of species and habitats) and processes (hydrological, biological, and ecological) that characterize the ecosystems and landscapes of the Eastside have been heavily altered by recent human activities. Such alterations in turn jeopardize the life-support services provided to human society by these elements and processes. Only by implementing an ecologically sound management program can future generations continue to benefit from forests and their associated resources.

The following recommendations are designed to protect the remaining resources until, and only until, a long-term strategy of protection and restoration can be developed. The recommendations concentrate on remaining late-successional/old-growth forests, aquatic diversity areas, roadless regions, riparian corridors, and soils because these elements constitute the basic building blocks for restoring the eastside landscape. Unless these elements are protected, opportunities will be limited for ensuring sustainable supplies of eastside natural resources.

Interim Recommendations of the Eastside Panel

1. Do not log late-successional/old-growth forests (LS/OG) in eastern Oregon and Washington.

The significantly reduced area, fragmentation, and degraded condition of eastside late-successional/old-growth forests caused by past logging and road construction threaten many forest and aquatic species. These impacts—and consequent loss of critical aquatic and terrestrial habitats—have significantly diminished the region's ability to absorb and buffer disturbances, thus leading us to conclude that all remaining LS/OG blocks and fragments are ecologically significant. Deferring LS/OG logging on all remaining LS/OG will create a "time out," allowing scientists and resource specialists to rigorously assess the status of LS/OG forests and develop a strategy to protect them.

2. Cut no trees of any species older than 150 years or with a diameter at breast height (DBH) of 20 inches or greater.

It is essential to conserve as many of the mature trees of eastside forests as possible in the short term to sustain these forests in the long term. Mature trees have lived for decades, even centuries; their very existence demonstrates that they have the genetic characteristics to survive the full range of environmental variation present in eastern Oregon and Washington. They serve as reservoirs of genetic diversity and irreplaceable seed sources for forest regeneration; they replenish the depleted supply of large snags and fallen logs, providing nest and den sites for many animals; and they furnish unique historic records. As entomologist Boyd Wickman puts it, "These trees are living examples of our long-term objectives."

3. Do not log, build new roads, or mine in aquatic diversity areas (ADAs).

ADAs are defined as (1) locations where native aquatic species are at risk of extinction and vulnerable to future disturbance, (2) whole watersheds exemplifying native aquatic ecosystems, or (3) essential corridors linking habitats required to support fish populations at critical times in their life cycles. Such areas contain the last vestiges of quality habitat and genetic resources for native fish and other aquatic biota (and much of the terrestrial biota, or living things, as well). They serve as cornerstones for any future efforts to protect dozens of at-risk stocks or to rebuild lost production of native fishes. In addition, they provide benchmarks for evaluating the effects of land management and defining the ecological processes that restoration should emulate.

4. Do not construct new roads or log within existing (1) roadless regions larger than 1000 acres or (2) roadless regions smaller than 1000 acres that are biologically significant.

Roadless regions constitute the least-human-disturbed forest and stream systems, the last reservoirs of ecological diversity, and the primary benchmarks for restoring ecological health and integrity. Roads fragment habitat; alter the hydrological properties of watersheds; discharge excessive sediment to streams; increase human access and thus disturbance to forest animals; and influence the dispersal of plants and animals, especially exotic species, across the landscape. Because many forested areas in eastern Oregon and Washington are heavily dissected by roads, the ecological value of existing roadless regions is especially high.

5. Establish protected corridors along streams, rivers, lakes, and wetlands. Restrict timber harvest, road construction, grazing, and cutting of fuelwood within these corridors.

Protection of riparian corridors is essential to the integrity of aquatic systems. Such corridors keep habitats healthy by providing shade, large wood, and detritus and by moderating water temperatures. Riparian areas also serve as buffers, reducing the effects on waterways of human land use, including runoff of fertilizers and pesticides. Such riparian zones are particularly important in the semiarid environments of eastern Oregon and Washington. Seventy-five percent of terrestrial species known in the Blue Mountains, for example, either depend directly on riparian zones or use them more than other habitats.

Perennial streams, with or without fish, must be protected by buffer zones at least 300 horizontal feet wide on each side, or within the 100-year floodplain, whichever is greater. Lakes, ephemeral and intermittent streams, seeps, springs, and wetlands must be protected by a minimum of 150 feet horizontally on all sides.

6. Prohibit logging of dominant or codominant ponderosa pine from any forest, regardless of whether the stand meets the criteria for LS/OG.

Restoring ponderosa pine to its former dominance in eastside forests must be done to protect and restore eastside forest ecosystems. Mature ponderosa pines that remain constitute important focal points for any recovery, whether or not these trees are in LS/OG patches. Their protection must be a high priority independent of the size of the patch where the trees are located.

7. Permit timber harvest in areas prone to landslides or erosion *only* if peer-reviewed scientific study conclusively demonstrates that harvest does not degrade the soils or release sediment to streams.

Protecting soil fertility and stream water quality must be given high priority in all land management plans. Therefore, no logging should be permitted on slopes with a gradient steeper than 30% on pumice soils and 60% on other soil types. Logging on slopes between 30 and 60% should retain 40% of the sum of the area in a stand occupied by tree boles (maximum basal area), with at least half this area consisting of trees larger than the mean size of trees in the stand before logging (quadratic mean diameter).

8. Permit livestock grazing in riparian areas *only* under strictly defined conditions that protect those riparian areas from degradation.

Poorly managed grazing in riparian zones often contributes to degradation of terrestrial and aquatic components of regional landscapes. Grazing may therefore be incompatible with protecting LS/OG and ADAs as sources of colonists for restoring adjacent areas.

We encourage USFS to work actively with ranchers to develop techniques for keeping stock out of riparian areas. The first step is to evaluate the condition of riparian areas in eastside forests, including to what extent grazing is injuring those areas. The second step is to initiate long-term monitoring programs to track the condition of grazed and ungrazed areas. If either of these investigations demonstrates a threat to the health or integrity of LS/OG and ADAs, grazing should be prohibited.

Elsewhere, (a) in areas not degraded by previous livestock use, grazing could be permitted, but only when allotment management plans are revised to incorporate ecological standards consistent with the long-term protection of streams, and grazing does not degrade the riparian zone; (b) no grazing should be permitted in degraded riparian zones until conditions have been restored; (c) after restoration, livestock grazing should only be permitted to the extent that it does not damage restored areas, and management plans have been revised to meet appropriate ecological standards.

9. Do not log or mine on fragile sites until peer-reviewed scientific study conclusively demonstrates that soil integrity is protected and that forest regeneration after logging is assured.

Many eastside forests grow on areas that are transitional to grassland or desert (at low elevation) and to alpine habitat (at high elevation). Mature trees probably became established in transition areas only when the weather was unusually favorable, and forest regeneration on such sites may be difficult. The persistence of mature trees helps maintain soil structure and populations of beneficial soil organisms, and mature trees can survive low-intensity groundfires. Furthermore, soils such as ash soils may be relatively productive but vulnerable to compaction and loss of topsoil. Noxious weeds (usually introduced exotic species) contribute to site degradation if the cover of mature trees is removed from fragile sites. With proper silvicultural techniques, soils may be protected and, with adequate time, forest may regenerate on many transition sites. Before logging is permitted on a site, therefore, site-specific logging plans should be required to demonstrate that silvicultural techniques will not diminish the productive capacity of local soils.

10. Establish a panel with broad expertise to develop long-term management guidelines for securing the ability of eastside forests to resist drought, crown fires, and catastrophic outbreaks of insects and pathogens.

Fire prevention and early logging practices have altered some LS/OG systems, making them vulnerable to drought, insects, and fire. Salvage (removing dead, fallen wood) and thinning (cutting small live trees) are two legitimate techniques—but not the only ones—for lowering risk from such disturbances. Lack of consensus and past abuses, in which large healthy trees were cut in the guise of salvage, lead us to recommend a comprehensive study of this issue. Scientists disagree over how to define the goals of salvage and thinning and over the rules for selecting areas where salvage or thinning is required. No consensus exists on silvicultural practices for minimizing effects from drought, fire, insects, and pathogens; on the conditions under which LS/OG should be entered to reduce risk of catastrophic loss; or on the levels of treatment that reduce risk without compromising ecological values. Sustaining regional natural resources and their use depends on enlightened and comprehensive approaches to protecting forest health.

11. Establish a second panel to develop a coordinated strategy for restoring the eastside landscape and its component ecosystems. Emphasize protecting the health and integrity of regional biological systems as well as the processes on which they depend.

Existing forest plans are inadequate to address the complex ecological issues in eastside forests, especially with regard to managing late-successional/old-growth systems. Forest plans must be revised to integrate new ecological understanding of the influences of Euroamerican settlement with the changing societal attitudes now defining desirable conditions of regional landscapes and their resources. Before those plans can be revised, comprehensive inventories of the status of natural resources must be completed for each forest.

National policies need to be brought into line with national priorities for public lands. To meet current needs for protection and restoration, Forest Service personnel need to be supported with appropriate funding and incentives.

Because federal lands are only a part of landscapes that often contain significant private, state, and tribal holdings, regional programs must be grounded in cooperation among diverse ownership groups. The ecological integrity of regional landscapes depends on protecting both the elements (genetic diversity, richness of species and habitats) and processes (demography, hydrology, species interactions, nutrient cycling, fire) within regional landscapes. Long-term management programs designed to protect that integrity must be given the highest priority on private as well as public lands.

Silvicultural approaches designed to improve forest health and hasten development of old-growth structure in younger forests can probably contribute to restoring eastside forests and landscapes. Nevertheless, these techniques do not justify further logging of existing old growth. We strongly recommend that future silvicultural strategies be developed by multidisciplinary teams comprising not only silviculturalists but also ecologists, wildlife biologists, fisheries biologists, botanists, soil scientists, hydrologists, entomologists, and pathologists. No technique should be widely applied until approved by such an interdisciplinary team.

Consideration of aquatic habitat—protection, restoration, and management—should be an integral component of all forest and silvicultural plans. The role of aquatic systems as crucial integrators of forest condition must be recognized.

The panels called for in recommendations 10 and 11 should include representatives from all relevant subject areas and members from federal and state agencies, Indian tribes, academia, scientific societies, and other groups with appropriate expertise.

12. Establish a comprehensive quantitative biological monitoring program.

Data on a broad range of biological conditions within eastside forests are simply not available. This shortfall, added to inconsistency in what data are available and inadequate synthesis of those data, prevents comprehensive assessment of resource condition and poses a challenge to resource managers. Moreover, such inadequate monitoring of public lands suggests a cavalier attitude toward public resources on the part of the federal government that poses a barrier to public trust. A federal mandate and federal support for improving data quality are essential.

Data collection should be done from an appropriate sampling design that tracks ecological condition and change. Development of this monitoring and assessment strategy should be a central task of the committee called for in recommendation 11.

Chapter 2

EASTSIDE FOREST OVERVIEW

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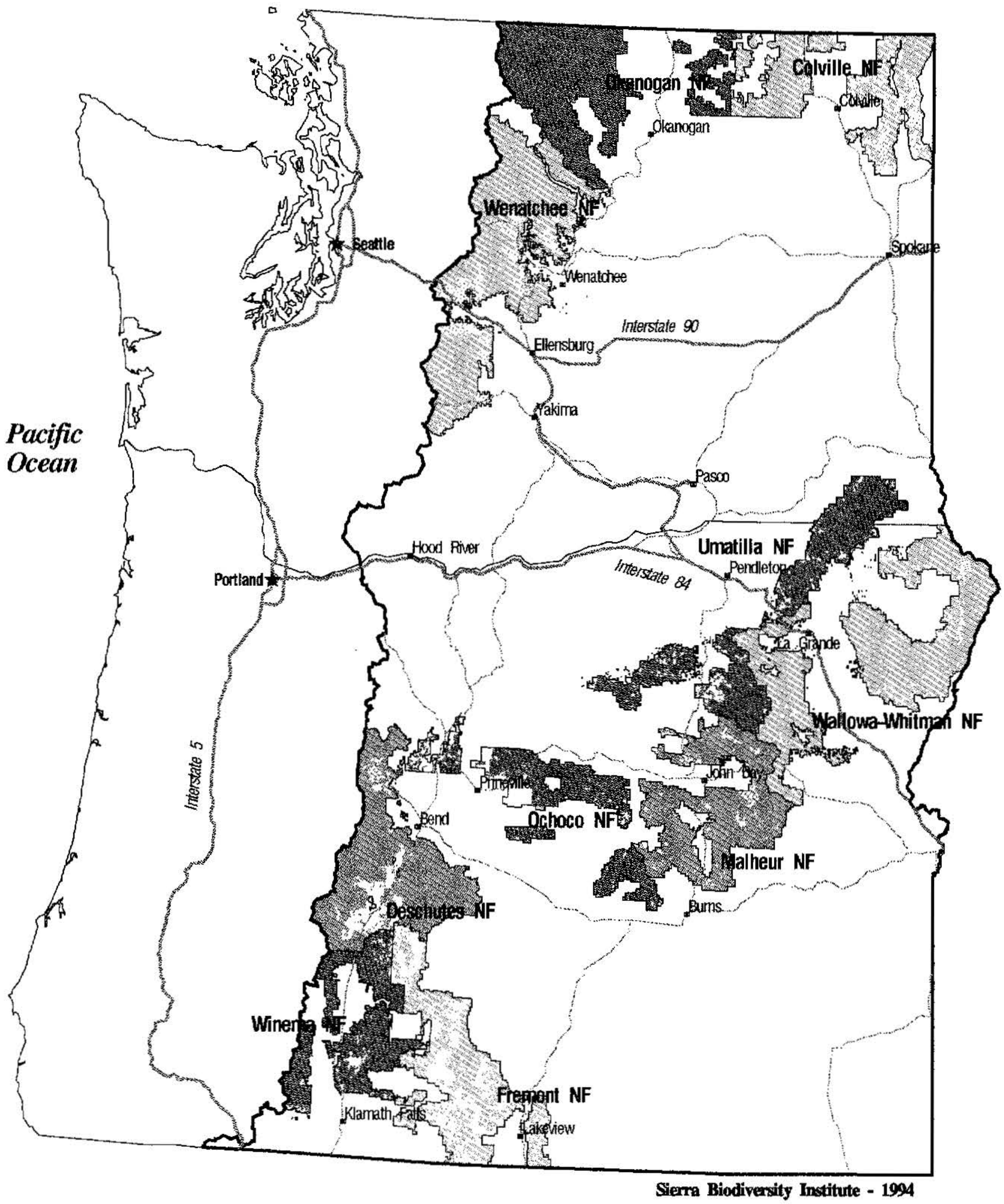
This report considers the national forests east of the Cascade crest in Oregon and Washington, specifically Colville, Deschutes, Fremont, Malheur, Ochoco, Okanogan, Umatilla, Wallowa-Whitman, Wenatchee, and Winema (Figure 2.1). The study area includes all or part of the high Cascades, southern Washington Cascades, northern Cascades, Okanogan Highlands, Columbia Basin, Blue Mountains, High Lava Plains, and Basin-and-Range provinces of the Pacific Northwest.

Forest ecosystems east of the Cascade crest differ significantly from those to the west. Eastside forests grow in a more extreme climate—hotter and drier in summer and colder in winter—and often on soils that are less productive. Johnson et al. (1991) remark, "Ecosystems on the eastside are less productive and more fragile (less resilient and resistant to disturbance) than those on the west side of the Cascades because of the climate and greater environmental stress. Thus, management activities suitable for westside forests often do not yield satisfactory results when applied to eastside forests." In discussing the forest associations of eastside Oregon and Washington 20 years ago, Franklin and Dyrness (1973) pointed out that "the abundance of climax forest types and the complex array of seral communities result from an abundance of coniferous species and environmental diversity. These factors . . . pose a significant challenge to resource managers in their efforts to protect and restore eastside ecosystems."

Figure 2.1 National forests east of the Cascade crest in Oregon and Washington.



HISTORIC EASTSIDE FORESTS

Early settlers of eastern Oregon wrote of extensive forests dominated by large old ponderosa pines *(Pinus ponderosa)*, with grassy understories maintained by frequent, light groundfires. Surveyors' notes, which recorded species and size of one to several "witness" trees at each section corner, provide some measure of historic forest structure. Surveys in the late 1800s in what is now Ochoco National Forest, for example, recorded ponderosa pines at 93% of the section corners except in the wettest forests (northern slopes above 5000 feet); in these areas, ponderosa pine was recorded at 69% of the corners. On average, 40% of witness trees on all but the wettest sites were 21 inches or larger in diameter at breast height (DBH). In short, journal accounts confirm that large ponderosa pine dominated these forests until recently.

The first comprehensive survey of forest resources in eastern Oregon and Washington (excluding Stevens and Spokane Counties in northeastern Washington) was completed in 1936, when "[t]he area of commercial forest land [was] characterized by a high proportion of old growth" (Cowlin et al. 1942). Accounting for logging before 1936, it is likely that the original low- and midelevation ponderosa pine forests were nearly 90% old growth. These stands typically contained trees up to 60–70 inches DBH, with most of the stand volume concentrated in trees from 20 to 44 inches DBH. The 1936 survey found that old growth of all forest types made up 89% of sawlog-sized stands and 73% of all commercial forestlands in eastern Oregon and Washington.

Logging began in earnest in the area during the 1920s, but even so, ponderosa pine dominated nearly two-thirds of forested lands in 1936, and most of it was still old growth. At that time, large-scale cutting occurred almost exclusively in the extensive stands of old-growth ponderosa on the Klamath Plateau and eastern slopes of the Oregon Cascades and in northeastern and central Washington (Wall 1972). Cowlin et al. (1942) estimated that logging, insects, and catastrophic fire (many a consequence of logging) had reduced the region's old-growth ponderosa pine from "an original" 12 million acres to 9.1 million acres at the time of the 1936 survey. "Originally, a virgin forest of this type extended the length of Oregon along the east slopes of the Cascade Range from within a few miles of the summit to the desert's edge. From about 10 miles in width on the north, it ranged to nearly 100 miles on the Klamath Plateau in the south, interrupted only by comparatively small openings of nonforest land. Extensive cutting from Bend south has broken it up with large areas of pine second growth" (Cowlin et al. 1942).

A 1936 inventory in the Blue Mountains (today's Malheur, Ochoco, Umatilla, and Wallowa-Whitman National Forests) found that forests containing a significant proportion of ponderosa pine occupied about 80% of commercial forestland (Cowlin et al. 1942). As on the Klamath Plateau and the eastern slopes of the Cascades, the great majority of pine forests consisted of old growth (86%). By the mid-1960s, however, the proportion of commercial forests dominated by ponderosa pine in the Blue Mountains had dropped to 40% (Bolsinger and Berger 1975), a loss of half over a 30-year period. Bolsinger and Berger (1975) conclude that "cutting in [ponderosa pine] has greatly exceeded the growth rate. Prospects for increased growth of ponderosa pine in the near future are poor, especially on private lands where cutting has removed a large percentage of the trees where growth could be occurring; the remaining stands are often poorly stocked, made up of inferior trees left after logging, or consist of other species such as Douglas-fir or true firs."

Recent Trends

Loss of ponderosa pine in the Blue Mountains was accompanied by a declining abundance of large trees of all species. Referring to the 1960s inventory, Bolsinger and Berger (1975) write, "Since the previous inventory (in the 1950s), the forests of the Blue Mountains have been heavily logged. In the mid-1950s, the acreage in sawtimber trees 21.0 DBH and larger was 2.5 million acres; the present inventory shows 1.4 million acres—a reduction of 44%." Heavy logging has continued since the 1960s, and Wickman et al. (in press) estimate that "remaining commercial ponderosa pine easily could be reduced now to 20–25% of the total forest area in the Blue Mountains."

Losses of ponderosa pine in the Blue Mountains are not the only concern. Douglas fir *(Pseudotsuga menziesii)* forests were also abundant at low and middle elevations in northeastern and south-central Washington. The 1936 survey found that 60% of these forests were either old growth or "large second growth," in other words, consisting of trees large enough to qualify as old growth under current definitions. Whereas the earliest logging in Washington took predominantly ponderosa pine, roughly equal amounts of ponderosa and Douglas fir were being logged by 1970 (Wall 1972). We do not know how much old-growth Douglas fir remains today, but the amount is almost certainly well below historic levels.

As elsewhere, logging in eastern Oregon and Washington progressed from high-value, accessible stands in the lowlands to lower-value stands higher in the mountains and to public lands (Wall 1972). Between 1949 and 1958, timber harvest from eastside Oregon and Washington was split about equally between private and public lands. The cut from private lands reached a plateau in the mid-1950s at the same time that cutting from public lands was accelerating. During the second half of the 1960s, two-thirds to three-fourths of the total regional cut came from public lands—almost exclusively from national forests in Oregon and from a mix of national forest and tribal lands in Washington. This trend has held to the present, at least in Oregon, where two-thirds of the cut between 1983 and 1987 came from public lands (Sessions et al. 1990).

Coincident with the increasing importance of public lands in overall harvest was a sharp increase in the cut. Log production from national forests in eastern Oregon and Washington increased nearly fourfold between 1949 and 1968. By the late 1960s, harvest from all lands, regardless of ownership, stood at 50% higher than the most optimistic estimate of sustained yield from eastside forests (Cowlin et al. 1942). Log production in eastern Oregon during the mid-1980s resembled that in the late 1960s and early 1970s (Sessions et al. 1990; no comparable data exist for Washington).

In addition to logging, heavy grazing by domestic livestock began on the land 100 years ago, and in some areas, mines altered the vegetation and even local topography.

In summary, the forest landscapes of eastern Washington and Oregon have been transformed during the past century. Continued logging in unprotected areas could reduce LS/OG to less than 10% of total forest area in the region, raising concerns about risks to species and ecological processes. Eastside forests—and the fish, wildlife, and watersheds associated with them—have become the subject of controversy in the late 1980s and early 1990s as logging rates have risen to make up for declining timber cutting in westside "spotted owl" forests. Generally, decisions have been made in a relative vacuum of scientific information regarding distribution and occurrence of eastside old-growth forest watersheds and their associated fisheries, fauna, and critical habitats. The goal of this report is to take the first steps toward filling that vacuum.

Chapter 3

DEFINING AND MAPPING OLD-GROWTH FORESTS AND WATERSHEDS

Chapter 3

DEFINING AND MAPPING OLD-GROWTH FORESTS AND WATERSHEDS

Because our panel had neither the resources nor time to collect new data, our study used only existing map information. We defined the study region as the states of Washington and Oregon east of the Cascade crest, a region including vast areas of public and private lands with varying histories. Because our focus was late-successional and old-growth forest on public lands, we restricted our project to the region's 12 national forests. We excluded two of these (Gifford Pinchot and Mt. Hood) because their land area east of the crest is small.

During the study, we identified a number of existing data sources, determined the quality of the data, and acquired the best available data, in digital form when possible, for a total of more than 50 data sets. These data sets, referred to as "map layers" in the geographic information system (GIS) we used, were available at several scales; they included physical, biological, political, and administrative information (Tables 3.1 and 3.2). Because the same information was not available for all forests, our ability to complete analysis varied among forests. Even when the "same" data were available, we often found that definitions or collection methods differed.

Throughout this report, we use English units of measure because these are used by the Forest Service. In presenting results of cited studies, we use metric or English units, following the units used in the original work.

Table 3.1 Geographic information system (GIS) map layers used by the Eastside Forests Scientific Society Panel to assess condition of eastside national forests (see Table 3.2 for a description of each map layer).

Map layer			National forest or region [a]											
Feature	Scale	Source [b]	CO	DE	FR	MA	OC	OK	UM	WW	WE	WI	EO	EW
Physical and biological data														
Precipitation zones	—	USFS									X			
Digital elevation models	1:24,000	USFS	X	X	X	X	X	X	X	X	X	X		
Digital elevation models	1:250,000	TWS	X	X	X	X	X	X	X	X	X	X	X	X
Elevation zone grids	100-m cell size	EFSSP	X	X	X	X	X	X	X	X		X		
Slope grids (in percent)	100-m cell size	EFSSP	X		X	X	X	X	X	X	X	X		
Fire-occurrence zones	1:126,720	USFS					X							
Rivers, streams and water bodies	1:24,000	USFS			X		X	X						
Rivers, streams, and water bodies	1:100,000 1:250,000	TWS	X	X	X	X	X	X	X	X	X	X	X	X
River basins	1:24,000	USFS					X							
USEPA river basins	1:100,000	TWS	X	X	X	X	X	X	X	X	X	X	X	X
Subwatershed boundaries	1:63,360	USFS	X		X	X	X		X			X		
Soil resource inventory	1:24,000	WA DNR USFS			X			X				X		
State soil geographic database	1:250,000	ORSSC		X	X	X	X		X	X		X	X	
Detailed roads	1:24,000	USFS	X				X	X			X	X		
TIGER roads	1:100,000	ODFW		X	X	X	X		X	X		X	X	
Riparian connective habitat	1:24,000	USFS					X							
Aquatic diversity areas	1:100,000	AFS		X	X	X	X		X	X		X	X	
Washington rivers information system	1:100,000	WDFW	X					X			X			
Spring-summer chinook salmon status	1:250,000	TWS	X			X	X	X	X	X	X		X	X
Fall chinook salmon status	1:250,000	TWS	X		X					X	X	X	X	X
Chum salmon status	1:250,000	TWS							X				X	
Coho salmon status	1:250,000	TWS							X	X	X		X	X
Sockeye salmon status	1:250,000	TWS					X		X	X			X	
Summer steelhead status	1:250,000	TWS	X	X		X	X	X	X	X	X		X	X
Winter steelhead status	1:250,000	TWS			X							X	X	X
USEPA ecoregions	1:250,000	TWS		X	X	X	X		X	X		X	X	
Oregon gap analysis actual vegetation types	1:250,000	ORSSC		X	X	X	X		X	X		X	X	
LS/OG forest	1:24,000 1:126,720	NAS USFS SBI	X	X	X	X	X	X	X	X	X	X		

continues

Table 3.1 continued

Map layer			National forest or region [a]											
Feature	Scale	Source [b]	CO	DE	FR	MA	OC	OK	UM	WW	WE	WI	EO	EW
Designated old growth	1:12,000	USFS	X	X		X	X		X	X	X	X		
Timber inventory plots	1:24,000	USFS				X								
Forest condition	1:63,360	USFS	X											
Spotted owl habitat	—	USFS		X				X			X	X		
Spotted owl critical habitat	1:100,000	USFWS		X				X			X	X		
Aerial insect and disease survey	1:100,000	USFS	X	X	X	X	X	X	X	X	X	X		
Political and administrative boundaries														
USFS forest boundaries and ownerships	1:24,000 1:100,000	USFS	X	X	X	X	X	X	X	X	X	X		
USFS management areas	1:24,000	USFS	X			X	X		X					
USFS existing LMP land allocations	1:24,000	USFS	X	X	X	X	X	X	X	X	X	X		
USFS fire management zones	1:24,000	USFS					X							
USFS designated wilderness	1:100,000	USFS	X	X	X	X	X	X	X	X	X	X		
Federally protected areas	1:1,000,000 1:24,000	TWS	X	X	X	X	X	X	X	X	X	X	X	X
Tribal lands	—	TWS											X	X
BLM lands	1:1,000,000	TWS											X	X
National parks	—	TWS											X	X
Ancient Forest Alliance proposal maps	1:126,720	TWS		X				X			X	X		
RARE II roadless areas	1:24,000	USFS	X	X	X	X	X	X	X	X	X	X		
EFSSP roadless regions	100-m cell size	EFSSP	X			X	X	X			X	X		
Public land survey	1:24,000	USFS	X	X	X		X	X			X			
State boundaries	1:500,000	TWS											X	X
County boundaries	1:24,000	USFS	X				X							
County boundaries	1:500,000	ORSSC	X	X	X	X	X	X	X	X	X	X	X	X

[a] CO = Colville National Forest, DE = Deschutes, FR = Fremont, MA = Malheur, OC = Ochoco, OK = Okanogan, UM = Umatilla, WW = Wallowa-Whitman, WE = Wenatchee, WI = Winema, EO = eastern Oregon, EW = eastern Washington.

[b] AFS = American Fisheries Society; EFSSP = Eastside Forests Scientific Society Panel NAS = National Audubon Society; ODFW = Oregon Department of Fish and Wildlife; ORSSC = Oregon State Service Center for Geographic Information Systems; SBI = Sierra Biodiversity Institute; TWS = The Wilderness Society, Seattle, WA; USFS = United States Forest Service, Pacific Northwest Office and National Forests; USFWS = United States Fish and Wildlife Service; WA DNR = Washington State Department of Natural Resources; WDFW = Washington State Department of Fish and Wildlife

Table 3.2 Description of the GIS map layers used by the Eastside Forests Scientific Society Panel to assess condition of eastside national forests (see Table 3.1 for identification and sources of map layers and for abbreviations).

Map layer	Description	Date
Digital elevation models	USGS cell-based elevation data. 1:250,000 data contain one elevation value for each 70-m cell; 1:24,000 data, one per 30-m cell. Data can be used to determine slope, aspect, and elevation of any other data layer in the eastside GIS.	—
Fire-occurrence zones	Zones created by tracking the number of fires per thousand acres per year.	1991
River basins	River basin data from EPA (1:100,000) and USFS (1:24,000).	—
Subwatershed boundaries	Watersheds defined by USFS from 1:24,000 and 1:63,360 topographic maps.	1988–1992
Soil resource inventory	Soil data based on aerial photo interpretation at scales of 1:24,000 and 1:63,360.	1979–1989
State soil geographic database	Soil data assembled at a scale of 1:250,000 from higher-precision soil maps and geological, topographical, climatic, and vegetation data. Map units combine associated soil phases and series. Includes site index data, erodibility factors, and management recommendations. Minimum mapping unit: 1,544 acres.	1991
TIGER roads	Digital road information assembled by the US Census Bureau as part of its census.	1990
Riparian connective habitat	Streams computer mapped by USFS (at 1:24,000) with buffer zones of 100 feet on each side.	1991
Aquatic diversity areas	Critical watersheds identified by the American Fisheries Society as those needed to maintain native aquatic biodiversity, provide ecological refugia, and protect ecosystem integrity. Delineates watersheds supporting critical fish stocks; narrowly endemic populations of native species; and unique, important, or sensitive aquatic assemblages. Includes data on the occurrence of 57 fish and 34 bird, mammal, and amphibian species in identified watersheds.	1990–1993
Washington rivers information system	Washington State GIS database of major rivers and streams, including occurrence and status of aquatic species	1993
Spring-summer chinook, fall chinook, chum, sockeye, and coho salmon and steelhead status	Anadromous fish population status data assembled by Christopher A. Frissell, Oak Creek Laboratory of Biology, Department of Fisheries and Wildlife, Oregon State University. Contains population status by watershed and river basin for tracked species: stable, of special concern, threatened, endangered, very endangered, and extinct. Includes identical status codes for migration corridors. Data automated by TWS in consultation with WDFW, UC Davis, Idaho Department of Fish and Game, and Oregon Trout.	1991–1993
USEPA ecoregions	Ecological regions and subregions for water quality management. Based on data from Landsat MSS, USGS 1:250,000 and 1:100,000 land use–land cover maps, USGS 1:250,000 digital elevation model, 1:750,000 US Soil Conservation Service soil maps, and USGS 1:250,000 topographic maps.	1991

continues

Table 3.2 continued

Map layer	Description	Date
Oregon gap analysis actual vegetation types	Vegetation map representing 1991–92 vegetation in Oregon. Data based on photo interpretation of Landsat multispectral scanner (MSS) prints.	1989–1992
LS/OG forest	Cooperative National Audubon–USFS old-growth mapping project: USFS aerial photo interpretation and field work. Old-growth definition from USFS. Okanogan and Wenatchee data from SBI.	1989–1993
Designated old growth	Forest designated by USFS for protection as old growth.	—
Forest condition	Delineates nonforest and forest lands, lands producing less than 20 ft^3 of wood per year, and lands silviculturally treated.	1984
Spotted owl habitat	Forest determined by the US Forest Service to be suitable nesting, roosting, and foraging habitat for the northern spotted owl. Compiled at each national forest.	—
Spotted owl critical habitat	Critical habitat for the northern spotted owl defined by USFWS.	—
Aerial insect and disease survey	Insect and fungus damage to conifers as observed in USFS aerial surveys. Data from 1:126,720 and 1:100,000 maps created during overflight.	1989 1990 1991
USFS forest boundaries and ownerships	National forest and private lands within the boundaries of the national forest.	—
USFS management areas	USFS management areas for project planning.	—
USFS existing LMP land allocations	Current management status for national forest lands according to preferred forest plans.	—
USFS fire-management zones	USFS fire-management analysis zones. Divide lands into four categories.	1992
USFS designated wilderness	Congressionally designated wilderness on national forestlands.	—
Federally protected areas	Wilderness, national wildlife refuge, national park, national monument, wild and scenic river, research natural area experimental forest, recreation area, scenic area and special protected watershed boundaries.	1992
Tribal lands	Native American tribal lands.	—
Ancient Forest Alliance proposal maps	Proposed ancient-forest biological reserves from the Ancient Forest Protection Act (HR 842).	1992
RARE II roadless areas	USFS roadless area review and evaluation.	1992
EFSSP roadless regions	Lands without roads according to analysis of 1992–93 digital road data from the national forests.	1993
Public land survey	Township, range, and section data.	—
County boundaries	Boundaries of Oregon and Washington counties.	—

Defining Old Growth

Our definition of late-successional and old-growth forests east of the Cascades refers to coniferous forests with trees more than 150 years old or greater than 21 inches in diameter in the overstory (dominant or upper part of the forest as seen from above); dead standing and fallen trees are usually present on every acre. Within mapped stands, specifics of tree age, canopy closure, species composition, diameter at breast height, and number per acre of trees and snags larger than 21 inches DBH vary by forest type, region, and site productivity (Table 3.3).

Table 3.3 LS/OG definitions and criteria used by the Eastside Forests Scientific Society Panel in mapping eastside national forests.

Definition		LS/OG attribute (per acre)						Forest[a]
Species	Region	Trees > 21 in. DBH	Snags	Downed wood	No. canopy layers	% herb/shrub cover	Gap size	
Hopkins (1992)[b]								
White fir/ grand fir	Blue Mountains	20–45	2–12 > 14 in. DBH	20–50 pieces > 12 in. by 5 ft	2–3	10–50	Up to 0.5 acre	OC, UM, WW
	Central Oregon	15–50	2–12 > 14 in. DBH	20–50 pieces > 12 in. by 5 ft	2–3	10–50	Up to 0.5 acre	DE, FR, WI
Ponderosa pine		15–25	3 > 14 in. DBH or 10% of stand w/ spire tops	3–6 pieces > 12 in. by 8 ft	1–2	20–40	< 0.5 acres	DE, FR, OC, UM, WI, WW
Large sawtimber[c]								
Ponderosa pine		> 10 w/ >75% of overstory ponderosa pine	1 broken-top tree	3 logs (> 1.5 tons/acre)	Unspecif.	Unspecif.	Unspecif.	MA
Douglas fir/grand fir		> 15	2, plus broken-top trees	3 logs (> 3 tons/acre)	Unspecif.	Unspecif.	Unspecif.	MA
Lodgepole pine		>12 >6 in. DBH	13 (average)	>3 tons/acre, including 3 logs	Unspecif.	Unspecif.	Unspecif.	MA
Unmanaged (roadless) coniferous forest mapped in interagency grizzly bear habitat study								
—	—	—	—	—	—	—	—	West OK North WE

[a] CO = Colville National Forest, DE = Deschutes, FR = Fremont, MA = Malheur, OC = Ochoco, OK = Okanogan, UM = Umatilla, WW = Wallowa-Whitman, WE = Wenatchee, WI = Winema, EO = eastern Oregon, EW = eastern Washington.

[b] Data for moderately productive stands only; see Hopkins (1992) for complete definitions.

[c] From USFS (1984).

Generally we agree with the definitions outlined by USFS publications (Hopkins 1992; Hopkins et al. 1992a,b; Williams et al. 1992a,b) with two important exceptions. First, because small patches often retain critical components of regional biological diversity and serve as sources of colonists in regional restoration efforts, we include a minimum LS/OG stand size of 0.5 acres. Forest Service definitions, in contrast, do not include stands smaller than 60 acres (for white and grand fir; Hopkins et al. 1992b) or 10 acres (all other forest types; Hopkins 1992, Hopkins et al. 1992a). Second, we define old-growth trees by either size or age, not both.

USFS definitions apply to Oregon national forests in the study area except Malheur and to Colville National Forest in Washington (see Table 3.3). For Malheur National Forest, "large sawtimber" was mapped as defined by the US Forest Service Pacific Northwest Regional Guide (USFS 1984). In Okanogan and Wenatchee National Forests in Washington, LS/OG was defined as roadless (unmanaged) coniferous forest.

Sources of LS/OG Map Information

The panel used three major sources of LS/OG map data (Table 3.4): (1) the Audubon and USFS cooperative Adopt-a-Forest mapping project, (2) mapping done by Pacific Meridian Resources under contract to USFS, and (3) an interagency grizzly bear habitat study, which was limited to the North Cascades of Washington.

Audubon-USFS Adopt-a-Forest Project

In 1988, the National Audubon Society initiated a cooperative project with USFS to map old-growth forests in the Pacific Northwest and California. Audubon based its study on existing USFS maps for total timber resource inventory (TRI). Available for all national forests in the Pacific Northwest, these maps are used for forest inventory, planning timber sales, and wildlife habitat analysis. Such "timber-typing" maps separate broadleaf and coniferous forests, scrublands, grass, and barrens. Within coniferous forests, they separate stands by the average diameter of the trees in the overstory. They also separate different density or canopy-closure classes, distinguishing, for example, ponderosa pine forests with open, grassy glades from dense pine forests where the sky is largely hidden from below.

Using timber-typing maps, Audubon volunteers highlighted the distribution of stands with trees larger than 21 inches DBH ("large sawtimber" with mature and old-growth forest). Next, Audubon used recent USFS field data, direct visits to stands, and aerial photographs from the late 1980s and early 1990s to

Table 3.4 Sources of LS/OG data used by the Eastside Forests Scientific Society Panel in mapping eastside national forests.

National forest	Source	Survey date	Most recent update	Raw data source[a]	LS/OG definition
Colville	Audubon	1991	1991	Aerial photography	—
Deschutes	Adopt-a-Forest	Late 1980s 1991	1991	Landsat TM satellite imagery, TRI, field plots	USFS LMP
Fremont	Adopt-a-Forest	1992	1992	Aerial photographs, stand exams, field plots	Hopkins (1992)
Malheur	Adopt-a-Forest	1991	1992	TRI, field plots	Large sawtimber Hopkins (1992) in designated areas
Ochoco	Adopt-a-Forest USFS	1992	1992	Satellite images, aerial photographs, field plots	Hopkins (1992)
Okanogan	Interagency grizzly bear habitat study	1988–91	Unknown	Plot data, satellite imagery	Unmanaged (roadless) coniferous forest
Umatilla	Adopt-a-Forest	1984	1989	1979 aerial photos, field plots	Hopkins (1992)
Wallowa-Whitman	Adopt-a-Forest	1990–91	1991	TRI, stand exams, aerial photography, ecoclass data	Hopkins (1992)
Wenatchee	Interagency grizzly bear habitat study	1988–91	Unknown	Field plot data, satellite imagery	Unmanaged (roadless) coniferous forest
Winema	Adopt-a-Forest	1991	1991	TRI, stand exams, aerial photographs, field plots	Hopkins (1992)

[a] Landsat TM = Landsat thematic mapper, TRI = timber resource inventory.

update the maps with recently logged lands. Finally, Audubon or USFS district biologists and other USFS staff field-checked most or all of the large sawtimber stands in each national forest. Field crews used "walk-through" transects, gathering plot data to determine if each stand met USFS regional definitions for old growth. Stands that did not meet LS/OG definitions were removed from the map database.

Individual national forests varied in percent of stands actually checked in the field; timing of updating of maps for recent logging also varied among the forests (Table 3.5).

Table 3.5 LS/OG mapping used by the Eastside Forests Scientific Society Panel to assess condition of eastside national forests.[a]

						Accuracy assessment	
National forest	Mapping process	Updating	Original scale	Digital conversion	Digitized scale	Field-check	Map evaluation and known flaws
Colville	LS/OG west of Columbia River mapped by Audubon from 1991 orthophotos	1991	1:24,000	Digitized by Eastside Panel	1:126,720	Stands randomly field-checked by Audubon	Maps not assessed by Audubon-USFS; accuracy unknown Data available only for Colville lands west of the Columbia River
Deschutes	Original Audubon study based on TRI system in 1989–90 Fort Rock district mapped by USFS staff person Large LS/OG regions identified visually on satellite images and transferred to mylar overlays	Visual interpretation of Landsat satellite images for western Deschutes in 1991	Original: 1:64,560 Landsat update: unknown	Scanned at ESRI for Eastside Panel	1:126,720	Extensive field plots in Sisters and Bend ranger districts No sampling in Fort Rock and Crescent districts	Maps identify regions containing fragmented LS/OG, plus smaller LS/OG stands Accuracy checked by district biologists and other USFS staff Spatial errors of up to 1000 ft; maps miss stands near Crane Prairie and Wickiup Reservoir Designated old growth accurate within 1000 ft because of USFS digitizing errors
Fremont	Old growth mapped from USFS aerial photo interpretation in 1990 Many stands coded by species composition	Updated from stand examination data and aerial photograph interpretation in 1992	1:24,000	Half digitized by USFS-Audubon Half scanned at ESRI for Eastside Panel	1:24,000	Field plot examination plus "walk-through" Existing USFS field plots	Maps checked for accuracy by district biologists and other USFS staff Maps detailed, spatially accurate; no known flaws

Malheur	Large sawtimber mapped from TRI, ecoclass maps, and some aerial photograph interpretation	Updated from field plots and stand examination in 1992	1:12,000	Designated old growth digitized by USFS LS/OG scanned at ESRI for Eastside Panel	USFS: 1:24,000 ESRI: 1:126,720	All USFS designated stands field-checked in 1992	Maps checked for accuracy by district biologists and other USFS staff Spatial accuracy within 300 ft because of 1:126,720 digitized scale Overall accuracy expected to be high
Ochoco	Final map from three sources: Audubon maps from USFS vegetation data LS/OG mapping by Pacific Meridian Resources from mid-1980s Landsat satellite imagery Independent LS/OG stand verification study, based on aerial photograph interpretation, under contract for USFS	Updated by USFS contractor from aerial photographs in 1992	30-m cell size for satellite image 1:24,000 for aerial photo work	Satellite data–based maps imported into ARC/INFO® GIS software from ERDAS image-processing program Contractor's study digitized by USFS	30-m cell size 1:24,000 maps	Forest entirely field-checked using a plot-based sampling system	Maps checked for accuracy by district biologists and other USFS staff No known flaws; highly consistent results in all studies Snow Mountain district: LS/OG may be overestimated by 20% because of spatial errors
Okanogan	Coniferous forest in unmanaged zone derived from grizzly bear habitat mapping study Roadless areas used to distinguish unmanaged-zone proxy for LS/OG forests	1987 satellite imagery 1990 road data	MSS imagery: 57-m cell size	Remote sensing and ecological modeling in a GIS	57-m cell size	Location of basic coniferous forest 93% accurate No field-check for LS/OG	Covers only western Okanogan Evaluation against smaller Okanogan study area revealed overestimation of LS/OG by 20% Significant LS/OG stands occur in the managed zone excluded by mapping

continues

National forest	Mapping process	Updating	Original scale	Digital conversion	Digitized scale	Accuracy assessment: Field-check	Accuracy assessment: Map evaluation and known flaws
Umatilla	Audubon mapping based on 1984 vegetation maps created by interpretation of 1979 aerial photographs	Updated for cutting from field data and aerial photos in 1989	1:24,000	Digitized by USFS	1:24,000	Designated old-growth stands in Walla Walla, Pomeroy, and Hepner districts 100% field-checked with plots and visual inspection N. Fk. John Day district: walk-throughs completed	Maps checked for accuracy by district biologists and other USFS staff No known flaws; highly accurate and detailed Adopted by USFS for land management planning in the Umatilla
Wallowa-Whitman	Separate mapping done by ranger districts; basic Audubon-USFS mapping process except in La Grande district Hells Canyon Recreation Area and Wallowa Valley district old growth mapped from ecoclass data Pine district: silviculturalist assisted with mapping based on TRI and updated with aerial photo interpretation La Grande district mapped from TRI and stand exam plots	TRI source data updated for all districts in 1991–92 Circulated to Wallowa-Whitman staff for updating and corrections in July 1993	1:12,000	Scanned at ESRI for Eastside Panel	1:126,720	Hells Canyon area: extensive plot work plus visual survey Wallowa Valley district covered in 1992 pileated woodpecker study (Bull and Holthausen 1993) Baker and Unit districts: field assessment of selected designated LS/OG; also by district biologists in project planning Pine district: field assessment of selected designated LS/OG only	Original 1:12,000 study highly accurate except for La Grande district, where no accuracy assessment was done Some spatial inaccuracy introduced in digital scanning process

	Baker district mapped from TRI plus stand exams and field plots Unity district mapped from TRI						
Wenatchee	Coniferous forest in unmanaged zone derived from grizzly bear habitat mapping study Roadless areas used to distinguish unmanaged-zone proxy for LS/OG forests	1987 satellite imagery 1990 road data	MSS imagery: 57-m cell size	Remote sensing and ecological modeling in a GIS	57-m cell size	Location of basic coniferous forest 93% accurate No field-check for LS/OG	Assessment covers only Wenatchee National Forest lands north of Highway 90 LS/OG mapping not intent of original data
Winema	Audubon mapping based on TRI, USFS stand exam data, aerial photographs, and field examination	1991	1:12,000	Digitized by USFS	1:12,000	All stands field-checked with plot-based sampling and walk-throughs	Maps checked for accuracy by district biologists and other USFS staff No known flaws; highly accurate mapping

[a] ESRI = Environmental Systems Research Institute, MSS = Landsat multispectral scanner.

US Forest Service Mapping

Another source of map data on old-growth distribution was the information gathered independently by Pacific Meridian Resources under contract with the US Forest Service. These data, available for Ochoco National Forest, came from Landsat satellite imagery of conditions in the mid 1980s. Maps were updated from 1992 aerial photography in all areas to account for recent logging.

Interagency Grizzly Bear Habitat Study

Although Audubon and USFS cooperative old-growth mapping was done for Wenatchee and Okanogan National Forests, the work was incomplete, and we were not able to use it. Fortunately, the interagency grizzly bear habitat study had just completed a vegetation-mapping project for coniferous forests that used satellite, slope, aspect, and elevation data to map vegetation types. The study mapped stands by forest type, separating, for example, ponderosa pine forests from those dominated by lodgepole pine. Although this study did not map forests by size class (as USFS timber-typing maps do), it was extremely accurate (93%) in locating coniferous forests (Almack et al. 1993).

Compilation of Digital Map Data

After identifying all relevant LS/OG map information for national forests within the study area, we compiled paper and digitally scanned maps. Many of the Adopt-a-Forest maps were digitized by USFS (Ochoco, Umatilla, and Winema National Forests). For Fremont, Malheur, and Wallowa-Whitman National Forests, no digitized maps were available. For Fremont National Forest, Audubon digitized LS/OG maps for us. For Malheur and Wallowa-Whitman National Forests, map data were scanned and edited into geographically referenced computer files by the Environmental Systems Research Institute (see Table 3.5).

Not all maps were scanned or digitized at the same scale at which the original maps were created (most were scanned at 2.25 inches to a mile); consequently, some spatial inaccuracy was introduced by the scanning process. Spatial inaccuracy refers to error arising because an object is drawn on a map in a different location from its real location on the ground. Some LS/OG maps compiled or scanned by our eastside panel have spatial inaccuracies of up to 300 feet (Malheur National Forest) or 1000 feet (Deschutes National Forest). Overall spatial accuracy for the other national forests was generally high (see Table 3.5).

Assembly of Geographic Information System Map Layers

A geographic information system is made up of computerized maps linked to databases. For example, a line on a map (or computer screen) might represent a section, or reach, of a river. A river name might be attached to that line in a GIS data layer; other information attached to that line might be a defined watershed, a list of fish species found in that river reach, or the water quality data from that reach. In a GIS, all such information would be stored in a "river" layer.

The GIS that we created contains dozens of layers in the same coordinate system, each dealing with a single subject. The eastside GIS contains data on LS/OG forests; rivers and streams; roads; land ownership; USFS administrative status; wilderness; rare, threatened, and endangered species; and other relevant biological and physical parameters (see Tables 3.1 and 3.2).

Evaluation of LS/OG Map Accuracy

LS/OG map accuracy was assessed in three distinct processes:

1. During completion of the Audubon and USFS cooperative mapping process
2. By USFS employees in 1993 at our panel's request
3. By USFS personnel as part of timber sale screening in summer and fall 1993 after our analysis was completed.

Audubon-USFS Process

During the final stages of Audubon-USFS cooperative LS/OG mapping, both Audubon and USFS employees visited "large sawtimber" (potential old-growth) stands color-coded on USFS maps to determine if they actually were old growth as defined by USFS (Hopkins 1992; Hopkins et al. 1992a,b; Williams et al. 1992a,b).

First, field crews reviewed existing data from USFS stand examination sample plots: areas of regular size and shape in which vegetation characteristics (such as tree height) were measured to estimate conditions throughout the stand. USFS measured diameter at breast height and overstory species composition (the relative number of trees of each species). These data existed for most stands, enabling field crews to determine whether trees in the stand were large enough to qualify as old growth and to identify the vegetation type of prospective old-growth stands.

In the field, crews used two sampling systems to compare mapped stands with USFS interim old-growth definitions. The first was a "walk-through" transect: field crews walked a straight line through the stand, verifying whether all old-growth attributes described in the old-growth definitions (see Table 3.3) were actually present in the stand. Generally, these attributes included overstory trees older than 150 years or larger than 21 inches DBH, dead standing and fallen trees larger than 21 inches DBH, two or more canopy layers (branch networks of two or more trees between the observer and the sky), and native herbs and shrubs on the forest floor.

In the second sampling process, field crews established randomly located sample plots within each stand. They then examined aerial photographs of the stand to determine if the mapped area contained more than one vegetation type—for example, open-canopy pine and dense, closed-canopy fir. If the stand contained more than one vegetation type, crews planned plot locations to give an equal number in each type. Within each plot, crews measured stand attributes such as diameter at breast height, tree species, standing dead trees larger than 21 inches DBH, downed trees larger than six inches, and canopy layers.

In addition to Audubon-USFS accuracy assessment, USFS district biologists also checked completed maps within their districts, comparing maps with their own knowledge of the areas they managed and correcting errors. Finally, for Ochoco National Forest, USFS hired an independent contractor to assess map accuracy by remapping old-growth stands from new infrared aerial photography.

The percentage of stands checked by all these methods varied by national forest. One district in the study area (La Grande, in Wallowa-Whitman National Forest) was not checked. In some forests (Malheur, Umatilla), 100% of designated (administratively protected) old-growth stands were field-checked, but little work was done in unprotected stands. In other forests (Ochoco, Winema), 100% of mapped old-growth stands, both protected and unprotected, were field-checked (see Table 3.5).

EASTSIDE PANEL PROCESS

When the eastside panel received the computerized old-growth maps, some national forests (e.g., Wallowa-Whitman) had not completed their reviews of the accuracy of Adopt-a-Forest maps. For these national forests, we printed the maps at a scale of 0.5 inch to 1 mile and circulated them to USFS staff who were familiar with field conditions. Corrected maps came back to us, and we then updated computerized LS/OG maps for these forests.

US Forest Service Timber-Sale Screening

In June 1993, USFS initiated a timber sale "screening" process to protect old-growth stands east of the Cascade crest and began further accuracy assessment of the Audubon LS/OG maps; this process continues in 1994. Meanwhile, Audubon maps are being used daily as the old-growth maps for the national forests of eastern Oregon.

Geographic Information System Analysis

Our panel put together a series of overlays for LS/OG in the geographic information system. USFS land-allocation maps, lands administratively designated as "old growth," wilderness boundaries, streams, roads, slope, and elevation maps, among others, were laid over LS/OG maps. The size and distribution of LS/OG stands (patches) were analyzed in relation to these other geographic features; for example, the mean size of LS/OG patches inside wilderness was compared with mean patch size in lands allocated to timber cutting. This overlay process produced the statistics presented for each national forest in Chapter 4.

