Pacific Northwest

The Pacific Northwest has a tremendous wealth of natural resources. Spectacular forests, expansive rangelands, and plentiful salmon have drawn people from throughout the country for more than a century. Many biodiversity issues are debated in this region, but four primary concerns are currently emphasized and are the main focus of this chapter: status of mature and old-growth coniferous forests west of the Cascade Range (commonly called the westside); status and health of forests east of the Cascade Range (commonly called the eastside); status and health of eastside rangelands; and status and health of riparian and aquatic ecosystems and anadromous fish populations.

Physiographic Overview

To help with regional assessments, scientists divide the North American continent into a series of ecoregions (biogeographical regions) that represent distinct landscape units characterized by unique combinations of vegetation, geology, topography, hydrology, climate, and