Within this GIS, map information can be stored and analyzed in two distinct formats: vector (lines) and raster (cells). In vector format (little used in this study), an LS/OG stand is defined by a set of coordinates (e.g., latitude-longitude) connected by lines to form a polygon. Accuracy depends on how close the coordinate points defining stand boundaries come to the actual stand boundaries on the ground; accuracy also depends on distance between each coordinate point. If boundary-defining coordinates are far apart, the complex natural boundaries of the stand become simplified into straight lines representing the average extent of the stand.

By comparison, raster, or cell-based, analysis (extensively used in this study) superimposes a graph-paper-like set of square cells over a mapped LS/OG stand. Within that LS/OG stand, all cells might be labeled LS/OG. At the edge of the stand, cells with more than 50% LS/OG might also be labeled LS/OG; stands with less than 50% LS/OG might not be considered LS/OG. With a raster system, accuracy of the stand boundaries depends on cell size in the analysis and the spatial accuracy of the original mapping. If cell size is one foot on each side, for example, each tree will be represented by hundreds of cells; stand boundaries can thus be stored in the GIS more accurately than they can be mapped in the field.

For most of this study, cell-based analysis was used; cell size was one hectare (100 m^2, or 2.471 acres), which represents a compromise between accuracy and processing speed. At this size, a million-acre comparison of the distribution of two geographic features, such as road density and LS/OG forests, takes one to three minutes. In all, it took four staff-months—most of the time in checking the computer routines to avoid errors—to perform the analysis.

Aquatic Diversity Areas and Critical Watersheds

Oregon Aquatic Diversity Areas

A watershed classification subcommittee of the Oregon chapter of the American Fisheries Society compiled a database of "critical watersheds" throughout Oregon (Oregon AFS 1993). The subcommittee's goal was to provide information needed to conserve the diversity of watersheds, habitats, and indigenous aquatic fauna of Oregon; to establish refugia for native aquatic assemblages and corridors for their migrations; and to designate "reference watersheds." Reference watersheds were intended to serve as benchmarks for evaluating effects of human disturbance and to help agencies assess compliance with biological standards.

These key watersheds, which became known as aquatic diversity areas (ADAs), were defined by the subcommittee as any or all of the following:

1. Locations where native aquatic species are at risk of extinction or vulnerable to future disturbance.
2. Whole watersheds representing the best remaining examples of native aquatic ecosystems and their associated biological assemblages.
3. Connecting corridors linking habitats essential to support native aquatic populations.

The subcommittee established specific ADA selection criteria to accommodate a range of biodiversity objectives that could prove important in designing a statewide conservation or restoration strategy (see Chapter 6). Such a strategy should address multiple ecological levels—genetic, population, and assemblage—because conservation measures intended for one level may or may not benefit all others. Conservation priorities should also address many spatial scales. A fish population, for example, may be considered unique or threatened within a watershed, across a larger river basin or region (e.g., the Columbia Basin or the Pacific Northwest), or worldwide. The subcommittee's criteria for selecting ADAs thus apply to multiple spatial scales and levels of ecological organization.

Genetic-Population Criteria

Oregon ADAs were defined as watersheds with unique, sensitive, or highly productive populations of native species that may be vulnerable to disturbance or that require immediate protection to conserve genetic or life-history diversity. ADAs identified on the basis of genetic or population criteria contain one or more of the following:

1. Known sensitive taxa or populations whose range or abundance has been severely reduced relative to historic levels (remnant populations)
2. Stocks having life-history or genetic traits uniquely adapted to local conditions, or populations near the edge of the range of a more widely distributed species (unique fauna).
3. Narrow specialists or relict fauna believed to occur in no other habitats worldwide (narrow endemics).

ADAs were also defined as watersheds and corridors with important core populations, that is, relatively abundant populations that may be critical to sustaining local fish productivity or providing a source of colonists for recovery of adjacent streams or watersheds.

The aquatic taxa used to identify these ADAs do not constitute a complete inventory of species in each of the watersheds or corridors; complete information does not exist for most of the region's watersheds.

Assemblage-Ecosystem Criteria

The subcommittee also defined some areas as ADAs because they offer the best remaining examples of native aquatic ecosystems and their associated fish assemblages. Selection criteria included:

- Condition or health: watersheds chosen because they are relatively unaltered, presenting a characteristic example of a particular ecosystem type that may serve as a benchmark for evaluating management programs or understanding ecological processes; reference watersheds.
- Genetic characteristics: watersheds (preferably with few exotic species or a limited history of hatchery stocking) that could serve as an important genetic refuge for protecting the diversity of native taxa or assemblages.
- Species richness: streams or watersheds harboring a relatively high number of native taxa.
- Ecological processes: aquatic systems that perform a critical ecological function, for example, streams or springs supplying cool or clean water to downstream areas.

- Connecting corridors: streams or watersheds that link protected areas with other important habitats, connect disjunct or potentially disjunct populations within or between basins, or connect habitats needed to support the various life stages of native fish populations.
- Sensitivity: relatively intact watersheds that may be particularly vulnerable to natural disturbance or to the cumulative effects of human alterations. Examples may include areas that are geologically unstable, streams where water temperatures already approach tolerance limits for native fauna, or watersheds where previous development activity may limit the resilience of the system to further stress.
- Scientific value: watersheds where valuable baseline data are available for future monitoring of management activities or where definitive research on the life history or ecology of native species or assemblages has been done.

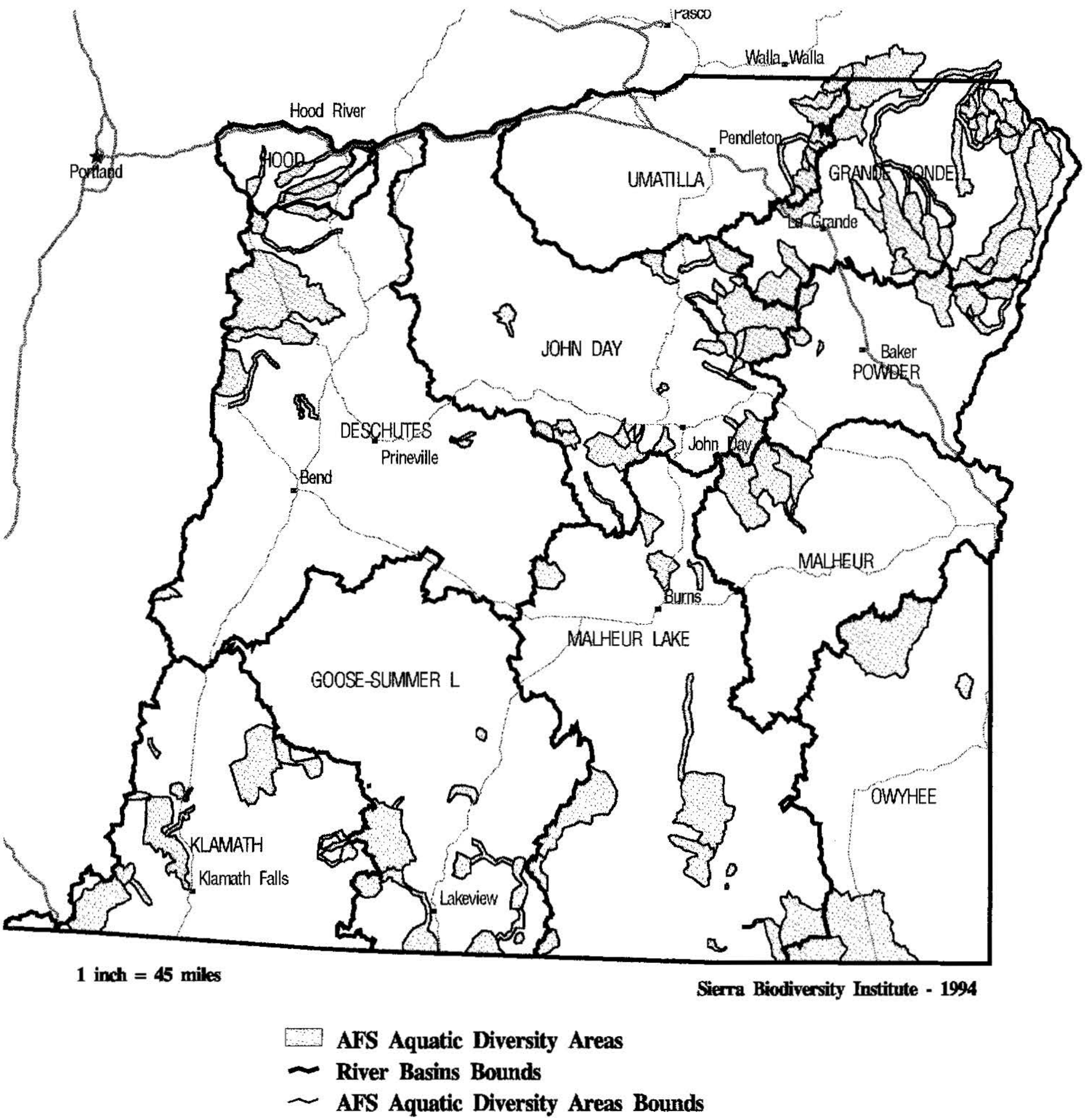
ADAs were identified on the basis of published and unpublished information on distribution of sensitive fish species and general condition of aquatic habitats. The information for each watershed was assembled in a computer database. ADAs were mapped on Oregon Department of Water Resources drainage basin maps at scales of 1:180,000 to 1:370,000. Copies of the draft database and maps prepared by the 13-member subcommittee were sent for peer review to 85 field biologists and aquatic resource professionals at federal, state, and tribal agencies and private firms. The maps and database were revised to reflect review comments to incorporate supplementary information provided on a standardized survey form by more than 40 respondents.

Our panel used this updated information for computer mapping and analysis of Oregon eastside national forests. Printed maps were digitized for the panel by the Sierra Biodiversity Institute (Figure 3.1) and linked with the ADA database to form a layer in our geographic information system. We evaluated the relative condition of each ADA located partially or entirely in these forests according to habitat and water quality and the presence or absence of exotic species, according to the above criteria. We classified each ADA as

- undisturbed and largely intact, with high-quality habitat or a high-quality water source, or both or
- partially or moderately degraded and in need of recovery or active restoration.

As part of our mapping process, we also analyzed the percentages of LS/OG and roadless regions within each ADA.

Figure 3.1 Aquatic diversity areas (ADAs) defined by the Oregon chapter of the American Fisheries Society for the 11 Oregon drainage basins east of the Cascade crest.



WASHINGTON CRITICAL WATERSHEDS

No process like that for identifying Oregon ADAs has been completed for the state of Washington. Instead, for this report, a team of fisheries biologists with the North Pacific International chapter of the American Fisheries Society identified so-called critical watersheds in eastern Washington.

The team based its choices on published and unpublished information about the location and distribution of priority stream reaches required by salmon, bull trout, wild resident trout, and steelhead. Many reaches and subbasins are critical to more than one species. Critical reaches were identified on digital hydrographic maps (scale 1:100,000) provided by the Washington Department of Fish and Wildlife. Tributary basins and subbasins important to the quality of habitat in these reaches were also identified.

Chapter 4

EASTSIDE NATIONAL FORESTS

Chapter 4

EASTSIDE NATIONAL FORESTS

This chapter offers a précis of the geography, climate, and biological environment for each national forest on the east side of the Cascade crest in Oregon and Washington. It also summarizes the condition of the region's aquatic resources—streams and rivers and their associated biota in particular—and discusses special aquatic diversity areas (ADAs) that were identified for the national forests in Oregon by the Oregon chapter of the American Fisheries Society (see Figure 3.1 and Appendix II). Overall forest condition is illustrated with maps (key in Figure 4.1) and tables (summarized in Table 4.1).

- **General statistics:** The information in the first cells of each forest table comes from forest maps and recent USFS national forest plans. The tables also include information on "designated old growth" (a USFS land-management category), late-successional old growth (LS/OG; defined by Adopt-a-Forest surveys), and aquatic diversity areas (defined for Oregon by Oregon American Fisheries Society [AFS] analyses). Critical watersheds in Washington were defined by a team of fisheries biologists associated with the North Pacific International chapter of the American Fisheries Society.
- **LS/OG stand data:** The Audubon Adopt-a-Forest and USFS surveys identified LS/OG stands within each national forest. We compared those spatially explicit data with areas that are protected (designated by statute as wilderness areas or set aside by the Forest Service as "designated old growth") and with areas that are unprotected (defined in USFS forest plans

as available for scheduled or unscheduled timber cutting). Analyzing these LS/OG stand data layers within the GIS gave us acreage of LS/OG, number of patches, and patch sizes for each category of protected and unprotected forest.

- **Relationship between late-successional old growth and USFS-designated old growth:** We evaluated each USFS-designated old-growth patch to determine how much of the patch actually was LS/OG forest. We expressed the results in three arbitrary categories: percentage of patches with no LS/OG cover, with 1–70% LS/OG cover, and with more than 70% LS/OG cover.

- **LS/OG and forest type:** For three national forests (Deschutes, Okanogan, and Wenatchee), surveys of LS/OG (and related forest areas) often yielded information on dominant species in different areas. For these three forests, we provide LS/OG stand data (acreage, number of patches, patch sizes) by forest type (e.g., ponderosa pine, lodgepole pine, and so on) as well as protection category.

- **LS/OG acreage within subwatersheds:** Entire watersheds that have never been logged are likely to provide the best available habitat for terrestrial as well as aquatic species, so we determined for each watershed how much of LS/OG it contains. For each forest, we tabulate the number and size of watersheds within it, the mean percentage of each watershed consisting of LS/OG forest, and relative proportion of LS/OG cover across all watersheds.

- **LS/OG classification by slope:** Steep slopes are generally more susceptible to erosion than level ground; less-steep areas are often easier to log. We show the distribution of LS/OG by protection status and three classes of slope: 0–30%, 31–60%, and >60%).

- **Riparian status:** Riparian areas provide critical habitat for terrestrial and aquatic species. Streams should therefore be buffered from logging impact by adjacent intact old-growth forest. We assess the distribution of riparian areas and their association with LS/OG, including the number of miles of streams within mapped LS/OG areas; number of miles of stream per 1000 acres of LS/OG; and percentage of LS/OG within specified distances from streams.

- **Roadless patch size and distribution:** Roadless regions, logged or not, provide refuge for wildlife from day-to-day disturbances by human activity. Our tables provide information from two analyses of roadless regions: the Roadless Area Review and Evaluation II (RARE II) started in 1980 and our own, more inclusive study. Our analysis defined a roadless region as any region where all points within an LS/OG stand were at least 100 meters from a road or trail. Unlike the RARE II study, we did not include a minimum size limit (e.g., 5000 acres) in our definition.

- **Relationship between protected and unprotected LS/OG, roadless areas and regions, and Oregon ADAs:** LS/OG acreage that is roadless or within Oregon ADAs represents a valuable resource; protected LS/OG in these categories is especially valuable.

- **Relationship between roadless areas and ADAs:** For six forests, we were able to define the number of acres and percentage of total RARE II roadless areas included within Oregon ADAs.

- **Road density within watersheds:** Roads, like logging, tend to fragment forest areas and open them to continuing human disturbance. We therefore determined mean, maximum, and minimum road density for subwatersheds with roads in each national forest.

- **Classification of Eastside Panel roadless regions by slope and land use:** Roads on steep slopes are especially detrimental because they increase erosion and become stress points for unstable slopes, which can collapse in catastrophic landslides and debris torrents. For Okanogan and Colville National Forests, we analyzed roadless acreage by slope and protection category.

Figure 4.1 Key to Eastside Forests Scientific Society Panel maps of eastside national forests. In this and all following maps, "LS/OG" refers to actual late-successional or old-growth forest; "dedicated old growth" refers to areas labeled by USFS as "designated old growth." Maps produced by the Sierra Biodiversity Institute, North San Juan, California.

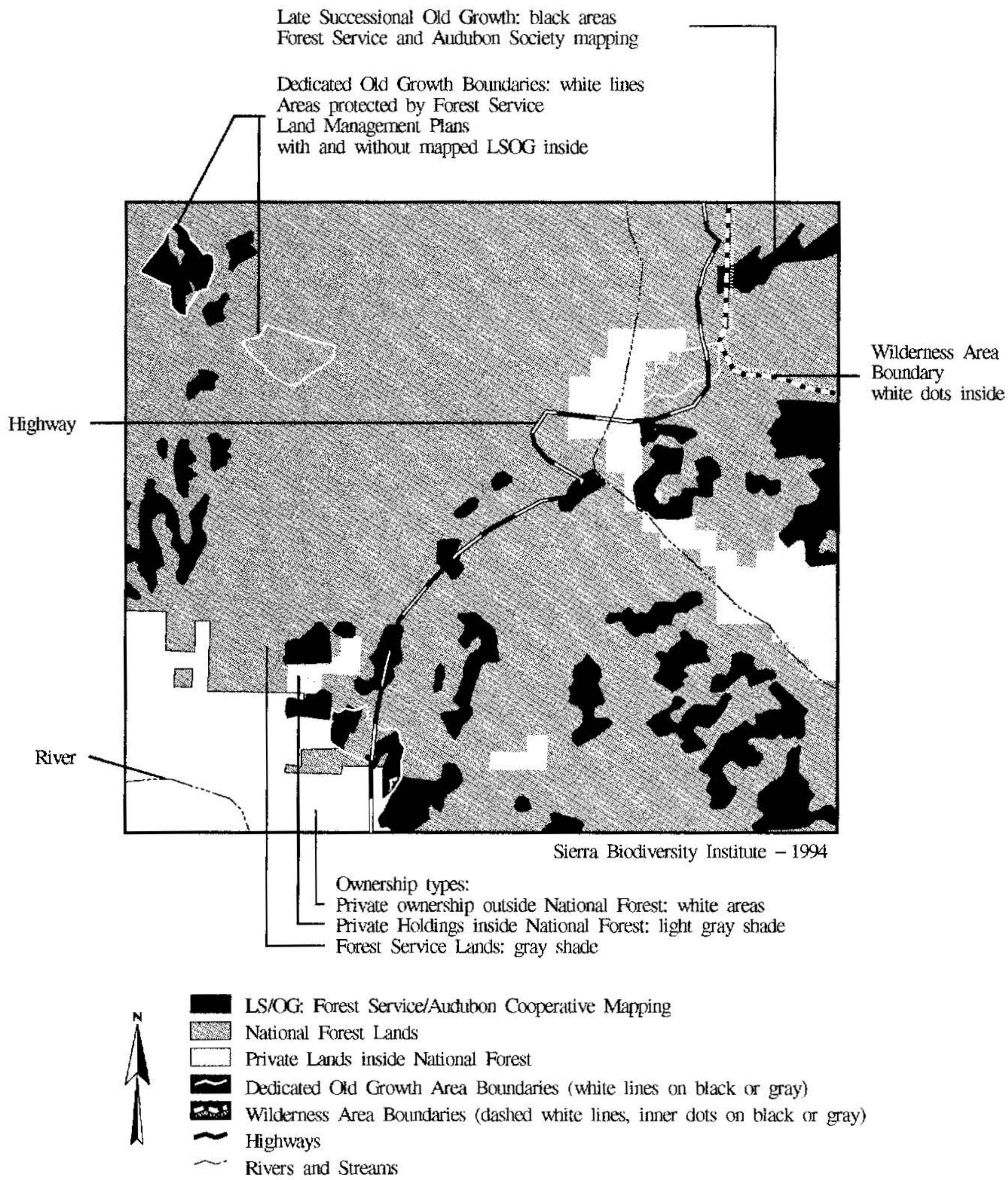


Table 4.1 Key to tables of eastside national forest facts. Forest tables compiled and produced by the Sierra Biodiversity Institute.

Information available	Forest[a]									
General statistics	CO	DE	FR	MA	OC	OK	UM	WW	WE	WI
LS/OG stand data	CO	DE	FR	MA	OC		UM	WW		WI
LS/OG density within watersheds	CO		FR	MA	OC		UM			WI
LS/OG classification by slope	CO	DE		MA	OC		UM	WW		WI
LS/OG-riparian relationship	CO			MA	OC		UM	WW		WI
Roadless region patch size and distribution	CO			MA	OC	OK	UM	WW	WE	WI
Relationship between LS/OG and roadless regions	CO			MA	OC		UM[b]	WW		WI
Relationship between roadless regions and ADAs				MA	OC		UM[b]	WW		WI
Road density within watersheds	CO				OC	OK				WI
Roads in riparian zone										WI
Classification of Eastside Panel roadless regions by slope and land use	CO					OK				
Relationship between LS/OG and designated old growth					OC					WI
Extent of potential climax and seral ponderosa pine stands										WI

[a] CO = Colville National Forest, DE = Deschutes, FR = Fremont, MA = Malheur, OC = Ochoco, OK = Okanogan, UM = Umatilla, WW = Wallowa-Whitman, WE = Wenatchee, WI = Winema.

[b] Oregon only.

Colville National Forest

Colville National Forest (Figure 4.2, Table 4.2) covers slightly more than one million acres in northeastern Washington near the British Columbia and Idaho borders. Elevations range from 1400 feet on the Kettle River to 7309 feet on Gypsy Peak. The western portion of the Colville has a dry continental climate, with valleys receiving 15–25 inches of rain per year. Rainfall increases to the east, averaging 30–40 inches per year in the Kettle Range and as much as 55 inches in the Selkirk Mountains. Vegetation includes dry Douglas fir and grass, western red cedar, western hemlock, and subalpine fir forests; meadows; marshes; and dry, rocky scrub grassland.

Much of our analysis of Colville National Forest is restricted to lands west of the Columbia River because data were not available from eastern sections of the forest.

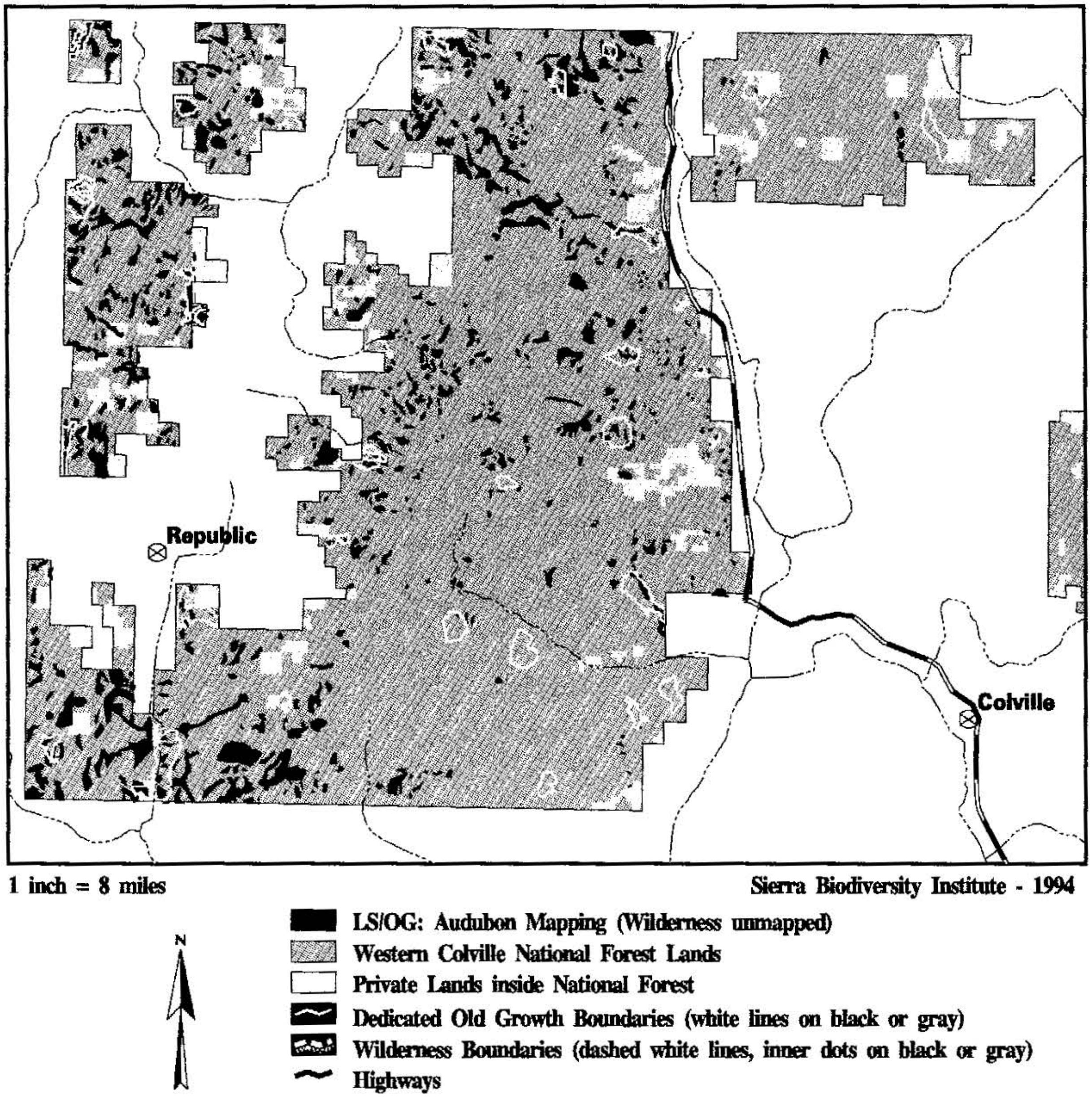


Figure 4.2 Western Colville National Forest, showing public and private lands, actual late-successional/old-growth forest, and USFS designated old growth.

Table 4.2 Western Colville National Forest facts.

General Statistics[1] (acres x 1000)

Net national forest[2]	Total wilderness[2]	Percent of total national forest	Total forested area[2]	Percent of total national forest	USFS-determined lands suitable for timber management[2]	Percent of total national forest	Nonforest area[2]	Percent of total national forest
1092	27	2	1013	92	771	70	83	8

USFS designated old growth	Percent of designated old growth actually LS/OG	Total administratively protected LS/OG	Percent administratively protected LS/OG of national forest lands west of Columbia River	Audubon-USFS LS/OG	Percent Audubon-USFS LS/OG of national forest lands west of Columbia River
19	21	4	1	49	9

[1] Unless otherwise noted, analysis includes only lands west of the Columbia River. All statistics from Eastside Forests Scientific Society Panel analysis unless otherwise noted.
[2] Data from the USFS Land and Resource Management Plan, which covers entire Colville National Forest.

LS/OG Stand Data

LS/OG status		Total acres (thousands)	Percent of total LS/OG	Number of stands (n)	Stand size (acres)				Stand size distribution (acres)						
					Mean	Minimum	Maximum	Standard deviation	1–100	101–300	301–500	501–1000	1001–2500	2501–5000	5000+
Protected	In Wilderness	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Administratively	3,919	8	88	45	2	398	63	79	7	2	0	0	0	0
	Total	3,919	8	88	45	2	398	63	79	7	2	0	0	0	0
Unprotected	Within management areas available for scheduled timber cutting	38,594	79	586	66	2	1,905	128	494	68	17	6	1	0	0
	Within management areas available for unscheduled timber cutting	6,083	12	115	53	2	773	101	103	9	1	2	0	0	0
	Total	44,681	91	655	68	2	1,905	132	550	78	18	7	2	0	0

Percent LS/OG within Subwatersheds

Total number of subwatersheds	Average subwatershed area (acres)	LS/OG (percent of subwatershed)				Number of watersheds classified by percent LS/OG				
		Mean	Minimum	Maximum	Standard deviation	0–10%	11–20%	21–40%	41–60%	61–80%
192	3,372	4.4	0	48.6	8.4	69	37	24	2	0

LS/OG Classification by Slope[1]

LS/OG status		Acres within slope classes (percent) 0–30	30–60	60+
Protected	In wilderness			
	Administratively	1,552	1,105	173
	Total	1,552	1,105	173
Unprotected	Within management areas available for scheduled timber cutting	13,241	12,432	1,359
	Within management areas available for unscheduled timber cutting	2,286	2,130	138
	Total	15,627	14,562	1,497
Total: Western national forest		283,965	198,426	15,004

[1] Available digital elevation data were incomplete for the western Colville; analysis excludes a strip ~ 8 miles wide at the extreme western edge of the forest.

LS/OG-Riparian Relationship

LS/OG Status		Miles of stream in stands	Stream miles per 1000 acres	Percent of LS/OG within each distance range from stream (feet) 0–250	250–500	500–750	750–1000	1000–1250	1250–1500	1500+
Protected	In wilderness									
	Administratively	10	2.6	13	19	12	8	8	9	31
	Total	10	2.6	13	19	12	8	8	9	31
Unprotected	Within management areas available for scheduled timber cutting	67	1.7	8	15	9	6	6	8	48
	Within management areas available for unscheduled timber cutting	11	1.8	8	14	9	6	6	8	50
	Total	78	1.7	8	15	9	6	6	8	48

Roadless Region Patch Size Distribution[1]

Type	Total acres	Number of patches	Patch size (acres): Mean	Minimum	Maximum	Standard deviation	Patch area distribution (acres): 250–500	500–750	750–1000	1000–2000	2000–5000	5000–10000	10000–50000	50000+
RARE II	186,811	18	10,378	434	35,403	9,927	1	0	2	0	5	1	9	0
Eastside Forests Scientific Society Panel	387,484	188	2,061	238	41,091	4,707	65	26	21	35	24	8	8	0

[1] Analysis covers the entire Colville National Forest.

Relationship between LS/OG and Roadless Regions

LS/OG status		Distribution: Within RARE II roadless areas: Acres	Percent of total LS/OG	Within Eastside Forests Scientific Society Panel roadless regions: Acres	Percent of total LS/OG
Protected	In wilderness	0	—	0	—
	Administratively	1,611	41	2,476	63
	Total	1,611	41	2,476	63
Unprotected	Within management areas available for scheduled timber cutting	4,067	11	16,511	43
	Within management areas available for unscheduled timber cutting	5,014	82	5,953	98
	Total	9,081	20	22,464	50

Road Density within Roaded Subwatersheds

Road density (miles/mile^2): Mean	Minimum	Maximum	Standard deviation
2.5	0.01	8.8	1.3

Classification of Eastside Panel[1] Roadless Regions by Slope and Land Use

Roadless region status		Slope	Acres
Protected	On administratively protected lands	<30%	6,934
		30–60%	8,518
		>60%	1,134
		Slope unknown	1,730
	Total		18,316
Unprotected	Within management areas available for scheduled timber cutting	<30%	122,307
		30–60%	125,972
		>60%	12,313
		Slope unknown	13,573
	Within management areas available for unscheduled timber cutting	<30%	31,372
		30–60%	52,847
		>60%	6,328
		Slope unknown	4,421
	Total		369,515

[1] As part of this study, the panel conducted a new inventory of roadless regions based on contemporary digital maps of road networks (Chapter 3).

DESCHUTES NATIONAL FOREST

Deschutes National Forest (Table 4.3), which extends for about 100 miles along the eastern slope of the Cascades in central Oregon, encompasses more than 1.6 million acres of considerable topographic and ecological complexity, including glaciers on high peaks and, to the east, wet forest, dry forest, and desert. Mt. Washington, at 7734 feet, is the highest point in this national forest.

Unlike mapping for the other national forests in this report, so-called LS/OG regions (which include actual LS/OG, managed lands, and nonforested lands) were mapped as part of the FEMAT evaluation of spotted owl habitat. Deschutes map data suffer from spatial errors of as much as 2500 feet. Because not all Deschutes wilderness areas were surveyed for LS/OG, they are not included in our LS/OG figures. Because of these limitations, direct comparisons cannot be made with the data given for other national forests.

ADAs in Deschutes National Forest (Figure 4.3) include a number of tributaries in the Deschutes River system that are used by sensitive bull trout populations (see Appendix II). In the Metolius River, which has been designated a wild and scenic river, adults spawn and juveniles are reared in the coldest spring-influenced tributaries (ADA 502); the uppermost portions of these watersheds begin in the Mt. Jefferson wilderness area. Historic distribution of bull trout has been reduced or eliminated in some adjacent tributaries because of accumulating effects from overfishing, habitat loss, and introduction of nonnative brook trout (Ratliff 1992). The Metolius serves as a corridor (ADA 503) for adult bull trout moving between Lake Billy Chinook and the upper Metolius tributaries to spawn. Bull trout also occur in upper tributaries of Odell Lake, which drains from the Diamond Peak wilderness (ADA 506). Ratliff and Howell (1992) classify Odell Lake bull trout as at high risk of extinction because of habitat degradation, overfishing, and interactions with nonnative brook trout. Deschutes ADAs contain no roadless regions.

Table 4.3 Deschutes National Forest facts.

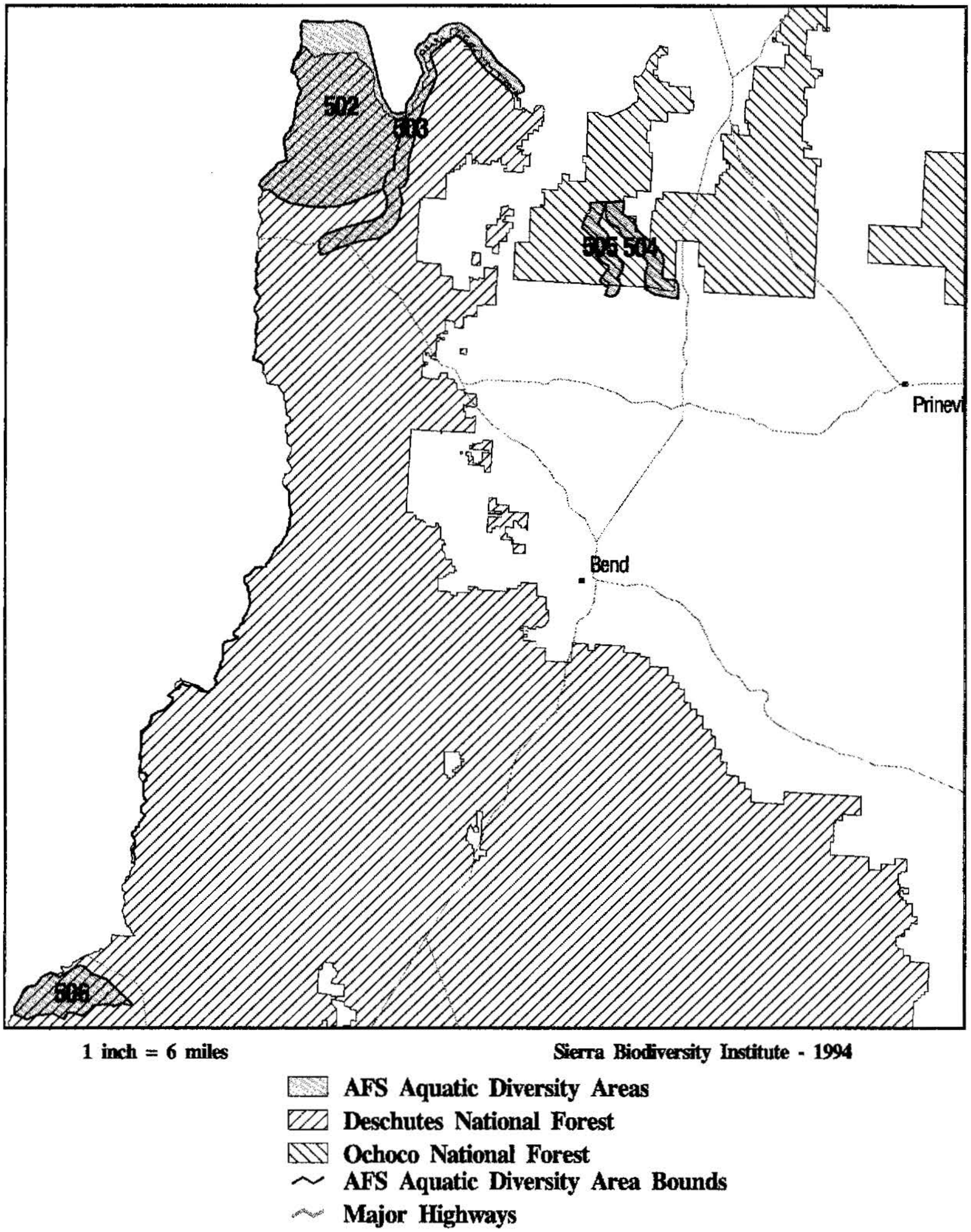
General Statistics (acres x 1000)[1]

Net national forest[2]	Total wilderness[2]	Percent of wilderness forested	Percent of total national forest	Total forested area[2]	Percent of total national forest	USFS-determined lands suitable for timber management[2]	Percent of total national forest	Nonforest area[2]	Percent of total national forest
1,617	181	84	11	1,430	88	1,151	71	191	12

USFS designated old growth	American Fisheries Society aquatic diversity areas	Percent of total national forest
36	87	5

[1] All statistics from Eastside Forests Scientific Society Panel analysis unless otherwise noted.
[2] From the Final US Forest Service Land and Resource Management Plan.

Figure 4.3 Aquatic diversity areas (ADAs) in Deschutes and Ochoco National Forests in central Oregon (see also Figures 2.1 and 3.1).



FREMONT NATIONAL FOREST

Fremont National Forest (Figure 4.4, Table 4.4) encompasses 1.2 million acres of arid mountainous lands in the Great Basin desert of south-central Oregon on the California border. Elevations range from 4000 to 8000 feet. Rainfall ranges from 16 to 40 inches.

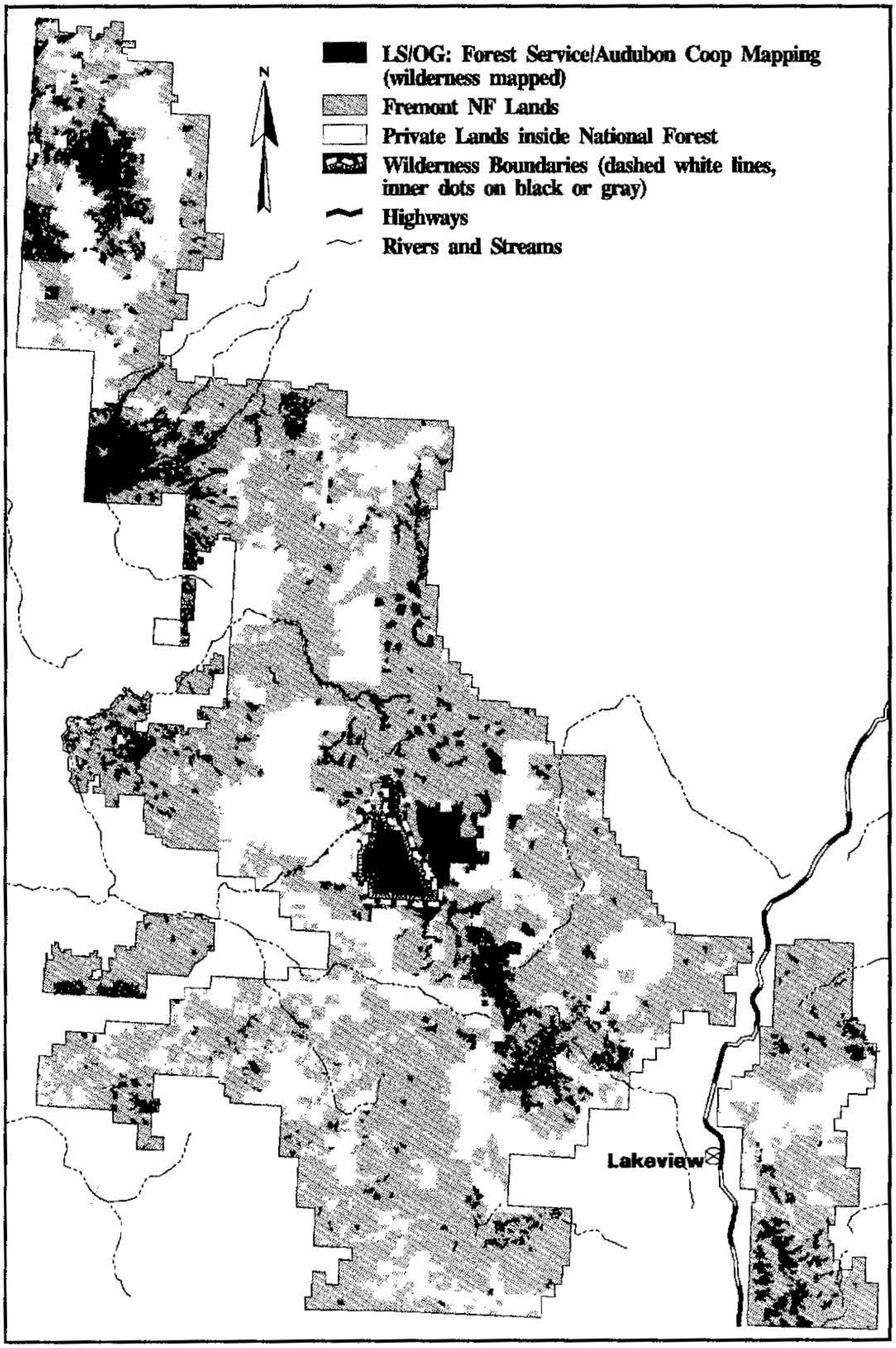
Vegetation types include ponderosa and lodgepole pine, and white fir forests. Only 28,400 acres (2%) of verified LS/OG ponderosa pine and mixed conifer forest survive in the Fremont, much of the area in the Auger Creek and Deadhorse Rim regions. Much of the lodgepole pine persists after removal of mature ponderosa pine because fire prevention, human disturbances, grazing, or other factors inhibit succession to mature ponderosa pine forest. Oregon juniper and various chaparral (scrubland) associations are also common, along with scattered stands of western white pine, red fir, sugar pine, whitebark pine, incense cedar, and mountain hemlock. Nonforest vegetation includes sagebrush-bunchgrass prairies, wet meadows, and scrub flats. Because relevant computerized maps were not available, we have no information on the timber-management status of mapped LS/OG in Fremont National Forest.

Fremont ADAs (Figure 4.5) are home to a high diversity of native fish taxa unique to interior lake basins in southeastern Oregon (see Appendix II). Among the taxa inhabiting one or more ADAs in the Goose Lake system (ADAs 1303, 1307, and 1312) are a genetically unique form of redband trout; pit sculpin, a species common in California that is rare in Oregon; and an undescribed subspecies of landlocked Pacific lamprey. Drews Creek (ADA 1303) has one of the most intact native aquatic communities on the Oregon side of the Goose Lake basin (Oregon AFS 1993). ADAs in the Warner Lakes basin (ADAs 1304 and 1311) include several tributaries that are critical refugia for unique native fishes (e.g., Warner basin tui chub, threatened Warner sucker, and Warner Valley redband trout) and highly vulnerable to periodic drought and drying up of the lakes. Finally, a form of bull trout that has been declared genetically distinct from all Columbia River basin populations (Leary et al. 1993) lives in the Upper Klamath Lake basin (ADAs 1404, 1406, 1407, 1409, and 1411). One of several distinct groups of interior rainbow trout identified within the Klamath basin (Buchanan et al. 1990a, 1991) occurs in ADAs in the upper Williamson and Sprague Rivers (ADAs 1404, 1405, 1407, and 1411).

ADAs in Fremont National Forest include the last vestiges of habitat for native species in the region, yet most have been degraded to some degree. Temperature and flow in many of the tributaries to the interior lake basins have been changed by the combined effects of grazing, logging, and irrigation withdrawals and diversions (Oregon AFS 1993). The Twentymile Creek system (ADA 1304), for example, is subject to low flows and temperatures that approach the tolerance limits of native species. A high incidence of parasites and disease among threatened Warner suckers may be associated with poor water conditions (Kennedy and North 1993, Tait and Mulkey 1993). In the Chewaucan River (ADA 1312), reportedly the most productive native trout system in the Goose and Summer lake basins, overgrazing has been a major reason behind the lack of cover, excessive temperature, and siltation. In combination with a long history of hatchery trout releases, habitat losses have "reduced or eliminated the wild trout population in much of the river" (ODFW 1983). Road construction on sensitive pumice soils, together with logging and grazing, is considered a major cause of fish habitat decline in the upper Williamson River (ADA 1405; Oregon AFS 1993). Remnant bull trout populations in tributaries draining the Gearhart wilderness (ADAs 1407, 1409, and 1411) are isolated and fragmented because of logging and grazing; they are now considered vulnerable to extirpation as a result of their limited distribution and small population size (Ziller 1992).

Nine of 14 ADAs (64%) in the Fremont contain no roadless areas. ADAs in several small watersheds still contain a relatively high proportion of LS/OG, for example, ADA 1404 (73%) in the upper portion of Long Creek in the upper Williamson River drainage. Nearly one-fourth of the more than 120,000 acres in ADA 1312 (Chewaucan River) is LS/OG.

Figure 4.4 Fremont National Forest, showing public and private lands, actual late-successional/old-growth forest (LS/OG), and wilderness areas.



1 inch = 13 miles

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Table 4.4 Fremont National Forest facts.

General Statistics (acres x 1000)[1]

Net national forest[2]	Total wilderness[2]	Percent of wilderness forested	Percent of total national forest in wilderness	Total forested area[2]	Percent of total national forest	USFS-determined lands suitable for timber management[2]	Percent of total national forest	Nonforest area[2]	Percent of total national forest
1,198	23	—	2	858	72	816	68	340	28

USFS designated old growth[2]	Percent of designated old growth actually LS/OG	Total administratively protected LS/OG	Percent of total national forest	Audubon-USFS LS/OG	Percent of total national forest	American Fisheries Society aquatic diversity areas	Percent of total national forest
51	—	—	—	198	17	205	17

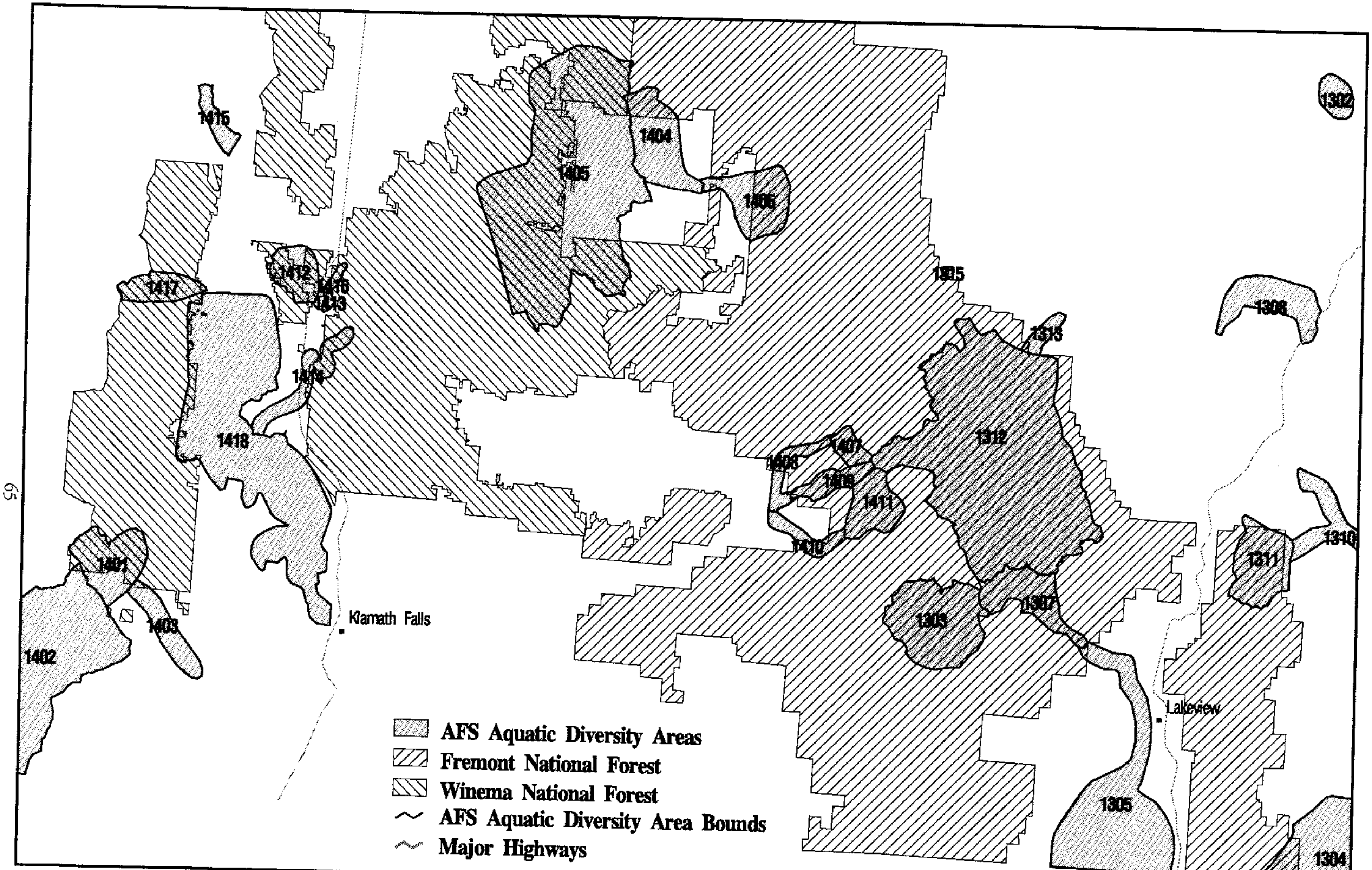
[1] All statistics derived from Eastside Forests Scientific Society Panel analysis unless otherwise noted.
[2] Data from the USFS Land and Resource Management Plan.

LS/OG Stand Data

LS/OG status and type	Total acres	Percent of total LS/OG	Number of stands (n)	Stand size (acres)				Stand size distribution (acres)						
				Mean	Minimum	Maximum	Standard deviation	1–100	101–300	301–500	501–1000	1001–2500	2501–5000	5000+
In wilderness	21,694	11	23	984	7	15,165	3,213	10	5	4	0	2	0	1
Out of wilderness	176,055	89	932	189	1	17,113	891	693	195	44	23	12	2	6
Ponderosa Pine	8,765	4	106	83	12	463	58	84	21	1	0	0	0	0
Mixed Conifer	19,635	10	117	168	20	942	150	52	46	13	4	0	0	0
Lodgepole Pine	88,665	45	170	522	3	28,275	2,756	98	51	8	9	0	0	4
Undifferentiated LS/OG	81,453	41	526	155	1	7,984	565	391	81	26	10	10	2	2

Percent LS/OG within Subwatersheds

Total number of subwatersheds	Average subwatershed area (acres)	LS/OG (percent of subwatershed)				Number of watersheds classified by percent LS/OG				
		Mean	Minimum	Maximum	Standard deviation	0–10%	11–20%	21–40%	41–60%	61–80%
25	68,523	13	0	41	12	12	8	4	1	0



1 inch = 12 miles

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Figure 4.5 Aquatic diversity areas in or near Fremont and Winema National Forests, south-central Oregon (see also Figures 2.1 and 3.1).

Malheur National Forest

Malheur National Forest (Figure 4.6, Table 4.5) comprises 1.46 million acres in the Strawberry and southern Blue Mountains of eastern Oregon. Elevations range from 4000 to just above 9000 feet. Alpine lakes and meadows dominate the highest elevations and forests, and open habitats, such as grassland and sage, dominate drier and lower sites. The most recent LS/OG surveys included little of the designated wilderness lands within the Malheur.

Malheur National Forest comprises watersheds within the John Day River, Malheur River, and Silvies River basins. ADAs in the Malheur (Figures 4.7, 4.8) target a high diversity of salmonids, which have lost habitat in large portions of the John Day basin, particularly because of high water temperatures. Among the affected species are summer steelhead, indigenous rainbow trout, westslope cutthroat trout, bull trout, and spring chinook salmon (see Appendix II).

ADAs include watersheds that contribute critical sources of cool water or streamflows to the Middle Fork John Day River (ADAs 609, 614, and 624), the upper mainstem John Day River (ADA 607), and the South Fork John Day River (ADA 603). Active restoration measures to counter the effects of logging, grazing, and irrigation may be necessary to restore some ADAs, for example, the lower portions of ADAs 611, 617, 625, and 626 (Oregon AFS 1993).

Malheur ADAs include the last remaining tributaries for bull trout in the Malheur River basin, and these watersheds require rehabilitation. Upper tributaries of the Middle Fork (ADA 1001) and upper North Fork Malheur Rivers (ADA 1002) contain bull trout, redband trout, and mountain whitefish. Overgrazing, irrigation withdrawals, and high temperatures may have eliminated bull trout in the Little Malheur River (ADA 1003) and have reduced suitable habitat in the Middle and North Fork systems (Buckman et al. 1992; Oregon AFS 1993). Reconnection of disjunct bull trout populations in the uppermost tributaries requires restoration of habitat and temperature conditions in mainstem corridors (e.g., ADA 1005).

Myrtle Creek (ADA 1213) contains the least-altered, best remaining habitat for native redband trout in the Silvies River basin. Malheur mottled sculpin—listed by the state of Oregon as a sensitive species and by USFWS as a category 2 species (one that qualifies for protection but for which USFWS needs more information before it can be listed as an endangered or threatened species)—occurs in Poison (ADA 1214) and Rattlesnake Creeks (ADA 1215). Both creeks grade from ponderosa pine in upper areas to sagebrush and juniper at lower levels; both ADAs are threatened by riparian degradation from livestock grazing (Oregon AFS 1993).

Only 108,167 acres (about 3%) of Malheur National Forest are closed to grazing, and roughly 25% of this area is taken up by roads. The Malheur forest plan notes that unsatisfactory conditions occur on all grazing allotments (there are 104 within the forest), particularly in riparian zones (USFS 1990a). As of 1990, only 2 of the 35 allotment management plans scheduled for 1993 update (USFS 1990d) have been formally completed (Jon Rhodes, Columbia River Intertribal Fish Commission, personal communication).

Figure 4.6 Malheur National Forest, showing public and private lands, wilderness areas, designated old growth, and actual late-successional/old-growth forest (LS/OG).

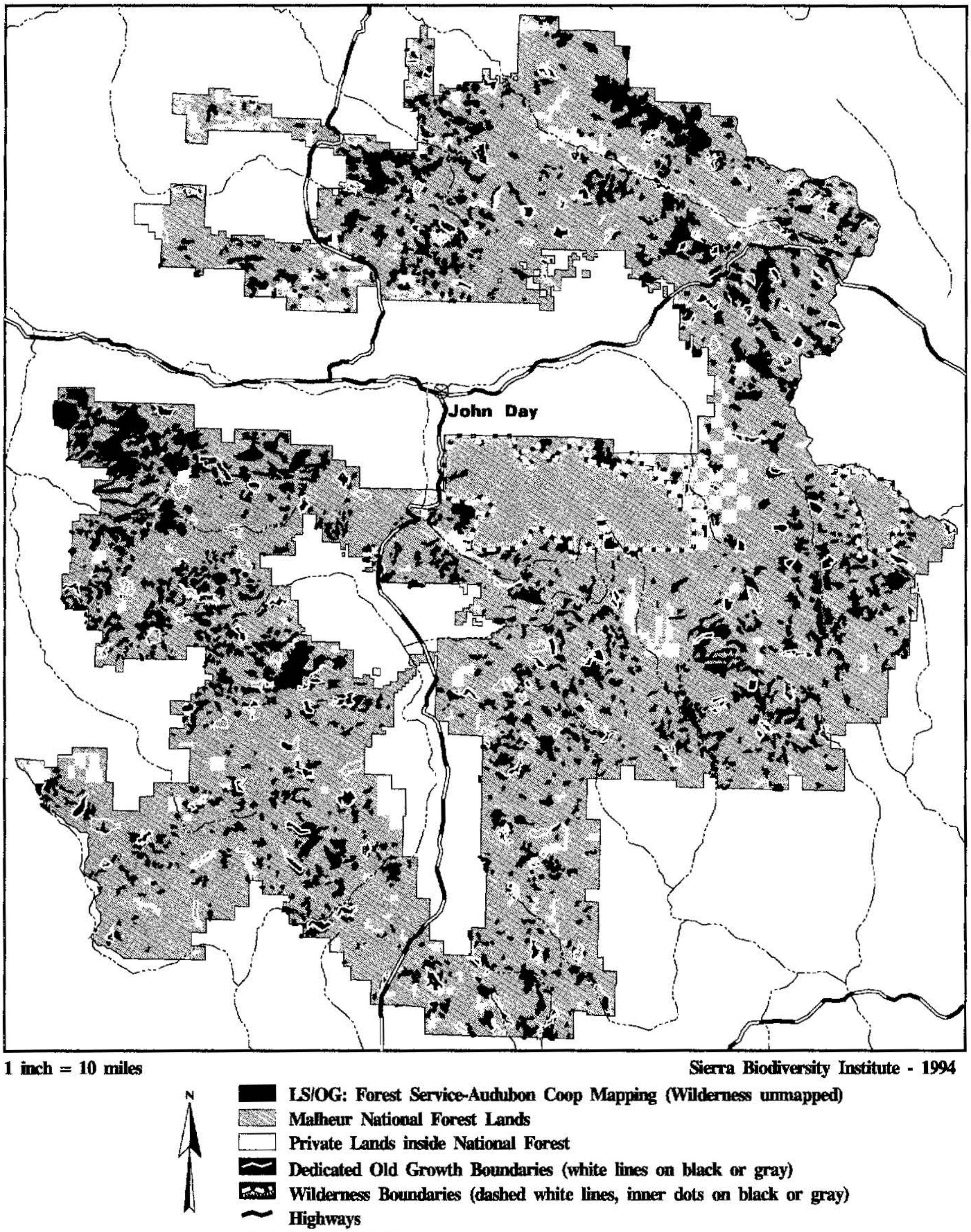


Table 4.5 Malheur National Forest facts.

General Statistics (acres x 1000)[1]

Total national forest[2]	Total wilderness[2]	Percent of wilderness forested	Percent of total national forest	Total forested area[2]	Percent of total national forest	USFS-determined lands suitable for timber management[2]	Percent of total national forest	Nonforest area[2]	Percent of total national forest
1,459	81	79	6	1,175	80	1,040	71	285	20

USFS designated old growth	Percent of designated old growth actually LS/OG	Total administratively protected LS/OG[3]	Percent of total national forest	Audubon-USFS LS/OG	Percent of total national forest	American Fisheries Society aquatic diversity areas	Percent of total national forest
61	50	33	2	266	18	488	33

LS/OG Stand Data

LS/OG status		Total acres	Percent of total LS/OG	Number of stands (n)	Stand size (acres)				Stand size distribution (acres)						
					Mean	Minimum	Maximum	Standard deviation	1–100	101–300	301–500	501–1000	1001–2500	2501–5000	5000+
Protected	In wilderness	3,802[4]	2	67	57	2	949	133	54	10	2	1	0	0	0
	Administratively	32,892	12	347	95	2	704	138	244	50	47	6	0	0	0
	Total[5]	36,692	14	414	76	2	949	126	298	60	49	7	0	0	0
Unprotected	Within management areas available for acheduled timber cutting	195,560	81	1383	141	2	5088	326	950	338	120	48	22	3	2
	Within management areas available for unscheduled timber cutting	33,509	5	164	204	2	4008	526	119	18	10	6	9	2	0
	Total[5]	229,075	86	1547	173	2	5088	852	1069	256	130	54	31	5	2

[1] All statistics from Eastside Forests Scientific Society Panel analysis unless otherwise noted.
[2] From the Final US Forest Service Land and Resource Management Plan.
[3] Includes LS/OG on all lands where logging has been administratively prohibited.
[4] LS/OG only partially mapped in wilderness; actual total higher.
[5] Stand size distribution totals may not equal sum of subtotals because some stands cross management area boundaries.

Percent LS/OG within Subwatersheds

Total number of subwatersheds	Average subwatershed area (acres)	LS/OG (percent of subwatershed)				Number of watersheds classified by percent LS/OG				
		Mean	Minimum	Maximum	Standard deviation	0–10%	11–20%	21–40%	41–60%	61–80%
195	8,537	16	0	61	13	72	59	42	10	0

LS/OG-Riparian Relationship

LS/OG Status		Miles of stream in stands	Stream miles per 1000 acres	Percent of LS/OG within each distance range from stream (feet)						
				0–250	250–500	500–750	750–1000	1000–1250	1250–1500	1500+
Protected	In wilderness	12.3	3.1	17	30	20	11	7	7	8
	Administratively	65	2.2	12	20	13	8	7	9	30
	Total	77.4	2.3	13	21	14	9	7	9	27
Unprotected	Within management areas available for scheduled timber cutting	337.7	1.7	8	17	12	8	7	10	39
	Within management areas available for unscheduled timber cutting	21.5	1.9	9	18	13	9	9	12	31
	Total	360.3	1.7	8	17	12	8	7	10	39

Roadless Region Patch Size Distribution

Type	Total acres	Number of patches	Patch size (acres)				Patch area distribution (acres)							
			Mean	Minimum	Maximum	Standard deviation	250-500	500-750	750-1000	1000-2000	2000-5000	5000-10000	10000-50000	50000+
RARE II	111,835	16	6,995	405	28,743	8,163	1	0	0	0	3	5	3	0

Relationship between LS/OG, Roadless Regions and Aquatic Diversity Areas

LS/OG status		Distribution			
		Within RARE II roadless areas		Within American Fisheries Society Aquatic Diversity Areas	
		Acres	Percent of total LS/OG	Acres	Percent of total LS/OG
Protected	In wilderness	0	—	2,894	76
	Administratively	2,982	9	13,327	46
	Total	2,982	8	12,110	49
Unprotected	Within management areas available for scheduled timber cutting	4,290	2	53,818	27
	Within management areas available for unscheduled timber cutting	27,460	82	17,287	57
	Total	31,750	14	71,105	29

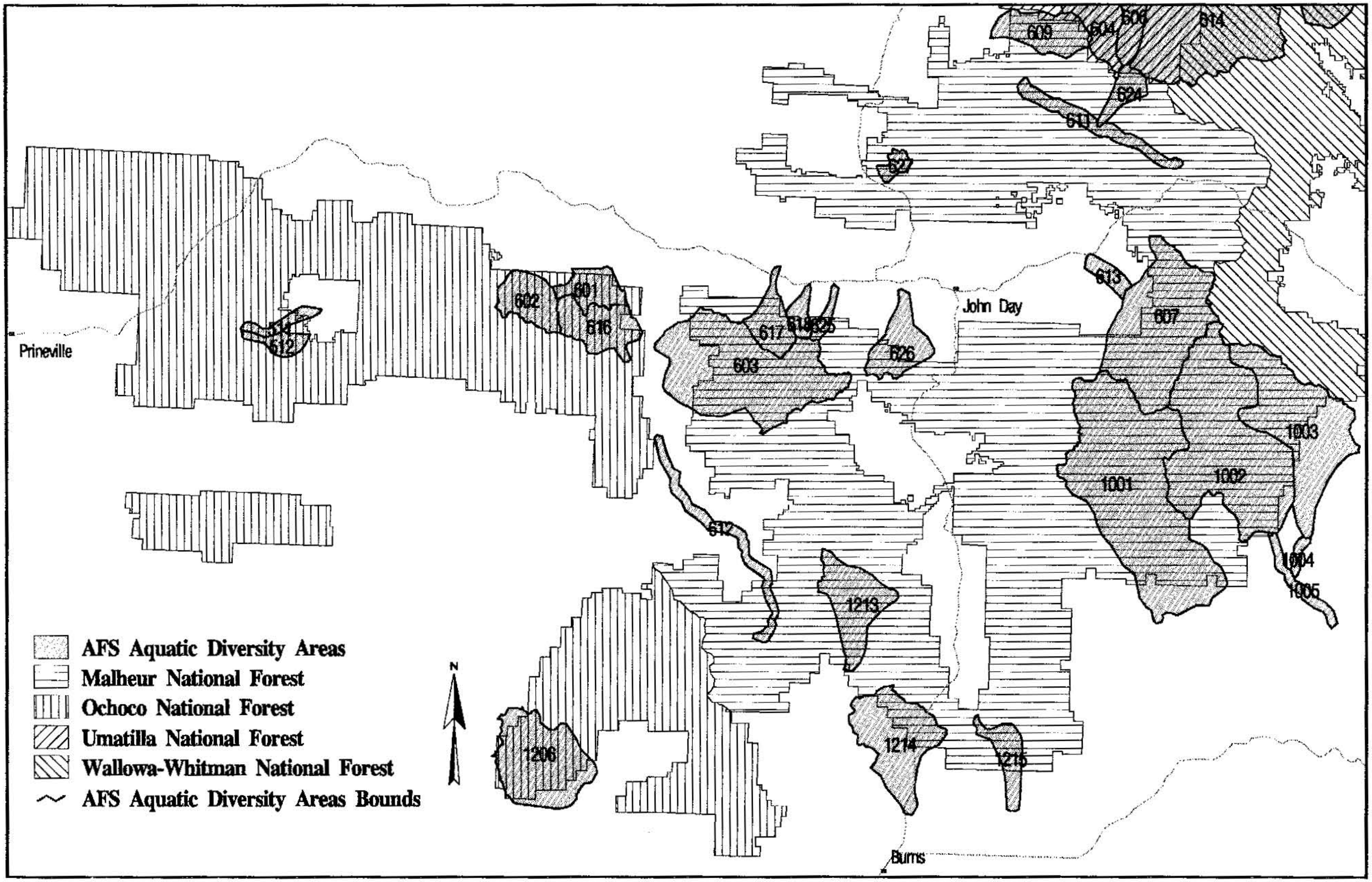
Relationship between Roadless Regions and Aquatic Diversity Areas

Roadless region type	Within American Fisheries Society Aquatic Diversity Areas	
	Acres	Percent of total
Roadless Area Review and Evaluation II	66,969	60

LS/OG Classification by Slope

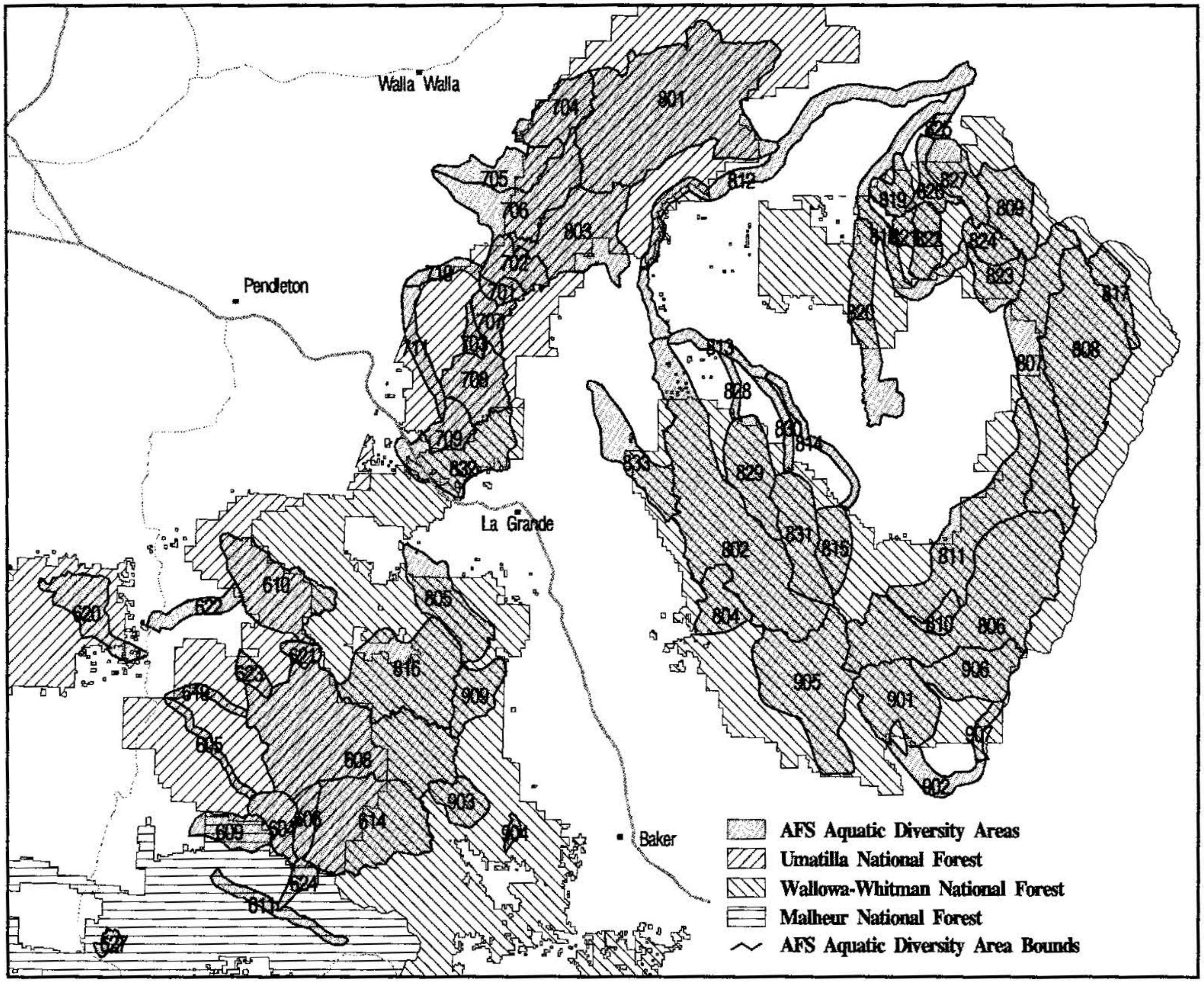
LS/OG status		Acres within slope classes (percent)		
		0–30	30–60	60+
Protected	In wilderness[1]	1,806	1,591	420
	Administratively	22,830	9,716	306
	Total	24,636	11,307	726
Unprotected	Within management areas available for scheduled timber cutting	155,545	38,004	739
	Within management areas available for unscheduled timber cutting	15,337	16,469	1,725
	Total	170,882	54,473	2,464
Total: national forest		1,197,620	319,355	19,442

[1] LS/OG only partially mapped in Wilderness.



1 inch = 13.5 miles **Sierra Biodiversity Institute - 1994**

Figure 4.7 Aquatic diversity areas (ADAs) in or near Malheur, Ochoco, Umatilla, and Wallowa-Whitman National Forests in central Oregon (see also Figures 2.1, 3.1, and 4.8).



1 inch = 18 miles

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Figure 4.8 Aquatic diversity areas (ADAs) in or near Malheur, Umatilla, and Wallowa-Whitman National Forests in central and northeastern Oregon (see also Figures 2.1, 3.1, and 4.7).

OCHOCO NATIONAL FOREST

Ochoco National Forest (Figure 4.9, Table 4.6) encompasses 845,000 acres of relatively arid lands in the southern Blue Mountains of central Oregon. Rainfall ranges from less than 10 inches to a little more than 30 inches per year at high elevations. Elevations range from 2200 to 7000 feet. The vegetation consists of mixed-conifer forests (24% of the national forest), ponderosa pine forests (40%), pine-juniper scrub (14%), juniper scrub (20%) and scrub grasslands (USFS 1989b). In contrast to many eastside forests, Ochoco wilderness areas were surveyed for LS/OG (Adopt-a-Forest project, Pacific Meridian Resources).

ADAs in Ochoco National Forest (see Figures 4.3 and 4.7) include a number of relatively small watershed refugia or corridors widely scattered across several river basins (see Appendix II). These areas are used by various cold-water-dependent salmonids: bull trout in the mainstem Crooked River and Deschutes Canyon below Lake Billy Chinook (ADA 504 and 505); native redband trout in the North Fork Crooked River system (ADA 511 and 512); unique westslope cutthroat populations; and reduced populations of summer steelhead in several tributaries of the John Day River (ADA 601, 602, and 616). Cool water sources and high dissolved oxygen in upper portions of Nicol and Dairy Creeks in the Silver Creek drainage (ADA 1206) may be critical to an endemic subspecies of mottled sculpin, which is limited to parts of the Harney basin in Harney County, Oregon (Oregon AFS 1993).

The relatively small number of ADAs identified in Ochoco National Forest reflects the degraded condition of many of the streams. The final EIS for the Land and Resource Management Plan for this forest (USFS 1989b) notes that habitat conditions in 50% of Ochoco streams (401 stream miles of 817 miles evaluated) are unacceptable, failing to meet standards of 80% bank stability and a minimum of 80% shade (or 100% potential shade when the 80% standard is not attainable). Responsible factors cited in the plan include timber harvest, roads and skid trails, and livestock grazing, all of which have contributed to unstable banks, sedimentation, lack of riparian cover, and high water temperatures. A 1991 temperature survey by Ochoco National Forest personnel found that 48 of 50 streams monitored in the Crooked and Deschutes river systems exceeded Oregon State's maximum temperature standard of 58° F for some portion of the summer (USFS 1991a). Twenty-nine of the streams (58%) monitored reached 70° F or higher. In the John Day and Silver and Immigrant Creek drainages, where the state's temperature standard is 68° F, 9 of 16 monitored streams exceeded the standard, and 7 reached 75° F or higher.

The Ochoco forest plan calls for updating range allotment management plans for 21 of the 85 grazing allotments by 1993 (USFS 1989c: appendix A4-2). As of 1992, only one allotment management plan had been finalized since the forest plan was completed (Jon Rhodes, Columbia River Intertribal Fish Commission, personal communication).

Some of the best aquatic habitats in the Crooked River system lie within ADA 511 and ADA 512 (Oregon Department of Fish and Wildlife, Aquatic Resource Inventory, unpublished data) . Roadless regions constitute 80% and 31% of these watersheds, respectively; LS/OG, 48% and 30%. In addition, substantial proportions of ADAs 601 (Cottonwood Creek; 72%) and 602 (Rock Creek; 52%) in the John Day system are roadless.

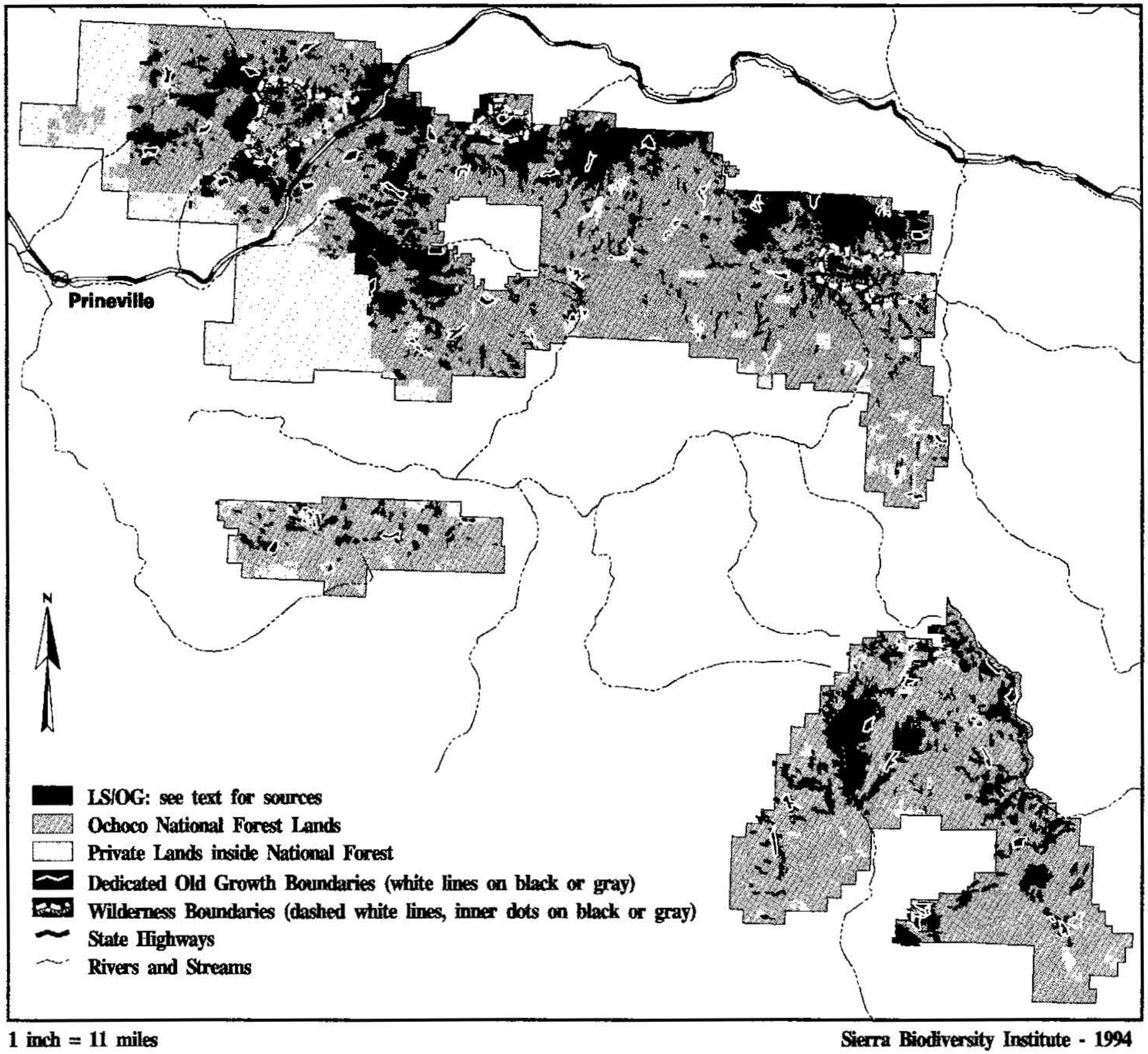


Figure 4.9 Ochoco National Forest, showing public and private lands, wilderness areas, designated old growth, and actual late-successional/old-growth forest (LS/OG).

Table 4.6 Ochoco National Forest facts.

General Statistics (acres x 1000)[1]

Net national forest[2]	Total wilderness2	Percent of total national forest	Total forested area[2]	Percent of total national forest	USFS-lands suitable for timber management[2]	Percent of total national forest	Nonforest area[2]	Percent of total national forest
845	27	3	573	68	533	63	272	32

USFS designated old growth	Percent of designated old growth actually LS/OG	Total administratively protected LS/OG[3]	Percent of total national forest	Composite LS/OG (USFS, PMR, Audubon)	Percent of total national forest	American Fisheries Society aquatic diversity areas	Percent of total national forest
21	74	23	3	204	24	80	9

LS/OG Stand Data

LS/OG status		Total Acres	Percent of total LS/OG	Number of stands (n)	Stand size (acres)				Stand size distribution (acres)					
					Mean	Minimum	Maximum	Standard deviation	1–100	101–300	301–500	501–1000	1001–5000	5000+
Protected	In wilderness	14,428	7	176	82	2	2,891	320	158	9	2	2	5	0
	Administratively	22,919	11	295	78	2	1,829	164	235	38	19	1	2	0
	Total[4]	37,354	18	431	87	2	3,156	257	354	45	21	4	7	0
Unprotected	Available for scheduled timber cutting	154,608	76	2114	73	2	16,316	504	1929	117	23	19	22	4
	Available for unscheduled timber cutting	11,196	5	57	196	2	4,697	699	50	1	0	3	3	0
	Total[4]	165,828	81	2067	80	2	18,434	657	1894	111	20	16	22	4

[1] All statistics derived from Eastside Forests Scientific Society Panel analysis unless otherwise noted.
[2] From the US Forest Service Land and Resource Management Plan.
[3] Includes LS/OG on all stands where logging has been administratively prohibited.
[4] Totals may not equal sum of subtotals because some stands cross management zones.

Percent LS/OG within Subwatersheds

Total number of subwatersheds	Average subwatershed area (acres)	LS/OG (percent of subwatershed)				Number of watersheds classified by percent LS/OG				
		Mean	Minimum	Maximum	Standard deviation	0–10%	11–20%	21–40%	41–60%	61–100%
92	9,701	18	0	81	20	46	12	18	10	3

LS/OG-Riparian Relationship

LS/OG status		Miles of stream in stands	Stream miles per 1000 Acres	Percent of LS/OG within each distance range from stream (feet)						
				0–50	250–500	500–50	750–1000	1000–1250	1250–1500	1500+
Protected	In wilderness	18.9	1.3	6	12	9	7	7	9	51
	Administratively	59.5	2.6	12	19	11	7	6	8	37
	Total	79.3	2.1	10	16	10	7	6	8	43
Unprotected	Available for scheduled timber cutting	339.1	2.2	10	18	12	8	7	9	35
	Available for unscheduled timber cutting	31.4	2.8	15	27	17	9	8	8	16
	Total	370.9	2.2	11	19	12	8	7	9	34

LS/OG Classification by Slope

LS/OG status		Acres within slope classes (percent)		
		0–30	30–60	60+
Protected	In wilderness	8,905	5,112	439
	Administratively	17,927	4,536	210
	Total	26,832	9,648	694
Unprotected	Available for scheduled timber cutting	124,150	29,355	859
	Available for unscheduled timber cutting	4,183	5,100	353
	Total	128,333	34,455	1,212
Total: national forest		737,596	105,072	4,230

Roadless Region Patch Size Distribution

Type	Total acres	Number of patches	Patch size (acres)				Patch area distribution (acres)							
			Mean	Minimum	Maximum	Standard deviation	250–00	500–750	750–1000	1000–2000	2000–5000	5000–10000	10000–50000	50000+
RARE II[1]	70,760	11	6432	409	15,988	5758	1	1	0	3	0	2	4	0
Eastside Forests Scientific Society Panel	175,160	169	1036	250	18,125	1932	99	27	8	17	12	5	1	0

[1] Includes Crooked River National Grassland, administered by the Ochoco NF.

Relationship between LS/OG, Roadless Regions and Aquatic Diversity Areas

LS/OG status		Distribution					
		Within RARE II roadless areas		Within Eastside Forests Scientific Society Panel roadless regions		Within American Fisheries Society Aquatic Diversity Areas	
		Acres	Percent of total LS/OG	Acres	Percent of total LS/OG	Acres	Percent of total LS/OG
Protected	In wilderness	0	—	0	—	4,807	33
	Administratively	3,057	13	11,162	49	1,371	6
	Total	3,069	8	24,399	65	6,176	17
Unprotected	Available for scheduled timber cutting	22,837	15	53,836	35	13,235	9
	Available for unscheduled timber cutting	10,331	92	9,617	86	7,420	66
	Total	33,168	20	63,453	38	20,655	12

Relationship between Roadless Regions and Aquatic Diversity Areas

Roadless region type	Within American Fisheries Society Aquatic Diversity Areas	
	Acres	Percent of total
Eastside Forests Scientific Society Panel	20,373	26
Roadless Area Review and Evaluation II	17,351	22

Road Density within Subwatersheds

Road density (miles/mile^2)*			
Mean	Minimum	Maximum	Standard Deviation
3.7	0.4	5.7	1.2

* Only watersheds with > 0 miles of road per square mile represented.

Relationship between LS/OG and USFS Designated Old Growth

Stand Information (number of stands)			
Total designated old growth	Total with 0% LS/OG	Total with 1-70% LS/OG	Total with >70% LS/OG
85	4	31	66

Okanogan National Forest

Okanogan National Forest (Table 4.7) comprises 1.7 million acres in the North Cascade Range of north-central Washington and the gently rolling terrain of the Okanogan Highlands just south of the British Columbia–Washington border. Highest elevations range from 7200 feet in the east to 9000 feet in the west. Average precipitation declines rapidly from west to east, from 80 to 10 inches per year; rainfall in the Okanogan Highlands averages 35 inches per year.

Vegetation in the Okanogan includes both forest and nonforest associations; coniferous forests are most abundant. Douglas fir is the most common conifer; ponderosa pine, lodgepole pine, Englemann spruce, and subalpine fir are also widely distributed. Western larch, quaking aspen, black cottonwood, and other riparian deciduous forests grow there as well. Nonforest associations include wet meadows, sagebrush, and grasslands.

Audubon Society–USFS maps for late-successional old growth are unavailable for Okanogan National Forest, except for Tonasket Ranger District, and these were not available in digital form. Our analysis of LS/OG distribution is therefore based on the extent of roadless, unmanaged coniferous forest as mapped by the interagency North Cascades grizzly bear habitat study (Almack et al. 1993) and provides detailed information on the species composition of these forests.

The Okanogan contains no designated old-growth sites; instead, all old-growth stands were theoretically located and protected by the Okanogan National Forest's forest plan during planning for timber sales. Thus all LS/OG outside of wilderness areas has theoretically been protected. The actual implementation of this protection has been fraught with problems, including inconsistency. For comparison with other national forests, however, we compiled statistics for "firmly protected" LS/OG, that is, LS/OG located within the geographic boundaries of wilderness areas or administratively protected for reasons other than setting aside old growth.

Table 4.7 Okanogan National Forest facts.

General Statistics (acres x 1000)[1]

Total national forest[2]	Total wilderness[2]	Percent of total national forest	Total forested area[2]	Percent of total national forest	USFS-determined lands suitable for timber management[2]	Percent of total national forest	Nonforest area[2]	Percent of total national forest
1,706	626	37	1,487	87	542	32	219	13

Administratively protected LS/OG[3]	Percent of total national forest	Unmanaged coniferous forest mapped by Grizzly Bear habitat study[4]	Percent of total national forest
15	2	550	31

Roadless Region Patch Size Distribution

Type	Total acres	Number of Patches	Patch size (acres)				Patch area distribution (acres)							
			Mean	Minimum	Maximum	Standard Deviation	250–500	500–750	750–1000	1000–2000	2000–5000	5000–10000	10000–50000	50000+
RARE II	448,439	14	32,031	3,847	128,720	—	0	0	0	0	2	2	7	3
Eastside Forests Scientific Society Panel	625,508	116	5,392	250	109,038	16,201	32	19	13	22	14	6	6	4

[1] All data from the Eastside Forest Science Society Panel unless otherwise noted.
[2] From the Final Okanogan National Forest Land and Resource Management Plan.
[3] There is no designated old growth on the Okanogan National Forest. Includes only lands administratively protected for other purposes.
[4] Includes open and closed canopy stands. All LS/OG data excludes the Tonasket Ranger District and covers lands east of the Cascade Crest only.

Relationship between LS/OG and Roadless Regions

LS/OG status		Distribution			
		Within RARE II roadless areas		Within Eastside Forests Scientific Society Panel roadless regions	
		Acres	Percent of total LS/OG	Acres	Percent of total LS/OG
Protected	In wilderness	0	—	0	—
	Administratively	14,402	100	14,096	100
	Total	14,402	5	14,096	5
Unprotected	Within management areas available for scheduled timber cutting	107,469	56	191,954	100
	Within management areas available for unscheduled timber cutting	46,741	98	49,129	100
	Total	154,210	64	241,083	100

Classification of Eastside Panel Roadless Regions by Slope and Land Use

Roadless region status		Slope class	Acres
Protected	Nonforested		21,562
	Forested on administratively protected lands	<30%	3,756
		30–60%	11,208
		>60%	6,390
	Total		42,916
Unprotected	Nonforested		269,281
	Forested within management areas available for scheduled timber cutting	<30%	62,837
		30–60%	176,852
		>60%	19,037
		Slope unknown	44
	Forested within management areas available for unscheduled timber cutting	<30%	12,391
		30–60%	36,184
		>60%	9,264
		Slope unknown	450
	Total		582,592

Umatilla National Forest

Umatilla National Forest (Figures 4.10a,b; Table 4.8) consists of 1.4 million acres mostly in Oregon, with a small extension into southeastern Washington. Elevations range from about 2000 to 6900 feet. The vegetation of the Umatilla ranges from forested slopes to sagebrush plains. LS/OG in Umatilla wilderness areas was completely mapped. Discussion of aquatic diversity areas for the Umatilla applies only to regions within Oregon.

In the Umatilla and Walla Walla river basins (see Figures 4.7 and 4.8), ADAs comprise critical habitats for cold-water-dependent species, including native bull trout, interior rainbow (redband) trout, summer steelhead, spring chinook salmon, and margined sculpin (see Appendix II). Margined sculpin are believed to exist only in the Umatilla, Walla Walla, and Willow Creek basins. The South Fork Walla Walla (ADA 706) is a critical source of cool water to the rest of the system; it contains relatively healthy populations of native fish and is the primary spawning area for summer steelhead in the Oregon portion of the Walla Walla basin. Most of the ADAs in the Umatilla River basin have undergone some habitat loss from grazing or logging (Oregon AFS 1993). Nevertheless, summer low-flow temperatures in this northern half of the forest are excellent (50–60° F range; USFS 1993b).

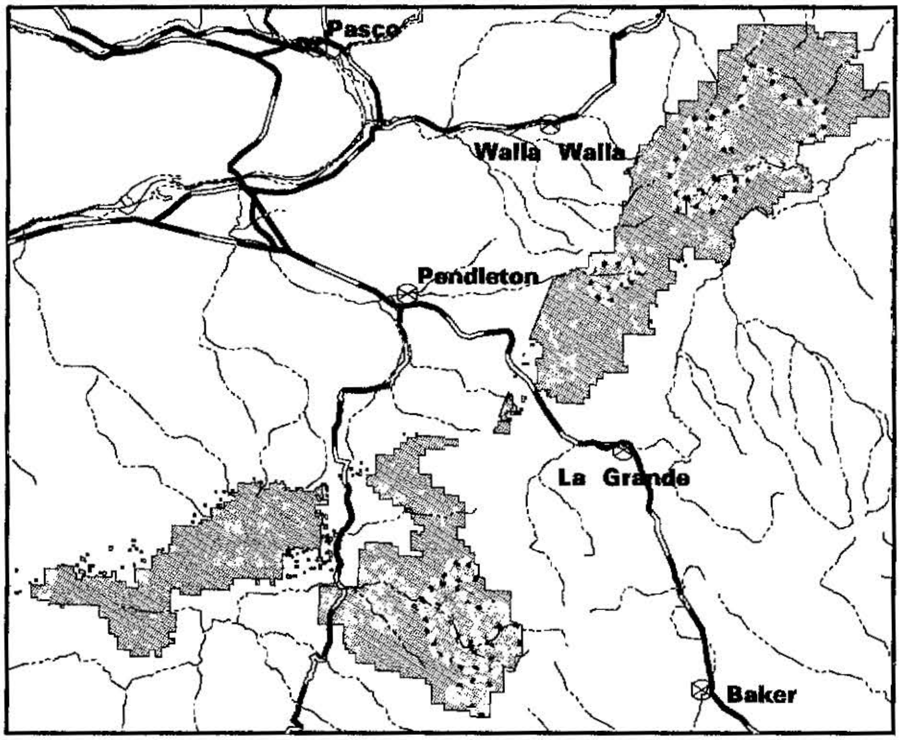
The Wenaha River system in the Grande Ronde River basin lies almost entirely within a wilderness area. This ADA (ADA 801) may contain the healthiest remaining bull trout population in Oregon (Oregon AFS 1993). Large bull trout also occur in Lookingglass Creek (ADA 803), but habitat degradation, dams that limit access to upstream spawning areas, and angling may suppress this population (Ratliff and Howell 1992). The lower portion of the Grande Ronde River (ADA 812) provides critical spawning habitat for threatened stocks of Snake River fall chinook salmon and a migration corridor to upper spawning and rearing habitats for threatened stocks of spring chinook salmon and fluvial populations of bull trout (Oregon AFS 1993).

The USFS forest plan reports that grazing allotments in the Umatilla National Forest cover 1,075,000 acres, which include nearly all commercial forestland in the national forest (USFS 1990b). Twenty-four of the 51 Umatilla range allotment management plans were scheduled for update between 1990 and 1993 (USFS 1990e: table 4.12), but none of these had been finalized as of 1992 (Jon Rhodes, Columbia River Intertribal Fish Commission, personal communication).

ADAs in the North Fork John Day River system (ADAs 604, 606, 608, 609, 614, and 623) and Granite Boulder Creek in the Middle Fork John Day River (ADA 624) provide critical sources of cool water for diverse salmonids that are excluded by temperature elsewhere in the John Day basin. Among these are bull trout, spring chinook salmon, summer steelhead, native interior (redband) rainbow trout, and unique populations of westslope cutthroat trout. About 70% of the native spring chinook salmon in the John Day basin come from upper tributaries of the North Fork John Day River (ADA 608). ADAs in portions of Camas Creek (ADAs 610, 620, and 622) and lower Desolation Creek (ADA 605) need restoration because of sedimentation, loss of riparian cover, and increased temperatures caused by grazing and logging on highly erodible soils. Mining, salvage logging, grazing, and encroachment of smallmouth bass, an introduced species in Oregon, threaten native fish in many ADAs in the North Fork John Day River system (Oregon AFS 1993).

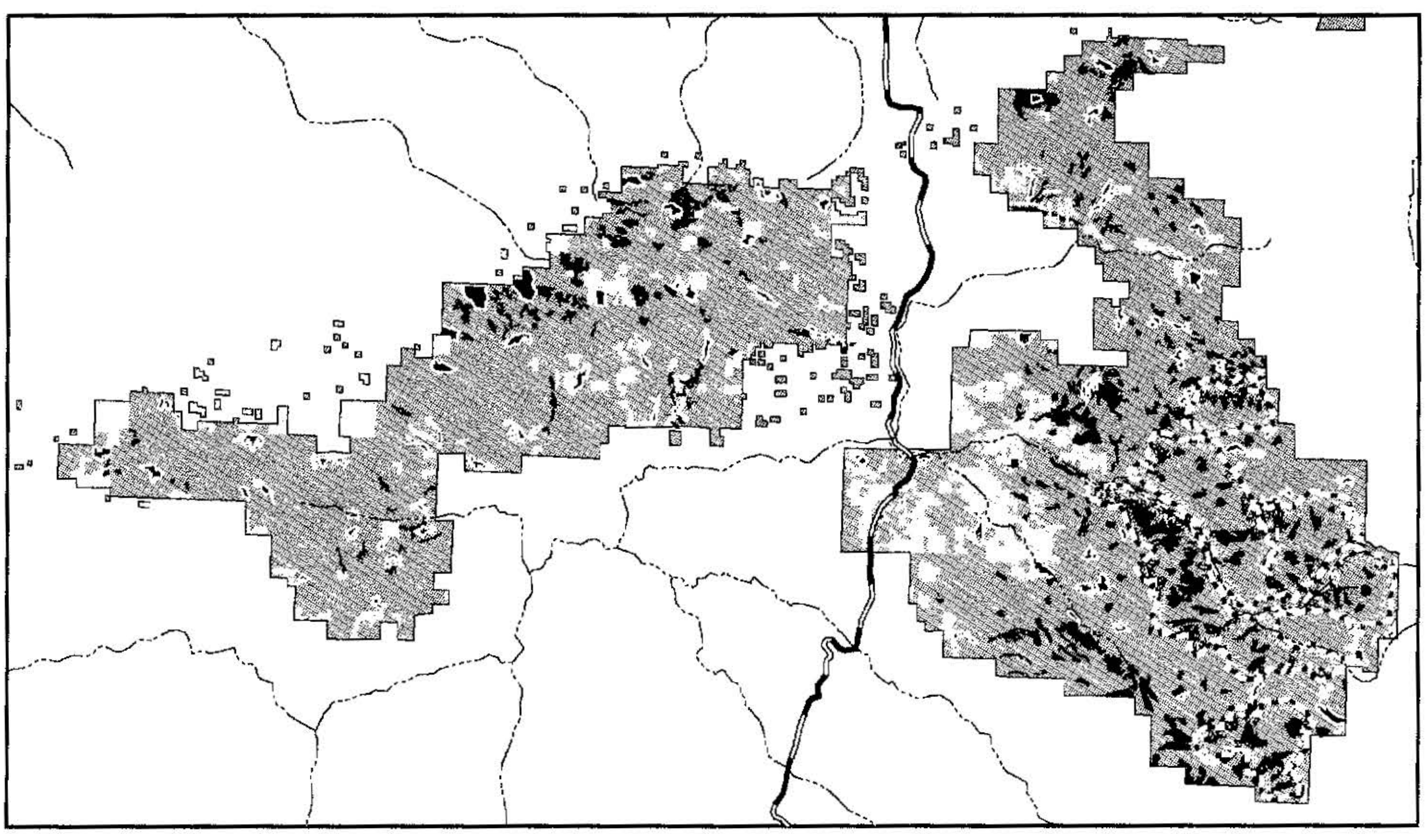
Monitoring of the North Fork John Day basin reveals that maximum temperatures frequently exceed the state of Oregon's 68° F standard. In 1991, summer low-flow temperatures ranged consistently between 70 and 80°. Twenty of 27 tributaries in the North Fork John Day district had summer temperatures exceeding state standards in 1992 (USFS 1993b), even though summer 1992 temperatures were well below average (Jon Rhodes, Columbia River Intertribal Fish Commission, personal communication, 1994). Temperatures above the state standard were recorded in several streams within or directly below ADAs: Hidaway Creek (ADA 621), Camas Creek (ADA 610 and 622), and Fivemile Creek (ADA 620).

Figure 4.10a Umatilla National Forest and detail of southwestern portion, showing public and private lands, wilderness areas, designated old growth, and actual late-successional/old-growth forest (LS/OG).



1 inch = 30 miles

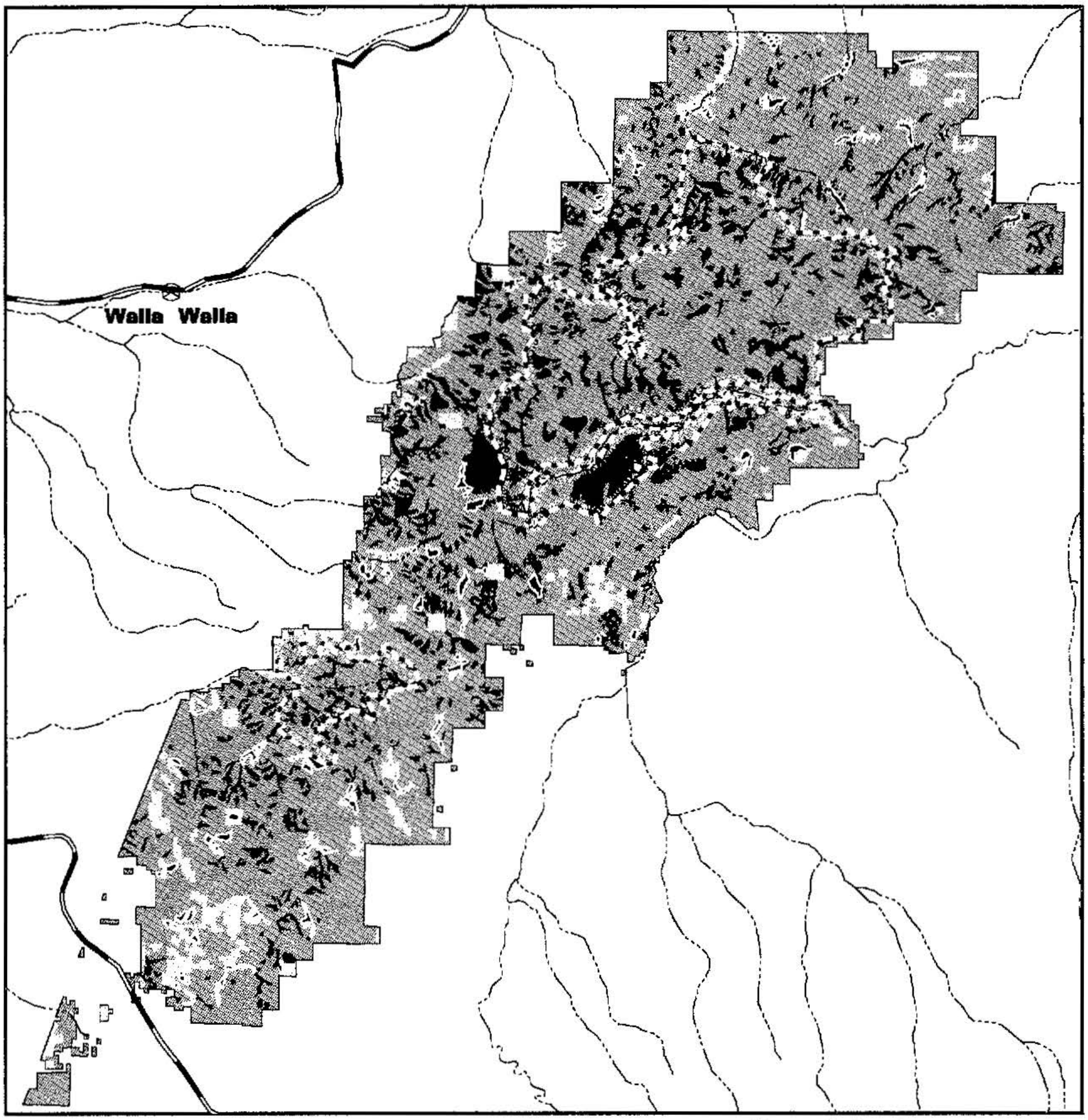
SW Umatilla NF



1 inch = 11 miles

Figure 4.10b Northeastern Umatilla National Forest, showing public and private lands, wilderness areas, designated old growth, and actual late-successional/old-growth forest (LS/OG).

NE Umatilla NF



1 inch = 10 miles

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- LS/OG: Forest Service/Audubon Coop Mapping (wilderness mapped)
- Umatilla NF Lands
- Private Lands
- Dedicated Old Growth Boundaries (white lines on black or gray)
- Wilderness Boundaries (dashed white lines, inner dots on black or gray)
- Highways
- Rivers and Streams

Table 4.8 Umatilla National Forest facts.

General Statistics (acres x 1000)[1]

Net national forest[2]	Total wilderness[2]	Percent of wilderness forested	Percent of total national forest in wilderness	Total forested area[2]	Percent of total national forest	USFS-determined lands suitable for timber management[2]	Percent of total national forest	Nonforest area[2]	Percent of total national forest
1,400	304	—	22	1,086	78	619	44	314	22

USFS-designated old growth	Percent of designated old growth actually LS/OG	Total administratively protected LS/OG[3]	Percent of total national forest	Audubon-USFS LS/OG	Percent of total national forest	American Fisheries Society aquatic diversity areas	Percent of total national forest
40	91	39	3	198	14	665	48

LS/OG Stand Data

LS/OG status		Total acres	Percent of total LS/OG	Number of stands (n)	Stand size				Stand size distribution (acres)[5]					
					Mean	Minimum	Maximum	Standard deviation	1–100	101–300	301–500	501–1000	1001–5000	5000+
Protected	In wilderness[4]	68,000	34	341	188	2	7,450	500	198	95	22	19	6	1
	Administratively	40,000	20	283	135	5	1,010	135	150	99	30	3	1	0
	Total	108,000	54	613	166	2	7,450	388	341	190	52	21	8	1
Unprotected	Within management areas available for scheduled timber cutting	66,000	33	770	81	1	3,480	192	606	98	13	10	6	0
	Within management areas available for unscheduled timber cutting	24,000	12	297	69	2	1,050	100	237	52	5	2	1	0
	Total	90,000	45	945	87	1	3,490	186	756	145	22	14	8	0

[1] All statistics from Eastside Forests Scientific Society Panel analysis unless otherwise noted.
[2] From the Final US Forest Service Land and Resource Management Plan.
[3] Includes LS/OG on all lands where logging has been administratively prohibited.
[4] LS/OG only partially mapped in wilderness; actual total higher.
[5] Total stand size distribution may not be the sum of subtotals because some stands cross management areas.

Percent LS/OG within Subwatersheds

Total number of subwatersheds	Average subwatershed area (acres)	LS/OG density (percent of subwatershed)				Number of watersheds classified by percent LS/OG			
		Mean	Minimum	Maximum	Standard deviation	0–20%	21–40%	41–60%	61–80%
236	9,888	10%	0%	58%	9.2%	208	32	2	0

LS/OG-Riparian Relationship

LS/OG status		Miles of stream in stands	Stream miles per 1000 acres	Percent of LS/OG within each distance range from stream (feet)						
				0–250	250–500	500–750	750–1000	1000–1250	1250–1500	1500+
Protected	In wilderness	98.3	1.4	11	19	11	7	6	9	34
	Administratively	124.4	3.1	17	25	12	7	5	7	24
	Total	222.7	2.1	13	21	11	7	6	8	30
Unprotected	Within management areas available for scheduled timber cutting	112.1	1.7	12	19	11	7	6	8	33
	Within management areas available for unscheduled timber cutting	59.6	2.5	16	24	12	7	6	7	25
	Total	171.7	1.9	13	21	11	7	6	8	31

LS/OG Classification by Slope

LS/OG status		Acres within slope classes (percent)		
		0–30%	30–60%	60+%
Protected	In wilderness	40	44	16
	Administratively	41	46	14
	Total	40	44	15
Unprotected	Within management areas available for scheduled timber cutting	50	40	10
	Within management areas available for unscheduled timber cutting	37	46	17
	Total	44	43	13
Total: national forest lands		54	34	12

Roadless Region Patch Size Distribution

Type	Total acres	Number of patches	Patch size				Patch area distribution (acres)							
			Mean	Minimum	Maximum	Standard deviation	250–500	500–750	750–1000	1000–2000	2000–5000	5000–10000	10000–50000	50000+
RARE II	233,000	19	12,240	2,103	60,000	14,230	0	0	0	0	6	7	5	1

Relationship between LS/OG, Roadless Regions and Aquatic Diversity Areas

LS/OG status		Distribution			
		Within RARE II roadless areas		Within American Fisheries Society Aquatic Diversity Areas	
		Acres	Percent of total LS/OG	Acres	Percent of total LS/OG
Protected	In wilderness	0	—	62,664	92
	Administratively	14,000	35	16,900	42
	Total	14,000		79,563	74
Unprotected	Within management areas available for scheduled timber cutting	17,000	26	33,101	50
	Within management areas available for unscheduled timber cutting	14,000	58	11,081	46
	Total	31,000	34	44,183	49

Relationship between Roadless Regions and Aquatic Diversity Areas

Roadless region type	Within American Fisheries Society Aquatic Diversity Areas	
	Acres	Percent of total
Roadless Area Review and Evaluation II	152,004	65

Wallowa-Whitman National Forest

Wallowa-Whitman National Forest (Figure 4.11, Table 4.9) includes 2.4 million acres in the Hells Canyon, Wallowa, and northern Blue Mountains of northeastern Oregon on the Idaho border. Elevations range from 1000 to more than 8000 feet in the Eagle Cap Mountains. Rainfall varies from near 10 inches per year in low-elevation grasslands to 80 inches in the high Wallowa Mountains.

Vegetation is closely related to soil depth and ash content. Soils and vegetation vary with slope, aspect, precipitation, and elevation. Northern slopes and broad ridgetops where volcanic ash is concentrated produce a mixed forest of Douglas fir, grand fir, larch, ponderosa, pine and lodgepole pine. Southern slopes and lower elevations with less precipitation have open stands of predominantly ponderosa pine with a grassy understory.

No mapping of LS/OG was done in Wallowa-Whitman wilderness areas.

The Wallowa-Whitman is especially rich in rare and endangered aquatic species and communities. The many ADAs in the national forest include portions of the Grande Ronde, Imnaha, John Day, and Powder River and Pine Creek systems (see Figures 4.7 and 4.8, Appendix II). These systems contain some of the last remaining refugia for many sensitive salmonid stocks indigenous to the upper Columbia River basin, including threatened Snake River spring and fall chinook salmon, native upper Columbia River summer steelhead, and some of the few remaining fluvial populations of bull trout in Oregon. All these salmonid taxa are represented in one or more of the ADAs in the Imnaha River system (ADAs 806, 807, 810, and 811). In the Minam (ADA 802) and the upper Wallowa (ADAs 815, 829, and 831) systems, ADAs provide habitat for sensitive salmonids and serve as a critical source of cool water to downstream areas. ADAs in the Pine Creek (ADAs 901, 906, and 907) and Powder River (ADAs 903, 904, 905, and 909) systems constitute the last few refugia for now disjunct populations of local bull trout (Ratliff and Howell 1992). Several small tributaries (ADAs 809, 817) that drain directly into the Snake River are believed to have genetically distinct populations of native rainbow trout. The uppermost tributaries of the Grande Ronde River (ADA 816) provide spawning and rearing habitat for migratory bull trout, and they harbor summer steelhead and remnant populations of wild spring chinook salmon. The upper Grande Ronde now accounts for 5–7% of the entire remaining run of threatened Snake River spring chinook salmon (Anderson et al. 1992).

Steep canyon terrain and highly erodible, granitic soils in portions of the Imnaha River, Joseph Creek, Wallowa River, upper Minam River, and upper Grande Ronde River drainages make them highly vulnerable to disturbance.

Lower portions of the Wallowa system, including lower Bear Creek (ADA 828), have been moderately degraded by logging, log drives, grazing, and channelization (Oregon AFS 1993). Much of the Joseph Creek system needs restoration because of intensive grazing, very high road densities, logging, and increased sediment from erodible soils (Oregon AFS 1993). Grazing effects on riparian systems have intensified in the Joseph Creek system over the past several decades as increased road building and logging have made stream bottoms more accessible to cattle (Bill Knox and Ken Witty, Oregon Department of Fish and Wildlife, personal communication). In recent years, summer temperatures as high as 86° F have been recorded in Joseph Creek at river mile 44 near the confluence with ADA 821 (Oregon Department of Fish and Wildlife, unpublished data).

ADAs in the upper Wallowa, Minam, Imnaha, Pine, and Eagle Creek systems include tributaries that drain from the Eagle Cap wilderness or Hells Canyon National Recreation Area. Eight of 40 ADAs (20%) in Wallowa-Whitman National Forest are at least 40% roadless; 16 of 40 (40%) are less than 10% roadless. Of the 26 ADAs for which we have complete LS/OG maps, only 2 (8%) have LS/OG over more than 15% of their area.

The Wallowa-Whitman forest plan estimates that approximately 1.3 million of the forest's 2.4 million acres are classified as suitable for grazing—a figure about equal to the total amount of forested area in the national forest. The plan also notes that uncontrolled grazing early in the century caused severe damage and that, "in some specific instances," current management is insufficient to correct the damage or prevent additional damage. Wallowa-Whitman National Forest administers 143 grazing allotments. Altogether 29 range allotment management plans were scheduled for update during 1991–93 (USFS 1990f), but only 1 had been finalized as of 1992 (Jon Rhodes, Columbia River Intertribal Fish Commission, personal communication).

Figure 4.11 Wallowa-Whitman National Forest, showing public and private lands, wilderness areas, designated old growth, and actual late-successional/old-growth forest.

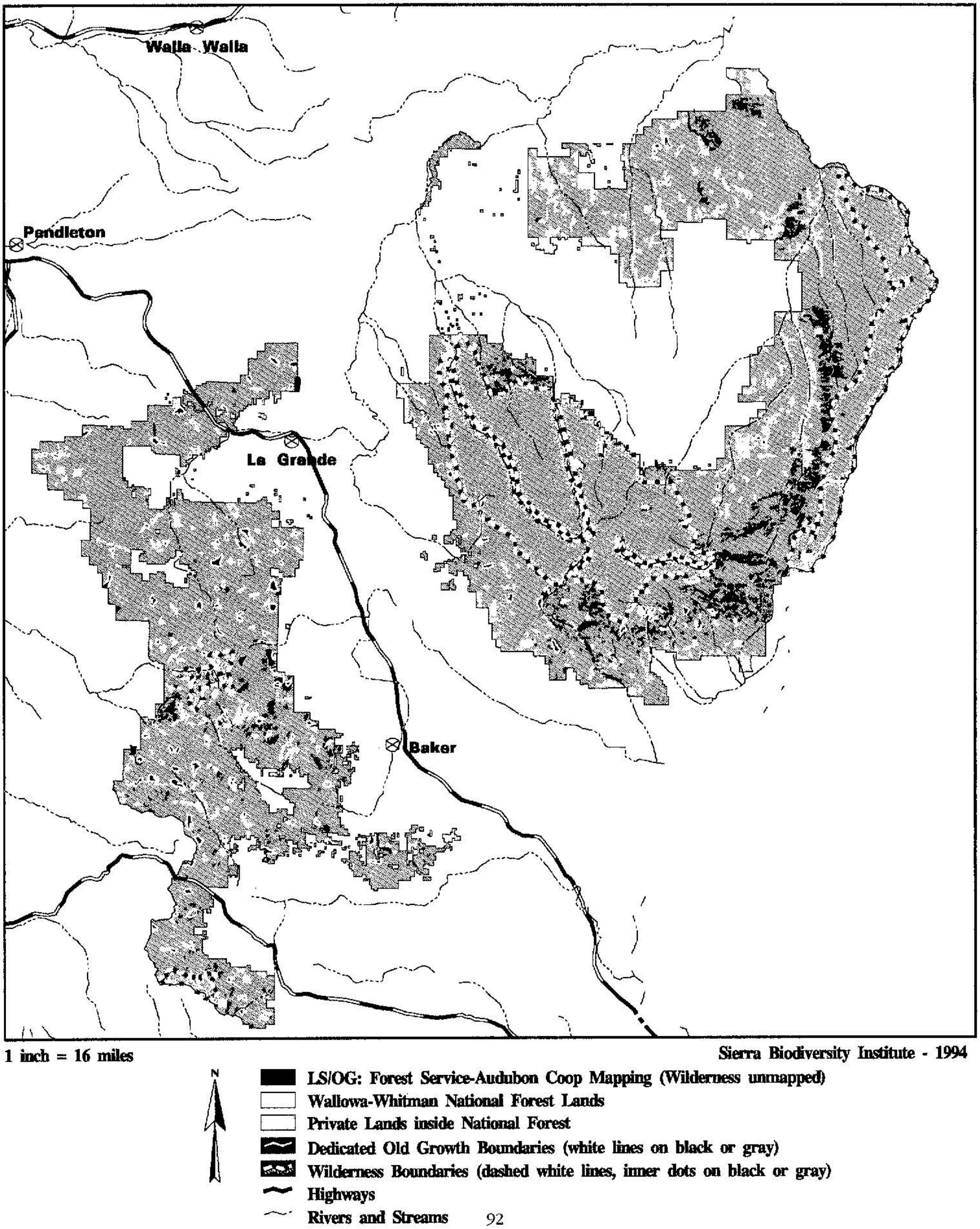

Table 4.9 Wallowa-Whitman National Forest facts.

General Statistics (acres x 1000)[1]

Net national forest[2]	Total wilderness2	Percent of wilderness Forested	Percent of total national forest in wilderness	Total forested area[2]	Percent of total national forest	USFS-determined lands suitable for timber management[2]	Percent of total national forest	Nonforest area[2]	Percent of total national forest
2,406	583	69	24	1,412	59	1,090	45	937	39

USFS designated old growth	Percent of designated old growth actually LS/OG	Total administratively protected LS/OG[3]	Percent of total national forest	Audubon-USFS LS/OG	Percent of total national forest	American Fisheries Society aquatic diversity areas	Percent of total national forest
55	80	45	2	131	5	1,248	53

LS/OG Stand Data

LS/OG status		Total acres	Percent of total LS/OG	Number of stands (n)	Stand size (acres)				Stand size distribution (acres)					
					Mean	Minimum	Maximum	Standard Deviation	1–100	101–300	301–500	501–1000	1001–5000	5000+
Protected	In wilderness	5,353[3]	4	104	57	2	1011	116	90	11	2	0	1	0
	Administratively	44,564	34	501	89	2	660	123	362	89	39	11	0	0
	Total[4]	49,917	38	605	70	2	1011	120	452	100	41	11	1	0
Unprotected	Within management areas available for scheduled timber cutting	44,176	34	1725	26	2	1470	78	1618	74	23	9	1	0
	Within management areas available for unscheduled timber cutting	35,950	27	407	88	2	1720	208	326	52	11	13	5	0
	Total[4]	80,126	72	2132	38	2	1720	161	1944	126	34	19	6	0

1 All statistics derived from Eastside Forests Scientific Society Panel analysis unless otherwise noted.
2 From the US Forest Service Land and Resource Management Plan.
3 LS/OG largely unmapped in wilderness; actual total unavailable.
4 Totals may not equal sum of subtotals because some stands cross management zones.

LS/OG-Riparian Relationship

LS/OG status		Miles of stream in stands	Stream miles per 1000 acres
Protected	In wilderness	17	3.4
	Administratively	126	2.8
	Total	143	2.9
Unprotected	Within management areas available for scheduled timber cutting	92	2
	Within management areas available for unscheduled timber cutting	72	2.1
	Total	164	2

LS/OG Classification by Slope

LS/OG status		Acres within slope classes (percent)		
		0–30%	30–60%	60+%
Protected	In wilderness	2523	2029	919
	Administratively	23405	16724	2708
	Total	25928	18753	3627
Unprotected	Within management areas available for scheduled timber cutting	24273	19331	2577
	Within management areas available for unscheduled timber cutting	7151	18,723	10111
	Total	31424	38054	12688
Total: national forest		1,112,825	828,694	381,789

Roadless Region Patch Size Distribution

Type	Total acres	Number of Patches	Patch size (acres)				Patch area distribution (acres)							
			Mean	Minimum	Maximum	Standard deviation	250–500	500–750	750–1000	1000–2000	2000–5000	5000–10000	10000–50000	50000+
RARE II	456,357	41	8451	278	97,378	15,393	6	1	0	5	4	13	10	2

Relationship between Roadless Regions and Aquatic Diversity Areas

Roadless area type	Within American Fisheries Society Aquatic Diversity Areas	
	Acres	Percent of total AFS areas
Roadless Area Review and Evaluation II	327,704	26

Relationship between LS/OG, Roadless Regions and Aquatic Diversity Areas

LS/OG status		Distribution			
		Within RARE II roadless areas		Within American Fisheries Society Aquatic Diversity Areas	
		Acres	Percent of total LS/OG	Acres	Percent of total LS/OG
Protected	In wilderness	0	—	4,747	89
	Administratively	7,393	17	19,953	45
	Total	7,393	15	24,700	49
Unprotected	Within management areas available for scheduled timber cutting	12,212	28	29,882	68
	Within management areas available for unscheduled timber cutting	24,084	67	29.430	82
	Total	36296	45	59,312	74

[1] Stands largely unmapped in wilderness: actual total higher.

WENATCHEE NATIONAL FOREST

Wenatchee National Forest (Table 4.10) covers 2.2 million acres on the eastern slope of the Cascades in central Washington. Elevations range from 800 feet at the area's eastern edge to 9500 feet in the Glacier Peak wilderness. Rainfall varies from 90 to 140 inches per year near the Cascade crest to 10 inches per year along the eastern forest boundary. Vegetation includes dry coniferous forest (ponderosa pine, Douglas fir), wet coniferous forests (some ponderosa pine but more grand fir; silver fir; western hemlock; western red cedar; and, rarely, western larch, noble fir, and western white pine). Nonforest vegetation includes subalpine parkland, mountain meadows, and shrublands.

Table 4.10 Wenatchee National Forest facts.

General Statistics (acres x 1000)[1]

Net national forest[2]	Total wilderness[2]	Percent of wilderness forested	Percent of total national forest	Total forested area[2]	Percent of total national forest	USFS-determined lands suitable for timber management[2]	Percent of total national forest	Nonforest area[2]	Percent of total national forest
2,164	431	86	20	1,451	67	792	37	1,006	46

USFS designated old growth[2]	Percent of designated old growth in unmanaged coniferous forest	Total administratively protected unmanaged coniferous forest	Percent of total national forest North of Highway 90	Unmanaged coniferous forest mapped by Interagency Grizzly Bear habitat study[3]	Percent of total national forest North of Highway 90
87	36	107	6	779	44

Roadless Region Patch Size Distribution

Type	Total acres	Number of patches	Patch size (acres)				Patch area distribution (acres)							
			Mean	Minimum	Maximum	Standard deviation	250–500	500–750	750–1000	1000–2000	2000–5000	5000–10000	10000–50000	50000+
RARE II	545,150	60	10,330	257	150,746	23,348	8	5	7	10	7	10	10	3
Eastside Forests Scientific Society Panel	882,383	258	3,412	255	161,159	12,546	92	49	16	42	32	10	15	2

[1] All statistics from Eastside Forests Scientific Society Panel analysis unless otherwise noted. Includes Wenatchee National Forest Lands north of Highway 90 only, unless otherwise noted

[2] From the Final US Forest Service Land and Resource Management Plan; covers the entire Wenatchee National Forest.

[3] Includes open and closed canopy stands. LS/OG data includes lands east of the Cascade Crest and north of Interstate 90.

Relationship between LS/OG and Roadless Regions

LS/OG status		Distribution			
		Within RARE II roadless areas		Within Eastside Forests Scientific Society Panel roadless regions	
		Acres	Percent of total LS/OG	Acres	Percent of total LS/OG
Protected	In wilderness	0	0	0	0
	Administratively	95,059	89	106,735	100
	Total	95,059	89	106,735	100
Unprotected	Within management areas available for scheduled timber cutting	120,736	54	222,647	100
	Within management areas available for unscheduled timber cutting	100,266	96	104,222	100
	Total	221,002	68	326,869	100

Winema National Forest

Winema National Forest (Figure 4.12, Table 4.11) includes 1.04 million acres in two major blocks. Highest elevation in the forest is 9495 feet at Mt. McLoughlin. Forest types range from mountain hemlock at higher elevations near the Cascade crest to dry ponderosa pine climax in the east; lodgepole pine covers extensive areas.

LS/OG was only partially mapped in wilderness areas within this national forest, but we were able to evaluate the extent of potential climax and seral ponderosa pine forest as a function of elevation.

Winema National Forest ADAs (see Figure 4.5) encompass habitats associated with a highly productive lake-wetland-river ecosystem. Upper Klamath and Agency Lakes are shallow and rich in nutrients (eutrophic), with a diverse and unique fish fauna (see Appendix II). Among the endemic taxa present in or immediately downstream of Winema National Forest are three sucker species, including two that are listed as threatened (ADAs 1405, 1414, and 1418); three sculpin species (ADA 1418); a remnant population of sensitive bull trout (ADA 1417); and a genetically distinct subspecies of smallscale sucker and stock of native rainbow (redband) trout isolated above the falls on Jenny Creek (ADA 1402). Two of three genetically distinct stocks of interior rainbow (redband) trout identified within the Klamath basin are represented in ADAs in Winema National Forest: populations in the upper Williamson-Sprague River and Jenny Creek (ADAs 1402 and 1405) are distinct from those in tributaries associated with Klamath River and Klamath Lake (ADAs 1401, 1403, 1412, 1414, 1416, and 1418) (Buchanan et al. 1990a, 1991). The entire native fish assemblage of the upper Williamson River (including Klamath largescale sucker, speckled dace, tui chub, and rainbow trout in ADA 1405) is geologically isolated and may include populations that are genetically distinct from those in the rest of the basin (Oregon AFS 1993). ADAs also include a critical source of spring water (ADA 1412) and spawning habitat (ADA 1416) for trophy-size native trout in the Middle Williamson River and an important source of water to lower Spencer Creek and the Klamath River (ADA 1401).

Aquatic habitats throughout the entire Upper Klamath basin have been severely altered through dam construction, draining and diking of wetlands, water diversions, grazing, logging, road building, and introduction of many exotic fish species (Oregon AFS 1993). Spawning runs of suckers from Upper Klamath Lake were once large enough to serve as a major food source for Klamath Indians and local settlers and supported a major sport fishery in the 1960s and 1970s. The historic range and numbers of shortnose and Lost River suckers in the Klamath system have been reduced by more than 95% through effects of dams and habitat alteration (USFWS 1988). Historic runs of anadromous chinook salmon into the middle and upper Klamath basin of Oregon have been blocked by dams since 1917 (Fortune et al. 1966), with unknown consequences for other native fish populations within the system. Most of the Klamath basin ADAs need restoration. Pumice soils in portions of the basin (e.g., ADA 1405) are highly erodible and vulnerable to disturbance. As in other forests, factors contributing to the degradation of habitat within Winema ADAs include clearcutting, road building, and livestock grazing (e.g., in ADAs 1401, 1402, 1405, 1416, and 1417).

Of the seven ADAs for which we have complete LS/OG maps, two (ADAs 1405 and 1414) contain LS/OG amounting to 20 and 32%, respectively, of total Winema national forest acreage. Most of the remaining national forest land within ADAs is 6% or less LS/OG. The largest proportion of remaining roadless acreage within Winema ADAs falls between 19 and 34% (ADAs 1401, 1414, and 1418).

Figure 4.12 Winema National Forest, showing public and private lands, wilderness areas, designated old growth, and actual late-successional/old-growth forest (LS/OG).

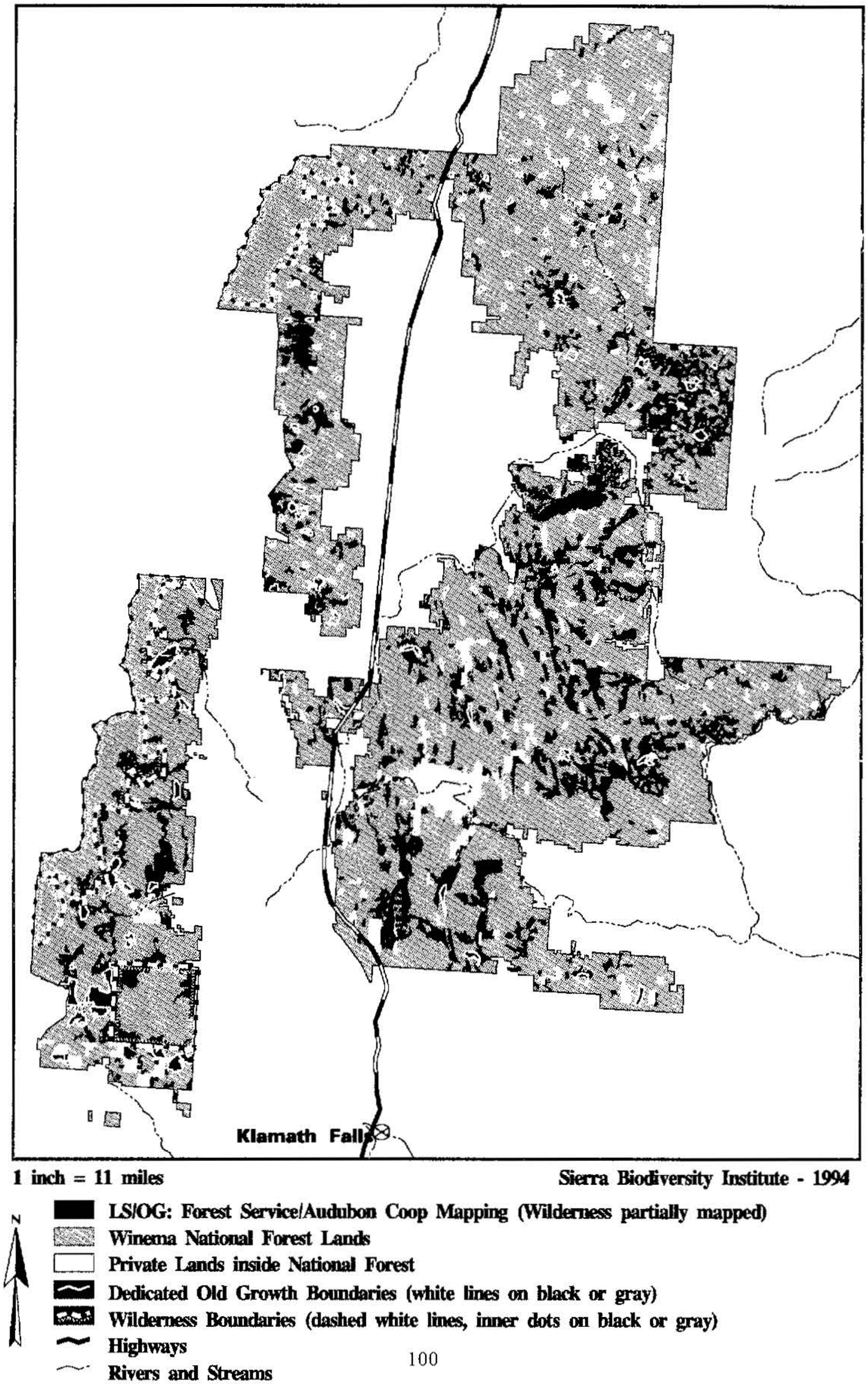

Table 4.11 Winema National Forest facts.

General Statistics (acres x 1000)[1]

Net national forest[2]	Total wilderness[2]	Percent of wilderness foreseted	Percent of total national forest	Total forested area[2]	Percent of total national forest	USFS-determined lands suitable for timber management[2]	Percent of total national forest	Nonforest area[2]	Percent of total national forest
1,039	91	—	9	1,002	96	753	72	38	4

USFS designated old growth	Percent of designated old growth actually LS/OG	Total administratively protected LS/OG[3]	Percent of total national forest	Audubon-USFS LS/OG	Percent of total national forest	American Fisheries Society aquatic diversity areas	Percent of total national forest
60	61	38	4	170	16	139	13

LS/OG Stand Data

LS/OG status		Total acres	Percent of total LS/OG	Number of stands (n)	Stand size (acres)				Stand size distribution (acres)					
					Mean	Minimum	Maximum	Standard deviation	1–100	101–300	301–500	501–1000	1001–5000	5000+
Protected	In silderness	13,844	8	68	203	2	2,523	495	50	8	5	0	5	0
	Administratively	37,725	22	176	214	2	3,311	519	124	25	6	10	11	0
	Total[4]	51,573	30	227	227	2	3,341	574	165	29	7	11	15	0
Unprotected	Within management areas available for scheduled timber cutting	83,260	49	1165	71	2	3,917	241	986	121	31	16	11	0
	Within management areas available for unscheduled timber cutting	34,254	20	724	47	2	3,415	201	655	47	7	13	2	0
	Total[4]	117,683	69	1284	92	2	4,030	292	1049	149	44	27	20	0

[1] All statistics from Eastside Forests Scientific Society Panel analysis unless otherwise noted.
[2] From the Final US Forest Service Land and Resource Management Plan.
[3] Includes LS/OG on all lands where logging has been administratively prohibited.
[4] Stand size distribution totals may not equal sum of subtotals because some stands cross management area boundaries.

Percent LS/OG within Subwatersheds

Total number of subwatersheds	Average subwatershed area (acres)	LS/OG (percent of subwatershed)				Number of watersheds classified by percent LS/OG				
		Mean	Minimum	Maximum	Standard deviation	0–10%	11–20%	21–40%	41–60%	61–80%
142	7,589	13	0	89	18	82	25	24	6	5

LS/OG-Riparian Relationship

LS/OG status		Miles of stream in stands	Stream miles per 1000 acres	Percent of LS/OG within each distance range from stream (feet)						
				0–250	250–500	500–750	750–1000	1000–1250	1250–1500	1500+
Protected	In wilderness	5.1	1.1	5	10	7	4	4	5	61
	Administratively	25	0.66	3	7	5	3	2	4	72
	Total[1]	41.4	0.8	4	8	5	4	3	4	69
Unprotected	Within management areas available for scheduled timber cutting	32.9	0.4	2	5	4	3	2	5	76
	Within management areas available for unscheduled timber cutting	43.5	1.27	6	10	6	4	3	5	63
	Total[1]	85.2	0.73	3	7	5	3	3	4	72

[1] Total mileage of streams within stands may not be the sum of subtotals because some streams form management area boundaries; they are not detected in subtotal analysis.

LS/OG Classification by Slope

LS/OG status		Acres within slope classes (percent)		
		0–30	30–60	60+
Protected	In wilderness	9,593	2,578	131
	Administratively	28,823	4,990	167
	Total	38,416	7,568	298
Unprotected	Within management areas available for scheduled timber cutting	73,488	4,456	23
	Within management areas available for unscheduled timber cutting	28,001	3,692	75
	Total	101,498	8,148	98
Total: national forest		977,765	57,147	3,593

Roadless Region Patch Size Distribution

Type	Total acres	Number of patches	Patch size (acres): Mean	Minimum	Maximum	Standard deviation	Patch area distribution (acres): 250–500	500–750	750–1000	1000–2000	2000–5000	5000–10000	10000–50000	50000+
RARE II	8,473	1	8,473	8,473	8,473	—	0	0	0	0	0	1	0	0
Eastside Forests Scientific Society Panel	174,734[1]	208	840	250	13,341	1,158	108	35	19	32	13	0	1	0

[1] Road data upon which this analysis in based is only 90% complete for the Winema NF: total acreage is higher.

Relationship between LS/OG, Roadless Regions and Aquatic Diversity Areas

LS/OG Status		Distribution: Within RARE II roadless areas: Acres	Percent of total LS/OG	Within Eastside Forests Scientific Society Panel roadless regions: Acres	Percent of total LS/OG	Within American Fisheries Society Aquatic Diversity Areas: Acres	Percent of total LS/OG
Protected	In wilderness	0	—	0	—	1,327	9
	Administratively	0	—	9,180	24	2,427	6
	Total	0	—	9,251	18	2,975	6
Unprotected	Within management areas available for scheduled timber cutting	0	—	9,825	12	14,172	17
	Within management areas available for unscheduled timber cutting	793	2	11,280	33	5,184	15
	Total	793	0%	21,105	18	19,358	16

Relationship between Roadless Regions and Aquatic Diversity Areas

Roadless region type	Within American Fisheries Society Aquatic Diversity Areas: Acres	Percent of total
Eastside Forests Scientific Society Panel	16,281	12
Roadless Area Review and Evaluation II	7,850	6

Roads in Riparian Zone

Total length of rivers and streams in national forest (miles)	Road influence on rivers and streams: Length of rivers and streams within 328 feet of roads (miles)	Percent of total length of rivers and streams within 328 feet of roads (miles)
908	331	36

Road Density within Subwatersheds

Road density (miles/mile^2)[1]: Mean	Minimum	Maximum	Standard deviation
3.5	0.23	11.9	1.7

[1] Only watersheds with > 0 miles of road per square mile represented.

Extent of Potential Climax and Seral Ponderosa Pine Stands

Climax stands < 5000 foot elevation, level and south facing slopes (acres)	Seral stands 5000–6000 foot elevation, south-facing slopes (acres)
59,045	22,217

Relationship between LS/OG and USFS Designated Old Growth

Stand information (number of stands)			
Total designated old growth	Total with 0% LS/OG	Total with 1–70% LS/OG	Total with >70% LS/OG
305	204	53	48

Chapter 5

STATE OF THE RESOURCE

Chapter 5

STATE OF THE RESOURCE

Eastside national forests encompass, and are embedded in, diverse landscapes ranging from low-elevation desert to rocky glaciated areas at high elevations. The region's biological communities are equally diverse and, like the topography and geology, defy simple summary.

People have influenced resources on the Eastside for thousands of years. The earliest arrivals to the region came soon after the first humans crossed the Bering Strait and discovered the Americas. Their native descendants thrived on the abundance east of the Cascade crest. Rivers "crouded with salmon" (as Lewis and Clark described them; see Wilkinson 1992) not only provided food and sustained commerce but figured at the heart of tribal culture and religion. Later, Europeans traveled through and settled in the forests, grasslands, and deserts of the Eastside. Each successive wave of people influenced these landscapes by harvesting plants and animals for food and fiber, and the landscapes influenced them in turn.

Changes happened especially fast in the twentieth century (e.g., Langston, in press), which brought alterations to major habitats and shifts in the abundance and distribution of many species. The changes began with hunting, trapping, and fishing to feed a growing human population and continued as mining, smelting, logging, livestock grazing, and farming spread across the land. Damming of rivers for irrigation and hydropower is the most recent in this series of transformations.

Current Forest Resources

The extent of old-growth forest ecosystems on the Eastside has been dramatically reduced during the twentieth century (Table 5.1). The proportion of LS/OG that remains and is protected in eastside forests is much greater for high-elevation than low-elevation forest types. Taking public and private lands together, the amount of protected LS/OG drops below 10% of eastside national forest lands.

Current LS/OG status raises several causes for alarm. First, little LS/OG (22%) is protected by either wilderness classification or administrative designation; three-fourths of the unprotected LS/OG lies within management areas scheduled for timber cutting.

Second, USFS defined and labeled areas as "designated old growth" to ensure existence of ancient forests into the future. Unfortunately, only little more than half (54%) of this designated old-growth acreage overlaps with actual late-successional old growth. Moreover, the spatial distribution of these patches suggests that the rules used to define them were not consistent among national forests. In Umatilla National Forest, for example, 91% of designated old growth is actually LS/OG; in the Malheur, the overlap is only 50%.

Third, LS/OG patch sizes are generally too small to maintain viable populations of many forest species. An alarming 80% of LS/OG patches cover less than 100 acres. Three forests (Colville, Wallowa-Whitman, Winema) contain no LS/OG patches larger than 5000 acres; three other forests (Malheur, Ochoco, Umatilla) contain seven patches larger than 5000 acres, but only one is protected.

Fourth, treating LS/OG as a homogenous forest type does not fully portray the current status of eastside LS/OG habitats. Low- and mid-elevation forests, once dominated by old-growth ponderosa pine *(Pinus ponderosa)* or, in some areas, Douglas fir *(Pseudotsuga menziesii),* have been mostly logged. Forests dominated by either ponderosa pine alone ("climax" ponderosa pine) or ponderosa pine mixed with Douglas fir, larch (*Larix* spp.), and true firs (*Abies* spp.; "seral" ponderosa pine) were especially hard hit because they had big, valuable trees and grew at lower elevations, where they were readily accessible. The data we have do not allow a detailed accounting of forest types; even so, statistics on historic log production indicate that nearly three-quarters of the original old-growth ponderosa pine volume in eastern Oregon was logged by 1970 (Cowlin et al. 1942; Wall 1972). We do not know precisely how much old-growth ponderosa pine remains today, but it seems reasonable to assume that, for the region as a whole, it is less than 15% of the original extent. In some areas, such as the Klamath Plateau and eastern slopes of the Oregon Cascades, less than 5% remains.

Table 5.1 State of eastside national forests. Except where otherwise noted, values represent means for those forests (number of forests in parentheses) for which data were available.

Total area, 10 national forests	14.6 million acres
Total percentage forested	79%
Total percentage of national forest suitable for timber management	57%
Wilderness areas, average acreage per forest	238,000 acres
Percentage of wilderness that is forested (3 forests)	83%
Percentage of wilderness that is LS/OG (7 forests)	9.7% (range, 2–34%)
LS/OG, percent of total area (6 forests)	16%
LS/OG, percent of forested lands (8 forests)	25%
Designated old growth that is actually LS/OG (average for 7 forests)	54% (range, 7–91%)
Designated old growth sites containing more than 70% LS/OG	47% (range,7–91%)
Designated old growth containing no LS/OG	31% (range, 3–67%)
Protected LS/OG[a] (in wilderness or administratively protected) (8 forests)	22%
Unprotected LS/OG (8 forests)	78%
Within management areas scheduled for timber cutting	58%
Within management areas not scheduled for cutting	20%
LS/OG patches smaller than 100 acres (8 forests)	82%
LS/OG patches larger than 5000 acres (3 forests)[b]	None
LS/OG patches larger than 5000 acres (3 forests)[c]	7 (1 protected, 6 unprotected)
LS/OG within watersheds of 3000–10,000 acres (6 forests)	12%[d]
Watersheds containing less than 10% LS/OG (6 forests)	58%
Watersheds containing more than 60% LS/OG	
4 forests[e]	None
2 forests[f]	3%
Percentage of roadless regions smaller than 500 acres (6 forests)	36%
Percentage of roadless regions larger than 5000 acres (6 forests)	15%
Road density (miles of road per square mile) (3 forests)[g]	3.2 (range, 2.5–3.7)

[a] Protected LS/OG tends to be disproportionately located on steep slopes. In Deschutes National Forest, for example, less than 1% of the forest consists of slopes steeper than 60%, but 9.8% of wilderness consists of slopes steeper than 60%.

[b] Western Colville, Wallowa-Whitman, and Winema National Forests.

[c] Malheur, Ochoco, and Umatilla.

[d] No watershed is 100% LS/OG.

[e] Western Colville, Fremont, Malheur, and Umatilla (0 of 648 watersheds).

[f] Ochoco and Winema (8 of 234 watersheds).

[g] Western Colville, Ochoco, and Winema.

What remains of ponderosa pine and Douglas fir LS/OG is the least protected today. In the four national forests within the Blue Mountains,[3] 48% of the land base above 6000 feet lies in wilderness areas, whereas only 10% of the land below 6000 feet, where ponderosa pine occurs, receives such protection (Table 5.2). A similar pattern prevails in Okanogan National Forest, where only 15% of the old growth remaining at lower elevations is protected. A shift to logging at high elevations and on steep slopes over the past 25 years has reduced the abundance of LS/OG in these forests as well. Continued logging of unprotected LS/OG would reduce the area that these unique pine ecosystems occupy to between 7 and 13% of forested lands in national forests of eastern Oregon and Washington, raising concerns about inevitable impacts on species distribution, abundance, and population viability as well as on the ecological processes that sustain regional ecosystems.

Fifth, roads, whose impact on aquatic and terrestrial resources is well documented, are widely distributed in eastside forests. Road densities in western Colville, Winema, and Ochoco National Forests average 2.5, 3.5, and 3.7 miles per square mile, respectively. Densities reach 8.8 and 11.9 miles per square mile in some watersheds. In the national forests of Oregon's Blue Mountains (Table 5.2), less than 10% of roadless regions on slopes steeper than 60% are now protected, less than 15% on slopes of 30–60%. Moreover, roadless regions, like LS/OG patches, are extensively fragmented. In northern Ochoco National Forest, nearly one-third (38,882 acres) of 128,140 acres of roadless region consists of patches smaller than 1000 acres. (RARE II surveys underestimated total roadless area in this region [45,700 acres] because they considered only areas larger than 5000 acres.)

Finally, although watersheds are now widely recognized as ecologically sound planning units for land managers (Doppelt et al. 1993), few watersheds within eastside national forests contain substantial areas of LS/OG. Fifty-eight percent of watersheds in six national forests contain less than 10% LS/OG (see Table 5.1). Four of the six forests (Colville, Fremont, Malheur, Umatilla) encompass no watersheds with more than 60% LS/OG. Only 3 of 92 watersheds in the Ochoco and 5 of 142 watersheds in the Winema have more than 60% LS/OG.

The status of the forests themselves tells only part of the story. LS/OG provides essential habitat for many species from diverse taxonomic groups, including fungi, plants, invertebrates, and vertebrates (see Chapter 7). Old-growth forest depends on many of these species to speed uptake of nutrients,

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[3] The four national forests that make up the Blue Mountains of eastern Oregon (Malheur, Ochoco, Umatilla, and Wallowa-Whitman) lie within a circumscribed geographic area that makes a logical unit for analysis of selected issues.

Table 5.2 National forest facts for Oregon's Blue Mountains.

Roadless areas by slope and land use

Roadless area status		Slope	Acres
Protected	Total nonforested land		4,733
	Forest on administratively protected lands	<30%	34,295
		30–60%	41,879
		>60%	10,386
	Total p rotected land		91,311
Unprotected	Total nonforested land		52,100
	Forest within management areas available for scheduled timber cutting	<30%	127,012
		30–60%	102,729
		>60%	30,196
	Forest within management areas available for unscheduled timber cutting	<30%	110,424
		30–60%	165,325
		>60%	100,197
	Total unprotected land		687,983

Roadless areas by elevation

	Acres within each elevation range (feet x 100)																			
	0–5	5–10	10–15	15–20	2025	25-30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	95–100
Roadless lands	0	558	2,197	6,111	17,831	35,867	64,419	90,466	109,359	125,211	119,848	98,808	84,755	53,438	33,104	16,336	5,229	603	5	0
Total national forest lands	0	2,039	17,618	32,966	57,812	100,342	222,165	459,193	941,780	1,517,920	1,521,597	903,343	351,932	204,411	142,115	89,818	45,696	15,772	3,395	287
Percent of national forest lands roadless	0	27	12	19	31	36	29	20	12	8	8	11	24	26	23	18	11	4	0	0

Wilderness areas by elevation

	Acres within each elevation range (feet x 100)																			
	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	95–100
Wilderness lands	0	0	393	6,746	16,237	28,439	46,316	69,559	86,282	102,250	115,999	108,568	90,229	93,285	92,440	70,638	40,043	15,100	3,388	287
Total national forest lands	0	2,039	17,618	32,966	57,812	100,342	222,165	459,193	941,780	1,517,920	1,521,597	903,343	351,932	204,411	142,115	89,818	45,696	15,772	3,395	287
Percent of national forest lands in wilderness	0	0	2	20	28	28	21	15	9	7	8	12	26	46	65	79	88	96	100	100

LS/OG and forestlands by elevation

	Acres within each elevation range (feet x 100)																			
	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	95–100
Total acres LS/OG in elevation range	0	0	0	56	1,650	7,133	17,887	48,733	63,292	87,619	147,254	154,894	44,809	14,346	4,227	681	657	34	0	0
Percent of total LS/OG in Blue Mountain NFs	0	0	0	0	0	1	2	6	8	12	19	20	6	2	1	0	0	0	0	0
Total forest acres in elevation range	0	326	304	6,137	13,558	58,987	106,285	488,860	525,801	710,323	886,009	808,955	250,450	107,246	61,943	42,303	37,845	22,355	6,096	195
Percent of total forest acres in Blue Mountain NFs	0	0	0	0	0	1	2	9	10	14	17	16	5	2	1	1	1	0	0	0
Percent of forest acres LS/OG	0	0	0	1	12	12	17	10	12	12	17	19	18	13	7	2	2	0	0	0

decomposition of organic material, and dispersal of gametes and seeds. Furthermore, many species inhabiting other forest types, including successional forests, depend on LS/OG at certain times in their life histories. Yet species of plants, insects, molluscs, and vertebrates are at risk regionally. Continued declines in the distribution and abundance of these taxa within eastside landscapes threaten not only what remains of the integrity of eastside landscapes but also the ability of those landscapes to provide benefits and products (including timber resources) to humans.

In this report, we highlight vertebrate resources, partly because of the expertise of panel members and also because more is known about fish, birds, and mammals and their ecological interactions than about less conspicuous forms such as arthropods and fungi. A variety of vertebrate species occupy and thrive in mature and late-successional/old-growth eastside forests. These include species that are associated with old-growth forests (e.g., spotted owls, northern goshawks, pileated woodpeckers, fishers, and pine martens) and species characteristic of younger forests that occasionally require access to mature trees to maintain healthy and viable populations (e.g., great gray owls, red crossbills, chestnut-backed chickadees, lynx, and elk).

The declining abundance and diversity of vertebrates—including fish, reptiles, birds, mammals, and especially amphibians—provide a coarse measure of the deteriorating ecological machinery of eastside forests. More detailed biological information will likely reveal ecological dysfunction among invertebrates, plants, and fungi as well. Comprehensive resource inventories are needed for each of the eastside forests because decisions made without adequate data behind them are likely to be incorrect. Such inventories should be started soon, but they must be grounded in newly defined resource goals. Current definitions of old growth, for example, concentrate on vegetation instead of a more comprehensive view of forests that includes wildlife and social considerations.

Because more is known about eastside aquatic systems than terrestrial systems, the rest of this chapter focuses on aquatic biota.

CURRENT AQUATIC RESOURCES

Streams and other aquatic systems are intimately connected with the watersheds they drain; consequently, the impacts of forestry and other human land uses affect all levels, from the watershed to fish assemblages. Some areas of eastside national forests have remained relatively healthy; others comprise the best remaining habitats and populations of native aquatic biota. Such regions have been defined by the Oregon Chapter of the American Fisheries Society as aquatic diversity areas (see Chapter 3).

STATUS OF NATIVE FISHES

Anadromous stocks of salmon and trout are declining throughout the Columbia River basin, a decline symptomatic of the poor condition of watersheds east of the Washington and Oregon Cascades. Production in the Columbia, once among the greatest salmon-producing rivers in the world (with estimated annual runs of 10–16 million fish; NPPC 1986), has declined to about 5% of its historic levels (Nehlsen et al. 1991). At least 106 major populations of salmon and steelhead have been extirpated on the West Coast, most from rivers in the Columbia Basin. The conservation group Oregon Trout identified 200 smaller streams in the basin where naturally produced salmon have become extinct (Nehlsen et al. 1991).

The remaining proportion of the region's historic salmon and steelhead production is in jeopardy. Of 214 breeding populations ("stocks") of Pacific salmonids throughout the Northwest recently classified as at risk of extinction or meriting special concern, 76 come from the Columbia River system (Nehlsen et al. 1991). Most of these stocks inhabit watersheds east of the Cascade crest. An updated review of 51 stocks of naturally spawning salmon and steelhead in eastern Washington identified 35 as "depressed" and one as "critical" (WDF et al. 1992). The overall trend in resource condition is downward: none of the stocks listed by Nehlsen et al. (1991) have shown any measurable improvement, but 13 that were not considered at risk are now categorized as depressed. Three stocks of Snake River chinook salmon *(Oncorhynchus tshawytscha)* and one stock of Snake River sockeye salmon *(O. nerka)* were recently added to the federal list of threatened and endangered species. A petition filed in June 1993 also requests listing upper Columbia River summer-run chinook stocks from the Okanogan, Methow, and Wenatchee Rivers in eastern Washington.

Declining fish production east of the Oregon and Washington Cascades is not confined to the highly migratory salmon and steelhead. Many resident species that complete their entire life cycle within freshwater habitats are also threatened with extinction (Table 5.3). The Endangered Species Committee of the American Fisheries Society, for example, lists 25 resident fish species or subspecies as at risk in Oregon, making Oregon's at-risk list the fifth longest in the United States (Williams et al. 1989). Twenty-four of these stocks occur exclusively in eastside waters. Fourteen inhabit watersheds within the boundaries or immediately downstream of national forests (Li and Castillo 1994); many of the remaining at-risk species occur in watersheds under the jurisdiction of the Bureau of Land Management (BLM). Seven resident eastside fishes in Oregon are already on the federal list of threatened or endangered species (see Table 5.3). Three species of suckers included on the list (*Catostomus warnerensis*, *Chasmistes brevirostris*, and *Deltistes luxatus*) occur in

Table 5.3 At-risk taxa of resident fish east of the Washington and Oregon Cascades. The list includes nonanadromous fish identified by the American Fisheries Society (Williams et al. 1989), the Oregon State list of sensitive species (Marshall et al. 1992), and the federal list of threatened and endangered species. Also listed are "species of limited distribution," defined by Li and Castillo (1994) as those whose current ranges are less than 8400 km^2 in Washington (WA) or Oregon (OR).

Common name	Scientific name	AFS[a]	OR sensitive[b]	Federal (year listed)[c]	Limited distribution
Klamath lamprey	*Lampetra similis*	—	—	—	X (OR)
Pit-Klamath brook lamprey	*L. lethophaga*	—	—	—	X (OR)
Pacific lamprey	*L. tridentata*	—	V[d]	—	—
Goose Lake lamprey	*L. tridentata* ssp.	SC	C	—	—
River lamprey	*L. ayresi*	—	—	—	X (WA)
White sturgeon	*Acipenser transmontanus*	—	V	—	X (WA)
Lahontan cutthroat trout	*Oncorhynchus clarki henshawi*	T	—	E (1973)	—
Whitehorse cutthroat trout	*O. clarki* ssp.	SC	—	—	—
Westslope cutthroat trout	*O. clarki lewisi*	—	V	—	X (OR)
Interior redband trout	*O. mykiss* ssp.	SC	V	—	—
Catlow Valley redband trout	*O. mykiss* ssp.	SC	—	—	—
Goose Lake redband trout	*O. mykiss* ssp.	SC	—	—	—
Warner Valley redband trout	*O. mykiss* ssp.	SC	—	—	—
Pygmy whitefish	*Prosopium coulteri*	—	—	—	X (WA)
Bull trout	*Salvelinus confluentus*	SC	C	SR (1993)	—
Alvord chub	*Gila alvordensis*	SC	V	—	—
Sheldon tui chub	*G. bicolor eurysoma*	SC	C	—	X (OR)
Lahontan Creek tui chub	*G. bicolor obesa*	SC	—	—	—
Oregon Lakes tui chub	*G. bicolor oregonsis*	—	V	—	X (OR)
XL spring tui chub	*G. bicolor oregonsis*	SC	—	—	—
Goose Lake tui chub	*G. bicolor thalassina*	—	C[d]	—	—
Catlow tui chub	*G. bicolor* ssp.	SC	V	—	X (WA)
Summer Basin tui chub	*G. bicolor* ssp.	E	C	—	—
Warner Basin tui chub	*G. bicolor* ssp.	—	C[d]	—	—
Hutton tui chub	*G. bicolor* ssp.	T	—	T (1985)	—
Borax Lake chub	*G. boraxobius*	T	—	E (1982)	—

continues

Table 5.3 continued

Common name	Scientific name	AFS[a]	OR sensitive[b]	Federal (year listed)[c]	Limited distribution
California (pit) roach	*Hesperoleucus symmetricus mitrulus*	—	P	—	X (OR)
Foskett speckled dace	*Rhinichthys osculus* ssp.	—	—	T (1985)	—
Lahontan redshide shiner	*Richardsonius egregius*	—	P	—	—
Goose Lake sucker	*Catostomus occidentalis lacusanserinus*	SC	C	—	X (OR)
Jenny Creek sucker	*C. rimiculus*	SC	NR[d]	—	—
Klamath largescale sucker	*C. snyderi*	—	—	—	X (OR)
Tahoe sucker	*C. tahoensis*	—	P	—	—
Warner sucker	*C. warnerensis*	E	—	T (1985)	X (OR)
Shortnose sucker	*Chasmistes brevirostris*	E	—	E (1988)	X (OR)
Lost River sucker	*Deltistes luxatus*	E	—	E (1988)	X (OR)
Margined sculpin	*Cottus marginatus*	—	V	—	X(OR, WA)
Malheur mottled sculpin	*C. bairdi* ssp.	SC	C	—	—
Slimy sculpin	*C. cognatus*	—	—	—	X (WA)
Klamath Lake sculpin	*C. princeps*	—	—	—	X (OR)
Marbled sculpin	*C. klamathensis*	—	—	—	X (OR)
Slender sculpin	*C. tenuis*	SC	—	—	X (OR)
Pit sculpin	*C. pitensis*	—	P	—	X (OR)

[a] SC = Special concern; T = threatened; E = endangered.
[b] V = Vulnerable; C = critical; P = peripheral; NR = naturally rare.
[c] T = Threatened; E = endangered; SR = petitioned for listing, status under review by USFWS.
[d] Proposed (draft) revision to Oregon sensitive species list (ODFW 1993).

watersheds at least partially on USFS land. The other threatened and endangered species occur on BLM or private lands (Oregon AFS 1993).

Li and Castillo (1994) propose that the number of stocks and species at risk of extinction, or with a very limited distribution, provides a measure of the resiliency of a watershed to human disturbance. To assess the resiliency of watersheds associated with eastside forests, these authors mapped distributions of eastside fish species relative to national forest boundaries and they report the highest total number of native species associated with each forest: Wallowa-Whitman (22), Malheur (21), Umatilla (20), and Fremont (18) National

Forests in Oregon and the Wenatchee (21), Okanogan (18), and Umatilla (16) National Forests in Washington (Table 5.4). For each eastside forest, Li and Castillo (1994) identified the total number of native fishes and salmonid stocks that are (1) considered at risk by the American Fisheries Society (Williams et al. 1989; Nehlsen et al. 1991); (2) included on the Oregon State list of sensitive vertebrates (Marshall et al. 1992); or (3) very limited in distribution (having a range of less than 8400 km^2). Forty percent of the 52 native fish species associated with eastside forests in Washington and Oregon have been identified as at risk in one state or the other or both.

Table 5.4 Number and status of native fish species within, and within 25 miles of, eastern Washington and Oregon national forests (Li and Castillo 1994: table 1).

National forest	Native species		At risk[a]		Limited distribution[b]	
	Within forest	Within 25 miles	Within forest	Within 25 miles	Within forest	Within 25 miles
Washington forests						
Colville	4	8	3	0	0	1
Okanogan	5	13	3	0	0	1
Umatilla	5	11	4	0	0	2
Wenatchee	19	2	4	0	1	0
Oregon forests						
Deschutes	6	5	3	3	—	—
Fremont	10	8	6	5	6	7
Malheur	13	8	3	5	1	0
Ochoco	2	11	2	2	—	—
Umatilla	9	11	4	4	1	1
Wallowa-Whitman	14	8	7	2	0	1
Winema	14	1	4	0	8	0

[a] Numbers in this column represent resident species identified by Williams et al. (1989) as threatened, endangered, or sensitive; of salmonids identified by Nehlsen et al. (1991) as at moderate or high risk of extinction; and, for Oregon only, any additional species included on the state list of sensitive vertebrates (Marshall et al. 1992). The totals for Washington and Oregon are not directly comparable because Washington does not have a state sensitive species list.

[b] Species of limited distribution are those defined by Li and Castillo (1994) as distributed over an area smaller than 8400 km^2 within each state. Some of these species are also listed as threatened, endangered, or sensitive; at risk according to Nehlsen et al. (1991); or on the Oregon sensitive list. The last two columns are therefore not additive.

According to this measure, the resiliency of watersheds in Oregon seems particularly low; from 27 to 61% (mean, 43%) of the native fish of eastside forests in Oregon are considered in jeopardy. Forests with the greatest number of narrowly distributed species, which may be particularly vulnerable to local disturbances, include Fremont (13) and Winema (8). The proportion of at-risk species in Washington is difficult to compare directly with the proportion in Oregon because Washington totals do not include sensitive species. Nevertheless, recent assessments by the Washington Department of Fisheries and others (WDF et al. 1992) suggest a declining trend in the status of anadromous salmonids in eastern Washington and may also indicate that resilience of Washington watersheds is low.

Recently, petitions were filed with the US Fish and Wildlife Service (USFWS) to review the status of bull trout *(Salvelinus confluentus)* for potential listing as a threatened or endangered species. Bull trout is classified by Williams et al. (1989) as "of special concern," and it is listed as a sensitive species by Oregon's Department of Fish and Wildlife (Marshall et al. 1992), Washington's Department of Fish and Wildlife, and USFS Region 6 (USFS 1990c). The species serves as a useful indicator of watershed conditions because it is distributed across a diversity of eastside basins; most populations do not go to sea but remain in freshwater drainages throughout their life cycle (Bond 1992); individuals can exhibit a variety of migratory patterns within freshwater systems, including headwater tributary, mainstem river, or lake environments; and the species demands high-quality habitat also suitable for many other cold-water-dependent species (Ratliff and Howell 1992; Li and Castillo 1994; Rieman and McIntyre 1993).

Mongillo (1992) reviewed the status of 31 bull trout–Dolly Varden populations from creeks, lakes, and large rivers in eastern Washington. Nearly half of these (14) were listed as remnant populations (Table 5.5). Seven populations are considered declining, 12 are secure or stable, and the status of 12 others is unknown.

A recent review of the status of bull trout populations throughout Oregon identified 65 populations distributed in 13 major drainage basins (Ratliff and Howell 1992). All but 8 of these populations and one of these basins occur east of the Cascade crest (Table 5.6). Many of these populations have been reduced to fragmented nonmigratory stocks isolated from one another in the upper tributaries of larger drainages. The small number of fish remaining in headwater drainages and the lack of gene flow between disjunct populations greatly increase their risk of extinction. Fifty-five percent of the eastside populations of Oregon bull trout known to exist are believed to face at least moderate risk of extinction. If we also include those ranked as worthy of "special concern," then more than 80% of the remaining bull trout populations

Table 5.5 Status of bull trout–Dolly Varden populations east of the Washington Cascades (Mongillo 1992).

		Status			
Population	**Remnant?**	**Secure**	**Stable**	**Declining**	**Unknown**
Pend Oreille River	Yes	—	—	—	X
Priest Lake	No	—	X	—	—
Roosevelt Lake	Yes	—	—	—	X
Entiat River	Yes	—	X	—	—
Early Winters	No	X	—	—	—
Hidden Lakes	No	—	X	—	—
Lost River	No	—	X	—	—
Methow River	No	—	—	X	—
Bumping Lake	?	—	—	—	X
Naches River	?	—	—	—	X
Rimrock Lake	No	—	X	—	—
Chiwawa River	No	—	X	—	—
Lake Wenatchee	Yes	—	X	—	—
Wenatchee River	Yes	—	X	—	—
Kachess Lake	Yes	—	—	X	—
Keechelus Lake	Yes	—	—	X	—
North Fork Teanaway River	?	—	—	—	X
Waptus Lake	?	—	—	—	X
North Fork Asotin Creek	Yes	—	—	X	—
South Fork Asotin Creek	Yes	—	—	X	—
Charley Creek	Yes	—	—	X	—
Grande Ronde River	No	—	—	—	X
Pataha Creek	Yes	—	—	—	X
Tucannon River	No	—	X	—	—
Mill Creek	No	—	X	—	—
North Fork Touchet River	?	—	—	—	X
South Fork Touchet River	?	—	—	X	—
Wolf Fork	No	—	X	—	—
Klickitat River	Yes	—	—	—	X
Trappers Creek	Yes	—	—	—	X
White Salmon River	Yes	—	—	—	X
Total	14 Yes 11 No	1	11	7	12

Table 5.6 Status of bull trout populations in Oregon (Ratliff and Howell 1992).

Basin	Status				
	Low risk	Special concern	Moderate risk	High risk	Probably extinct
Westside drainages					
Willamette River	—	—	2	2	4
Total Westside	—	—	2	2	4
Eastside drainages					
Hood River	—	—	—	1	1
Klamath River	—	—	4	4	2
Deschutes River	2	—	1	1	2
John Day River	—	1	1	2	1
Umatilla River	1	1	—	—	—
Walla Walla River	2	1	—	—	—
Malheur River	—	1	—	1	—
Burnt River	—	—	—	—	1
Powder River	—	—	4	1	—
Pine Creek	—	2	2	—	—
Grande Ronde River	3	4	5	—	1
Imnaha River	1	3	—	—	—
Total Eastside	9	13	17	10	8

in Oregon can be considered at risk. The healthiest remaining populations occur in northeastern portions of the state and in the Metolius River of the Deschutes River basin (Ratliff and Howell 1992).

In sum, a large proportion of the native fish fauna east of the Washington and Oregon Cascades is now at risk of extinction. The decline is widespread and involves species and stocks with a broad range of geographic distributions and habitat requirements (see Table 5.3):

- Rare endemic species or subspecies limited to one small spring, stream, or watershed in the entire world (e.g., XL Spring tui chub, *Gila bicolor oregonsis;* Foskett speckled dace, *Rhinichthys osculus*)
- Resident species of intermediate distribution scattered throughout many eastside river basins and lakes (e.g., interior redband trout, *Oncorhynchus mykiss* ssp.; bull trout)

- Anadromous salmon and steelhead that migrate hundreds or thousands of miles across the Cascade boundary to and from ocean rearing environments and freshwater spawning tributaries.

Many of the anadromous and resident fishes at risk in Washington and Oregon spend much of their life history in aquatic habitats located in or directly downstream of federal forestlands. Sound conservation practices on federal lands alone cannot guarantee the continued viability of the many eastside populations at risk, but further degradation of aquatic ecosystems on these lands will certainly increase the likelihood of future extinctions.

CONDITION OF EASTSIDE WATERSHEDS

Stream and riparian ecosystems in many eastside watersheds have suffered continuous degradation for the past century or more (Wissmar et al. 1994). Effects include loss of riparian vegetation; reduction of large wood in streams; higher water temperatures; accumulation of fine sediments in pools and on spawning grounds; and altered hydrological processes, including loss of cool water seeps. Different factors cause degradation at different locations, but they generally include agriculture and irrigation, timber management, road construction, livestock grazing, and mining (McIntosh et al. 1994; Wissmar et al. 1994). Other factors include dams, introduction of alien species and stocks, water withdrawals, and overharvest.

STREAMSIDE VEGETATION AND TEMPERATURE

Although data are not available for the entire Eastside, wherever information has been collected, the results indicate that riparian systems have been severely degraded. In 1981 and 1982, for example, more than half of 3062 miles of streams inventoried in the Deschutes, Umatilla, Grande Ronde, and John Day basins were deemed in need of restoration (Bottom et al. 1985). In USFS and BLM field evaluations of grazing allotments in the Silvies, Malheur, John Day, and Burnt River systems, Phillips (1987) found streams without woody vegetation, with incised stream channels, and with lowered water tables. He concluded that past grazing practices, particularly season-long grazing by cattle, were responsible for most of the damage; logging, road building, and browsing by big game contributed to a lesser degree.

In some areas of northeast Oregon, riparian damage by cattle appears to have increased in recent years because of new road construction and salvage logging. New roads and streamside logging of beetle-infested pines removed woody material in riparian zones, making some stream bottoms more accessible to livestock and thus more vulnerable to overgrazing (Phillips 1987; Duane West and Bill Knox, Oregon Department of Fish and Wildlife, personal communication). Beschta et al. (1991) report widespread damage to stream and riparian systems of the Grande Ronde and John Day basins, damage they attributed to grazing, logging, road building, and mining. The authors conclude that the degraded condition of riparian tree-dominated communities in these basins is one of the factors most responsible for loss of salmonid habitat. Among the 16 sites they evaluated, including 7 in Umatilla and Wallowa-Whitman National Forests, no new cottonwood, alder, or willow-dominated communities had become reestablished in 50–100 years.

Many eastside rivers and streams have lost the capacity to support cold-water fish species because of high summer temperatures associated with cumulative loss of riparian cover from logging and grazing activities. The effects of these land uses are further aggravated where irrigation diversions and withdrawals also reduce natural streamflows, and vegetative loss contributes to widening of stream channels (Bottom et al. 1985; Platts 1991). Elevated water temperatures caused by loss of vegetation are particularly severe in the Upper Grande Ronde, where average stream shading is about 28% in contrast to a potential of about 72% (Anderson et al. 1992, 1993). Removal of vegetation and stream widening associated with heavy grazing, agriculture, road construction, and some logging have greatly increased water temperatures in downstream areas of Washington's Tucannon River. Theurer et al. (1985) estimate that these increases have made 24 miles of salmonid spawning and rearing area unusable, reducing the river's productive capacity for spring chinook salmon and steelhead by 40%.

Buckman et al. (1992) report that cattle grazing and irrigation withdrawals in Oregon's North Fork and Middle Fork Malheur Rivers may now limit the distribution and production of bull trout by raising temperatures to approach or exceed the species' tolerance limits. Temperature effects accumulate downstream and contribute to the loss of mainstem rearing areas used by populations of large adult bull trout (Ratliff and Howell 1992). Other factors related to the removal of riparian cover—reduced wood debris, increased siltation, and negative interactions with more temperature-tolerant fish species—also play a role in these losses and in the fragmentation and isolation of remnant populations in small upper tributary streams (Ratliff and Howell 1992).

Cumulative effects of higher stream temperatures and habitat loss have also reduced available habitat for production of salmonids in the John Day River basin. Wissmar et al. (1994) report that in many portions of this basin, riparian cover has been completely eliminated, and shading from overhanging trees is less than the 75% recommended to maintain low water temperatures and high fish populations. Protecting the few remaining cold-water refuges for salmonids in the John Day Basin may thus be critical to prevent extinctions and to maintain sources of cool water to larger tributaries downstream. For example, of 13 Middle Fork John Day streams that historically contained bull trout, only 3 (Big Creek, Granite Boulder, and Clear Creek) now have any, and these populations are limited (Oregon Department of Fish and Wildlife, Habitat Inventory Project, unpublished data; Ratliff and Howell 1992). Water temperatures in the mainstem Middle Fork John Day River bar fish from wider distribution in the basin. In June 1992, temperatures in the Middle Fork reached 27° F (80° C), killing adult spring chinook salmon before they could spawn. Repeated human incursion for timber harvest in several subwatersheds and the destruction of riparian vegetation by livestock are considered the principal causes of decline among spring chinook salmon *(Oncorhynchus tshawytscha)* and bull trout in the Middle Fork John Day River (G. Hattan and E. Claire, Oregon Department of Fish and Wildlife, Comment letter on Vinegar-Vincent salvage timber sale to John Shoberg, Long Creek District Ranger, 23 December 1992).

In the mainstem John Day River, clean, cold water for bull trout is limited to a relatively small area of the basin's uppermost section (e.g., Call Creek, Roberts Creek, and upper main stem). State fishery biologists have requested that the upper John Day be excluded from further timber harvest, salvage, and road building to maintain a last refuge for several sensitive salmonid species (bull trout; spring chinook salmon; westslope cutthroat trout, *Oncorhynchus clarki lewisi*) until adjacent forested watersheds can recover sufficiently to meet goals for water quality and fish habitat (G. Hattan and E. Claire, Oregon Department of Fish and Wildlife, Comment letter on Crescent Planning Area to William E. Ray, Jr., Prairie District Ranger, 23 March 1993).

Forest Service monitoring data for many streams in Umatilla, Malheur, and Ochoco National Forests verify that temperatures exceed state water-quality standards, reaching well above the 64° F limit suitable for adult bull trout (see Chapter 6, "Bull Trout" and Figure 6.2) and the 68° F limit that may impair the growth of or indirectly kill salmon (Theurer et al. 1985). In 1991, summer low-flow temperatures in streams on the southern half of Umatilla National Forest (Heppner and North Fork John Day Districts), for example, ranged consistently between 70° and 80° F (USFS 1993b). A draft environmental impact statement for the East End salvage sales and restoration projects on the Umatilla cited poor stream shading, "indicating that higher than desirable temperatures are likely to occur in these streams" (USFS 1992b). Temperatures well above the 68° F standard are also reported for miscellaneous streams in Malheur National Forest (e.g., USFS 1992c). In Ochoco National Forest in 1991, 58% of 66 streams surveyed in the John Day River, Silver and Immigrant Creek, Deschutes, and Crooked River systems exceeded 70° F during some portion of the summer (USFS 1991a).

SEDIMENTATION AND STREAM HABITAT

Sedimentation caused by the cumulative effects of past land-use practices has widespread impact on fish habitat in eastside watersheds. Numerous laboratory and field studies indicate that excessive sediment reduces salmon survival and production (Hicks et al. 1991; Rhodes and McCullough 1994). Because of the Eastside's climate and geology, this region is particularly prone to develop sediment problems (Everest et al. 1987).

Results of a detailed evaluation in the Bear Valley basin of the Middle Fork Salmon River (Lowman Ranger District, Boise National Forest, Idaho) probably also apply to other, geologically similar eastside watersheds, such as the North Fork John Day, upper Grande Ronde, and portions of the Middle Fork John Day River basins (USFS 1992a; Burton et al. 1993). Surface fine sediments in Bear Valley Creek today average 56%, compared with 29% in 1941. In contrast, relatively "pristine" meadow streams in other portions of the Middle Fork basin register fine sediment levels between 15 and 30% (USFS 1992a). Furthermore, spawning sites in Bear Valley are found in mainstem locations where sedimentation is most severe, and deep pools and cover required by adult fish have been most affected by land-use practices. The total number of large pools in a sample section of Bear Valley Creek decreased from 42 in 1941 to 13 in 1991. Pools number less than 10 per 100 channel widths, whereas unaltered streams in nearby wilderness areas average between 15 and 25 pools per 100 channel widths (USFS 1992a).

Bank erosion related to grazing in the Bear Valley basin is estimated to account for a 60% increase (of a total 115% increase) in sediment input over natural levels. Less sediment was attributed to historic mining (50% increase) and roads and timber harvest (5% increase). Burton et al. (1993) found a correlation between increased surface fine sediments in meadow streams and decreases in bank stability caused by livestock grazing. This correlation appeared even though average bank cover and cattle use usually came within the forest plan goal and standard. The researchers estimated that if bank stability were improved to meet the forest plan goal of 85%, survival of chinook salmon from eggs to feeding juveniles (parr) might increase from less than 3.3% to 29%. A biological assessment of the Bear Valley basin livestock grazing allotments concluded that streamside zones are grazed more heavily than upland areas; grazing causes banks to shear away and cave in, contributing sediment to the channel and covering the clean gravel substrate that salmon need to reproduce successfully (increased embeddedness); cattle grazing alters riparian vegetation in favor of shallow-rooted plants less resistant to streambank erosion, likely reducing bank cover and shade; salmonid populations decrease where cattle grazing has altered substrates, decreased cover, and reduced pool habitat; and improvements in aquatic habitat occur slowly after cattle grazing or after a period of rest and recovery and may not be detected by short-term evaluations (USFS 1992a, attachment D).

Documentation of cumulative changes in the condition of eastside watersheds comes from a recent survey of streams first inventoried 50 years ago by the Bureau of Fisheries (McIntosh 1992; McIntosh et al. 1994). The analysis includes a measure of change in available rearing habitat for juveniles and resting habitat for adults based on the number of large pools. Results from selected eastside river systems in Washington and Oregon are similar to those obtained for the entire Columbia Basin: in total, "managed" portions of the surveyed watersheds have lost 31% of their large pools, while "unmanaged" portions (e.g., in wilderness areas) have shown a threefold increase. There is approximately 50% more large woody debris in "unmanaged" vs. "managed" portions of the surveyed basins (McIntosh et al. 1994).

Differences in habitat condition among selected basins in Oregon and Washington reflect the history of grazing, timber harvest, and other land uses in the two regions. In eastern Oregon, many watersheds have experienced effects of continuous development pressure, including the rapid expansion of logging activity at about the time that livestock grazing became less intense (McIntosh et al. 1994; Wissmar et al. 1994). Since 1941, all managed watersheds in Oregon's Grande Ronde basin have shown decreases in large-pool habitat ranging from 43 to 83%. Managed portions of surveyed basins in eastern Washington, in contrast, show moderate improvement in large-pool habitat over the past 50 years. Timber was not harvested as rapidly there, and some habitats recovered during the post–World War I lull in the livestock industry. Despite this overall improvement in pool habitat, however, all streams surveyed in Washington's Yakima Basin remain below USFS habitat standards (McIntosh et al. 1994; Wissmar et al. 1994). The relatively late entry of timber harvest into some eastern Washington basins thus raises the possibility of future impacts on fish habitat (Wissmar et al. 1994).

Cumulative Degradation of Aquatic Habitat

Cumulative habitat loss was documented, and a detailed protection and restoration plan developed, for Oregon's upper Grande Ronde River basin (Anderson et al. 1992, 1993). Over the past half century, valley bottom, riparian systems, and streams in the basin have been widely degraded through the combined effects of forest and range management on private and public lands. Roads constructed in valley bottoms have increased sedimentation, removed hundreds of acres of riparian vegetation, and reduced shading of streams from an estimated 80% historical baseline level to 28% (NMFS 1993). These and other riparian losses from grazing, mining, and timber harvest (including salvage logging) have increased stream temperatures, in many cases beyond state standards and nearly to or above lethal limits for spring chinook salmon. Roads along the main river and tributary streams constrain the channel and limit interaction with the floodplain. Although precise amounts are unknown, the extensive road network is considered to be a major source of sediment to streams. Road mileage in Wallowa-Whitman National Forest doubled from 4,500 to 10,000 miles during 1978 to 1989. Today, the average density of roads in the upper Grande Ronde subbasin is 4.0 mi per mi^2 or, if roadless regions are excluded, 7.1 mi per mi^2 (McIntosh et al. 1994). Pool habitat in the upper basin has been reduced by 65%, and high levels of fine sediments occur in chinook spawning habitat. Large wood debris is uncommon throughout the upper Grande Ronde basin, occurring much less often than in adjacent unmanaged systems. Today, only remnant numbers of wild spring chinook salmon remain in the upper Grande Ronde River (Anderson et al. 1992; McIntosh 1992; McIntosh et al. 1994).

More than 45% of the streams reported in the upper Grande Ronde subbasin fail to meet even a 70% bank stability standard, a level that Burton et al. (1993) correlated with very low egg-to-fry survival for chinook salmon in Middle Fork Salmon basin streams. Fry emergence in the subbasin may be reduced to 25% of potential because of excessive sedimentation and embeddedness (Anderson et al. 1992). Wissmar et al. (1994) report that much of the upper Grande Ronde River basin lacks large wood debris, and more than 70% of the stream miles in the basin do not meet standards in the Wallowa-Whitman National Forest plan for fine sediments, stream shading, and water temperature.

Timber harvest activities may have changed flow conditions in the upper Grande Ronde basin as well, and these changes could have significant impact on salmonid migrations and the quality of fish habitat. Despite declining annual and winter precipitation since 1904, base flow in the basin has nearly doubled. McIntosh et al. (1994) suggest that this increase may partially represent the combined effects of a decrease in water take-up and declining losses to transpiration because so few trees remain after timber harvest. The timing of peak discharge has also advanced by as many as 30 days (McIntosh et al. 1994). Heavy logging in the basin could account for changes in peak flow through increased snow accumulation and more rapid snowmelt on an exposed landscape (McIntosh et al. 1994). A hydrological model developed for Wallowa-Whitman National Forest predicts that proposed timber harvest there could further increase peak flows and advance the peak another 6 to 12 days; such changes could interact with unstable streambanks to add even more sediment to streams (NMFS 1993). The effects of such changing flow patterns on the migrations of locally adapted stocks of threatened and endangered chinook salmon are poorly understood.

The small proportion and fragmented condition of late-successional and old-growth stands remaining in many eastside forests (Chapter 4), however, indicate past timber harvest has most likely affected hydrology and fish assemblages. Those effects are poorly quantified. Furthermore, high densities of roads may have substantially increased instream sediment in many eastside watersheds (e.g., Anderson et al. 1992; McIntosh et al. 1994). In Colville National Forest, for example, we estimate that road densities average 2.5 mi per mi^2 (range, 0.01 to 8.8 mi per mi^2). For all subwatersheds in Ochoco National Forest, mean road density is 3.7 mi per mi^2 (range, 0.4 to 5.7 mi per mi^2) (Figure 5.1). Mean road density for subwatersheds in Winema National Forest is 3.5 mi per mi^2 (range, 0.23 to 11.9 mi per mi^2). The location of roads has also had an important influence on habitat complexity and riparian condition. We estimate, for example, that approximately 36% of stream miles (331 of 908 miles mapped at a scale of 1:100,000) in Winema National Forest have a road running within 328 feet (100 m) of the channel.

CONCLUSION

Eastside forests, fish resources, and watersheds are severely degraded following changes caused by Euroamerican settlement. We turn now to the linkage between specific human activities and the decline in natural resources. Only by understanding these linkages can resource managers design effective management programs to prevent or reverse degradation and restore the health of both aquatic and terrestrial ecosystems.

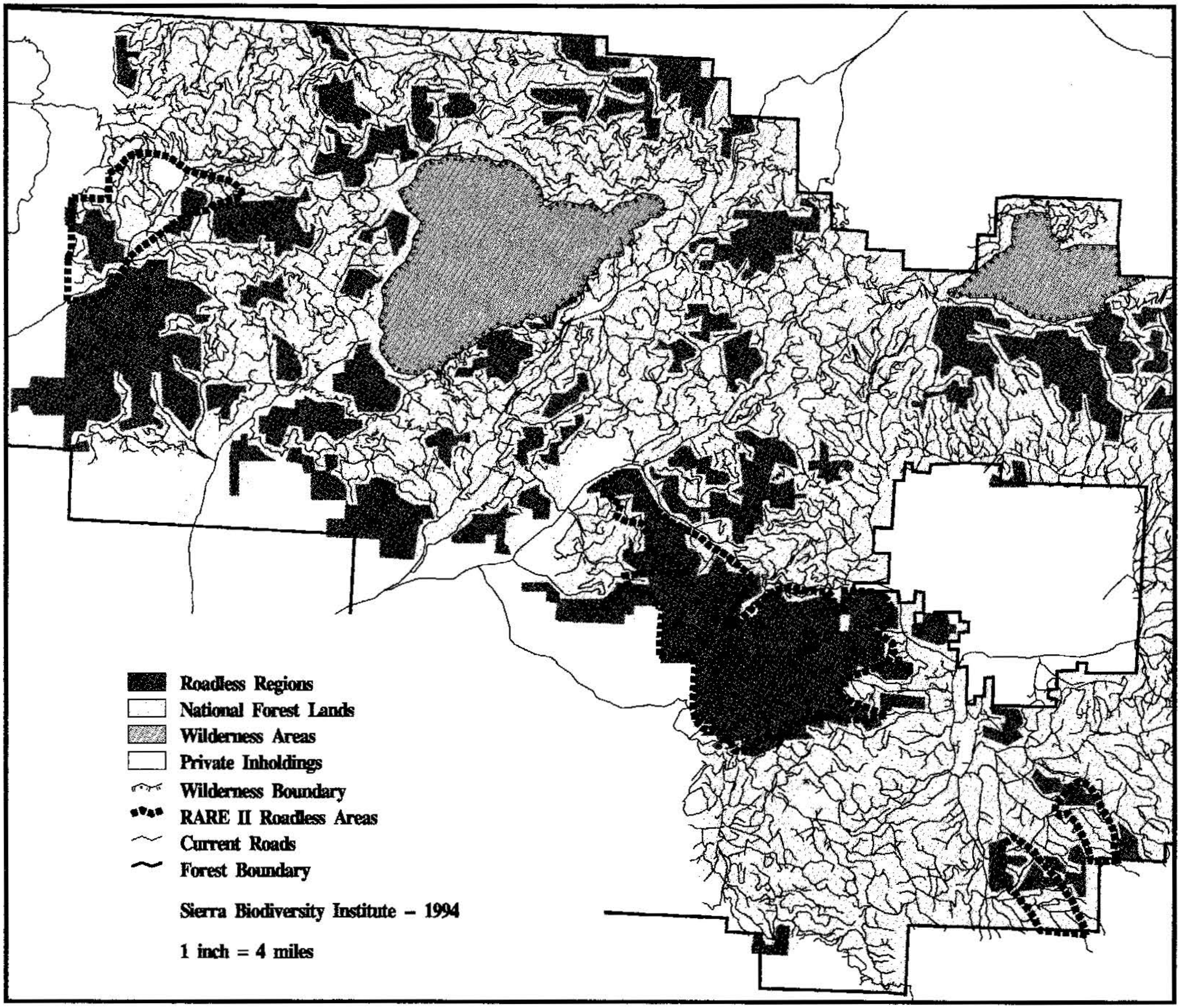

Figure 5.1 Network of roads, and areas without roads, in the western portion of Ochoco National Forest.

Chapter 6

EASTSIDE AQUATIC ECOSYSTEMS: DECLINE AND RESTORATION

Chapter 6

EASTSIDE AQUATIC ECOSYSTEMS: DECLINE AND RESTORATION

Because aquatic ecosystems reflect conditions within water bodies, the landscapes drained by those water bodies, and regional atmospheric systems, they integrate environmental conditions over great distances. Declines in the health of aquatic systems are thus often symptoms of degradation well beyond the banks of a single stream or lake.

Aquatic degradation is not unique to eastside forests (Moyle and Williams 1990; Hughes and Noss 1992; Allan and Flecker 1993). Some of the most dramatic declines in aquatic health have come about in the western United States, where continued regional-scale development and increasing demand for limited water engender not only reductions in species but the collapse of entire faunas within major drainage basins (Minckley and Douglas 1991). Such effects are increasingly obvious in the Pacific Northwest, where a substantial proportion of the native fishes and amphibians are at risk of extinction (e.g., Williams et al. 1989; Marshall et al. 1992; Walls et al. 1992; Frissell 1993). In the region east of the Oregon and Washington Cascades, where the climate is naturally warm and dry in summer and cold in winter, the additional stress of intensive land and water development has had particularly severe consequences for aquatic ecosystems.

Decline of Anadromous Salmonids

Current assessments of the status of native fishes throughout the Pacific Northwest point to a combination of factors responsible for their decline (e.g., Williams et al. 1989; Nehlsen et al. 1991; Mongillo 1992; Ratliff and Howell 1992; Frissell 1993). The Northwest Power Planning Council (NPPC 1986) attributes decreased productivity of Columbia River salmon to juvenile and adult mortality associated with Columbia Basin dams, habitat degradation, and overharvest of wild populations in mixed-stock fisheries. In addition, large-scale production of hatchery fish may have adversely altered genetic and other characteristics of many of the basin's native salmon and steelhead stocks NPPC 1986; Goodman 1990; Nehlsen et al. 1991; White et al. 1994).

Superimposed on freshwater and harvest mortality are fluctuations in the nearshore marine environment, which may markedly influence juvenile chinook and coho *(Oncorhynchus kisutch)* salmon populations during their early coastal migrations. Survival of juvenile coho salmon off Oregon is influenced by the intensity of coastal upwelling and the strength of ocean currents flowing southward from the Subarctic (Bottom et al. 1986; Nickelson 1986). The return of an entire year-class of coho salmon appears to be determined by these or other ocean factors within a few weeks of the time juveniles leave freshwater (Pearcy 1992).

Lichatowich (1993) notes that a 40-to-60-year productivity cycle described for the upwelling zone of the Northeast Pacific Ocean (Ware and Thomson 1991) may help explain coincidental fluctuations in the populations of a variety of marine pelagic species, including salmon (Figure 6.1). Added to long-term patterns like these are abrupt shifts in oceanic climate across the North Pacific region (Ebbesmeyer et al. 1991; Kerr 1993). The most recent climatic shift, in 1976, corresponded to the start of an extended period of warm ocean temperatures, weak upwelling, low precipitation and stream flows (Greenland 1993), and poor return of coho salmon off Oregon (Johnson 1984; Bottom et al. 1986; Nickelson 1986). Record-high ocean temperatures off Oregon and Washington in 1993 suggest that the unfavorable climatic conditions affecting marine survival of juvenile salmon in this region since the mid-1970s continue.

Degradation of freshwater habitat and overharvest by sport and commercial fisheries may have critical additive or synergistic effects when reinforced by half-century or decadal cycles in nearshore ocean conditions (e.g., Lawson 1993; Lichatowich 1993). The periodic recurrence of major troughs in oceanic productivity underscores the importance of those habitat qualities that determine the "buffering capacity" of the other (estuarine and freshwater) environments that make up the salmon ecosystem. Such buffering capacity is

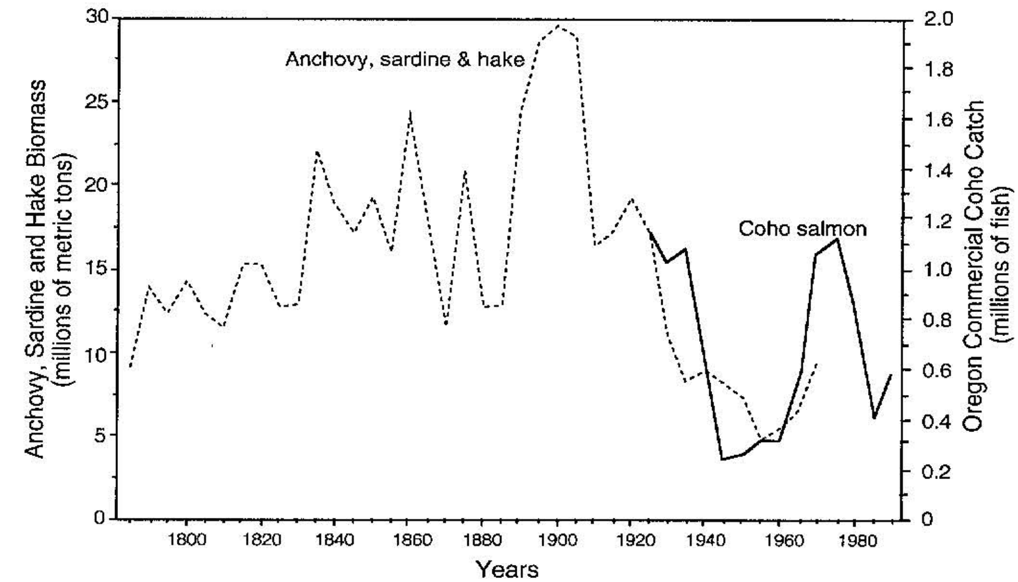

Figure 6.1 Total biomass of anchovy, sardine, and hake in the California Current compared with five-year averages of the annual commercial harvest of coho salmon in Oregon (adapted from Lichatowich 1993). Standing stock of California Current species is inferred from contemporary stock sizes and scale deposition rates in the eighteenth and nineteenth centuries (reported by Smith 1978).

particularly important in the ocean region off southern Washington, Oregon, and northern California, which forms a transition zone between large subarctic and subtropic circulation systems (Favorite et al. 1976) and encompasses the southern periphery of the range of many subarctic salmonids. Salmonid populations in this region are the first to be influenced by latitudinal shifts in oceanic and climatic regimes (e.g., Fulton and LeBrasseur 1985; Bottom et al. 1993), and the shape of the coastline affords relatively little protected estuarine habitat to moderate the effects of such changes (Nickelson and Lichatowich 1983; Bottom et al. 1986).

Predictions of global warming raise the possibility of still more risks to southern salmonids (e.g., Neitzel et al. 1991). The ability of the Columbia Basin salmonid assemblage to withstand abrupt climatic shifts may already be compromised by the extinction of many locally adapted stocks (Nehlsen et al. 1991) and the very poor condition and reduced buffering capacity of much of the freshwater habitat east of the Washington and Oregon Cascades (e.g., ODEQ 1978; Bottom et al. 1985; Beschta et al. 1991; Anderson et al. 1992; Ratliff and Howell 1992; McIntosh et al. 1994; Wissmar et al. 1994).

Decline of Resident Fish Species

Within freshwater environments, the decline of nonanadromous (resident) fishes can also be attributed to multiple factors. Habitat destruction or modification was identified as a major threat to 23 of the 24 eastside Oregon fishes listed as at risk by the American Fisheries Society (Williams et al. 1989). Biological factors such as hybridization, introduction of exotic or transplanted species, predation, and competition were considered a major concern for 14 of the species. Almost one-third (7) of eastside resident taxa at risk are considered vulnerable because their range is very restricted (Williams et al. 1989).

Many of the resident eastside fish taxa that are threatened, endangered, or of special concern inhabit interior basins in south-central Oregon. In this high-desert environment, climatic conditions are extreme; endemic fishes are often limited to a single spring or pluvial lake system; habitat types are not highly diverse; and drainages contain only a few species. Such ecosystems may be less resilient to flash floods, drought, or other disturbances than drainages of some other eastside physiographic regions, particularly where land-use practices have reduced the complexity of instream habitat (e.g., Pearsons et al. 1992; Currens 1994). Loss of a single taxon in some interior basins constitutes a 50% loss of the native fauna (Frissell 1993). Introduction of exotic species and effects of irrigation diversions and withdrawals, livestock grazing, and timber harvest are among the principal threats to native species of Oregon's interior desert basins (e.g., Long and Bond 1979; Williams et al. 1990; Marshall et al. 1992; Ratliff and Howell 1992; Oregon AFS 1993).

Bull Trout

Bull trout populations are widely distributed in the northern portion of the Columbia River basin and in mountainous areas to the south. Believed to be a remnant of the preglacial fauna of western North America (McPhail and Lindsey 1986), the species requires very cold water for most of its life history (Figure 6.2). Adult bull trout prefer temperatures in the 48–56° F range and are not reported in waters above 64° F (Shepard et al. 1984). Published temperature preferences and tolerances for bull trout are much lower than for other salmonids for spawning (39–50° F) and egg incubation (34–43° F) (e.g., McPhail and Murray 1979; Fraley and Shepard 1989).

In Oregon, bull trout reach the southern limit of their range and may therefore be particularly vulnerable to increased water temperatures resulting from land-use practices or climate change. The populations in Oregon's Klamath River basin inhabit the extreme edge of this range (Haas and McPhail 1991). Believed to have been isolated for at least 10,000 years and exhibiting

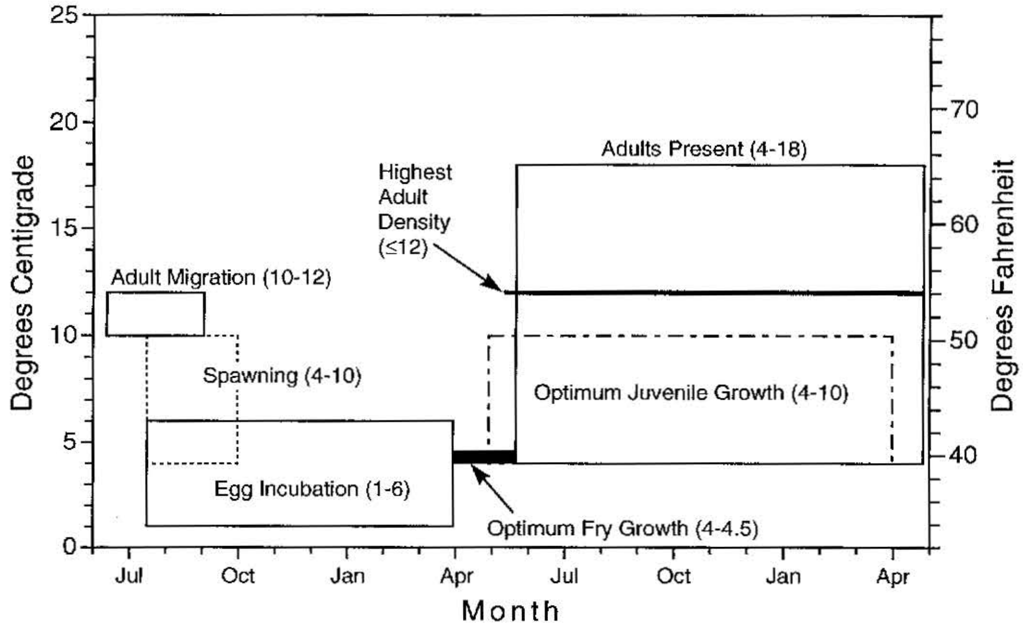

Figure 6.2 Water temperature requirements for bull trout for each life stage and respective period (from Buchanan and Gregory, in press).

substantial genetic divergence from others in the Columbia Basin, these populations may qualify as a "unique species" under the Endangered Species Act (Leary et al. 1993).

Bull trout populations throughout Washington and Oregon have been reduced by degradation of habitat and interactions with exotic species. The most frequently cited factors adversely affecting 31 bull trout–Dolly Varden populations in eastern Washington include forest management (17 populations), interaction with nonnative species (15), access to (13) or degradation of (12) physical habitat, poaching (12), agriculture (8), and grazing (6) (Mongillo 1992). East of the Oregon Cascades, nearly 80% (45) of known bull trout populations are threatened by habitat degradation and 28% (16) by hybridization or competition with nonnative eastern brook trout. Additional "suppressing factors" include overharvest (11 populations), barriers to passage (10 populations), and downstream losses through unscreened stream diversions or dams (6 populations) (Ratliff and Howell 1992). These factors may likewise have synergistic effects. For example, high stream temperatures caused by removal of riparian vegetation may heighten the risk of negative interactions with more temperature-tolerant species such as rainbow trout *(Salmo gairdneri),* brook trout *(Salvelinus fontinalis),* and brown trout *(Salmo trutta)* (Ratliff and Howell 1992; Rieman and McIntyre 1993).

Watershed Processes and Landscape Modifications

A common thread in the coincidental decline of so many different fish taxa—those that do and do not migrate to sea, those that are and are not harvested in fisheries, those found in areas affected and unaffected by large dams—is the degradation and simplification of freshwater environments caused by human land-use practices (Bottom et al. 1985; Williams et al. 1989; Hicks et al. 1991; Nehlsen et al. 1991; Walls et al. 1992; Frissell 1993; Rhodes and McCullough 1994). Human modifications of the landscape alter the processes that create habitat in streams; such modifications also reorder the distribution and structure of stream environments (e.g., Vannote et al. 1980). For example, changed patterns of forest cover caused by clearcut logging, fire suppression, or other activities (e.g., Teensma 1987; Morrison and Swanson 1990) can profoundly affect hydrological processes such as runoff and absorption rates within drainage systems. Changes like these inevitably differ from established patterns of variation in the physical environment, patterns that have provided the evolutionary template for biological organization (e.g., Vale 1982; Sullivan et al. 1987; Poff and Ward 1990). Reorganization of that template reduces biological diversity by (1) decreasing the total amount and diversity of habitat available for native fishes and other organisms and (2) fragmenting habitats and connections among habitats, both of which are needed to support the migrations and ecological requirements of multiple species, populations, and life stages. Alterations in land cover also alter the release and delivery of nutrients to streams (Bormann and Likens 1979).

Land-use effects often accelerate and intensify natural disturbances. Modifications of a forested landscape by timber harvest and road building, for example, may alter processes that control the delivery of wood, water, and sediment to stream channels (Chamberlain et al. 1991; Hicks et al. 1991; Swanston 1991). These changes in turn shift channel morphology—channels can become shallower and wider, and habitats more uniform—and these shifts may persist for long periods in an unstable, or "transitory," state. Natural landslides or bank failures furnish important structural components (e.g., woody debris or sediments) necessary to form productive fish habitat (e.g., Bisson et al. 1987). Clearcut logging and road building, particularly on steep or unstable terrain, however, can supply so much wood or sediment that any apparent benefits derived from increased "structure" are overwhelmed.

Basins with similar geomorphology and flow may harbor aquatic communities historically adapted to similar frequencies and intensities of disturbance (Resh et al. 1988; Poff and Ward 1990). Different disturbance and recovery patterns among watersheds may thus benefit overall biological diversity because different species and life histories have the competitive advantage in different watersheds (Holling 1986). In contrast, disturbances associated with timber harvest, grazing, mining, and other land uses tend to reduce the complexity of physical habitat both within streams and among watersheds (Li et al. 1987; Hicks et al. 1991; Pearsons et al. 1992). When these effects are viewed across large portions of the landscape, entire watersheds, even regions, become more uniform and thus less able to maintain a diverse regional fauna.

Today, the effects of habitat simplification across much of the Eastside show up at multiple levels of biological organization: loss of diversity within fish populations and subpopulations, illustrated by the lack of genetic variation among bull trout (Leary et al. 1991); reduced diversity of stocks within species, shown by the loss of numerous populations of anadromous salmon and steelhead throughout the Columbia River basin (Nehlsen et al. 1991); and decreased diversity of native species within assemblages, illustrated by the eight taxa of native fish (or 40% of the indigenous fauna) from the Upper Klamath River basin now extinct, endangered, or threatened (Frissell 1993).

Habitat simplification and the decline of native fish populations in the Pacific Northwest may also have affected whole-system levels of organization, although specific effects are still poorly understood. Large runs of salmon and steelhead, for example, historically transported an abundant supply of oceanic carbon and nutrients to inland waters. Reduced salmon runs (and the lack of woody structure needed to retain salmon carcasses in streams) may directly influence the cycling of nutrients and stream productivity (e.g., Gilbert and Rich 1927; Donaldson 1967; Mathisen 1972; Richey et al. 1975; Cederholm and Peterson 1985; Northcote 1988) and, consequently, the availability of food for many invertebrates, birds, fish, and mammals (Cederholm et al. 1989; Frissell 1993). The key roles of Pacific salmon populations in streams and the severity of their decline throughout the Columbia Basin raise important concerns about long-term consequences of declines in salmonids for entire aquatic and terrestrial ecosystems. Conceivably, the simultaneous declines of Pacific lamprey (ODFW 1993) and predatory bull trout in the region are somehow associated with a decline in salmonid prey. Ratliff and Howell (1992) suggest that lack of passage for salmon and steelhead over Hells Canyon Dam on the Snake River may have removed a primary food source for piscivorous bull trout populations in the Powder, Burnt, Malheur, and Pine Creek systems in northeastern Oregon (Ratliff and Howell 1992).

Specific Effects of Forestland Management Activities

The effects of forest management activities on stream systems and salmonid habitat have been intensively studied (e.g., Chamberlain et al. 1991; Furniss et al. 1991; Hicks et al. 1991; Bisson et al. 1987, 1992). Nevertheless, because these effects are multiple and interactive, it is often impossible to segregate the influence of individual factors. Natural variability within and among drainage systems and the short duration of most scientific research projects contribute to contradictions and uncertainties in the scientific literature (Hicks et al. 1991). Many ecological responses to timber harvest are delayed, and they may continue for long periods. Often, effects accumulate without becoming apparent until severe climatic or other "triggering" events dramatically change habitat conditions. The following modifications on eastside forestlands are among the cumulative factors contributing most heavily to the decline of native fish production.

MODIFICATION OF UPLANDS

EROSION AND SEDIMENTATION

Timber harvest, road construction, and other disturbances to the soil alter erosion, sedimentation, and the development of stream channels. These disturbances may degrade environmental conditions for fish by contributing large amounts of sediment to streams (Chamberlain et al. 1991). High sediment loads can fill rearing pools, silt spawning beds, decrease channel stability, alter channel morphology, and reduce survival of emerging salmon fry (Bottom et al. 1985; Furniss et al. 1991; Hicks et al. 1991; Frissell 1992; Burton et al. 1993; Rhodes and McCullough 1994).

Roads modify drainage patterns and accelerate erosion. Sediment contributed per unit area of roads may be more than from all other management activities combined (Furniss et al. 1991). Relative to undisturbed lands in the same locations, roads may increase the severity and frequency of landslides from several to hundreds of times, depending on local conditions (Morrison 1975; Swanson and Dyrness 1975; Swanston and Swanson 1976; Furniss et al. 1991), and such effects may continue for decades after the roads are built (Furniss et al. 1991).

Clearcut harvesting and the loss of plant roots binding the soil can also trigger landslides, particularly on steep terrain and unstable soils; these effects may be delayed for several years (Gresswell et al. 1979). In the western Cascades, clearcutting accelerated landslide erosion by two to nine times the rate for unharvested lands (Morrison 1975; Swanson and Dyrness 1975; Marion 1981). Although the increased frequency of landslides may be relatively lower per unit area than that caused by roads, clearcuts contribute similar total amounts of sediment because they are so large (Swanson and Dyrness 1975).

In addition, riparian and stream systems are directly tied to upslope processes. Buffer strips or streamside management zones can moderate the impact of some upland disturbances but, by themselves, cannot maintain productive stream systems (Hicks et al. 1991). Riparian zones contribute large woody debris and control water temperature (see "Modification of Riparian and Stream Systems," page 141). But other critical processes, such as hydrological properties and sediment delivery, are only controlled to the extent that the buffer zone can prevent the formation of erosive channels into the stream.

On some unstable landscapes, landslide and erosion rates may accelerate after timber harvest and road construction. In a sensitive region of southwest Oregon, for example, Frissell (1992) found that upstream activities led to damaging levels of sediment transport and channel instability. The result was a loss of nearly half the area of instream pools in alluviated canyons (despite a doubling in the amount of large woody debris)—an effect still apparent several decades after disturbance. Steep slopes and shallow, coarse soils in the Idaho batholith region are particularly vulnerable to erosion after disturbance (Gray and Megahan 1981). Timber harvest in the South Fork Salmon River, Idaho, damaged chinook spawning habitat after heavy rainfall (Platts and Megahan 1975), and even with a moratorium on timber harvest and efforts to reestablish vegetation and stabilize roads, substrate conditions in the South Fork Salmon River have not entirely recovered after 25 years (Platts et al. 1989; Bohn and Megahan 1991).

Most mass erosion events that carry sediment into streams start in upper watersheds (Ketcheson and Froehlich 1978). Yet riparian protection standards are generally less stringent for small upper tributaries (e.g., streams with no fish and intermittent flow) than for perennial fish-bearing waters (flowing year-round) downstream (Table 6.1). Failure to protect streams without fish ignores the connection between upstream and downstream areas within a single river basin—a connection that defines upper tributaries as critical determinants of downstream processes and conditions. Indeed, small first- and second-order streams may constitute more than 70% of the cumulative channel length in mountain watersheds of the Pacific Northwest (Benda et al. 1992). As timber harvest activity proceeds upslope on more steeply dissected and unstable terrain, the risk to entire stream systems and fish production increases. Regardless of which standards apply on small upper tributaries, lands highly susceptible to erosion are especially vulnerable to timber management activities.

Table 6.1 Standards for riparian protection in eastern Oregon national forests.

National forest	Streamside zone management direction	Page in forest plan
Deschutes	No scheduled timber cutting within 100 feet of perennial water bodies, including class II[b] and III[c] streams. Streamside zone available for unscheduled harvest. Road construction permitted, but stream crossings and length within streamside zone to be minimized.	4-61
Fremont	Streamside zone available for scheduled timber cutting using long-rotation, uneven-aged management. Minimal road construction permitted.	200
Malheur	No scheduled timber cutting within 100 feet of class I[a] and II streams; no scheduled cutting within 66 feet of class III streams. Class I, II, and III zones designated as unsuitable for timber cutting; cutting permitted only to enhance streamside values. All other streamside zones and riparian areas designated suitable for timber cutting with uneven-aged logging systems. Road construction allowed, but road density and impact to fisheries to be minimized.	IV-58
Ochoco	Streamside lands classed as suitable for timber management and included in lands available for scheduled timber cutting. Even- and uneven-aged silvicultural systems allowed in streamside zones. Road construction allowed, but stream crossings and road construction through the length of riparian areas to be minimized.	4-74 4-216
Umatilla	Streamside lands managed on a scheduled basis for timber production. Even- and uneven-aged silvicultural practices permitted, but clearcuts must be smaller than 2 acres. Uneven-aged strategies emphasized within 50 feet of stream channels. Road construction permitted where consistent with streamside management goals. Stream-crossing construction permitted.	4-59 4-163
Wallowa-Whitman	No scheduled timber cutting within 100 feet of high-water line along class I and II streams. Cutting allowed within these zones for nontimber management purposes. Within class III and IV[d] streamside zones, timber cutting allowed, provided that shade, ground cover, and water quality standards are met. Road construction allowed in riparian zones, but construction through the length of riparian areas prohibited. Stream-crossing construction allowed.	4-22
Winema	No scheduled timber cutting within 100 feet of class I and II or 50 feet of class III streams. Scheduled timber cutting permitted in other streamside zones. Uneven-aged management emphasized where logging permitted. Road construction to be avoided, and crossings constructed only perpendicular to the stream.	4-74 4-136

[a] Class I streams = Perennial or intermittent streams or segments thereof having one or more of the following characteristics: direct source of water for domestic use; used by large numbers of fish for spawning, rearing, or migration; flow enough water to be a major contributor to the quantity of water in a class I stream (USFS 1990g).

[b] Class II streams = Perennial or intermittent streams or segments thereof having one or more of the following characteristics: used by moderate though significant numbers of fish for spawning, rearing, or migration; flow enough water to be a moderate or not clearly identifiable contributor to a class II stream (USFS 1990g).

[c] Class III streams = All other perennial streams or segments thereof not meeting higher class criteria (USFS 1990g).

[d] Class IV streams = All other intermittent streams or segments thereof not meeting higher class criteria (USFS 1990g).

Stream Flows

Timber and rangeland management disturbs ground cover and soil and influences stream flow, one of the most critical determinants of the quantity and quality of fish habitat (Bottom et al. 1985; Chamberlain et al. 1991). Patterns of runoff vary regionally, reflecting differences in the amounts and types of precipitation (rain or snow) that a watershed typically receives (Swanston 1991). This flow regime is important in controlling the complexity and stability of channels and the transport of organic matter that serves as both habitat and food for fish (Poff and Ward 1990). Peak flows affect erosion rates and the amount of sediment in streams (Harr 1986). Changes in the timing and intensity of stream flows may particularly affect locally adapted salmon stocks, whose life histories and migrations are often closely linked to established flow patterns.

Forest management activities often alter typical regional flow patterns, particularly the timing or intensity of high and low flows (Chamberlain et al. 1991). An important concern in the western United States is the increase in peak flows that may come from rain falling on snow in the transient snow zone after clearcut logging (Hicks et al. 1991). Clearcutting may also affect flows by increasing snow deposition and advancing the time and rate of snowmelt (Chamberlain et al. 1991). Soil compaction or changes in vegetative cover from road building and other disturbances can alter pathways to stream channels and increase (or decrease) the volume of peak flows (Vale 1982; Bottom et al. 1985; Chamberlain et al. 1991). Soil compaction and runoff also increase as grazing increases (Rauzi and Hanson 1966; Platts 1981; Bauer and Burton 1993).

Modification of Riparian and Stream Systems

Timber harvest and other land-use practices in riparian zones may directly alter the quantity and quality of food and habitat for fish. The environment along stream channels shades streams and moderates water temperatures, buffers the input of nutrients and sediments from hillslopes, and contributes organic matter and woody debris (Gregory et al. 1991). Riparian vegetation controls channel morphology; stabilizes stream banks; and maintains underground flow within the streambed (hyporheic zone), which supplies cool or nutrient-rich water to streams during periods of low flow (Hicks et al. 1991; Naiman et al. 1992). Riparian vegetation along small streams is also responsible for maintaining the physical integrity of channels, especially during extreme environmental conditions such as drought or flood (Sedell et al. 1990).

Constrained Stream Channels

Construction of roads or other development along previously unconfined streams narrowly constricts channels and prevents interactions with riparian and floodplain systems. Naturally unconstrained reaches of streams are characterized by complex braided channels and extensive floodplains, which offer diverse habitat and refugia and contain more fish than narrow, constrained reaches (Gregory et al. 1991). Construction of roads and bridges often reduces habitat complexity by removing meanders, preventing the formation of undercut banks and pools, and reducing the amount of riparian-stream contact (e.g., Sedell and Froggatt 1984; Sedell et al. 1990). Streamside development may remove and prevent regrowth of riparian vegetation and increase erosion and sedimentation (Beschta et al. 1991; Furniss et al. 1991). Numerous studies (e.g., Whitney and Bailey 1959; Peters and Alvord 1964; Elser 1968; Gebhards 1970) report decreases in trout production following channelization of small streams.

Woody Debris

Among the most critical effects of forest management on fish habitat are changes in the amounts and distribution of large woody debris in streams. Although the role of large wood varies with its placement in a stream, wood is a major structural component in rivers of all sizes (Bisson et al. 1987). Large wood may enter streams from adjacent riparian zones or float downstream from upper tributaries and hillslopes (Naiman et al. 1992). Wood traps potential spawning gravels and organic material; furnishes cover; interrupts the river's current, thereby offering foraging sites for fish; controls channel morphology; and influences the distribution of habitat types in streams (Bisson et al. 1987). Complex side channels and backwater areas created by large wood and vegetation in undisturbed floodplains provide critical rearing habitat and refuges for fish during high flows (Sedell et al. 1990; Gregory et al. 1991). Woody debris also creates the large pools and complex cover that a variety of stream fishes require (Sedell et al. 1988). Deep pools with ample cover may reduce competitive interactions and allow streams to support many fish species and age classes (e.g., Schwartz 1991).

Logging and removal of debris decrease the number and volume of pools in streams (Bisson and Sedell 1984). Removal of woody debris from riparian zones may destabilize channels, reduce habitat complexity and cover, and increase winter mortality of eggs and juvenile salmonids (Bisson et al. 1987). Pearsons et al. (1992) found that fish assemblages in a high-desert region of eastern Oregon (John Day basin) lost a smaller proportion of fish and had higher fish diversities after peak floods in reaches of streams with complex habitat than in reaches with little habitat diversity. Complex habitat creates eddies and other complicated flow patterns, slows flow during floods (presents hydraulic resistance), and provides slackwater refugia for fish (Kaufmann 1987; Pearsons et al. 1992). The abundance of woody debris in streams has often been linked to the abundance of salmonids (Hicks et al. 1991).

Stability of woody debris in channels is therefore considered important in maintaining quality fish habitat. Forest management activities often quickly deposit a large amount of relatively small, unstable woody debris into streams and adjacent riparian corridors; such activities may also shift the vegetation to earlier successional stages (Bisson et al. 1987). Debris from second-growth stands tends to remain for a shorter time in stream channels than debris generated from the original forest before harvest. Old-growth conifers also decay more slowly and remain longer in streams than deciduous species. Harvest and salvage operations reduce the future supply of large wood to associated streams and may therefore have a long-term impact on fish production (Bisson et al. 1987). Even harvesting in buffer zones around small tributaries that have no fish populations may affect the future supply of wood required by downstream populations (Naiman et al. 1992).

RIPARIAN VEGETATION

Riparian vegetation influences virtually all aspects of stream ecology, including water quality, structure of the stream bank and channel, and living organisms in the river; removing riparian vegetation thus has multiple effects on stream systems. Unfortunately, human activities such as logging, grazing, agriculture, and road building are often concentrated in riparian corridors, with catastrophic consequences for aquatic ecosystems. The effects vary with the degree of disturbance, size of the stream, local geomorphology, and the stage of succession following removal (Murphy and Meehan 1991).

Among the most important consequences of riparian destruction are increased water temperatures, destabilized stream banks, increased sedimentation, reduced woody debris, and simplification of the stream channel. Although an opening in the riparian canopy may temporarily increase fish production, any apparent benefits are typically short-term if temperatures eventually exceed tolerance limits, or instream habitat is degraded. When riparian vegetation is removed, the abundance and distribution of organisms fluctuate more widely than in streams within mature forests (Gregory et al. 1987). Even if the riparian canopy recovers, nutrients and aquatic productivity may not return to levels characteristic of old-growth forest (Murphy and Meehan 1991).

Loss of the temperature-moderating effects of riparian cover because of timber harvest and overgrazing is a particular concern east of the Cascades because temperatures there vary greatly from winter to summer, and the climate is naturally dry. Temperature increases in a watershed's upper reaches can build up, excessively raising water temperatures downstream (Brown 1969; Murphy and Meehan 1991). In interior streams with low flows and large exposed areas, summer temperatures may rise substantially. Conditions are particularly severe where overgrazing widens streams, makes them shallower, and exposes more surface area to solar heating (Bottom et al. 1985; Platts 1991). Without cool water flowing from upstream, even shaded downstream reaches may become too hot for fish (Beschta et al. 1987; Swanston 1991). Fish in some eastside watersheds are also vulnerable to winter temperature extremes where loss of riparian cover permits ice to form (Platts 1991). Freezing of Meadow Creek (Grande Ronde basin, Oregon) in Wallowa-Whitman National Forest, for example, may be exacerbated by past riparian management practices. The most effective method of reducing ice formation may simply be to restore riparian vegetation (Beschta et al. 1991).

Besides increasing temperature variation, grazing by livestock may intensify extreme flows. Riparian vegetation controls stream hydrology by storing and gradually releasing water, a process that dampens flood peaks and increases base flows during the summer and early fall (Elmore and Beschta 1987). During the past century, grazing of riparian vegetation east of the Cascades has dried many streamside aquifers and wet meadows, lowered water tables, and turned perennial streams into intermittent ones (Elmore 1989).

Grazing and trampling by livestock also reduce the capacity of stream banks and channels to accommodate high flows. Whereas streams with healthy riparian zones tend to have stable stream banks even during major floods, grazing of vegetation accelerates erosion and prevents the interception of sediment from upslope and upstream locations (Platts 1991). Gullying and downcutting of the channel may further accelerate erosion and downstream transport of sediment (Schumm et al. 1982; Harvey and Watson 1986), to the detriment of fish and fish habitat. In northeast Oregon, annual stream-bank losses were estimated to be more than three times greater (12 in.) in grazed than ungrazed areas (less than 4 in.; Kauffman et al. 1983).

Along some streams and mountain meadows, the benefits of temperature moderation, stream-bank stabilization, and habitat complexity are provided solely by brush or grasses rather than by woody shrubs or large tress. These areas pose a particular concern for riparian management because they are highly productive for both fish and livestock. Grasses form clumps that reduce erosion and develop undercut banks, preferred as cover by many salmonids. Low-gradient, unconstrained stream channels through wet meadows provide productive fish habitat and sources of cool water for downstream reaches. Yet riparian meadows also offer some of the best forage for livestock. One acre of mountain meadow may have a potential grazing capacity equal to 10 to 15 acres of forested range (Kauffman and Krueger 1984). Cattle tend to concentrate in productive areas, and in one Blue Mountain grazing allotment, 81% of the herbaceous vegetation removed by cattle came from the riparian zone (2% of the allotment area; Roath and Krueger 1982).

Numerous studies have reported adverse effects of grazing by livestock on fish habitat and fish production. The average biomass of salmonids for seven streams in eastern Oregon, for example, was five times greater in well-vegetated reaches than in sparsely vegetated reaches (Bottom et al. 1985). Twenty of the 21 published studies reviewed by Platts (1991) concluded that improper grazing had degraded riparian and aquatic systems. All but a few of these studies also reported a coincidental decline in abundance and biomass of fish in the presence of grazing (Platts 1991; Rinne 1988). Overgrazing of eastside streams may decrease the proportion of salmonids and increase other species more tolerant of warm water and poor habitat conditions (e.g., Bowers et al. 1979; Kauffman and Krueger 1984).

Some grazing management strategies are advocated for their positive influence on fish habitat because they maintain riparian ecosystems (Kauffman and Krueger 1984). The compatibility of improved grazing strategies with restoration of already degraded riparian zones is more dubious, however. In severely degraded areas, modified grazing has not promoted riparian recovery (Platts 1991). For rapid reestablishment of woody shrubs and trees, excluding livestock is the best approach (Anderson et al. 1992).

Where livestock are excluded from overgrazed riparian zones, dramatic regrowth of vegetation can follow (Beschta et al. 1991; Platts 1991). Rates of regrowth vary by site. Along low-gradient streams that cross alluvial valleys and carry much silt during high flows, recovery can take place quickly (Elmore and Beschta 1987). Recovery of stream morphology, on the other hand, proceeds more slowly, and fish populations may or may not respond (Platts 1991). Several years of rest from grazing may be required to reestablish riparian forests and restore processes that generate quality salmonid habitat (Beschta et al. 1991). These authors recommended "five years of rest alternating with five years of proper grazing" to allow reestablishment of riparian forests of cottonwood, aspens, and willows along eastern Oregon streams. On USFS and BLM grazing allotments in the Silvies, Malheur, John Day, and Burnt Rivers districts, Phillips (1987) estimated that it might take 25 to 50 years without grazing to restore late-successional or climax vegetation in riparian zones, and even longer under "proper grazing" strategies (Phillips 1987).

MODIFICATION OF INSTREAM HABITAT

Decline of fisheries throughout the Pacific Northwest has stimulated interest in techniques for rehabilitating instream habitat for salmonids. In eastside streams with degraded riparian zones, recovery of vegetation may be one of the most effective restoration methods. Recovery of riparian vegetation through grazing controls has decreased width-to-depth ratios for streams and increased summer base flows (e.g., Winegar 1977; Elmore and Beschta 1987; Elmore 1989; Ponce and Lindquist 1990; Platts 1991).

Benefits from artificial structures (e.g., rock check dams, boulder clusters, rock riprap, log weirs, and so on), which are often used in lieu of or in conjunction with riparian recovery projects, have not been substantiated. Reeves et al. (1991) note mixed success in past restoration efforts and caution that manipulation of instream habitat cannot be relied on to mitigate poor management practices. Furthermore, even though millions of dollars have been spent on stream habitat projects throughout western states, "little documented evidence [exists] of increased abundances of salmonids associated with these massive expenditures" (Reeves et al. 1991). Kauffman and Krueger (1984) review results of structural improvements and note that proposed benefits have frequently not been achieved. Platts and Nelson (1985) found that instream structures often trap fine sediment, thereby harming fish production. Structures placed in streams where banks are grazed by livestock may simply fail (Duff 1983).

Rigid instream structures are thus no replacement for natural processes responsible for transporting materials and the development and redevelopment of complex habitat within streams. Frissell and Nawa (1992) conclude that "commonly prescribed structural modifications often are inappropriate and counterproductive in streams with excessive sediment, high peak flows, or highly erodible bank materials. Restoration of fourth-order and large alluvial valley streams, which have the greatest potential for fish production in the Pacific Northwest, requires reestablishment of natural watershed and riparian processes over the long term." In a review of 16 habitat-improvement sites in the Grande Ronde and John Day River systems, Beschta et al. (1991) conclude that instream structures often converted previously unconstrained stream reaches to unproductive constrained reaches and prevented the formation of seedbeds and recovery of woody riparian vegetation. In their evaluation, corridors fenced off for extended periods along portions of the upper Grande Ronde and John Day Basins provided the best examples of recovered vegetation, channel morphology, and fish and wildlife habitat. Where corridor-fencing projects included instream structures, Beschta et al. (1991) attribute the greatest benefits for vegetative recovery to the exclusion of livestock.

Restoration of Aquatic Systems

Land-use practices for more than a century have fragmented and simplified eastside stream systems (e.g., McIntosh et al. 1994). Reduced diversity in fish assemblages, species, populations, and gene pools signals an expanding matrix of disturbance and the contraction and isolation of habitat refugia. Large streams and rivers are among the most severely affected by high temperatures and excessive sediment, which have steadily built up downstream from multiple upstream sources. Many of these rivers and streams can no longer support native cold-water fauna.

Existing eastside forest and range management plans on federal lands will keep degrading water quality and stream environments, including fish and wildlife habitat. The plans propose more road mileage, continued harvest of large trees, larger sediment loads, and widespread grazing in riparian areas. Even without these increases in human activity, the risk of future habitat damage from extreme climatic events is great because many watersheds are degraded already. Continued expansion of timber harvest and road building into steep, unstable headwater areas will encroach on the few remaining upstream refugia for native fish and alter still more the hydrologic patterns, water temperatures, and sediment loads in degraded downstream reaches. Criteria for evaluating management performance based only on economic targets (e.g., forage-use standards for cattle, board feet of timber) or on habitat conditions measured at a particular site are not enough to evaluate the cumulative effects of forest management activities throughout a watershed or to ensure the continued viability of diverse communities of organisms.

We conclude that present forest management practices in eastside watersheds will heighten the probability of future extinctions and further compromise the ecological integrity of these landscapes unless (1) the few remaining habitat refugia for native aquatic species are adequately protected and secured from the cumulative effects of riparian and upland modifications, and (2) management programs and standards are revised to redirect landscape alteration toward recovery.

A comprehensive recovery strategy for eastside landscapes, watersheds, and habitats is needed to restore the critical elements and processes that have until now provided the evolutionary template for biological organization and adaptation across the region. Such a strategy must include the reconnection of highly fragmented stream systems with their adjacent riparian forests, floodplains, and groundwater sources (Sedell et al. 1990; Gregory et al. 1991).

A move in this directions followed the federal listing of Snake River chinook salmon as an endangered species in the National Marine Fisheries Service's (1993) "biological opinion" governing salvage and timber sales in the upper

Grande Ronde watershed, the upper main Grand Ronde River watershed, and Catherine Creek. This document may provide useful guidelines for protection and restoration in other eastside watersheds with fish assemblages at risk. The opinion concludes that timber sales will not further jeopardize Snake River salmon species—provided special measures are taken to promote recovery and prevent additional habitat degradation. To satisfy these requirements, NMFS (1993) recommends that Wallowa-Whitman National Forest "complete and fully implement" the Upper Grande Ronde restoration plan (UGRRP; Anderson et al. 1992), develop a riparian area rehabilitation plan "to ensure the long-term health and viability of riparian conservation areas defined by streamside buffers," and (to minimize flow effects) limit the density of clearcuts and the proportion of stands converted to trees less than 30 years old. Among the other provisions required in implementing UGRRP are obliteration of at least 10% per year of the unimproved roads in riparian areas, and a general reduction of road densities.

The restoration plan also requires that all streams within the forested riparian zone be protected by horizontal no-cut buffer widths equal to 75 feet times the stream order plus the floodplain on each side of the stream. (Stream order classifies streams by the number of tributary junctions beginning from the headwaters. First-order streams are the smallest and begin in the uppermost reaches of a watershed. Two first-order tributaries join to form a second-order stream, two second-order streams join to make a third, and so on [Strahler 1957].) For all perennial streams in the subbasin, a minimum buffer 300 feet wide is required, regardless of stream order or floodplain width.

Amendments to UGRRP also restrict livestock access to riparian areas, or prohibit it where standards for riparian vegetation are not met or fish habitat standards (e.g., temperature, substrate, width-to-depth ratio) in downstream reaches are exceeded. The plan suggests that a herder be present every day on all active allotments to completely exclude livestock from riparian zones. Where livestock cannot be effectively excluded, the plan calls for corridor fencing or closing allotments to promote recovery of riparian systems and salmonid habitat. The plan notes that cattle must be completely excluded from riparian zones to regrow alder, cottonwood, and willow as quickly as possible.

Even if the Forest Service implements our recommendations and those of UGRRP, water temperatures that become too high because of management on nonfederal lands may still significantly reduce salmonid survival.

Elements of a Restoration Strategy

Past and present conservation efforts for the management and recovery of individual fish taxa have not been effective. In 1989, for example, 139 new taxa were added to a 1979 American Fisheries Society list of resident North American fishes considered at risk of extinction or of special concern. At the same time, not a single fish was removed from the original list as a result of successful recovery (Williams et al. 1989). Faunal decline and the failure of single-species recovery efforts represent failures to recognize the interacting components of aquatic systems. Close interactions in complex ecosystems mean that one species or habitat cannot be maximized without also changing others and that the key components of evolutionary processes—gene pools, populations, species, and species interactions—cannot be maintained or restored apart from the larger organization and processes that created them (McNaughton 1989).

Therefore, whole-watershed approaches to conservation are needed. Such approaches should emphasize the maintenance of ecological processes and the organization of entire communities of organisms within the native habitats of a region (Karr and Dudley 1981; Williams and Williams 1992). Moyle and Sato (1991) describe criteria for designing a network of aquatic reserves in order to protect "entire, naturally functioning, native communities . . . in their evolutionary context." Scientists developing management options to protect and restore native fishes within the range of the northern spotted owl, for example, have identified entire "key watersheds" as centerpieces for a regional conservation strategy (Johnson et al. 1991; Thomas et al. 1993; FEMAT 1993).

A comprehensive restoration strategy for eastside aquatic communities should:

1. **Define a system of reserves and restoration sites to protect the full variety of aquatic ecosystems and faunal assemblages found in the eastside landscape.**

The remaining eastside watersheds with relatively high-quality habitat and healthy native fish assemblages are critical building blocks for recovery of the larger landscape. A geographically dispersed network of aquatic reserves and priority restoration sites is needed to maintain and restore the integrity of eastside aquatic ecosystems. Such a network should incorporate the variety of landforms, habitats, hydrological conditions, and faunal groups characteristic of the region.

General patterns in the distribution and organization of eastside fish faunal groups reflect a dramatic geological and climatic history. Past connection and isolation of drainage basins appear in the broad distribution and composition of eastside fish assemblages (McPhail and Lindsey 1986; Minckley et al. 1986). Tectonic upheaval and glaciation limited the total number of fish taxa native to the region, but the resulting heterogeneity of landforms, geology, climate, and habitats created a considerable variety of endemics within those fish families that have managed to survive and adapt (Minckley et al. 1986;

McPhail and Lindsey 1986; Sheldon 1988). For example, at least 16 subspecies of cutthroat trout *(Oncorhynchus clarki)* are recognized today throughout the West (Allendorf and Leary 1988).

Detailed biological inventories are not now available for all fish assemblages, species, and populations in all river systems east of the Washington and Oregon Cascades. Classifying landscapes, river basins, and habitats can be a start to identifying the diverse types and functions of aquatic systems that management programs should strive to restore and protect (e.g., Frissell et al. 1986). Among the important physical features influencing fish distribution are (1) the connections among rivers within large drainage basins, which allow fish to move and use different habitats, and (2) landscape features that define hydrological conditions and the distribution of aquatic habitats within basins (e.g., Whittier et al. 1988). Hughes et al. (1987), for example, found that aquatic ecoregions and river basins were more useful than physiographic regions for explaining historical fish distribution patterns in Oregon, where ecoregions and subregions have been classified and mapped by combining information about land use, land cover, soil, topography, and vegetation (Clarke et al. 1991).

The watershed classification subcommittee of the Oregon chapter of the American Fisheries Society proposed a hierarchical strategy for classifying aquatic ecosystems by dividing the state into 18 major drainage basins. These basins are further subdivided into subbasins and mainstem river sections found in the state's previously defined ecoregions and sub-ecoregions (Oregon AFS, draft outline, 12 September 1990). Thus, at a minimum, a conservation strategy to maintain diversity of aquatic ecosystems and assemblages in Oregon should include representation from all 18 drainage basins and nearly 30 ecoregions or subregions (Clarke et al. 1991; Thiele et al., unpubl. map).

2. **Protect watersheds large enough to maintain self-sustaining populations of their full complement of native taxa.**

Because rivers are open systems, the processes, biota, and habitats within them are affected by the entire upstream network and surrounding landscape (Sheldon 1988). Management and restoration therefore require a whole-basin perspective (Sedell et al. 1990), including natural disturbances within the range of conditions that shaped the associated biota. Restoration efforts should be directed not only at representative systems but also to rare and unique habitats.

The area necessary for aquatic restoration varies geographically and with habitat type (Moyle and Sato 1991). Conservation of a rare endemic species in a relict spring habitat in southeastern Oregon can focus on a small area defined by the extent of the spring and its water source; anadromous salmonids on the other hand, require a widely dispersed network of habitats extending from upriver spawning tributaries to the North Pacific Ocean. Because larger watersheds generally support more taxa, conservation efforts for riverine systems should focus on intermediate-sized streams (fourth through sixth order) plus the upstream portion of their drainages (Sheldon 1988). Moyle and Sato (1991) suggest that protection strategies should target the largest and most migratory species, a goal that presumably would also provide adequate protection for smaller taxa whose specific habitat requirements may be poorly understood.

We concur with Li and Castillo (1994) that restoration goals for eastside watersheds should target the environmental conditions and processes needed to support species with the narrowest tolerances for warm water (e.g., sensitive cold-water species). Cold-water fauna demand the highest-quality habitat, which generally offers suitable conditions to support maximum diversity within native assemblages (Li and Castillo 1994). Practical considerations—the distribution of available healthy populations, the amount and distribution of remaining habitat in good or restorable condition, and the opportunities for whole-system management as dictated by land ownership patterns—will have an important influence on the spatial scale of restoration opportunities and the layout for a network of reserves across the eastside landscape.

3. **Protect multiple examples of each watershed type (a) to minimize the risks that catastrophic events will threaten associated assemblages and populations and (b) to accommodate multiple populations and subpopulations with diverse life histories and gene pools.**

Restoration and protection sites should be redundant to minimize risks to native aquatic fauna. Wherever possible, for example, aquatic reserves with similar fauna should be replicated in basins that are far enough away from one another to spread the risks of coincidental catastrophic loss (Moyle and Sato 1991).

To sustain native salmonid productivity, a conservation strategy must maintain multiple watersheds characteristic of the conditions from which diverse stocks have evolved. The tendency for migratory salmonids to home to their natal stream to spawn (and other causes of reproductive isolation) has led to genetic and life-history adaptations to diverse local environmental conditions. The result is a hierarchy of populations within a larger metapopulation (Currens1994; Rieman and McIntyre 1993). This organization is critical to the productivity and resilience of salmonids affected by environmental fluctuations and unpredictable catastrophic events. Multiple life-history types of bull trout within a river basin, for example, mean some spatial segregation of habitat use, and this segregation reduces the risk that all component subpopulations will be affected similarly by a disturbance or will react identically to the same set of environmental conditions (Rieman and McIntyre 1993).

The hierarchy of locally adapted populations has promoted the rapid evolution of salmonids and maintained their capacity to recolonize disturbed habitats throughout their range (Li et al. 1987; Frissell 1993). Habitat connections among watersheds must be maintained or restored to permit continued gene flow and recolonization of streams after disturbance.

4. **Begin restorations at headwater streams, working downstream and outward from healthy "core" areas to reconnect habitats and to promote recolonization of nearby streams and watersheds.**

The best remaining examples of native assemblages and aquatic habitats should be protected as critical watersheds from which adjacent degraded aquatic systems may be restored. Insofar as possible, these areas should include entire headwater sources to protect water quality and habitat conditions downstream. Because critical watersheds provide the basic elements for recovery, their protection and restoration should be given the highest priority—ahead of restoring more severely degraded habitats downstream or in distant watersheds. Human entry into critical watersheds for road building and logging may place at risk the few remaining refugia available to sustain diversity in eastside stocks and assemblages.

Critical watersheds with healthy fish populations should be regarded as genetic reserves that could provide the "seed" for recolonizing native fauna in adjacent habitats and watersheds. Reestablishment of native assemblages in areas far from such seed sources may take much longer and be less effective. As primary sources for recolonization, the genetic diversity of core populations within critical watersheds should be carefully protected, not only from the effects of habitat degradation, but also from overfishing, interactions with nonnative species, and the effects of hatchery fish.

5. **Restore and protect functional riparian, floodplain, and groundwater systems to reconnect fragmented stream habitats and to maintain conditions and processes supporting native fish assemblages.**

Restoration must focus on reestablishing links between stream channels and adjacent riparian forests, floodplains, and groundwater sources. By regulating stream temperatures, stream flows, habitat structure, and nutrient sources, intact riparian-floodplain systems provide connecting corridors among habitats, stream networks, and watersheds, and these in turn maintain diverse life histories of native fishes. In many eastside watersheds, restoration of healthy riparian systems will require reestablishing late-seral riparian vegetation and removing roads or other obstructions that prevent interactions between stream channels and adjacent floodplains.

Oregon Aquatic Diversity Areas

Oregon aquatic diversity areas (ADAs), identified by the watershed classification subcommittee of the Oregon chapter of the American Fisheries Society (Oregon AFS 1993), provide a starting point for a regional restoration strategy based on the general principles outlined in this chapter. ADAs were selected to represent Oregon's best remaining habitats as well as present locations of at-risk taxa (Chapter 3). Because of historic patterns of land use and habitat modification, the ADA network does not truly represents the region's full diversity of aquatic ecosystems and fish assemblages. Moreover, some have criticized ADAs because they are limited to small streams, excluding, for the most part, lakes, wetlands, and large rivers.

Although ADAs may be in relatively better condition than other eastside watersheds, they are not necessarily unaltered, self-sustaining, or "pristine." Active measures may be needed to secure and restore some ADAs from future natural or human-induced stress. Available options for their protection or restoration in turn may depend heavily on existing patterns of land ownership. Understanding the distribution, condition, and ownership of the proposed ADA network is therefore a critical first step in building a regional restoration strategy based on priority watersheds.

Distribution and Ownership

The AFS subcommittee's database lists a total of 307 ADAs statewide (Oregon AFS 1993). These encompass 9.2 million acres—nearly 15% of the total Oregon landscape. The region east of the Cascade crest accounts for slightly more than half the total number (158) and 5.9 million acres, or 64% of the total ADA area in the state; this area represents approximately 14% of the eastside landscape. Within the seven Oregon national forests that we reviewed, ADA acreage ranges from as little as 5% of Deschutes National Forest to as much as 53% of Wallowa-Whitman National Forest. The subcommittee lists approximately 30 unique, sensitive, or "core populations" of native fish instrumental in the identification of ADAs associated with eastside forests (see Appendix II).

ADAs are distributed among each of the 11 major drainage basins found east of the Oregon Cascades (see Figure 3.1), yet several ecoregions covering large portions of these basins are poorly represented. No ADAs were identified in the Columbia Plateau basin ecoregion, for example, and very few in the Columbia Plateau tablelands or dissected uplands (Table 6.2); these ecoregions encompass the lower portions of the Deschutes, John Day, and Umatilla River drainage basins. High-desert freshwater basins and high-desert dry barren basins of southeastern Oregon are also poorly represented; ADAs cover less than 3% of the total area of each of these ecoregions and exclude habitats in the lower Malheur River, lower Owyhee River, upper Deschutes River, or upper Goose and Summer Lakes basins. The lower Powder River drainage basin, which is classified in Blue Mountain basin and Blue Mountain upland and valley ecoregions, is also poorly represented in the present network.

Well represented in the ADA network are the high Blue Mountains and the Blue Mountain nonalpine forested ecoregions of northeastern Oregon (see Table 6.2). ADAs encompass 76% and 31%, respectively, of these two ecoregions, including upper portions of five eastside drainage basins: John Day, Umatilla,

Table 6.2 Distribution of Oregon aquatic diversity areas (ADAs) in eastside ecoregions (ER) and subregions (Clarke et al. 1991). High alpine areas, like the Blue Mountains, are better represented than lowlands.

				Aquatic diversity areas		
Ecoregion	Subregion	Slope, elevation[a]	Ecoregion area (ha)	Area (ha)	% of ER	% of Eastside
Blue Mountains	Basins	L	148,758	8626	5.8	<0.1
Blue Mountains	High	Mt	143,172	109,358	76.4	<0.1
Blue Mountains	Nonalpine forested	Mt	2,898,995	901,613	31.1	5.2
Blue Mountains	Uplands and valleys	U	2,376,524	162,381	6.8	0.9
Columbia Plateau	Basins	L	203,438	0	0	0
Columbia Plateau	Dissected uplands	U	728,422	54,435	7.5	0.3
Columbia Plateau	Tablelands	U	945,537	15,953	1.7	<0.1
Eastern Cascades	Lake basins	L	242,370	24,178	10.0	0.1
Eastern Cascades	Marshes	L	138,912	58,069	41.8	0.3
Eastern Cascades	Slope and foothills	U	2,280,777	348,152	15.3	2.0
High desert	Dry barren basins	L	667,954	17,436	2.6	0.1
High desert	Fresh water basins	L	375,151	9,515	2.5	<0.1
High desert	Mountain ranges	Mt	358,985	163,733	45.6	0.9
High desert	Uplands	U	5,310,431	382,145	7.2	2.2
Western Cascades	High mountains	Mt	491,866	128,830	26.2	0.7
Western Cascades	West mountains	Mt	103,532	12,536	12.1	<0.1
Totals			17,414,824	2,396,960	—	13.8

[a] L = lowland, U = upland, Mt = mountain.

Grande Ronde, Powder, and Malheur Rivers. Of the watershed areas classified as Blue Mountain nonalpine forested, only the upper Deschutes drainage basin is not represented among present ADAs (see Figure 3.1). The large proportion of ADAs in northeastern Oregon reflects relatively high quality habitat associated with several wilderness areas and a diversity of unique, sensitive, or threatened salmonids that remain in the upper Columbia River system: bull trout, redband trout, summer steelhead, westlope cutthroat trout, and spring and fall chinook salmon (see Appendix II).

Several ecoregions of southeastern Oregon are also highly represented in ADAs. Approximately 46% of the high-desert mountain ranges, which lie within the Malheur Lake drainage basin, and 42% of the eastern Cascade marshes, which are found within the Klamath Lake drainage basin, are included.

Compared with the relative proportions of major slope or elevation classes of eastside ecoregions (Clarke et al. 1991), the ADA network includes more high-elevation, steeply sloped areas classified as "mountains"; lower-elevation and more gradually sloped ecoregions classified as "uplands" or "lowlands" are underrepresented (Figure 6.3, see Table 6.2). Upland and lowland ecoregions

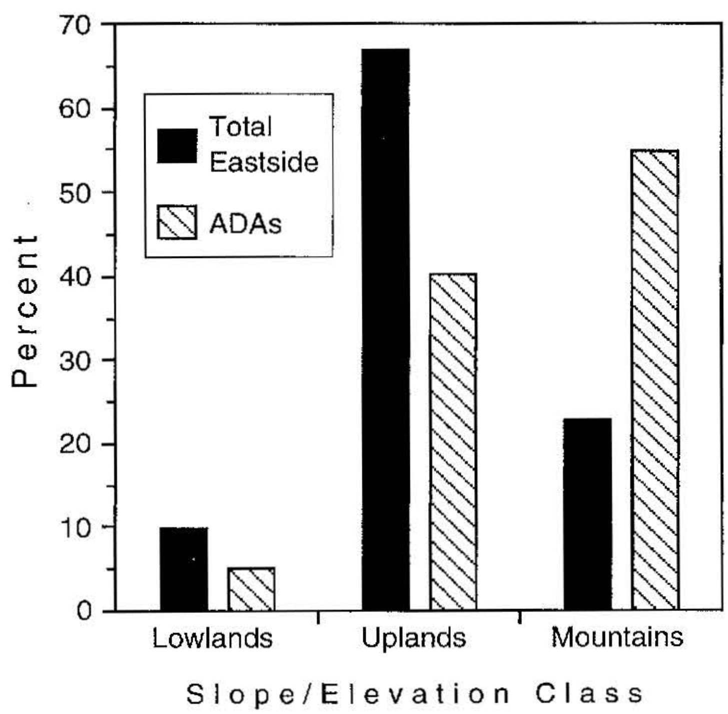

Figure 6.3 Percentages of the total eastside landscape and of eastside ADAs in each of three slope and elevation classes (categories from ecoregion and subregion classifications of Clarke et al. 1991).

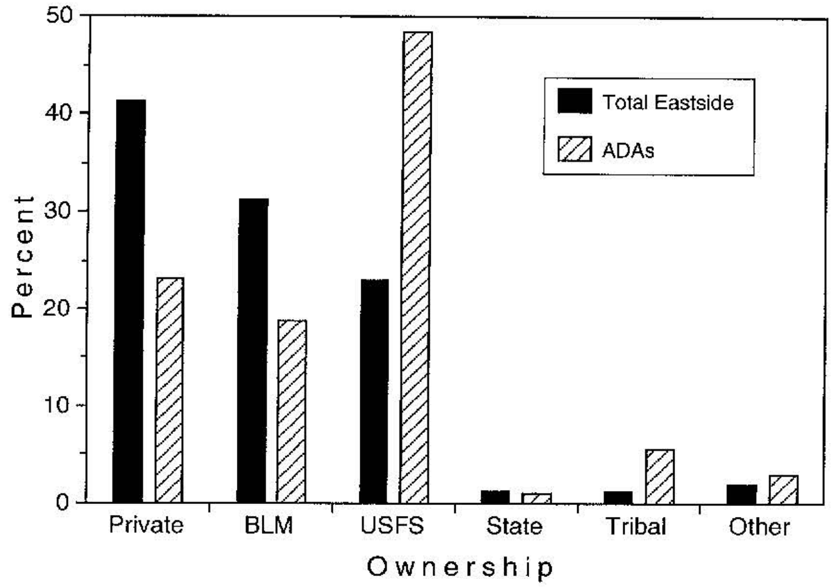

Figure 6.4 Percentages of the total eastside landscape and of eastside ADAs owned by different entities.

make up more than three-quarters of the eastside Oregon landscape but only 40% of the total area in ADAs. Such proportions illustrate that the area of remaining refugia for many native cold-water fishes has been reduced to upper tributaries of highly dissected forested landscapes. This pattern is consistent with the region's logging history, which progressed from lowland timber stands to higher-elevation stands on public lands (Chapter 2). Historically, many of these smaller tributaries of upper watersheds were marginal habitats, particularly for some salmonid species, compared with the more productive alluvial valleys of larger streams and rivers.

Ownership patterns within ADAs also reflect the selection of higher-quality, upper-basin refugia and mountainous ecoregions (Figures 6.4, 6.5). In each ownership category, the percent of mountainous area is considerably higher in ADAs than across the general landscape. USFS lands are overrepresented, private and Bureau of Land Management (BLM) lands underrepresented (see Figure 6.4). USFS manages about 6.2 million acres of mountainous ecoregions—or nearly 2.5 million acres more than all other eastside ownerships combined—a reflection of the generally poorer condition of riverine habitats on agricultural and range lands, which are predominantly private or BLM owned (see Figure 6.5).

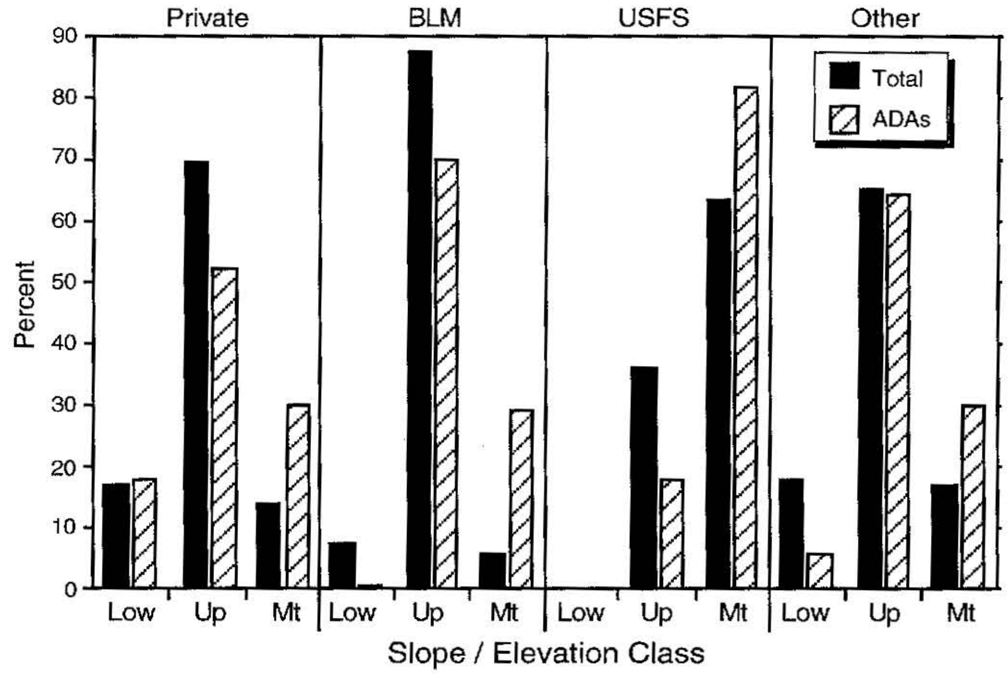

Figure 6.5 Percentage of each major ownership category and percentage of eastside ADAs within each ownership that falls into lowland (Low), upland (Up), and mountain (Mt) ecoregions (as classified by Clarke et al. 1991). Total area (in hectares) and total ADA area (in parentheses) within each ownership category are: Private = 7,200,000 (600,000); BLM = 5,400,000 (500,000); USFS = 4,000,000 (1,200,000); other = 800,000 (200,000).

ADA CONDITION

Although headwater ADAs include much of the best remaining aquatic habitat in Oregon, even many of these areas have been moderately degraded and need recovery or active restoration. We estimate that more than 70% of the area of all ADAs associated with national forests are partially or moderately degraded (Table 6.3; Appendix II).

Existing conservation reserves in Oregon—including wilderness areas, research natural areas, national parks, and wildlife refuges—do not represent or protect the full diversity of eastside aquatic ecosystems and species assemblages. Most reserves are concentrated in high-elevation mountainous terrain (see Table 5.2); most do not correspond to watershed boundaries or encompass small, fragmented tracts of land. Because they usually do not protect entire watersheds or floodplain systems, existing reserves also fail to meet the needs of highly migratory fishes and fish assemblages.

A relatively small proportion of eastside ADAs is currently protected within wilderness areas. Approximately 3.1 million acres, or 83% of ADA area, is

Table 6.3 Ownership of aquatic diversity areas located at least partly on US Forest Service land. ADAs classified as undisturbed are largely intact, with high-quality habitat, a high-quality water source, or both. Other ADAs are partially or moderately degraded and in need of recovery or active restoration.

	Total area (hectares)	
Ownership	Undisturbed	Degraded
Bureau of Land Management	1430	58,998
Private	37,517	291,409
State	320	1724
Tribal	—	5620
US Fish and Wildlife Service (national wildlife refuge)	—	5125
Other	—	2637
US Forest Service: Nonwilderness	228,457	619,686
Nonwilderness subtotal	267,724	985,199
US Forest Service: Wilderness	172,641	79,286
Grand total	440,365	1,064,485

located outside wilderness. Many unprotected ADAs contain significant patches of LS/OG or roadless regions and are vulnerable to future logging and road building (see Appendix II). Those ADAs that are protected in wilderness conserve only a few eastside aquatic ecosystems and assemblages. For example, 57% (355,505 acres) of ADA area within wilderness is concentrated within a single drainage basin (Grande Ronde River) and national forest (Wallowa-Whitman). Nearly 80% (491,190 acres) of eastside Oregon wilderness ADAs lies within the Blue Mountain ecoregions of either the Grande Ronde or the John Day River basins.

Despite these limitations, the quality of aquatic habitat within wilderness ADAs is often better than in "managed" landscapes. We categorized about 69% of the area in wilderness-associated ADAs as "undisturbed" watersheds, compared with only 21% undisturbed habitat in ADAs located on or partially on USFS land but outside wilderness boundaries (see Table 6.3 and Appendix II). McIntosh et al. (1994) similarly reported better habitat conditions—in terms of the number of large pools and complexes of woody debris—in eastside streams in wilderness watersheds than in managed systems. Grazing activities and introductions of exotic fish species, however, continue to threaten native fishes and other aquatic fauna even in many wilderness lakes, streams, and ADAs (e.g., Bahls 1992; Ziller 1992; Oregon AFS 1993).

Can the ADA Approach Be Effective?

Complex ownership patterns and the extensive drainage networks of large rivers and streams pose a difficult limitation to a priority-watershed conservation approach. In recognition of the importance of large riverine habitats and reaches, some ADAs were designated for limited "corridor" protection along critical river reaches. That few such corridors were found to satisfy the ADA selection criteria (see Appendix II), however, is another indication of the degraded condition of most lower river reaches and habitats. Protection of headwater ADAs is required to prevent more habitat loss and to secure the few remaining refugia for many remnant stocks and assemblages. Such protection alone will still not sustain migratory populations or restore the productivity in eastside watersheds of native cold-water species like salmon or bull trout.

Critical reaches and habitats on large streams and rivers also should be identified so that restoration plans can target areas with the highest potential benefits. Along with maintaining headwater ADAs, basin-level planning should define restoration sites along productive unconstrained channels or other critical stream reaches that could satisfy the requirements of migratory fish stocks. Widespread restoration of floodplains and late seral riparian vegetation will be particularly important to reconnect disjunct fish populations within and among ADAs and gradually restore habitat and cool water to downstream areas. An important prerequisite to restoration planning, therefore, is a basinwide assessment of riparian, floodplain, and instream conditions. On many agricultural and range lands, recovering highly degraded riparian systems, screening unscreened irrigation diversions, and maintaining adequate stream flows and temperatures will be necessary before drainage basins can sustain populations of native fauna. These activities must be integrated with control of dams, alien species, mining, water withdrawal, and harvest.

The distribution of Oregon's ADA network illustrates that USFS has a critical role but not sole responsibility for the conservation of eastside aquatic ecosystems. Cooperative management will be necessary to maintain aquatic diversity both within watersheds and across the entire Eastside. Migratory fish and diverse aquatic assemblages integrate habitat conditions over wide areas, across multiple ownership boundaries and agency jurisdictions. Their conservation will therefore require coordinated strategies for restoring the health and integrity of the regional landscape and its component aquatic ecosystems (Doppelt et al. 1993). So far, individual forest plans have not been developed with these realities in mind.

Within some eastside ecoregions, landowners and management agencies other than USFS carry the primary stewardship responsibility. Much of south-central and southeastern Oregon, for example, rests in BLM and private ownership.

Conservation of aquatic fauna in these areas will depend on improved grazing and agricultural practices to restore degraded watersheds and riparian systems. Many other state and federal resource and regulatory agencies that do not control the land directly also have critical conservation responsibilities. Fisheries, wildlife, water-quality agencies, and tribes, for example, should be directly involved in cooperative planning, on regional as well as watershed scales. Oregon's ADAs provide a starting point for identifying private landowners, tribes, and state and federal agencies with collective responsibility for priority watersheds. A similar effort to identify ADAs in Washington, Idaho, and Montana is needed to establish restoration priorities and coordinate management efforts across the entire region.

Thus, the eastside Oregon ADA network (much of it on federal forestland) provides a regional snapshot of much of the best remaining aquatic habitat; conservation efforts there should receive immediate priority. Because the selection of critical watersheds was defined by the present distribution of quality habitat or sensitive fish populations, however, the ADA network does not represent the full diversity of ecosystems and assemblages found throughout the Eastside. ADAs thus provide the cornerstones, but not the complete foundation, for eastside restoration; successful recovery requires better conservation of other productive habitats distributed along larger mainstem streams and rivers. The responsibility for this restoration must be shared by many agencies and individuals.

CONCLUSIONS

Watersheds outside wilderness and roadless regions in eastern Oregon and Washington are highly degraded. Without an intensive restoration effort on federal and private lands, many native aquatic stocks and species risk extinction. The foregoing review leads us to conclude that:

1. **Historic land-use practices have fragmented and simplified aquatic and riparian systems throughout the Eastside. The consequences of these practices diminish the resilience of fish assemblages against natural and human-induced change.**

Management practices on federal and private lands have reduced the complexity of habitat in eastside streams. On public lands, logging, road building, grazing, and mining are among the principal causes of landscape simplification. At the same time, variability of factors such as temperature and flow has become more extreme, and stream systems have become less able to withstand those extremes.

Loss of streamside vegetation has raised summer water temperatures to stressful, even lethal, levels for fish in summer and, in some areas, promoted ice formation during winter. Channelization of streams and loss of functional riparian systems have increased extreme high and low flows during winter and summer, and logging and other upland disturbances have altered established discharge patterns—patterns to which fish migrations have long been adapted. Cattle grazing in riparian areas has lowered water tables, turned streams intermittent, dried wetland meadows, and destabilized stream banks. Much of the complex habitat once provided by large wood, undercut banks, large pools, backwater areas, and floodplains is gone, and potential for flood damage has increased because hydraulic resistance has been lost.

Reduced diversity of habitat has made streams less able to support a diversity of aquatic species and life stages and removed the available refuges that enable fish to survive extreme temperatures and flows. At the same time, low population sizes, reduced and fragmented distribution patterns, loss of diversity in genetic material, and lessened variety among life-history types heighten the vulnerability of aquatic species to natural variations and chance events. For example, a 1989 flood following a catastrophic fire in Oregon's upper Grande Ronde River delivered a tremendous amount of sediment to a system where habitat had already been severely degraded and, consequently, further reduced a remnant population of salmon (Anderson et al. 1992, 1993). Among southern stocks of subarctic salmon and steelhead, the decreased buffering capacity of freshwater systems adds another mortality factor for populations that must also contend with heavy ocean harvesting, numerous dams and other barriers to upstream passage, and marked fluctuations in ocean productivity. The interactive ecological effects associated with dramatic decline of once-plentiful stocks and species of salmonids are potentially irreversible. Because Pacific salmon may function as keystone species responsible for nutrient cycling and the productivity of entire river systems and associated food chains, immediate action is required to protect remaining stocks and maintain healthy ecosystems.

2. **Degradation of eastside watersheds, including reduced biodiversity and declining fish productivity, is likely to continue if existing management programs for forestlands do not change.**

Because many eastside watersheds have already been degraded, they are primed for delayed responses to triggers such as floods, droughts, or mass soil movement. Even if new disturbances are prevented, many eastside watersheds will be slow to recover from the cumulative effects of past management activities. Declining supply of large wood may continue to affect habitat in streams long after logging has stopped; roads continue to contribute sediment to streams long after construction. Many stream and riparian systems with lowered water tables, unstable stream banks, and degraded channels will be slow to recover gallery forests, perennial flows, and satisfactory width-to-depth ratios. To the extent that additional logging, road building, and grazing in relatively unaltered watersheds delay downstream recovery or degrade new expanses of habitat, continuing incremental losses of aquatic populations can be expected. Cumulative habitat loss has become an even greater concern in recent years as logging and road building have moved into steep headwater areas more sensitive to disturbance and able to affect large areas downstream.

Implementation of present federal management plans for eastside forests means further degradation of habitat and water quality. These plans call for additional road mileage; widespread grazing in riparian systems; and logging in riparian zones, with consequent losses of woody debris. Forest plans propose more sediment deposition, which has already decimated pool habitat for native fish in many eastside watersheds (McIntosh et al. 1994). The management alternative selected in the Fremont Forest Plan, for example, presents the highest predicted sediment production and the "greatest risk of adversely impacting the fishery resource through degradation in water quality and creation of sediment instability, due to elevated sediment levels" (USFS 1989a: IV-18–19). It is unclear how the proposed mitigation for this risk—"increased riparian vegetation for shade and cover through intensive livestock management, selective timber harvest in riparian areas, and a moderate level of habitat improvement installation" (USFS 1989a: IV-73)—will compensate for more erosion and siltation. In fact, the plan predicts reduced habitat quality and a decline in bull trout populations that are already under review for possible listing as threatened or endangered. Likewise, existing management plans for forests within the range of the northern spotted owl have a minimal probability of satisfying the habitat needs of sensitive fish species and stocks (Johnson et al. 1991).

3. **Current performance standards and monitoring programs for livestock will not ensure that stream and riparian ecosystems will recover and maintain diverse assemblages of native fish.**

Degraded riparian conditions on federal, state, and private lands contribute significantly to fishery decline in eastside watersheds. Given the widespread impact of grazing throughout eastside forests, the time it may take to restore riparian vegetation and instream habitat, and the rapid decline among salmonids and other native species, further delay in riparian restoration will be very costly to future fish diversity and productivity. Unfortunately, the relationship between current forage standards for livestock and the recovery of riparian and stream ecosystems and fish productivity is not clear.

Recovery of stream and riparian systems requires reestablishment of shrubs and trees such as alder, cottonwood, and willow. Standard forage-use criteria used to manage livestock grazing may be incompatible with this goal. According to a USFS monitoring report for Malheur National Forest, forage-use criteria after the 1991 grazing season were met in most upland sites but exceeded in most riparian areas (forage use was greater than 70%; USFS 1991b). In this case, USFS established an interim 45% forage standard to limit grazing in riparian systems until site-specific standards could be set in revised allotment management plans (AMPs).

Trying to set standards raises many questions about their ecological significance. Assuming that a new 45% standard could be met, what would be the response rate for different types of riparian communities and stream systems throughout the forest? What are the recovery rates for stream channels, stream banks, or water quality at various use levels, and how do these rates compare with those that might be expected from excluding livestock altogether? Forage standards simply do not provide a useful ecological measure of the compatibility between grazing activity and fish production. For example, shearing and tearing of banks by livestock can be a major source of sediment to streams, and this process is independent of the productivity of meadows and rangelands for livestock (Burton et al. 1993). In short, we are aware of no data to indicate that a 45% forage standard either maintains or improves riparian and stream conditions for aquatic resources.

Evaluation of forage standards becomes even more difficult without adequate baseline data for existing riparian conditions throughout a forest. Again for Malheur National Forest, "No data evaluation has been completed to assess the condition of riparian vegetation" (USFS 1991b). Furthermore, despite the interim 45% forage standard, AMP revision seems to be delayed indefinitely (John E. Lowe, regional forester, 7 January 1993 letter to Stan Grace, chairman, Northwest Power Planning Council). Ochoco, Malheur, Umatilla, and Wallowa-Whitman National Forests administer a total of 383 grazing allotments. Although 109, or 28%, of these allotments were scheduled for updated management plans by 1993, we are aware of only 4 that have been completed to date (Jon Rhodes, Columbia River Intertribal Fish Commission, personal communication). If assessments of riparian condition in national forests are inadequate, if the rates of response of different stream systems and fish habitat to current use standards are variable but unknown, and if revised AMPs applying state-of-the-art grazing strategies appropriate for local conditions have not and will not be completed anytime soon, then the compatibility between current livestock management programs and the restoration and protection of the large numbers of fish stocks and species at risk of extinction remains in serious doubt.

4. **Widespread construction of in-channel structures to enhance fish habitat does not help stream restoration or substitute for sound conservation management of eastside watersheds and their associated riparian and stream systems.**

   Considerable emphasis continues to go toward structural solutions to fish habitat decline that in many areas might be solved more effectively through recovery of functional riparian and stream systems. In 1991, Malheur National Forest, for example, reported completion of 58, and plans for another 300, structures to improve anadromous fish habitat; another 127 structures were completed, and 50 more were planned to improve habitat for resident fish (USFS 1991a). In Idaho, in contrast, Keller et al. (1979) reported that rest from grazing obviated the need for artificial structures intended to enhance trout populations. In Oregon's John Day and Grande Ronde River basins, Beschta et al. (1991) noted that habitat structures may actually conflict with the creation of salmonid habitat coming from the interaction of streams with their riparian and floodplain systems. Frissell and Nawa (1992) concluded that structural solutions in the Pacific Northwest are not appropriate in streams with high sediment levels, high peak flows, or highly erodible banks.

   The lack of any demonstrated effectiveness for most structural modifications, high costs, questionable fishery benefits, and reports of adverse impacts on some stream and riparian systems call into question the current emphasis on structural mitigation for continued habitat loss. Instream structures do nothing to ameliorate high stream temperatures or sediment loads—two of the most important causes of fish habitat decline in eastside forests and watersheds. Furthermore, funding of instream habitat projects from timber receipts and an apparent "quota" of structures without careful watershed-level planning and analysis are counterproductive to sound conservation of aquatic ecosystems.

   Structures may be justified in some specific cases, but improved riparian management seems a far more effective and cost-efficient solution for restoring and protecting fish habitat. We conclude that protecting available sources of large wood to streams, restoring floodplain-stream interactions, recovering late seral riparian vegetation, and reducing sediment delivery to streams caused by upland and streamside land uses offer far better strategies for the long-term recovery of fish habitat in Eastside watersheds.

5. **Managers in each national forest should (1) devise broad strategies to maintain future options and minimize the ecological risks of their management programs, (2) establish specific standards and performance measures that allow adequate margins of safety under extreme**

environmental conditions, and (3) ensure that decisions do not adversely affect native species by altering natural stream processes.

The degraded condition of many eastside watersheds, delayed response of stream systems to many forest management activities, and inability of science to precisely forecast the synergistic effects of multiple landscape-level changes argue in favor of a prudent approach to land-use management—one that protects future options. The consequences of incorrectly assuming that disturbance will have no impact are plainly visible in the long lists of native fish species (Williams et al. 1989) and stocks (Nehlsen et al. 1991) now at risk or already extinct in the region. The burden of proof must shift to those planning specific land uses to demonstrate that their activities will *not* adversely affect conditions necessary to support diverse aquatic assemblages.

Such a shift will necessarily require more explicit attention to those conditions and processes responsible for the evolution and adaptations of diverse native species and assemblages. Management should maintain habitat conditions and processes like those found in unmanaged (protected) forests, including natural basin hydrology and input of sediment and large woody debris. Such a shift in focus does not necessarily mean that all landscape disturbance must cease. It does mean that landscape effects should be managed in a manner compatible with natural stream processes. To avoid causing further extinctions of native aquatic species, forest management will need to promote real recovery of degraded watershed systems and not simply slow the rate of further decline.

The listing of chinook salmon stocks as threatened or endangered has begun to shift the burden of proof in a few eastside watersheds, as illustrated by established standards in the Upper Grande Ronde restoration plan (Anderson et al. 1992). To prevent additional listings of aquatic species under the Endangered Species Act, ecologically based measures like these are needed throughout the region. New federal listings will ultimately force a change in the burden of proof—but at a cost of considerable management flexibility and little likelihood of saving severely depressed fish populations. Forest managers should implement adequate protection and restoration measures before listing of threatened and endangered species becomes the only remaining alternative.

Forecasting the precise cumulative influences of timber harvest, livestock grazing (Bauer and Burton 1993), and road building on a watershed or its biota is at best difficult. Actions having little or no effect in one circumstance may become more serious in another. The legacies of history substantially influence a system's response to additional natural or human-induced change. Management strategies should therefore minimize the risks of large-scale and potentially irreversible effects that science may be incapable of predicting in advance (Bella and Overton 1972).

Such an approach means building uncertainty into management by directing the intensities and patterns of management across the landscape in ways that keep options open for the future, place local actions in a regional context, and maintain physical and biological heterogeneity (Holling 1973). It is inconsistent with prudent management of ecological risks, for example, to convert large proportions of all watersheds and ecosystems to a similar level of disturbance. Appropriating more and more of the landscape to logging, road building, and grazing without sufficient recovery of previously altered watersheds guarantees continued incremental loss of habitat. Prudent management of risks will become all the more critical in the future if predictions of global climate change prove accurate.

Many current forest management standards and performance measures assume average or benign environmental conditions. Such criteria are unsatisfactory for minimizing risks to highly volatile eastside ecosystems, let alone for supporting their recovery. Allotment management plans for livestock, for example, target "average" years. Yet all riparian recovery made during good conditions can be lost during a single drought. Current streamside buffer requirements leave a minimum width of trees to shade fish-bearing streams with the least sacrifice to harvest. Such standards make no allowance for important functions of riparian and floodplain systems besides temperature control or for the increased risk of blow-down of narrow buffers during high winds, the role of riparian systems of non-fish-bearing streams in regulating downstream processes and water quality, or the importance of complex floodplains as refugia during floods.

Crises determine survival of individual gene pools of locally adapted salmonid stocks (Thompson 1965). Protection standards and performance measures for eastside forests should be designed (1) to maintain or restore the buffering capacity of freshwater systems, which allows them to absorb extreme environmental events (e.g., drought, flood, ice, catastrophic fire, landslides, and so on), and (2) to adequately protect small populations of locally adapted fish stocks, which are the fundamental units of conservation for entire species (Rich 1939; Nehlsen et al. 1991). Such standards require an adequate monitoring program to evaluate management performance under long-term (e.g., decadal and longer) as well as short-term (e.g., seasonal) fluctuations in environmental conditions.

Classifying watersheds according to geomorphic, hydrologic, and climatic regimes is an important step in determining natural disturbance patterns, from which appropriate management strategies may be designed. The reconstruction of disturbance histories in managed and unmanaged landscapes can also indicate watershed conditions and processes that forest management should emulate (e.g., McIntosh 1992; McIntosh et al. 1994). Protection of relatively unaltered and representative examples of all watershed types is necessary to evaluate the effects and minimize the ecological risks of land-use activities. Such reference watersheds are needed to establish performance standards for managing similar types of systems, as benchmarks for comparing effects of management activities relative to undisturbed conditions, and to provide refuges for aquatic species in the event that management "experiments" fail despite the best information and intentions.

6. **A recovery strategy for aquatic ecosystems and faunal assemblages should be devised for the entire Eastside. Conservation of whole watersheds will be the most effective means of maintaining biological diversity and sustaining the aquatic ecosystems that furnish many critical services to society.**

   A recovery strategy for eastside aquatic ecosystems should begin by identifying and protecting the best remaining examples of the diversity of whole watersheds and river corridors. These priority areas constitute critical refugia for aquatic assemblages and the basic building blocks required to reconnect fragmented habitats, degraded riparian and floodplain systems, and disjunct fish populations across the eastside landscape. Oregon's aquatic diversity areas constitute a regional network of priority watersheds and corridors that could serve as the cornerstones for building an eastside restoration strategy (Oregon AFS 1993). Yet even many of these areas have been degraded and will require specific restorative actions to secure native fish assemblages within them. A similar process for identifying priority watersheds is also needed for Washington, Idaho, Montana, and northern California to design a restoration strategy representing the full diversity of ecosystems and assemblages across an entire biophysical region.

   Protection of priority watersheds is thus necessary but not sufficient to sustain the productivity and integrity of eastside river systems. Priority watersheds contain many of the remaining "seed sources" for recolonizing degraded habitats, but priority watersheds do not encompass the full habitat complement required to support native fish populations. Many ADAs occur in the upper portions of drainage basins and exclude historically productive but more severely degraded downstream reaches of large rivers. Conserving the diversity of highly migratory cold-water populations of salmon and bull trout, for example, may depend on restoration of mainstem river habitats that have been lost to production as a result of lethal stream temperatures, excessive sedimentation, habitat simplification, diversions for irrigation, and other factors. Of particular importance to any successful restoration will be reconnecting fragmented stream systems with their riparian forests, floodplains, and groundwater sources. Restoring late-seral riparian vegetation and removing unnecessary roads or other obstructions to the interaction of stream channels with floodplains should be critical components of any regional restoration strategy.

Because the distribution of many native fishes in Oregon's national forests has receded into steep headwater areas, USFS has a vital role in protecting the few remaining watershed refugia and preventing further damage to already degraded habitats downstream. Critical to securing eastside ADAs as aquatic refugia are the remaining roadless regions, sources of large wood from LS/OG forests, and the integrity of riparian corridors on national forestlands. Responsibility for protection and restoration, however, also crosses multiple ownership boundaries defined by drainage connections and the distribution and habitat requirements of diverse faunal groups. Restoration of aquatic ecosystems and associated fish assemblages must therefore involve a cooperative effort among all landowners and agencies responsible for the use of resources within an interconnected drainage basin. A regional strategy must identify these responsibilities and provide the means for coordinating restoration efforts both within and beyond the boundaries of priority watersheds.

No single restoration design may equally benefit all levels or scales of biological organization. A restoration plan intended to conserve genetic or life-history diversity among salmon stocks, for example, may not afford the best protection for rare endemic taxa or the diversity of entire fish assemblages. Evaluation of alternative conservation designs will be required to understand ecological trade-offs and to choose an approach that offers the most complete range of biodiversity protection. Oregon's network of ADAs provides a useful model for evaluating implications of a priority-watershed approach at different levels of biological organization and at basin and regional scales. As part of such an evaluation, known distributions of fish stocks, species, and assemblages and the condition of riparian and instream habitats should be mapped and compared with the ADA network in selected drainage basins. Information on the distribution and habitat requirements of aquatic fauna other than fish (e.g., invertebrates, amphibians, and others) should also be considered in the design of a regional restoration strategy. Interdisciplinary expertise from state and federal agencies, academia, professional scientific societies, or other appropriate groups will thus be needed to devise a comprehensive eastside restoration plan.

Chapter 7

TERRESTRIAL ECOLOGY: ELEMENTS AND PROCESSES

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For thousands of years, forests dominated the landscapes now encompassed by eastside national forests. During the past 50 years, human activities have altered those landscapes on unprecedented scales. Urbanization, logging, road building, agriculture, and grazing have all contributed to forest destruction and fragmentation, which now jeopardize local and regional populations of many species and influence processes ranging from soil generation to the seasonal migrations of large mammals. Threats to forest health from fire, pests, and disease have also increased. Unfortunately, knowledge of those changes is inadequate, and this inadequacy will continue indefinitely. As Forest Service Chief Jack Ward Thomas observed at the 1993 Northwest Forest Conference, "Ecosystems are not only more complex than we think; they are more complex than we *can* think."

Nevertheless, we know enough to improve management programs in ways that will permit harvest of valued commodities while protecting the forests and associated resources for future generations. This chapter summarizes knowledge about terrestrial—especially forest—systems in eastside national forests. We describe the condition of the forests as left by status-quo management and develop the foundations for many of our interim recommendations (Chapter 8).

ECOLOGICAL PATTERNS AND PROCESSES

Healthy landscapes depend on the integrity of complex ecological systems comprising the atmosphere, soil and associated minerals, water, and living things (biota). Biological systems consist of elements (species, genetic diversity, and species complexes) and the processes that generate and maintain them (mutation, recombination, competition, predation, coevolution, population demography, nutrient cycling, energy flow). Biological diversity (biodiversity) and ecological processes form the core of functioning landscapes.

BIOLOGICAL DIVERSITY

Biological diversity refers to "the variety and variability among living organisms and the ecological complexes in which they occur" (OTA 1987). The concept encompasses diversity among ecosystems, species, genes, and their relative abundances.

As elsewhere, the biodiversity of the landscapes east of the Cascades in Oregon and Washington goes beyond the "charismatic megafauna" that attracts media attention. It includes the whole array of life-forms, their ecological roles, and their genetic variety. This biological diversity is essential to the integrity of eastside ecosystems. It furnishes many products and other benefits to human society and is thus also essential to maintaining cultural systems. Much of the rich terrestrial flora and fauna of eastside landscapes inhabits forest and forest-associated ecosystems.

Declining diversity is a strong signal that the health and integrity of an ecological system are at risk. The loss of biodiversity in eastside forests is thus a manifestation of declining ecological health in the region. Such impoverishment of biological systems leads the way for secondary crises such as fire, disease, and pest outbreaks. Loss of biological diversity is explicitly correlated with—and may be the direct cause of—numerous environmental pathologies (Ehrlich 1988):

1. Loss of large trees alters patterns of gas exchange, especially for carbon dioxide, changing global climate patterns.
2. Loss of biological diversity threatens sustainable supplies of timber and other forest products.
3. Changes in local and regional biodiversity threaten water quality and reduce water quantity, especially when wetlands and forests are degraded or disappear.
4. When forested floodplains, riparian corridors, and wetlands are altered, flood risk increases, as does the frequency of low-flow periods.

5. Loss of the natural predators of pests decreases tree growth and the production of fiber and other forest products.
6. Soil and soil fertility are lost.
7. Animal populations become more unstable.
8. Beneficial insects that pollinate plants, disperse seeds, and control populations of other insects decline.
10. A well-stocked genetic library capable of providing the raw materials for food, fiber, and medicinal products is lost.

The best-documented eastside environmental pathology is the conspicuous devastation of salmonid populations (see Chapters 5 and 6), a decline that comes largely from degradation of *terrestrial* environments. The devastation of eastside forest environments is visible from ground surveys, aircraft, or the space shuttle. And, although not as visible or as well documented as declines in stream fishes, local loss of unique terrestrial populations is rampant.

In complex terrestrial environments, inconspicuous does not mean unimportant. Many fungi, for example, are symbiotic species that help woody plants obtain nutrients and water. They speed the decomposition of organic materials and serve as important foods for many invertebrates and vertebrates, including humans. Morel and matasuke, for example, are important to commercial and recreational collectors. Nevertheless, we understand very little about the distribution, abundance, or role of fungi in eastside ecosystems. Some species are known only from late-successional and old-growth forests. Amaranthus et al. (1994) document that 180-year-old forest patches of approximately nine acres acted as refugia for a significantly higher diversity and greater volume of hypogeous (truffles and trufflelike) fungi than grow in young forests.

Native arthropod diversity of eastside forests is also thought to be relatively rich, although, again, we have little concrete information. John Lattin (Department of Entomology, Oregon State University, personal communication, 1994) estimates that at least 10,000 species, many of them dependent on old growth, occupy forest habitats in Oregon and Washington. At least 6000 species are presumed to exist east of the Cascades, and at least another 4000 species occupy the Rocky Mountain region of Oregon and Washington (John Lattin, personal communication, 1994). Arthropods are likely to be seriously affected by the loss of LS/OG habitats.

Finally, the highly specialized interdependencies between relatively obscure fungi or insects and vascular plants are especially sensitive to the kinds of stresses imposed by human actions.

ECOLOGICAL PROCESSES

To a substantial extent, degradation in biological systems results from actions that disrupt complex interactions among species—for example, those between trees and soils; fungi and trees; plants, their pollinators, and seed dispersers; predators and their prey. Biological systems rely on the ability of their component organisms to capture energy from sunlight and to use that energy to fuel metabolic activities. The capture of energy through photosynthesis and its dissipation through food webs are cornerstone processes that create ecological structure at various spatial and temporal scales. This structure influences energy and nutrient fluxes, species demographies, and virtually all phases of the evolutionary process.

A complex of physical, chemical, and biological processes and their interactions maintains the integrity of ecological systems; in a natural state, these systems are relatively robust against stresses occurring over ecological and evolutionary time. But the ecological systems produced by evolutionary processes in response to natural stresses cannot contend with the kinds and frequency of stresses imposed by human actions. When "foreign" stresses push an ecosystem beyond certain limits, the change may be difficult (or impossible) to reverse (Perry et al. 1989).

ECOSYSTEM HEALTH AND INTEGRITY

A healthy system is one that retains both its component parts and the functional interactions among those parts (Karr and Dudley 1981; Rapport 1989; Karr 1991). As for an individual organism, the health of an ecological system is more than the absence of disease. Health also involves an ability to resist or recover quickly from both natural and human-induced stresses without assistance from humans.

Because ecological systems seldom have clear boundaries, ecological health spans entire landscapes. The structure of landscapes shapes processes (e.g., hydrology, propagation of disturbances) that influence the functional integrity of forest stands and streams. The integrity of streams also depends on the integrity of riparian forests and of upslope forests controlling sediment yields and other inputs. Individual species influence processes that maintain ecosystems and local and regional ecological health. Species, stands, streams, landscapes, and regions compose an interlinked system, a "unit" in which the health of the parts cannot be considered separately from the health of the whole.

Trees and other perennial plants, for example, divert a high proportion of their photosynthetic energy below ground, especially on sites that are dry, have infertile soils, or are otherwise environmentally harsh (e.g., at high elevation).

Energy transferred below ground promotes further photosynthesis; thus, minerals are weathered to release nutrients; nutrients are cycled through food webs consisting of microbes and invertebrates; mycorrhizal (root) fungi increase the nutrient- and water-gathering power of trees by several thousandfold; and trees create soil structure that facilitates a proper balance between soil water and soil oxygen. In essence, the trees and soils constitute a single dynamic system maintained by close positive feedback among the parts. Clearcutting forests on environmentally harsh sites can break these mutually reinforcing interactions and lead to ecosystem collapse, a phenomenon widespread at high elevations in the western United States (Perry et al. 1989).

Historically, eastside forests included biotic and abiotic agents—tree-eating insects, pathogens, and fire—that were normal parts of the system but that also had the potential to become destructive. In the past, destructive tendencies were tempered because the structure of ecosystems and landscapes, along with ecological relationships, served as an "ecological immune system" that damped and absorbed the spread of disturbances (Perry et al. 1989, 1991).

Two factors lie at the root of current health problems. One is large-scale conversion from a landscape dominated by old-growth pine to one dominated by younger forests with a large proportion of true firs and Douglas fir. These species are susceptible to insect outbreak because irruptive insects prefer them as food. Consequently, their predominance has effectively converted the regional landscape from one that damps and absorbs to one that magnifies disturbances (Perry 1988, 1991); it is also the principal reason that we recommend shifting the landscape back toward its historic dominance by large ponderosa pine.

The second cause of landscape health problems is foreign disturbances, i.e., stresses that have not been present historically and against which the system has not evolved effective defenses. Exotic insects and pathogens are obvious examples. Foreign stresses also include clearcutting (which does not mimic natural fire); removing coarse woody debris (which weakens the ecological immune system by reducing habitat for organisms that consume pests); logging with heavy equipment (which compacts soils, thereby diminishing ecosystem resilience); and disrupting the historic regime of frequent, gentle fires (a disruption that, along with logging, has been the major contributor to change in forest structure and landscape patterns).

Eastside forest health problems may be grouped into three interrelated categories: loss of habitat; vulnerability to insects, pathogens, fire, and drought; and soil degradation. The health of individual trees or populations of trees is distinct from—although a factor in—the overall health of the forest biota or ecosystem.

LOSS OF HABITAT

Loss of habitat refers to the alteration of the physical conditions or biotic community at a site to the extent that a given organism can no longer successfully survive or reproduce at that site. Each plant or animal has specific habitat requirements for securing the resources it needs to survive and reproduce at a level that maintains a local population. In eastside forests, for example, the pileated woodpecker *(Dryocopus pileatus)* relies on large snags for roosting, nesting, and foraging sites. Loss of large trees eliminates habitat for this species. Because the woodpecker builds cavities that are in turn used by many other species, species besides the woodpecker can also disappear from a site when snags are removed. Loss of habitat can thus threaten the persistence of timber resources when cavity-nesting birds that consume pest insects or disperse tree seeds disappear.

Wildlife populations respond to loss of habitat only after significant time lags. Although animals may persist in marginal habitat for a long time, their presence can mask failure to reproduce and survive at replacement rates and thus not give warning of their eventual disappearance until it is too late for them to recover. Therefore, loss of critical habitat components may not be recognized until long after habitat alteration triggers a chain of events that is difficult or impossible to reverse.

VULNERABILITY TO FIRE, INSECTS, PATHOGENS, AND DROUGHT

FIRE

Fire exclusion and early logging practices altered eastside forests so that their vulnerability to drought, insects, and catastrophic fire increased. Successful fire suppression often allows understory trees to grow too closely together; this dense growth then threatens older overstory trees in at least two ways:

1. The understory uses large amounts of water, stressing the overstory trees and making them more vulnerable to insects and other stresses.
2. The understory increases the risk that groundfires will carry into the crowns and thus damage mature trees.

Excluding groundfires—in tandem with forestry practices that convert extensive old growth to younger, more densely stocked stands—has increased the probability on the Eastside, as elsewhere, of a groundfire moving into crowns (Perry 1988). The risk of catastrophic crown fires in remaining old growth stands increases when those stands are embedded within a matrix of fire-susceptible stands. Since the late 1970s, the frequent occurrence of large, catastrophic wildfires in the Blue Mountains and elsewhere in the West suggests that attempts to suppress fire have altered the natural fire regime and its ecological consequences: instead of small, frequent groundfires, one now sees uncontrollable fires burning through dense undergrowth with abundant fuels (Mutch et al. 1993), making eastside forests far more vulnerable to massive crown fires.

INSECTS

Eastside forests contain numerous species of insects and pathogens that attack trees, a few of which undergo damaging population irruptions, or outbreaks. Eastide insects prone to outbreak include several species of bark beetles (*Dendroctonus* spp., especially those that attack ponderosa and lodgepole pines, such as *D. ponderosae* Hopk.), western spruce budworm (*Choristoneura occidentalis,* which attacks true firs and Douglas fir as well as spruce, *Picea* spp.), Douglas fir tussock moth (*Orgyia pseudotsugata* [McD.], which attacks true firs as well as Douglas fir), and larch casebearer (*Coleophora laricella* [Hbn.], which attacks western larch, *Larix occidentalis*). Except for larch casebearer, the most prevalent tree-eating insects in eastside forests are indigenous species that normally inhabit these forests and play beneficial as well as destructive roles in regional ecosystems. Spruce budworm, for example, may actually increase overall stand health by killing weaker trees (Alfaro et al. 1982).

Radical modification in the structure and composition of the eastside forest landscape during the twentieth century, however, affected natural pests, making them more aggressive and effective in their attacks on trees. Considerable evidence from throughout the interior West indicates that spruce budworm outbreaks during this century have been more frequent and widespread, lasted longer, and killed more trees than before (Anderson et al. 1987; Swetnam and Lynch 1989; Wickman et al., in press).

Spruce budworm success in the Northwest is due, in large part, to the spread of true firs and Douglas firs, which have become more abundant during the twentieth century for two reasons. First, early loggers took only ponderosa pine, leaving behind the less valuable firs; the area of commercial forestland dominated by ponderosa pine has shrunk during the twentieth century by 75–95% or more depending on locale (see Chapter 2). Second, the spread of firs was facilitated by fire exclusion.

As susceptible plants increase in abundance, pest populations grow faster and have greater impact. Faster population growth increases the likelihood that pests will escape from natural ecological controls (birds and predatory insects), a likelihood exacerbated when forest management practices reduce the extent and quality of optimal predator habitat, especially coarse woody debris (Torgersen et al. 1990).

Larvae of spruce budworm and tussock moth are dispersed largely by wind currents. Larval survival, hence the rate at which an infestation spreads, depends partly on how many dispersing larvae land on suitable hosts. The relative proportion of suitable host and nonhost tree species across the landscape thus plays a major role in larval success (Perry 1988). When trees that support these defoliators (Douglas fir and true firs) existed as mountaintop forest islands surrounded by a sea of nonhost ponderosa pine at middle and low elevations, defoliator dispersal was restricted. Today's more continuous distribution of firs, in contrast, facilitates the spread of these insects. Abnormally high density in some stands because of fire exclusion also stresses trees, further reducing their ability to resist insect and pathogen attacks.

In 1986, the peak of the most recent spruce budworm infestation, 5.5 million acres—nearly two-thirds of all forestland in eastern Oregon—were affected (Oregon Department of Forestry 1992). The area of active infestation has since declined, to 2 million acres in 1992. Estimates in spring 1993 indicated that budworm populations were crashing in the remaining infestation centers. This decline should not create a false sense of security, however, for budworm numbers also dropped before the most recent infestation only to go up again.

We do not know what effect frequent infestations of tree defoliators will have on forest ecosystem health or on tree populations. Many low- and mid-elevation forests attacked by defoliators over the past several decades existed in vastly modified landscapes and forest stands. Historically, these stands did not contain large numbers of trees susceptible to these pest insects. In some cases, recent infestations tend to restore forests to their original tree composition, i.e., a predominance of ponderosa pine (at least where some pine have survived logging). But large numbers of dead and dying trees also create a much greater fire hazard than historically, and this situation may obstruct natural succession and recovery to the more resilient forest conditions predating human influence.

PATHOGENS

Several species of potentially pathogenic organisms, such as stem-decay and root-rotting fungi, are widespread in eastside forests. The effect of pathogens on forest health is likewise affected by tree species composition and stand structure.

Stem-decay fungi in true firs are important to cavity-nesting birds because they soften heartwood and thereby facilitate excavation of living trees and the creation of habitat (Bull et al. 1992). The "witch-broom" structures formed by dwarf mistletoe infections are used by nesting long-eared owls (*Asio otus*) (Bull et al. 1989) and for shelter by other species, such as porcupine *(Erithizon* *dorsatum).* Root rots (*Armillaria* spp.) create patchiness that diversifies plant species composition. Incidence of root rot may also have grown because of the spread and increased abundance of true firs and Douglas fir.

DROUGHT

Forests in eastern Oregon and Washington occupy much drier environments than those west of the Cascade crest, especially at the low and middle elevations once dominated by ponderosa pine. Historically, episodes of severe drought stress in trees were probably rare because frequent small fires maintained open, parklike stands, lowering the overall forest demand for water. Fire exclusion has led to stands more densely stocked with trees and shrubs, increasing drought stress and the susceptibility of individual trees to insects (Larsson et al. 1983) and of forests to fire.

Furthermore, firs tolerate drought less well than ponderosa pine; firs are particularly susceptible to drought stress at the lower elevations where they have become common after logging and fire exclusion. Abnormally low precipitation during the 1980s probably also contributed to the most recent spruce budworm infestation. The high potential for widespread infestations of budworm, tussock moth, and *Armillaria* will remain as long as current forest conditions persist; infestation potential worsens during drought.

SOIL DEGRADATION

Trees play an important role in creating and maintaining healthy soils, particularly at high- and low-elevation limits of forest cover and where soils are poorly formed (e.g., lava flows). Breaking the link between trees and soils on these sites can lead to rapid degradation that is difficult to reverse (Perry et al. 1989).

We do not have enough information to understand clearly how much of a problem soil degradation poses in eastside forests. Impacts on soils are seldom as dramatic and obvious as insect defoliation. Moreover, conspicuous effects of soil degradation may occur several years after actual damage is inflicted. Nevertheless, several detrimental impacts of soil loss have been well documented. The common practice of using heavy equipment for harvesting and preparing stands for harvest on relatively flat ground compacts soils and reduces fertility (Perry et al. 1982; Childs et al. 1989; Geist et al. 1989; Harvey et al. 1989; Powers 1989), severely degrading a site's productive potential. The practice should be abandoned immediately.

Soil organic matter, a critical determinant of water-holding capacity, fertility, and ecosystem resilience (Meurisse et al. 1991), is concentrated in the surface layers of most eastside forest soils. Surface soils are especially vulnerable to loss during harvest and site preparation and by erosion after harvest (Harvey et al. 1989). Soil organic matter can probably be protected during harvest, but past forestry practices too often ignored it and other aspects of soil fertility. Protecting soil should become a high priority in new management regimes for eastside forests.

Soil protection on steep slopes, especially those steeper than 30%, is particularly critical (Harvey et al. 1989; R. T. Meurisse, USFS Region 6, personal communication, 1993). Except to improve forest health, logging should therefore be limited or prohibited on slopes steeper than 30% on pumice soils and 60% on other soils. Logging on slopes between 30% and 60% should retain 40% of maximum basal area, with at least one-half of this area in trees larger than the prelogging quadratic mean diameter. Risk of erosion makes any logging or road building unacceptable in aquatic diversity areas.

Soils vary widely in their erosion potential, limiting the value of generalizations; site-specific determinations are most important. On pumice soils, clearcutting on slopes steeper than 30% can cause significant erosion. Partial harvesting may protect soils on slopes between 30% and 60%, but such an assumption needs to be evaluated case by case. The burden of proof should rest with harvesters to demonstrate that harvest will have no impact. Ground disturbance on slopes steeper than 60% is likely to cause unacceptable levels of soil loss. (Stands on 60% or steeper slopes that are at risk of catastrophic fire loss may be carefully thinned from below.)

Forest Regeneration

Compared with forests west of the Cascade crest, many eastside forests grow on sites marginal for tree growth. For example, 179,000 acres of LS/OG open to logging in the Bend ranger district of Deschutes National Forest are on lava fields; successful regeneration of forests on such marginal sites is unlikely.

Low-elevation forests frequently grow in zones that are transitional to grasslands or desert shrublands. Mature trees probably succeeded in these areas only during periods of unusually favorable moisture; they persist because they devote large amounts of energy to maintaining soil structure and populations of beneficial soil organisms and can survive low-intensity groundfires (Perry 1988; Perry et al. 1989). Breaking the links between mature trees and soils by cutting too many trees risks the long-term loss of forest cover on these sites. Similar risks exist in many high-elevation forests, which, throughout the western United

States, have been notoriously difficult to regenerate after clearcutting (Perry et al. 1989).

The widespread growth of noxious weeds on western range- and forestlands heightens the risk of site degradation on marginal sites if mature tree cover is not maintained. Should climate change play out as predicted, the resulting drier and hotter weather will compound the problem.

With proper silvicultural techniques, soils can probably be protected and new seedlings regenerated on some sites. Our point is that any logging plan should carry the burden of proof that silvicultural techniques are sustainable.

VERTEBRATE RESOURCES

A detailed account of the status and trends in vertebrates other than salmonid fish is difficult because data on terrestrial vertebrates are relatively limited. Existing information is scattered in a wide variety of databases, publications, and unpublished reports. Limited time and money precluded our reviewing those data comprehensively. Furthermore, much existing information has not been computerized (e.g., USFWS breeding bird survey data), although systematic efforts are under way to map woodpecker abundance in Oregon (E. O. Garton and colleagues, Wildlife and Forestry Sciences, University of Idaho, Moscow, personal communication, 1993). Richard E. Johnson and others (Department of Zoology, Washington State University, Pullman) are developing detailed distribution maps of mammals in Washington based on existing specimen data, and David A. Manuwal and colleagues (College of Forest Resources, University of Washington, Seattle) are developing current bird distribution maps for Washington from ongoing survey work. We have not had access to results of these studies.

Nonetheless, existing published accounts on wildlife resources suggest disturbing trends that parallel our findings on salmonids. Many conspicuous species seem to be declining, but the lack of historical data makes the severity of these declines difficult to ascertain. What do declines in conspicuous species say about the entire assemblages of organisms in these habitats? The declining abundance and diversity of vertebrate resources provide a coarse measure of deteriorating ecological health in the eastside forests of Oregon and Washington and the ability of those forests to continue servicing human society.

OLD-GROWTH-ASSOCIATED VERTEBRATES

Many vertebrate species depend on late-successional old growth. Although some of these are useful as indicators of the overall status and trends in terrestrial wildlife resources, an indicator-species framework is inadequate for achieving the broad goal of protecting ecological integrity (Karr 1987; Morrison and Marcot, in press). Too often, the indicator concept translates into management narrowly focused on a single species or single resource. Once a taxon like the spotted owl *(Strix occidentalis)* is dubbed an "indicator," management activities can ignore other critical associated species, ecological interactions, and other resources (Landres et al. 1988).

Ultimately, management programs must be grounded in a broader context than single species. They should be designed to maintain and restore the elements and processes within landscapes. Nevertheless, a fundamental reality of landscape management is that not all system components can be tracked effectively. Therefore, because of their size, sensitivity to human disturbance, relative ease of monitoring, and appeal to the public, vertebrates will be critical in final management programs. Managing for and conserving suites of interacting species associated with LS/OG habitats should form an early strategy, one that should help conserve many additional organisms and biological processes.

SENSITIVE SPECIES

Species vary in their sensitivity to human actions; conservation programs should give early attention to species vulnerable to extinction. We considered species that may be extinction-prone (Table 7.1) or are reported to have affinities to LS/OG forest (Table 7.2). Many of these species are important because they belong in one of the critical management categories identified by Soulé and Kohm (1989):

1. Keystone species, which directly and indirectly influence the abundance or distribution of other organisms or play a critical role in maintaining biological processes.
2. Indicator species, which, by changes in their abundance or distribution, signal changes in habitat or management activities.
3. Mobile-link species, which constitute important functional components of more than one food chain, plant-animal association, or ecosystem.

We included several woodpeckers in our preliminary list of significant old-growth species because they are primary cavity excavators, whose nesting behavior substantially influences populations of secondary cavity users (Raphael and White 1984); woodpeckers are thus important keystone species. Several raptors are also on our list because they are sensitive to habitat change, occupy the top of the trophic web, and are wide-ranging (Bednarz et al. 1990).

Table 7.1 Some characteristics of extinction-prone species (adapted from Perry 1994).

Top predators (vertebrates)

Their position in food webs means that these animals have low population densities and large territories, making them especially vulnerable to reductions in habitat. This group includes eagles, goshawks *(Accipiter gentilis)*, spotted owls *(Strix occidentalis)*, wolves *(Canis lupus)*, and mountain lions *(Felis concolor)*.

Species with specialized habitat requirements

The weedy species that frequently thrive around humans are hardly threatened in today's world, but many species that depend on old-growth forests, riparian zones, wetlands, big deadwood, and other special habitats are.

Species that disperse poorly

These species are at risk when their populations become isolated and fragmented. Gene flow is reduced, and loss of local populations (local extinctions) may not be offset by new colonizers. Poor dispersers will face a greater disadvantage if climate change plays out as predicted. Dispersal of a given species depends not only on its intrinsic ability to cover distance but on the characteristics of the landscapes through which it must disperse. Even very mobile species may not move successfully across unsuitable landscapes or those where they are vulnerable to predators.

Migratory species

As Terborgh (1974) puts it, "Migratory species are exposed to double jeopardy because they are subject to the pressures of change at both ends of their routes and may have to run a gauntlet of polluted waters and altered landscapes on the way." Migratory songbirds offer one of the better examples. Neotropical migrants winter in Central American forests, which are being rapidly cut down. Those that summer in western North America migrate through deserts and grasslands along riparian forests, at least some of which are threatened by overgrazing and falling water tables (because of heavy water use by sprawling suburbs).

Species with a low intrinsic rate of population growth

Low reproductive rates limit a species' ability to rebound quickly once its numbers are reduced. This category includes most, if not all, large animals and top predators.

Species sought by humans for meat, trophies, or other commodities

This group is vulnerable to overhunting.

Endemics

Such species have very restricted ranges, even though they may be locally abundant.

Species with low genetic variability

These species are particularly vulnerable to inbreeding; they possess little buffering power against environmental change.

Table 7.2 Preliminary list of old-growth-associated species that should be considered in the development of interim conservation and management guidelines for eastside forests.

Common name	Scientific name
Birds	
Bald eagle	*Haliaetus leucocephalus*
Northern goshawk	*Accipiter gentilis*
Flammulated owl	*Otus flammeolus*
Spotted owl	*Strix occidentalis*
Boreal owl	*Aegolius funereus*
Vaux's swift	*Chaetura vauxi*
White-headed woodpecker	*Picoides albolarvatus*
Three-toed woodpecker	*Picoides tridactylus*
Black-backed woodpecker	*Picoides arcticus*
Pileated woodpecker	*Dryocopus pileatus*
Red-breasted nuthatch	*Sitta canadensis*
Pygmy nuthatch	*Sitta pygmaea*
Brown creeper	*Certhia americana*
Golden-crowned kinglet	*Regulus satrapa*
Swainson's thrush	*Catharus ustulatus*
Hermit thrush	*Catharus guttatus*
Townsend's warbler	*Dendroica townsendi*
Mammals	
Pine marten	*Martes americana*
Fisher	*Martes pennanti*

Bald eagles, on the federal endangered species list for years, were once common in northwestern forests. Eagles use old-growth habitats that are close (less than two miles) to substantial fishery resources (Anthony et al. 1982; Frank Isaacs, Oregon Cooperative Wildlife Research Unit, Oregon State University, personal communication, 1993). Bald eagles in eastern Oregon and Washington require massive trees to support their nests; they often select ancient, partially dead ponderosa pine trees for nest sites (Lehman et al. 1980). Large trees with well-spaced branches provide suitable support and access for nesting, perching, and roosting; areas with many large trees, multilayered canopies, or LS/OG forests are therefore prime sites (Lehman et al. 1980; Bangs et al. 1982). Full recovery of Northwest bald eagle populations requires restoration of eastside forests, including extensive stands of LS/OG with mature ponderosa pines.

WOODPECKERS, CAVITIES, INSECT PESTS, AND DEADWOOD

Several LS/OG associates depend on tree cavities, including flammulated owls *(Otus flammeolus),* spotted owls, boreal owls *(Aegolius funereus),* Vaux's swifts *(Chaetura vauxi),* white-headed woodpeckers *(Picoides albolarvatus,* three-toed woodpeckers *(P. tridactylus),* black-backed woodpeckers *(P. arcticus),* pileated woodpeckers, red-breasted nuthatches *(Sitta canadensis),* pygmy nuthatches *(S. pygmaea),* and brown creepers *(Certhia americana)* (see Table 7.2).

Interactions among cavity nesters may be complex. Pileated woodpeckers depend on large snags for nesting and roosting (Bull et al. 1992). Within eastside forests, pileated woodpeckers seem to be closely tied to old grand fir *(Abies grandis)* stands with trees in advanced decay caused by the Indian paint fungus *(Echinodontium tinctorium)* (Bull at al. 1992; Bull and Holthausen 1993), a keystone organism that softens core wood. The woodpeckers in turn provide other keystone services by excavating nesting and shelter cavities in infected core wood, and these are eventually used by many birds and mammals (Thomas et al. 1979a).

Vaux's swifts, for example, are found significantly more often in old-growth stands than in logged stands, very likely because of the greater availability of suitable nesting trees in old growth (Bull and Hohmann 1993). All 21 Vaux's swift nests located by Bull and Cooper (1991) were found in cavities of grand fir trees excavated by pileated woodpeckers. Although Vaux's swifts are known to nest in chimneys and other structures, at least in small numbers (Baldwin and Zackowski 1963), much of the swift population may rely on interactions among large grand fir, Indian paint fungus, and pileated woodpeckers for access to suitable nesting habitat. If these interactions are disrupted, as they are when LS/OG is eliminated, a Vaux's swift population may collapse. Because Vaux's swifts feed exclusively on insects, their loss, along with significant reductions in populations of other insectivorous birds, could influence populations of injurious forest insects.

Pileated woodpeckers need fallen decaying logs, standing snags, and large stumps for foraging (Bull and Holthausen 1993). Other LS/OG-associated species—white-headed woodpeckers, three-toed woodpeckers, black-backed woodpeckers, and brown creepers (Franzreb 1985; Goggans et al. 1989; Adams and Morrison 1993)—depend on abundant large-diameter trees for foraging. Creepers require tiny cavities for nesting and shelter, which can be provided by small dead or dying trees. For foraging, however, large snags are important because they have more surface area per tree than small snags; creepers can forage longer on one tree instead of consuming energy flying from tree to tree (Franzreb 1985). Lowering the density of large snags in natural LS/OG can thus have significant consequences for populations of avian insectivores.

Black-backed and three-toed woodpeckers depend heavily on recently dead lodgepole pine trees *(Pinus contorta)* for foraging on wood-boring insects, especially the larvae of mountain pine beetles *(Dendroctonus ponderosae)* (Goggans et al. 1989). Wood in trees that have been dead for a long time dries out; wood-boring insects leave these older snags, which are then unsuitable for woodpecker foraging. Black-backed and three-toed woodpeckers therefore require a continuous supply of dead and dying trees. Such foraging needs cannot be adequately filled by maintaining a few snags in highly managed forests; they require the dynamic processes of tree growth and mortality occurring within LS/OG habitats.

Viable populations of black-backed and three-toed woodpeckers may be particularly important to forest ecosystems because they respond opportunistically to outbreaks of damaging forest insects. When wood-boring insects increase in numbers in an area, both black-backed and three-toed woodpeckers move in to feed. During insect epidemics, woodpecker densities may increase from 1 bird per 100 acres to more than 68 birds per 100 acres (Amman and Baldwin 1960). The response of woodpeckers to insect epidemics is both numerical (woodpeckers migrate into the infested area) and functional (they switch to feeding nearly exclusively on the insects causing the epidemic). If the outbreak lasts a long time, woodpecker species breed very successfully, and their offspring add to total predator numbers. Woodpeckers can consume as much as 84% of a damaging beetle population during an outbreak (Koplin 1972). Indirect effects of woodpecker activity on insect survival include removal of bark from infested trees, which enhances survival of beetle parasites and also desiccates many pest larvae and kills them (Otvos 1965).

The predatory impact of woodpeckers on pest insects is only part of the total predatory impact of the entire avian community. Many bird species continually feed on insect populations, and many depend on woodpeckers to construct the cavities they use. Therefore, maintenance of natural densities of woodpeckers may be crucial to the natural ecological response systems to insect irruptions.

Work in Australia has shown that diffuse bird predation can effectively control an insect pest (Homoptera; Psyllidae) (Loyn et al. 1983). Specifically, psyllids (*Glycaspos* spp.) caused severe defoliation and diebacks in eucalyptus trees (*Eucalyptus* spp.) within territories where bell miners *(Manorina melanophrys)*, a territorial group-living bird, chased out most other insectivorous birds. When the bell miners were removed, small flocks of insectivorous birds invaded the infested area and began eating large quantities of psyllids, causing insect populations to decline. The eucalyptus trees recovered within four months.

Although further research is required to quantify the influence of collective foraging by insectivorous birds in eastside forest ecosystems, we do know that insectivorous bird and ant populations consume significant numbers of the two most important defoliating insect pests in the Northwest: Douglas fir tussock moth and western spruce budworm (Torgerson et al. 1990). Bird predation alone on tussock moth larvae can reduce egg survival by 43–71%. In one study, survival of spruce budworm was nearly four times higher (49% compared with 13%) on tree branches from which both birds and ants had been excluded (Torgersen et al. 1990). Two sensitive LS/OG associates, red-breasted nuthatches and golden-crowned kinglets (*Regulus satrapa;* Table 7.2), were also among the most significant predators on tussock moth and spruce budworm (Torgerson et al. 1990). Most ants and many birds that prey on these pests are influenced by the availability of standing and downed deadwood.

A few scattered snags retained by forest management are not sufficient to provide nesting and roosting habitat into the future (McCelland et al. 1979; Mannan et al. 1980; Raphael and White 1984; Bull and Cooper 1991). Snags and logs in harvested areas and logs in streams remain only a finite time; the next generation of snags and large woody debris—in other words, live old trees—must be protected. Saving the remaining old-growth is thus a critical first step in conserving old-growth-dependent species, but preservation must be supplemented with plans for generating future old growth.

Forest management that preserves selected snags does not adequately meet the foraging needs of LS/OG-associated species. Eliminating foraging habitat by extensive salvaging or selective cutting will have adverse consequences for pileated woodpeckers and the other forest species dependent on cavities excavated by woodpeckers. Continual recruitment of standing and downed coarse woody material is absolutely necessary to support the diversity of organisms, including fungi and insects, that in turn provide a productive forest system for woodpeckers and other sensitive wildlife species.

Elimination of deadwood from the forest thus has adverse consequences on bird populations (Thomas et al. 1979a; Mannan et al. 1980; Balda et al. 1983; Mannan and Meslow 1984; Raphael and White 1984) and seriously skews natural predator-prey relationships that may have a major influence on insect populations.

Loss of LS/OG Affects Many Wildlife Species

Elimination of LS/OG in eastside forests affects many species (see Table 7.2) and the diverse values they offer human society. Many common forest birds found in younger stages of forest rely on LS/OG at certain times in their life histories (Manuwal and Huff 1987), especially during winter. LS/OG provides shelter in deadwood and snag habitat and, in some cases, in thick ground cover not available in younger forest. Winter foods are more abundant and more stable in LS/OG because of a diverse conifer flora, including the shade-tolerant western hemlock *(Tsuga heterophylla)* and its annual seed crop. Because single-species or low-diversity stands of conifers may produce cone crops cyclically, resident bird populations may be severely reduced during years of low cone production. Elimination of mixed-species LS/OG in the Washington Cascades could reduce quality winter habitat for many birds that use younger forests and consume large quantities of defoliating insects during the growing season (Knight 1958; Shook and Baldwin 1970; Holmes 1990; Torgersen et al. 1990).

Among mammals that do not depend exclusively on LS/OG habitat, some require access to old growth; the distribution of others is correlated with its presence. The wolverine *(Gulo luscus)*, a candidate for listing under the Endangered Species Act and classified as threatened in Oregon and as a "protected species" in Washington, prefers mature or intermediate-aged stands in Montana because of abundant food (Hornocker and Hash 1981).

The lynx *(Lynx canadensis)* is also a candidate for listing under the Endangered Species Act, and the Washington Department of Fish and Wildlife (1993) recommends threatened status in Washington. Lynx are associated with isolated spruce, subalpine fir *(Abies amabilis)*, and lodgepole pine *(Pinus contorta)* forests of mixed ages; they require mature forest (older than 200 years) for denning (Koehler and Bittel 1990).

Populations of many small mammals seem to be greatest in LS/OG forests (Corn and Bury 1991; Ruggerio-Aubry 1991; West 1991). Rosenberg and Anthony (1993) found that old-growth Douglas fir forests in western Oregon supported higher densities of chipmunks *(Eutamius townsendii)* than second-growth forests. Chipmunk density increased with density of large snags in old-growth forests; old-growth forest seems to support more stable chipmunk populations, which provide abundant food for predators.

Old-growth forest supports higher populations of Douglas's squirrel *(Tamisciurus douglasii)* than do younger forests (Buchanan et al. 1990b). When cone crops are low, local extinction may occur in poor habitats, especially younger forest stands. Residual populations in old-growth forest then serve as a source for recolonization of surrounding areas. Buchanan et al. (1990b) recommend several harvest prescriptions to improve habitat quality for squirrels in managed forests: (1) retain green trees to ensure continued production of cones, (2) plant mixed species to provide alternative seed sources, and (3) design harvests to produce multilayered canopies.

Finally, preliminary data from an ongoing study of black bears *(Ursus americanus)* in Wallowa-Whitman National Forest suggest that certain age and sex classes select large-diameter (> 40 in. DBH) standing trees for winter den sites (Mark G. Henjum, personal observation, 1994). These large remnant old-growth trees offer excellent protection from winter weather and predators (Henjum and Akenson 1994).

ROADLESS REGIONS AND RIPARIAN ZONES

Several wildlife species tend to move out of forest habitats when roads are constructed. These include the endangered gray wolf *(Canis lupus)* (Mech 1970; Jensen et al. 1986), Rocky Mountain elk *(Cervus canadensis)* (Lyon and Ward 1982), and wolverine (Hornocker and Hash 1981). These species are absent from areas with many roads. Although wolf, elk, and wolverine do not require LS/OG, they are often present in roadless areas and where some LS/OG habitat persists. Loss of these vertebrates from regional landscapes disrupts ecological systems and limits their value.

To conserve complete arrays of species and associated ecological interactions, management schemes must consider the density of roads. Road densities greater than 1 mi/mi^2 are considered detrimental to wolf and elk populations (Jensen et al. 1986). Wolf pup survival rates indicate that wolves may tolerate road densities higher than 1 mi/mi^2 if extensive roadless regions exist adjacent to wolf territories (Mech 1989). But road densities within much of eastside forests exceed 2.5 mi/mi^2 (e.g., Colville and Winema National Forests), and remaining roadless regions are quickly disappearing. Protection of terrestrial vertebrates, as well as fisheries resources, requires a moratorium on road building plus efforts to remove existing roads.

Protection of riparian areas and riparian vegetation is clearly critical to maintain a productive fishery and a reliable supply of clean fresh water (see Chapters 5 and 6). But sampling in a variety of habitats and regions clearly indicates that riparian zones are crucial to the conservation of terrestrial resources as well (Thomas et al. 1979b; Brooks et al. 1991; Ohmart 1994). Bird populations in riparian areas are more dense and species rich than in surrounding nonriparian habitats. "Best management practices" that maintain riparian buffer zones and minimize sedimentation sustain regional avifaunas (Triquet et al. 1990). Riparian zones also merit strict protection because they provide corridors for movement between patches of suitable habitat for many LS/OG-associated species.

WILDLIFE POPULATIONS AND HABITAT FRAGMENTATION

WHAT IS A VIABLE POPULATION?

A viable population is one containing the number of individuals "that will ensure (at some acceptable level of risk) that [the] population will exist in a viable state for a given interval of time" (Gilpin and Soulé 1986). Populations that drop below a minimum size are sucked into what Gilpin and Soulé call an extinction vortex: their disappearance is certain unless extraordinary measures are taken. Declining populations are at risk before that point, however, because they skirt the edge of the extinction vortex, vulnerable to being pushed over by some random environmental event such as drought, a particularly hard winter, a devastating wildfire, or an outbreak of infectious disease.

How many individuals constitute a viable population? The answer depends in part on:

1. The population structure, social dynamics, and breeding characteristics of the species in question.
2. Environmental fluctuations, particularly the possibility of catastrophic events that sharply reduce population size.
3. Environmental stresses that reduce the vigor of individuals.
4. Aspects of habitat quality, in particular, how habitats are arrayed across the landscape—in large blocks, isolated fragments, or fragments connected by suitable habitat corridors.

Catastrophic events are inevitable in all environments, and local populations of many species may periodically disappear from a given area. A species is not threatened by these local demographic fluctuations as long as an intact, healthy group of interacting subpopulations (a metapopulation) remains interconnected enough to provide a source of immigrants able to replace local losses, but not so interconnected to be threatened by the same stress that threatens local populations. When the metapopulation is in decline or uniformly threatened, or when remaining local populations are so fragmented and isolated that movements among them are inhibited, demographic losses within local ecosystems will not be replaced through natural mechanisms. The species then disappears from the region.

Both theoretical considerations and empirical observations suggest that, when one accounts for both genetic and demographic factors, viable populations of animals and plants are on the order of several thousand (Soulé 1987; Thomas 1990). No single number is universally applicable to all species, however; neither does the same number necessarily apply to one species in all environmental situations (Gilpin and Soulé 1986; Thomas 1990). Rarely is enough known about a species to say with certainty how many individuals constitute a "viable" population, and conservation biologists are loath to specify viable population numbers because such estimates are often interpreted as a low-risk (or risk-free) level to which a species can be reduced. As Soulé (1987) stresses, "several thousand" is an order-of-magnitude, lower-bound estimate—not a target to be used to justify maintaining species near the minimum threshold.

For the land manager, maintaining viable populations of a given species over long periods translates into maintaining an adequate quantity and quality of habitat.

HOW MUCH HABITAT IS ENOUGH?

Recently, scientists focused on how much habitat or what size of habitat patch is required to support viable populations of sensitive wildlife species. One approach for addressing this question is to determine the home-range size typical of a breeding pair. For many LS/OG species, breeding territories are large. Northern goshawks *(Accipiter gentilis)*, for example, require approximately 2500–9700 acres per pair (Austin 1993; Bright-Smith and Mannan 1994; Kean and Morrison 1994; Kennedy 1994). Within these home ranges, goshawks exploit closed-canopy stands of mature and old-growth habitat (Austin 1993). Austin (1993) recommends management areas for goshawks larger than 11,700 acres; less than 10% of this area should contain seedling-sapling-grass-forb habitats. Black-backed and pileated woodpecker pairs normally exploit average home ranges of 430 acres (very limited data; Goggans et al. 1989) and 1005 acres (Bull and Holthausen 1993), respectively. Pine marten *(Martes americana)* home ranges typically vary from 2000 to 5000 acres (Clark et al. 1987). Fisher *(Martes pennanti)* home ranges are extremely large, approximately 3840 to 10,500 acres (Arthur et al. 1989; Jones 1991).

Merely preserving suitable patches of these relatively large sizes, however, is inadequate. Protecting viable populations of sensitive species requires LS/OG areas substantially larger than the typical home range. Besides suitable habitat, sensitive neotropical migrant bird species need populations with which to interact reproductively (Morton 1992). Data from eastern and midwestern woodland birds provide compelling evidence that fragmentation of habitat interferes significantly with viable populations even if the fragments are much larger than a single pair needs (Galli et al. 1976; Lynch and Whitcomb 1978; Ambuel and Temple 1983; Temple 1986; Blake and Karr 1987; Temple and Cary 1988; Askins et al. 1990; Robinson 1992).

Specifically, habitat fragmentation indirectly influences mortality of populations via increased stresses from the surrounding habitat: either biotic stresses such as increasing pressure from predators, competitors, and parasites or abiotic edge-related effects such as altered moisture, wind, and light conditions (Rolstad 1991). Specific pathologies among fragmented populations include reproductive failure (Chasko and Gates 1982; Wilcove 1985; Robinson 1992; Porneluzi et al. 1993), low mating success (Gibbs and

Faaborg 1990), and high rates of nest parasitism by brown-headed cowbirds *(Molothrus ater)* (Brittingham and Temple 1983).

Although these phenomena have not been demonstrated for eastside forests, the generality that landscape fragmentation results in dysfunctional ecosystems certainly applies to these forests. Research on the effects of habitat fragmentation in western coniferous forest habitats is still in its infancy, but negative effects of fragmentation have been reported for the brown creeper (Rosenberg and Raphael 1986).

We do not know what landscape configuration of LS/OG forest (patch size, arrangement, and connectivity) is required to support viable populations of birds and mammals, but the existing distribution of LS/OG patch sizes (see Chapter 4), known geographic ranges and home-range sizes of many vertebrates, and current estimates of minimum viable population sizes suggest that many species may be near a minimum population threshold throughout much of their range in eastside forests. Home-range sizes for species such as the northern goshawk, pileated woodpecker, and pine marten suggest that a minimum of several thousand acres, primarily of LS/OG, are required to support multiple reproductive units of these species. Data collected from eastern woodland bird populations also indicate that forests of at least 500 acres are required to support many landbird species (Robbins et al. 1989).

To ensure long-term viable populations of many LS/OG-associated species (see Table 7.2), LS/OG patches larger than 5000 acres are crucial. Unfortunately, relatively few LS/OG forest patches larger than 1000 acres remain (see tables in Chapter 4). LS/OG patches exceeding 5000 acres do not exist in western Colville, Wallowa-Whitman, or Winema National Forests, and most of the remaining large patches in Fremont, Malheur, Ochoco, and Umatilla National Forests are scheduled for timber harvest. Current management programs that continue to fragment remnant LS/OG habitats threaten the remaining populations of LS/OG-associated species.

Strategies for Conservation

What strategies and tactics can help reverse the threats to eastside forests and protect their ecological integrity? One could take any of three approaches (Noss 1991):

1. The "fine-filter" approach emphasizes protection of individual species.
2. The "coarse-filter" approach emphasizes communities or habitats.
3. The "pluralistic" approach tries to integrate biological goals.

FINE-FILTER APPROACH

Past conservation efforts generally took a fine-filter, or single-species, approach—for example, spotted owl protection in the Northwest and red-cockaded woodpecker *(Picoides borealis)* protection in the Southeast. But conservation biologists are increasingly troubled by this direction. The logistical details and costs of tracking thousands of species are clearly prohibitive (Franklin 1993). "Too many" officially threatened species may even undermine societal support for the Endangered Species Act. Moreover, even a species-by-species approach is unlikely to be fine enough: species that get attention are either easy to see and track (e.g., birds) or appealing or symbolic to humans (e.g., grizzly bears, mountain lions, eagles). Many of E. O. Wilson's (1992) "little things that run the world" could easily slip through the mesh of even a fine filter. Finally, a focus on individual species ignores the interconnections and interdependencies in the system as a whole and thus risks failure in the long run.

Many contemporary conservation strategies hinge on establishing large reserves for a few charismatic but extinction-prone species. These species may serve as reasonable miners' canaries for species depending on the same set of resources, but the approach is inadequate for protecting taxa restricted to small, specialized habitats. A successful reserve system should therefore blend protection of large habitat areas with small reserves to include unique species, habitats, and metapopulation processes (Quinn and Karr 1993).

Efforts to save the spotted owl in the Pacific Northwest, for example, have set aside a series of reserves. But those reserves are threatened by potential climate change and by being embedded in a landscape of densely stocked younger forests. Those young forests are vulnerable to, and could even propagate, crown fires that could penetrate old-growth reserves. Similar threats could be more severe in the drier landscapes of the Eastside.

COARSE-FILTER APPROACH

The basic premise of the coarse-filter approach is that protecting habitats is the best strategy for conservation, a strategy that was pioneered in the United States by the Nature Conservancy. The approach makes sense from both ecological and practical perspectives. Rather than individual species, communities and landscapes are the focus of protection and, where necessary, restoration. Many ecologists carry this logic one step further by advocating protection of ecosystem processes as the primary management goal.

But like the fine-filter approach, the coarse-filter approach has its problems. Species can be lost from communities that appear intact. Lichens, for example, started disappearing from pollution-stressed European forests well before the trees began to die (Hawksworth 1990). Moreover, lakes enriched by nutrients and acidification indicate that species composition reacts more quickly and recovers more slowly than ecological processes such as primary production and nutrient cycling (Schindler 1990).

Pluralistic Approach

Protecting species, whole communities, and regional landscapes, along with the processes that generate and maintain them, requires a more integrative approach than either the fine or coarse filters can offer. The pluralistic approach recognizes the multiple dimensions of biological systems and their importance to human society and to system persistence (Noss 1990, 1991; Karr 1990). Four levels in the hierarchy require attention (Noss 1991):

1. Regional landscape
2. Community-ecosystem
3. Population-species
4. Genetics

The most successful approaches to protect ecological health are likely to be grounded in broadly conceived programs that span the hierarchy from genetics to landscapes and include both the elements and processes of biological systems (indicator species, species richness, production, trophic structure, individual health; Karr 1991).

What short-term management directions should be taken until these broader goals can be specifically defined and management programs developed for the Eastside? What are the keystones—the most vulnerable points in system structure? Where are the redundancies? What elements, if lost, will lead to unpleasant surprises? How do we integrate from individual forest stands to watersheds? Finally, if eastside national forests are managed according to current principles of conservation biology, what should the regional landscape look like? This question should be addressed by a specially selected panel; however, we wish to offer a few suggestions.

First, the concept of managing forests within their "natural range of variability" (NRV), which is reasonable in some circumstances, is totally inappropriate if applied at the wrong scale. The "correct scale" is almost certainly regional. The scale for managing and protecting salmon stocks differs from the scale for managing wolverines, migratory warblers, amphibians, or ponderosa pine. Managing eastside forests within NRV dictates that the area of ponderosa pine old growth be increased from 4 to 20 times in areas where it once dominated (i.e., nearly two-thirds of commercial forestland). To attain this goal, existing second-growth pine and isolated old-growth individuals must provide the cornerstones around which to rebuild the landscape. Any logging of remaining pine, except for thinning in overstocked stands, moves the landscape further from NRV. (Even thinning may better be left to natural processes if it threatens other resident biotic components.)

Second, any strategy for managing eastside forests must account for fire. Fire has been an important force in eastside forests since the glaciers withdrew 12,000 years ago, and it will remain an important force as long as the climate is characterized by summer drought. If the climate changes, fire may well become even more prevalent (Perry and Borchers 1990). The self-reinforcing dynamic of fire and forests has been disrupted, and the Eastside now faces a very real risk of another self-reinforcing system—stand-destroying fires. Protecting species and stabilizing regional landscapes is likely to require restoring the original forest structure, including gentle fire regimes.

Summary and Conclusions

1. Protect existing LS/OG to ensure long-term viability of eastside forest species, ecosystems, and landscapes.

The optimum proportion of LS/OG (near the natural range of variability) that should be maintained in a managed forest ecosystem is unknown, but it is substantially greater than what exists today. Relatively large areas of LS/OG are necessary to maintain viable populations of most LS/OG-associated species as well as many populations of economically and ecologically important species dependent on LS/OG during even a minor component of their life cycles (e.g., elk, lynx).

The proportion of LS/OG needed to ensure a healthy forest (e.g., maintenance of insect and avian populations in a dynamic equilibrium) is certainly greater than the "5% rule" often used in forest plans. The 5% rule has apparently been applied informally by the Forest Service in developing some past LS/OG policy, despite widespread recognition that northern spotted owls require 20–35% of a region in suitable stands (Thomas et al. 1990; McKelvey et al. 1992). Because many endangered species have narrower habitat requirements than the spotted owl, and many have less-developed dispersal abilities, they may require even higher densities of pristine patches to remain above the extinction threshold (Quinn and Karr 1992).

2. Low-elevation ponderosa pine LS/OG is the most endangered type of eastside forest.

Low-elevation ponderosa pine LS/OG was perhaps the most valuable forest type to the greatest diversity of wildlife (Harris et al. 1982); it is particularly important to bald eagles (Lehman et al. 1980) and white-headed woodpeckers (Ligon 1973; Jackman 1975). All remaining patches of ponderosa pine LS/OG should receive priority for protection. Forest management should emphasize the restoration of low- and mid-elevation natural ponderosa pine forest associations on relatively level ground.

3. LS/OG lodgepole pine communities merit protection because they furnish important wildlife habitat.

LS/OG lodgepole pine forests are important to several sensitive wildlife species and affect forest processes in adjacent forests. Specifically, black-backed and three-toed woodpeckers commonly inhabit and reach high densities in lodgepole pine forests. These forests act as refugia to ensure the regional persistence of these woodpeckers, enabling them to respond to outbreaks of harmful insects in nearby mixed-conifer forests.

4. Large and well-distributed patches of LS/OG habitat are critical for conserving vital LS/OG-associated vertebrates of eastside forests.

Many sensitive vertebrates (northern goshawks, pileated woodpeckers, back-backed woodpeckers, three-toed woodpeckers, American marten, fisher, and others) that have declined in numbers and distribution in eastside forests require large home ranges comprising mostly LS/OG habitat. Consolidated configurations (e.g., near-circle or square configurations) of LS/OG habitat larger than 500 acres are most important to wide-ranging vertebrate species. Landscapes with clusters (archipelagoes) of LS/OG patches are probably more valuable to LS/OG-associated vertebrates than landscapes with isolated patches.

5. Small, isolated patches of LS/OG habitat are also critically important for conserving sensitive plants, plant species with restricted distributions, or other unique resources.

Small, isolated patches of LS/OG habitat (e.g., smaller than one acre) may be crucially important to protect plants and specialized animal associates (rare plants, fungi, or specialized arthropods or other animals associated with those species or their microhabitats) or other unique resources (e.g., small natural bogs); they also help sustain populations of organisms that reside primarily in younger forests. LS/OG patches may ensure greater diversity and abundance of wildlife in these younger forests. For example, LS/OG habitats are selected by lynx for denning areas and are used as security and wintering habitat by elk. The resource value of each individual LS/OG patch, as well as a complete understanding of patch interactions with the surrounding landscape, should be thoroughly investigated and evaluated before timber management is contemplated in these stands.

6. Salvage cuts that remove a substantial proportion of standing, downed, or potential future coarse woody debris are detrimental to most forest organisms.

Salvage cuts that remove a substantial proportion of standing or future deadwood (Cline et al. 1980) in LS/OG habitats stress many vertebrates. The value and effect of salvage cuts in general, and for any forest patch in particular, need to be investigated and evaluated. We recommend limiting salvage cuts only to specific, carefully managed situations.

7. High road densities harm many forms of wildlife.

The ecological integrity of existing LS/OG patches and other roadless regions can only be maintained if these sites are not disturbed by the construction of roads. Roadless regions serve as critical refuges for terrestrial wildlife sensitive to human disturbance. Road densities in LS/OG patches that already have roads should be reduced to less than 1 mi/mi^2. Achieving this goal is vital to rehabilitation of eastside fisheries and terrestrial resources.

8. Timber harvesting and overgrazing of riparian areas have adversely affected avian populations and should be minimized and regulated.

Few detailed studies of grazing impact on riparian corridors are available for the Eastside, but research elsewhere has demonstrated substantial adverse impacts. Birds most likely to be negatively affected by grazing are those that depend on herbaceous and shrubby ground cover for nesting and foraging. Riparian zones serve as buffers protecting terrestrial as well as aquatic resources. No timber should be harvested in riparian zones; cattle grazing should be excluded unless it can be conclusively demonstrated that no degradation of riparian environments follows.

Chapter 8

INTERIM RECOMMENDATIONS

Existing forest and range management plans on federal lands east of the Oregon and Washington Cascades will further degrade these landscapes, including water quality, stream environments, and terrestrial wildlife habitat.[4] The plans propose more road mileage, continued harvest of large trees, and widespread grazing in riparian areas. Even without increases in human activity, the risk of future environmental damage from extreme climatic events is great because many watersheds are degraded already. Criteria for management performance based solely on economic targets (e.g., forage-use standards for cattle, board feet of timber) or on habitat structure measured at a particular site are not enough to evaluate the cumulative effects of forest management activities throughout a watershed or to ensure the continued viability of diverse communities of organisms.

A comprehensive recovery strategy for eastside landscapes, watersheds, and habitats should be put in place to restore the critical elements and processes that

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[4] Portions of Deschutes, Okanogan, Wenatchee, and Winema National Forests fell within the scope of the Forest Ecosystem Management Assessment Team (FEMAT 1993), which addressed forest management in spotted owl habitat. Our assessment and interim recommendations complement FEMAT's work. FEMAT's Option 9, however, fails to address specific issues that our eastside work emphasizes, such as protection of all roadless regions, specific LS/OG stands (as opposed to regions containing LS/OG and owls in Option 9), ponderosa pine, trees greater than 20 inches DBH throughout the landscape, aquatic diversity areas, and certain critical watersheds in Washington. Implementation of Option 9 alone thus does *not* satisfy our recommendations.

have until now provided the evolutionary template for biological organization and adaptation across the region. Only if policymakers implement an ecologically sound management program today can the benefits of forests east of the Cascade crest, and their associated resources, be available for generations in the future.

The interim recommendations in this chapter are aimed at protecting the resources remaining on the Eastside until, and only until, a long-term strategy of protection and restoration can be developed. The recommendations concentrate on remaining late-successional/old-growth forests, aquatic diversity areas, roadless regions, riparian corridors, and soils because these elements constitute the basic building blocks for restoring the eastside landscape. Unless these elements are protected, opportunities will be limited for ensuring sustainable supplies of eastside natural resources.

1. Do not log late-successional/old-growth forests (LS/OG) in eastern Oregon and Washington.

The current acreage of late-successional/old-growth (LS/OG) forests falls far below historic levels, particularly in low-elevation woodlands dominated by ponderosa pine, western larch, or Douglas fir. At present, LS/OG makes up between one-fourth and one-third of forested lands in eastside national forests (Chapter 5). Before extensive logging, low- and middle-elevation forests throughout much of the region were dominated by ponderosa pine, of which 90% or more was old growth (Chapter 2). We estimate that less than 15% of the original ponderosa pine forest remains on the Eastside and less than 5% in the eastern Cascades and on Oregon's Klamath plateau. Continued logging of now unprotected LS/OG would further reduce the area occupied by these unique ecosystems to between 7 and 13% of forestlands in eastern Oregon and Washington's national forests.

Present levels of protection are inadequate. We estimate that only 28–40% of the remaining LS/OG is protected by statute (in wilderness areas) or administratively (see Chapter 5). Protection is not distributed evenly across forest types. In the four national forests within Oregon's Blue Mountains, for example, 48% of the land above 6000 feet is protected wilderness, but only 10% of the land below 6000 feet has wilderness status.

Eastside forests, LS/OG, and associated species and watersheds have been degraded by logging, road construction, fire suppression, grazing, and other human disturbances. Consequently, much of the landscape is vulnerable to catastrophic fire, insects, and disease; riparian (riverine) areas are subject to excessive temperatures, sediment, and bank erosion; and many important fish stocks risk extinction. Loss of critical aquatic and terrestrial habitats has significantly diminished the region's ability to absorb and buffer natural and human-induced disturbances. Continued reductions of LS/OG could threaten several species that require old-growth habitat and further deteriorate streams and watersheds. Given what we do know of ecological processes, and what we do not know about LS/OG requirements of potentially threatened species, we conclude that all remaining LS/OG blocks and fragments are ecologically significant.

In sum, only a fraction of the original old-growth forest in eastern Oregon and Washington remains, with the greatest reductions in low-elevation forest types. Continued logging in unprotected areas could reduce LS/OG to less than 10% of the region's total forest area and jeopardize more species and ecological processes. Deferring logging of all remaining LS/OG will create a "time out," allowing rigorous assessment of LS/OG status, especially in low-elevation forests. A "time-out" will also permit more thorough evaluation of the implications of further logging for watersheds and species of special concern such as bull trout, Snake River chinook and sockeye salmon, American marten, northern goshawk, pileated woodpecker, flammulated owl, and white-headed woodpecker.

2. Cut no trees of any species older than 150 years or with a diameter at breast height (DBH) of 20 inches or greater.

Isolated mature trees occur throughout the region. These mature trees have lived for decades, even centuries; their very existence demonstrates that they have the genetic characteristics to survive the full range of environmental variation present in eastern Oregon and Washington. Their complex structure, the product of millennia of natural selection, offers unique niches for microbes, invertebrates, and vertebrates. They serve as reservoirs of genetic diversity and irreplaceable sources of seed for forest regeneration; they renew the supply of large snags and fallen logs, which furnish nest and den sites for many animals; they provide nutrients to the soil; and they stand as a unique historic record, an irreplaceable link between the past and the future. These trees are "living examples of our long-term objectives" (Wickman 1992).

3. Do not log, build new roads, or mine in aquatic diversity areas (ADAs).

Aquatic diversity areas contain the last vestiges of quality habitat and genetic resources for native fish and other aquatic biota (and much of the terrestrial biota as well). ADAs harbor native aquatic species at risk of extinction and vulnerable to future disturbance; they comprise whole watersheds exemplifying native aquatic ecosystems; and they form essential corridors linking habitats required to support fish populations at critical times in their life cycles. For these reasons, ADAs serve as cornerstones for any future efforts to protect dozens of at-risk stocks or to rebuild lost production of native fishes. In addition, they provide benchmarks for evaluating the effects of land management and defining the ecological processes that restoration should emulate. ADAs and roadless regions are the least-disturbed ecosystems east of the Cascade crest.

Degradation of ADAs would eliminate recovery options and impair efforts to restore fish populations. Because of their importance and the risk of additional listings of threatened and endangered species, ADAs warrant immediate protection and stabilization. Strategies for restoring watersheds across the rest of the landscape should be built outward from these ADAs to gradually extend quality habitat available to at-risk populations.

We suggest that USFS consider diverting the funds set aside for road construction in ADA and roadless regions to removing existing roads and otherwise restoring the watersheds.

4. Do not construct new roads or log within existing (1) roadless regions larger than 1000 acres or (2) roadless regions smaller than 1000 acres that are biologically significant.

Roadless regions contain the least-disturbed forests and stream systems on the Eastside. They serve as reservoirs of ecological diversity and benchmarks for restoring ecological health. Road building fragments landscapes; alters the hydrological properties of watersheds; discharges excessive sediment to streams; increases human access and thus disturbance to forest plants and animals; and affects the dispersal of plants and animals, especially exotic species. Roads make fish and wildlife more vulnerable to harvest; they open access to deep forest habitats for pests and predators. Large predatory mammals such as grizzly bears and wolves do not frequent areas crisscrossed by roads; elk, too, are sensitive to road density. Existing roadless regions thus offer important sanctuary. Because many forested areas in eastern Oregon and Washington are heavily dissected by roads, the ecological value of existing roadless regions is especially high.

5. Establish protected corridors along streams, rivers, lakes, and wetlands. Restrict timber harvest, road construction, grazing, and cutting of fuelwood within these corridors.

Protection of riparian corridors is essential to the integrity of aquatic systems. Such corridors keep habitats healthy by providing shade, large wood, and detritus and moderating water temperatures. Riparian areas also serve as buffers, reducing the effects on waterways of human land use, including runoff of fertilizers and pesticides. Such riparian zones are particularly important in semiarid eastern Oregon and Washington. Seventy-five percent of terrestrial species known in the Blue Mountains, for example, either depend directly on riparian zones or use them more than other habitats.

Perennial streams, with or without fish, must be protected by buffer zones at least 300 horizontal feet wide on each side, or within the 100-year floodplain, whichever is greater. Lakes, ephemeral and intermittent streams, seeps, springs, and wetlands must be protected by a minimum of 150 feet horizontally on all sides.

Furthermore, instream structures such as deflectors and cabled logs should not be regarded as surrogates for riparian-zone recovery. The greatest limitations to eastside fish production are high water temperatures and excessive sediment; structures rarely mitigate or reverse the effects of either factor. Instream structures should not be installed without thorough watershed-level analysis of which approach best protects and restores ecological elements and processes.

6. Prohibit logging of dominant or codominant ponderosa pine from any forest, regardless of whether the stand meets the criteria for LS/OG.

Protecting eastside forest ecosystems in the long term requires restoring ponderosa pine to its former dominance throughout much of eastern Oregon and Washington. Remaining mature ponderosa pines, both inside and outside LS/OG areas, constitute important focal points for any recovery, serving as seed sources, reservoirs of genetic diversity, and refugia for other species. Species from mycorrhizal fungi to vertebrates like bald eagles and white-headed woodpeckers depend on old-growth ponderosa pine. Protecting ponderosa pines must be a high priority independent of the size of the patch where the trees are located.

7. Permit timber harvest in areas prone to landslides or erosion *only* if peer-reviewed scientific study conclusively demonstrates that harvest does not degrade the soils or release sediment to streams.

Because effects of sedimentation are widespread and severe, human land use must be restricted on slopes and easily eroded soils is necessary to minimize future risks to sensitive and endangered species and to protect soil fertility, water quality, and aquatic habitat. Steep slopes are especially fragile. Logging such areas often triggers landslides that degrade the terrestrial landscape and nearby stream channels.

Soils vary widely in their likelihood of erosion, making it important to base land-use decisions on site-specific information. On pumice soils, for example, clearcutting slopes steeper than 30% can cause significant erosion. Partial harvesting may protect soils on slopes between 30% and 60%, but impact can only be determined case by case; the burden of proof that harvesting will have no impact should rest with the harvester. Disturbing the ground on slopes steeper than 60% is likely to produce unacceptable soil losses. Therefore, no logging should be permitted on slopes steeper than 30% on pumice soils and 60% on other soil types. Logging on slopes between 30 and 60% should retain 40% of the sum of the area in a stand occupied by tree boles (maximum basal area), with at least half this area consisting of trees larger than the mean size of trees in the stand before logging (quadratic mean diameter).

Stands excluded from logging under this recommendation but at risk of catastrophic loss to pests, fire, or disease should be dealt with under the provisions of interim recommendation 10.

8. Permit livestock grazing in riparian areas *only* under strictly defined conditions that protect those riparian areas from degradation.

Poorly managed grazing in riparian zones often degrades regional landscapes. Grazing may therefore be incompatible with protecting LS/OG and ADAs as sources of colonists for restoring adjacent areas. Stabilizing existing good habitat and restoring degraded habitat is essential for a healthy and productive eastside landscape. For this reason, and because so many of the region's streams are degraded, the burden of proof regarding the ecological effects of continued grazing should lie with those who would permit grazing, not with those who would protect streams.

We encourage USFS to work actively with ranchers to develop techniques for keeping stock out of riparian areas. We further recommend that new studies address how livestock grazing affects terrestrial and aquatic communities and the ecological processes sustaining them. The first step is to evaluate the condition of riparian areas in eastside forests, including the extent to which grazing is injuring those areas. The second step is to initiate long-term monitoring programs to track the condition of grazed and ungrazed areas. If either of these investigations demonstrates a threat to the health or integrity of LS/OG and ADAs, grazing should be prohibited.

Elsewhere, (a) in areas not degraded by previous grazing, grazing could be permitted, but only when allotment management plans are revised to incorporate ecological standards consistent with long-term protection of streams, and grazing does not degrade the riparian zone; (b) no grazing should be permitted in degraded riparian zones until conditions have been restored;

(c) after restoration, livestock grazing should be permitted only to the extent that it does not damage restored areas, and management plans have been revised to meet appropriate ecological standards.

Instream structures should not be used as surrogates for riparian recovery, nor should they be installed without a thorough assessment of both their positive and negative effects.

9. Do not log or mine on fragile sites until peer-reviewed scientific study conclusively demonstrates that soil integrity is protected and that forest regeneration after logging is assured.

Fragile sites are those susceptible to soil damage or, because of soils or other environmental constraints, sites where forest regeneration may be difficult or impossible; many are marginal for tree growth. For example, 179,000 acres of LS/OG available for logging in the Bend ranger district of Deschutes National Forest grew on lava fields, and successful regeneration of the logged areas is unlikely. Many fragile sites, however small, are nonetheless important to regional ecosystems. Low-elevation forests throughout the Eastside grow in zones that are transitional to grasslands or desert shrublands. Mature trees probably became established in these areas only when the weather was unusually favorable; their persistence helps maintain soil structure and populations of beneficial soil organisms, and they can survive low-intensity groundfires. Breaking the links between mature trees and soils by cutting too many trees risks permanent loss of forest cover on these sites.

The same risk exists in many high-elevation forests, which, throughout the western United States, have been notoriously difficult to regenerate after clearcutting. Noxious weeds (particularly introduced exotics) in western range- and forestlands heighten the risk of site degradation if mature trees are not maintained on marginal sites. Should climate change play out as predicted, the resulting drier and hotter weather will exacerbate degradation.

Certain other soil types, such as ash soils, pose a different problem in that they are fairly productive but vulnerable to compaction and loss of topsoil. At present, where slopes permit, on-the-ground equipment is widely used to harvest trees from such soils, resulting in compaction, soil loss, and reduced productivity. Heavy ground equipment should not be used. Low-impact ground equipment might be acceptable but only if it can be conclusively demonstrated that no associated compaction or loss of topsoil will follow. With proper silvicultural techniques, soils probably can be protected and new seedlings regenerated on at least some, and possibly many, of these sites. Before logging is permitted on a site, therefore, site-specific logging plans should be required to demonstrate that silvicultural techniques will not diminish the productive capacity of local soils.

10. Establish a panel with broad expertise to develop long-term management guidelines for securing the ability of eastside forests to resist drought, crown fires, and catastrophic outbreaks of insects and pathogens.

Fire prevention and early logging practices have altered some LS/OG systems, making them vulnerable to drought, insects, and fire. Salvage (removing dead standing or fallen wood) and thinning (cutting small live trees) are two legitimate techniques—but not the only ones—for lowering the risk from such disturbances. Lack of consensus and past abuses, in which large healthy trees were cut in the guise of salvage, lead us to recommend a comprehensive study of this issue. Scientists disagree over how to define the goals of salvage and thinning and how to select areas where salvage or thinning is required. At issue is the purpose of removing dead material: for ecological or economic enrichment? for short- or long-term return? No consensus exists on silvicultural practices for minimizing the effects of drought, fire, insects, and pathogens; on the conditions that warrant managing LS/OG to reduce risk of catastrophic loss; or on the levels of treatment that reduce risk without compromising ecological values. Sustaining regional resources and their use depends on enlightened and comprehensive approaches to protecting forest health.

Such approaches should include assessment of forest health and development of ecologically sound techniques for restoring unhealthy stands. In particular, stands should be identified where excessive understory fuel has accumulated (overstocked stands) or where fire prevention or selective logging of big, valuable trees has altered stand structure. We suggest that (1) controlled burning be done or natural fires be allowed to burn where fuel levels are low enough to avoid runaway fire; (2) selective logging be restricted to thinning from below in overstocked stands; and (3) dominant and codominant trees not be cut in the guise of improving forest health.

11. Establish a second panel to develop a coordinated strategy for restoring the eastside landscape and its component ecosystems. Emphasize protecting the health and integrity of regional biological systems as well as the processes on which they depend.

Existing forest plans are inadequate to address the complex of ecological issues in eastside forests, especially with regard to managing late-successional old growth. Eastside forest plans must be revised to integrate new ecological understanding of the impact of Euroamerican settlement, particularly logging, road building, and fire prevention. Efforts are already under way in some forests; we are especially impressed with the ecosystem management approach being developed for Ochoco National Forest—a strategy to restore the historic distribution and abundance of habitats on the landscape and to maintain those habitat patterns in the perpetually shifting mosaic characteristic of natural disturbance regimes. We suggest that other forest managers consider a similar approach along the following lines:

A. **Conduct a comprehensive inventory of LS/OG forests in all eastside national forests.** Data on the abundance and distribution of LS/OG remaining in eastside national forests vary widely. Our work shows that some currently mapped LS/OG no longer exists because of recent logging; LS/OG also exists that has not been mapped. We recommend that USFS, in cooperation with outside interests, undertake a mapping project with consistent methods applied across all forests; wilderness areas should be included in this effort.

B. **Begin restoring ponderosa pine to areas that it formerly dominated.** Available evidence indicates that, within the appropriate elevation zones, landscapes where most forests consist of large ponderosa pines with open understories better resist catastrophic fire and pest outbreaks. Like any LS/OG forest, such areas also provide important pathways for movement of LS/OG species. In Colville and northern Umatilla National Forests, where ponderosa pine forests were never as extensive as elsewhere in the region, low-elevation Douglas fir played a similar ecological role and should also be restored.

C. **Protect and restore riparian zones, starting with those in aquatic diversity areas.**

    1. Document current status relative to historic conditions of all streams and riparian zones on national forestlands in eastern Oregon and Washington.
    2. Establish a panel (or panels) of qualified ecologists to evaluate stream and riparian conditions with respect to their ability to protect critical ecological processes.
    3. Where ecological processes have been lost or degraded, develop concrete and scientifically defensible plans for restoration.

D. **Increase the amount of coarse woody debris.** Few snags and logs remain in many harvested forests, yet such debris is crucial to the health of these systems. Many terrestrial and aquatic invertebrates, fungi, and vertebrates are tied to the availability of woody debris. These species are often important as consumers and decomposers of plant material and as predators controlling pest populations.

E. **National policies need to be reassessed and brought into line with national priorities for public forestlands.** To meet current needs for protection and restoration, Forest Service personnel need to be supported with appropriate funding and incentives. USFS funding is still disproportionately tied to timber harvest, road construction, and other development, a situation that contradicts its mandate to preserve national forests for multiple uses. USFS personnel receive mixed messages from Congress and, in some cases, from their own superiors within the agency. Today's needs are new, but the reward system is old; this situation needs to be changed.

F. **Develop strategies for cooperation among regional landowners and forest users, including positive incentives aimed at protection and restoration.** Protecting endangered species and restoring ecological health require regional approaches involving all affected parties. We believe that, in the long run, resources can be most effectively protected by programs that draw on the creative power of local and regional communities. Because federal lands are only a part of landscapes encompassing significant private, state, and tribal holdings, regional programs must be grounded in cooperation among diverse ownership groups. The ecological integrity of regional landscapes depends on protecting both the elements (genetic diversity, richness of species and habitats) and processes (demography, hydrology, nutrient cycling, fire) within regional landscapes. Long-term management programs designed to protect that integrity must be given the highest priority on private as well as public lands.

Silvicultural approaches designed to improve forest health and hasten development of old-growth structure in younger forests can probably contribute to restoring eastside forests and landscapes. Nevertheless, these techniques do not justify further logging of existing old growth. We strongly recommend that future silvicultural strategies be developed by multidisciplinary teams comprising not only silviculturalists but also ecologists, wildlife biologists, fisheries biologists, botanists, soil scientists, hydrologists, entomologists, and pathologists. No technique should be widely applied until approved by such an interdisciplinary team.

The panels called for in recommendations 10 and 11 should include representatives from all relevant disciplines (terrestrial ecology, aquatic ecology, wildlife biology, conservation biology, pathology, entomology, hydrology, and silviculture) and members from federal, state, and tribal agencies, academia, scientific societies, and other groups with appropriate expertise.

12. Establish a comprehensive quantitative biological monitoring program.

Data on a broad range of biological conditions within eastside forests are simply not available. This shortfall, added to inconsistency in what data are available and inadequate synthesis of those data, prevents comprehensive assessment of resource condition and poses a challenge to resource managers.

Moreover, such inadequate monitoring of public lands suggests a cavalier attitude toward public resources on the part of the federal government that poses a barrier to public trust. A federal mandate and federal support for improving data quality are essential.

Data collection should be based on an appropriate sampling design that tracks ecological condition—especially the biological components—and change in that condition. Development of this monitoring and assessment strategy should be a central task of the committee called for in recommendation 11.

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Appendix I Letter from members of the US House of Representatives to scientific societies, requesting a "review and report on the eastside forests of Washington and Oregon."

JIM JONTZ
5th District, Indiana

COMMITTEE ON AGRICULTURE
Department Operations, Research, and Foreign Agriculture
Forests, Family Farms, and Energy

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National Parks and Public Lands
Mining and Natural Resources
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Retirement Income and Employment

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House of Representatives
Washington, D.C. 20515

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May 19, 1992

JUL 2 [illegible] 1992

American Fisheries Society
ATTN: Dr. Richard Gregory
5410 Grosvenor Lane
Bethesda, MD 20814

The Wildlife Society
ATTN: Richard Mackie
5410 Grosvenor Lane
Bethesda, MD 20814

American Ornithological Union
ATTN: Dr. Burt Monroe, Jr.
Univ. Louisville, Biology Dept.
Louisville, KY 40292

American Institute of
Biological Sciences
730 11th St. NW
Washington, DC 20001

Dear Gentlemen:

Recently, you received a request from a number of Members of Congress to assist in the process of identifying areas in the Sierra forests of California where damage to forest ecosystems could result in compromising the long-term ecological viability of these forests, their fisheries, and other resources which depend on them.

The letter also requested recommendations for interim management of critical areas, while a long-term plan for conservation of these forests and riparian ecosystems could be developed. As you are well aware, the eastern forests of Washington and Oregon State are as severely threatened, if not more so, than the Sierran forests and the westside forests which were the subject of the Scientific Panel Report on Late Successional Forest Ecosystems.

According to the American Fisheries Society, more than one-hundred runs of salmon and steelhead are threatened with extinction on the eastside, making the spotted owl controversy pale in comparison. The loss of the fisheries resource will impact more than 60,000 jobs in Oregon and Washington, resulting in the loss of more than $1 billion in the local economies.

We would like to encourage your positive response to the letter from Chairman Miller about the California forests but encourage you, at the same time, to initiate a similar review and report on the eastside forests of Washington and Oregon. We will be making every effort to include the eastside forests in whatever Ancient Forest legislation is considered by the Congress this year.

From the scientific standpoint, these forests deserve equal attention, if not more. The assistance of natural resource professionals in identifying the critical areas and making recommendations for their management on the eastside forests will insure that our efforts will be as scientifically credible as possible.

Thanks in advance for your assistance.

Sincerely,

ARTHUR RAVENEL, Jr.
Member of Congress

JIM JONTZ
Member of Congress

MEL LEVINE
Member of Congress

JIM WALSH
Member of Congress

GEORGE BROWN
Member of Congress

JOHN MILLER
Member of Congress

JIM McDERMOTT
Member of Congress

Appendix II Oregon aquatic diversity areas (ADAs), defined by the Oregon chapter of the American Fisheries Society (Oregon AFS 1993), located within or partially within eastside national forests.

ADA no.[a]	ADA Name	Total acres	Acres in specific forest	Ecological criteria[b]	LS/OG (%)	Roadless (%)	Wilderness (%)	Condition[c]	Species[d]
Deschutes National Forest									
502	Upper Metolius River complex	65,674	55,896	GR, SV	[e]	0	48	2	Bull, Rb, TF
503	Lake Cr.–Metolius R.	22,004	15,468	CC, GR	[e]	0	0	2	Bull, Rb, WF
506	Odell L.–Trapper Cr.	13,923	12,108	GR	[e]	0	84	2	Bull
Fremont National Forest									
1303	Drews Creek	34,962	23,200	GR, HS, RW	8	0	0	1	GL RedRb, PiRo, PiSc
1304	Twentymile Creek complex	37,860	5552	GR, HS, SR, SV	0	65	0	2	WBTC, WV RedRb, WaS
1307	Thomas Creek	17,471	15,616	GR, HS	26	0	0	2	GL RedRb, GLL, PiSc
1311	Honey Creek	20,161	18,376	GR	2	0	0	2	WV RedRb
1312	Chewaucan River	162,821	120,626	GR, HS	24	18	5	2	RedRb
1404	Long Creek	22,708	5211	EF, GR, HS	73	60	0	2	BT, Bull, RedRb
1405	Upper Williamson R.	149,300	328	GR, HS	97	92	0	2	KLgSu, KSD, KTC, RedRb
1406	Sycan Marsh	19,556	743	CC, SV	24	0	0	2	BT, Bull
1407	Boulder Creek	4703	1672	EF, GR, HS	[e]	0	93	2	Br, Bull, RedRb
1408	N. Fork Sprague River	6563	1504	CC	9	0	0	2	BT, Bull, RedRb
1409	Deming Creek	7171	4571	EF, GR, HS	[e]	0	15	2	Bull, RedRb
1410	S. Fork Sprague River	6109	1284	CC	0	0	0	2	Bull, RedRb
1411	Leonard–Brownsworth Creek	13,629	5895	EF, GR, HS	[e]	0	23	2	Br, Bull, RedRb
Malheur National Forest									
603	Murderers Creek	83,958	66,469	EF, SV	26	39	0	2	StS
604	Desolation Creek	18,470	168	EF, GR, HS	0	0	0	1	Bull, ChSp, StS, WCt

continues

ADA no.[a]	ADA Name	Total acres	Acres in specific forest	Ecological criteria[b]	LS/OG (%)	Road-less (%)	Wild-erness (%)	Condi-tion[c]	Species[d]
607	Call Creek	69,797	60,640	EF, GR, RW	11	20	6	2	Bull, WCt
609	Big Creek	19,593	15,372	EF, HS	11	23	0	2	Bull, ChSp
611	Mid. Fork John Day R.	14,133	14,111	CC, GR	6	0	0	2	ChSp
612	S. Fork John Day River	15,588	3560	GR	3	0	0	2	BrS, Rb, SD, SqF
614	Clear Creek	82,263	182	EF, GR, HS, SV	0	0	0	2	Bull, ChSp, RedRb, StS
617	Fields Creek	13,324	10,956	RW	45	33	0	2	StS, WCt
618	Moon Creek	5149	1598	RW	1	94	0	1	WCt
624	Granite Boulder Creek	7889	7193	EF, HS	38	0	0	1	Bull, ChSp
625	McClellan Creek	3653	1887	GR, HS	47	0	0	2	WCt
626	Laycock Creek	18,639	6471	GR, HS	3	2	0	2	WCt
627	Cottonwood Creek	3802	3805	GR, HS	25	0	0	2	WCt
1001	Middle Fork Malheur River complex	128,262	115,877	GR, HS	[e]	0	12	2	Bull, RedRb, WF
1002	North Fork Malheur River complex	100,966	97,765	GR, HS	16	13	1	2	Bull, RedRb, WF
1003	Little Malheur River	61,958	31,253	HS	[e]	0	37	2	RedRb
1005	N. Fork Malheur River	6,617	88	CC, GR, HS	[e]	0	42	2	Bull, RedRb, WF
1213	Myrtle Creek	27,086	27,035	GR, RW	17	18	0	1	RedRb
1214	Poison Creek	39,187	14,744	GR, HS	4	0	0	2	MMoSc, RedRb
1215	Rattlesnake Creek	11,840	8,478	GR, HS	15	0	0	2	MMoSc, RedRb
Ochoco National Forest									
504	Crooked River	7919	1410	CC, GR	0	0	0	2	Bull
505	Deschutes R. canyon	5582	1798	CC, GR	0	0	0	2	Bull
511	Brush Creek	5125	3509	GR, RW	48	80	0	2	RedRb
512	Lookout Creek	6071	5967	RW	30	31	0	2	RedRb
601	Cottonwood Creek	12,433	11,013	GR	72	72	0	1	StS, WCt
602	Rock Creek	16,446	16,427	GR	53	52	1	1	StS, WCt
616	Black Canyon Creek	20,606	18,984	RW, SV	40	5	66	1	StS

1206	Silver Creek complex	44,119	33,930	GR, HS	8	0	0	2	MMoSc, RedRb
Umatilla National Forest									
604	Desolation Creek	18,470	18,273	EF, GR, HS	19	40	16	1	Bull, ChSp, StS, WCt
605	Desolation Creek	9076	4334	CC, GR, HS	13	1	0	2	BMC, Bull, ChSp, RedRb, StS, WCt
606	Lost Creek	12,065	11,920	EF, GR, RW	15	3	54	1	TF, WCt
608	North Fork John Day River	149,606	104,298	CC, EF, GR, RW, SV	20	3	70	1	BMC, Bull, ChSp, RedRb, StS
609	Big Creek	19,593	2320	EF, HS	10	46	0	2	Bull, ChSp
610	Camas Creek	55,141	44,080	EF, GR, HS	6	0	0	2	BMC, ChSp, RedRb, StS, TF, WCt
614	Clear–Granite Creek	82,263	37,821	EF, GR, HS, SV	18	4	49	2	Bull, ChSp, RedRb, StS
619	N. Fork John Day River	6553	4222	CC, GR	9	0	1	2	Bull, ChSp, WCt
620	Fivemile Creek	30,475	25,658	EF, GR, HS	7	0	0	2	StS
621	Hidaway Creek	6185	6049	EF, GR, RW	23	68	2	1	BMC, ChSp, RedRb, StS, TF
622	Lower Camas Creek	13,683	805	CC, HS, SV	9	0	0	2	Bull, ChSp, RedRb
623	S. Fork Cable Creek	7398	7096	EF, GR, RW	25	60	1	1	BMC, TF
624	Granite Boulder Creek	7889	696	EF, HS	17	95	0	1	Bull, ChSp
701	Buck Creek	7721	7724	GR	25	0	57	2	Bull, MgSc, Rb, StS, WF
702	North Fork Umatilla River	19,567	17,096	GR	10	0	60	2	Bull, ChSp, MgSc, StS, WF
703	Shimmlehorn Creek	5652	5653	GR	16	47	0	2	Bull, MgSc, Rb, StS, WF
704	Mill Creek	29,323	24,408	GR	22	77	0	1	Bull, MgSc, Rb, StS, WF
705	North Fork Walla Walla River	27,702	10,039	GR, HS	33	68	0	2	Bull, MgSc, Rb, StS, WF
706	South Fork Walla Walla River	51,372	31,285	EF, GR, RW, SR	27	83	0	1	Bull, MgSc, Rb, StS, WF

continues

ADA no.[a]	ADA Name	Total acres	Acres in specific forest	Ecological criteria[b]	LS/OG (%)	Roadless (%)	Wilderness (%)	Condition[c]	Species[d]
707	Thomas Creek	12,816	12,807	RW, GR	9	18	18	1	Bull, MgSc, Rb, StS, WF
708	North Fork Meacham Creek	31,115	28,616	GR	12	84	0	2	Bull, MgSc, Rb, StS, WF
709	East Fork Meacham Creek	14,569	13,039	GR	7	3	0	2	Bull, MgSc, Rb, StS, WF
710	Umatilla River	8775	2075	CC	10	59	20	2	Bull, MgSc, Rb, StS
711	Meacham Creek	15,276	7482	CC	4	60	0	2	Bull, MgSc, Rb, StS
801	Wenaha River (Oregon portion only)	83,718	82,260	CC, GR, RW	21	1	69	1	Bull, ChSp, StS
803	Lookingglass Creek	60,575	47,416	GR	17	19	0	1	Bull, ChSp
812	Grande Ronde River	63,035	6992	CC, GR, HS	9	89	0	2	Bull, ChF, ChSp, StS
816	Upper Grande Ronde River complex	79,196	647	HS	0	17	0	2	Bull, ChSp, StS
Wallowa-Whitman National Forest									
608	North Fork John Day River	149,656	42,347	CC, EF, GR, RW, SV	[e]	8	28	1	BMC, Bull, ChSp, RedRb, StS
610	Camas Creek	55,141	6881	EF, GR, HS	2	0	0	2	BMC, ChSp, RedRb, StS, TF, WCt
614	Clear Creek	82,263	40,544	EF, GR, HS, SV	9	8	0	2	Bull, ChSp, RedRb, StS
621	Hidaway Creek	6185	172	EF, GR, RW	0	36	0	1	BMC, ChSp, RedRb, StS, TF
708	North Fork Meacham Creek	31,115	751	GR	0	20	0	2	Bull, MgSc, Rb, StS, WF
709	East Fork Meacham Creek	14,569	946	GR	0	8	0	2	Bull, MgSc, Rb, StS, WF
802	Minam River	150,032	135,134	GR	[e]	2	86	1	Bull, ChSp, StS

804	N. Fork Catherine Cr.	21,658	21,418	GR	*e*	22	46	2	Bull, ChSp, StS
805	Beaver Creek	38,456	29,792	EF	6	36	0	2	Bull, Rb
806	Upper Imanaha River	137,073	134,706	RW, SV	*e*	7	36	1	Bull, ChSp, StS, TF
807	Imnaha River	86,959	65,508	CC, GR	*e*	64	1	2	Bull, ChF, ChSp, StS
808	Lower Imanaha River complex	102,381	97,723	HS	6	89	1	1	StS, TF
809	Cook-Cherry Creek	30,907	30,581	GR, RW	0	75	0	2	SR RedRb, TF
810	Lick Creek	8848	8838	HS	*e*	4	15	2	Bull, ChSp, StS
811	Big Sheep Creek	77,971	60,423	HS, SV	*e*	14	15	2	Bull, ChSp, StS
812	Grande Ronde River	63,035	5119	CC, GR, HS	*e*	83	0	2	Bull, ChF, ChSp, StS
815	Hurricane Creek	21,582	21,122	GR	*e*	4	97	1	Bull
816	Upper Grande Ronde River complex	79,196	70,215	HS	5	18	0	2	Bull, ChSp, StS
817	Deep Creek	16,893	16,886	GR	*e*	4	98	1	SR RedRb
818	Joseph-Chesnimnus Creek	38,965	14,294	CC, EF, GR, HS, SV	*e*	37	0	2	StS
819	Little Peavine–Rush Creek	13,813	11,705	EF, GR, HS	15	39	0	1	StS
820	Swamp Creek	42,900	20,472	EF, GR	2	47	0	2	StS
821	Cougar Creek	6640	6488	EF, GR, HS	6	5	0	2	StS
822	Big Peavine Creek	16,446	15,552	EF, GR, SV	7	0	0	2	StS
823	Upper Chesnimnus Creek	19,118	14,662	EF, GR, RW, SV	14	2	0	1	StS
824	Devil's Run–Summit Creek	13,714	13,689	EF, GR, SR	5	2	0	2	StS, TF
826	Broady Creek	12,132	9159	EF, GR, HS, SR	14	13	0	1	StS, TF
827	Upper Cottonwood Cr.	25,005	18,851	EF, GR, HS	8	83	0	1	StS, TF
828	Bear Creek	4735	217	CC, EF, SR	0	0	0	2	Bull, ChSp, StS
829	Upper Bear Creek	37,364	35,476	EF, SR	*e*	16	68	2	Bull, ChSp, StS, TF
831	Lostine River	39,850	39,634	EF, SR	*e*	0	87	1	Bull, ChSp, StS, TF

continues

ADA no.[a]	ADA Name	Total acres	Acres in specific forest	Ecological criteria[b]	LS/OG (%)	Road-less (%)	Wild-erness (%)	Condi-tion[c]	Species[d]
832	Fivepoints Creek	45,023	35,406	EF	3	22	0	1	Rb
833	Indian Creek	36,011	15,191	EF, GR	10	34	0	2	Bull, Rb
901	Upper Pine Creek complex	45,196	42,580	GR	9	34	9	2	Bull, StS, TF
903	Upper Cracker Creek	17,035	14,287	GR	13	50	0	2	Bull
904	Lake Creek	2877	2873	GR	26	39	0	2	Bull
905	Eagle Creek	87,938	84,950	GR	[e]	19	34	2	Bull
906	Upper North Pine Creek complex	37,235	36,968	GR	25	49	0	2	Bull
907	N. Pine Creek	5898	4101	CC	6	32	0	2	Bull, StS
909	N. Powder R. complex	21,934	21,868	GR	10	4	0	2	Bull
Winema National Forest									
1401	Spencer Creek	19,347	11,680	CC, GR, HS	[e]	19	18	2	RedRb
1402	Jenny Creek	120,713	308	GR, HS	1	17	0	2	JCSu, RedRb
1403	Spencer Creek	11,186	328	CC, GR, SV	3	0	0	2	RedRb
1405	Upper Williamson River	149,300	99,015	GR, HS	20	11	0	2	KLgSu, KSD, KTC, RedRb
1412	Spring Creek	10,709	7,912	EF, GR, HS	17	0	0	1	RedRb
1414	Williamson-Sprague River	11,962	4474	CC, GR, HS, SR	32	21	0	2	KLgSu, LRSu, SNSu, RedRb
1416	Middle Williamson R.	2215	1440	EF, GR, HS	6	13	0	2	RedRb
1417	Threemile Creek	10,056	9864	GR, HS	[e]	6	47	2	BT, Bull
1418	Upper Klamath–Agency lakes	120,487	3340	EF, GR, HS, SR, SV	11	34	0	2	KLSc, KLgSu, LRSu, MbSc, RedRb, SNSu, SlSc

[a] The first digit in each three-digit number and the first two digits in each four-digit number correspond to the major drainage basin in which each ADA occurs, as defined by the Oregon Water Resources Board: 5 = Deschutes; 6 = John Day; 7 = Umatilla; 8 = Grande Ronde; 9 = Powder; 10 = Malheur; 12 = Malheur Lake; 13 = Goose and Summer Lakes; 14 = Klamath. ADAs in the Hood River basin (see Figure 3.1) were excluded from the Eastside Forests Scientific Society Panel analysis. ADAs in the Owyhee River basin do not occur on national forest land and do not appear in this table.

[b] CC = connecting corridor; EF = ecological function (e.g., cool-water source); GR = genetic reserve; HS = highly sensitive (e.g., unstable soils or cumulative disturbances that increase vulnerability to future effects); RW = reference watershed (relatively intact example of a particular ecosystem type); SV = scientific value (e.g., long-term data set).

[c] 1 = Relatively undisturbed and intact system: high-quality habitat, water source, or both; 2 = partially or moderately degraded: recovery or active restoration needed.

[d] Species codes: Only those aquatic species that were important in the selection of each ADA are listed. Some species (e.g., *Oncorhynchus mykiss*) or subspecies have been assigned more than one code to distinquish potentially unique populations (e.g., Warner Valley redband trout). A few exotic species (brook trout, brown trout) are also listed to indicate a potential risk to native fauna, but the list of exotics in ADAs is incomplete.

Br	Brown trout (exotic)	*Salmo trutta*
Bull	Bull trout	*Salvelinus confluentus*
BrS	Bridgelip sucker	*Catostomus columbianus*
BT	Brook trout (exotic)	*Salvelinus fontinalis*
BMC	Blue Mountain cryptochian	*Cryptochia neosa (trichoptera)*
ChF	Fall chinook salmon	*Oncorhynchus tshawytscha*
ChSp	Spring chinook salmon	*Oncorhynchus tshawytscha*
GLL	Goose Lake lamprey	*Lampetra tridentata* ssp.
GL RedRb	Goose Lake redband trout	*Oncorhynchus mykiss* ssp.
JCSu	Jenny Creek sucker	*Catostomus rimiculus* ssp.
KLSc	Klamath Lake sculpin	*Cottus princeps*
KLgSu	Klamath largescale sucker	*Catostomus snyderi*
KSD	Klamath speckled dace	*Rhinichthys osculus* ssp.?
KTC	Klamath tui chub	*Gila bicolor* ssp.?
LRSu	Lost River sucker	*Deltistes luxatus*
MbSc	Marbled sculpin	*Cottus klamathensis*
MgSc	Margined sculpin	*Cottus marginatus*
MMoSc	Malheur mottled sculpin	*Cottus bairdi* ssp.
PiRo	California (pit) roach	*Hesperoleucus symmetricus mitrulus*
PiSc	Pit sculpin	*Cottus pitensis*
Rb	Rainbow trout	*Oncorhynchus mykiss*
RedRb	Redband–inland rainbow trout	*Oncorhynchus mykiss* ssp.
SD	Speckled dace	*Rhinichthys osculus*
SqF	Squawfish	*Ptychocheilus oregonensis*
SlSc	Slender sculpin	*Cottus tenuis*
StS	Steelhead	*Oncorhynchus mykiss*
SNSu	Shortnose sucker	*Chasmistes brevirostris*
SR RedRb	Snake River redband trout	*Oncorhynchus mykiss* ssp.
TF	Tailed frog	*Ascaphus truei*
WaS	Warner sucker	*Catastomus warnerensis*
WBTC	Warner Basin tui chub	*Gila bicolor* ssp.
WCt	Westslope cutthroat trout	*Oncorhynchus clarki lewisi*
WF	Mountain whitefish	*Prosopium williamsoni*
WV RedRb	Warner Valley redband trout	*Oncorhynchus mykiss* ssp.

[e] Percentage LS/OG not calculated because 10% or more of the ADA lies in wilderness area where LS/OG was not mapped.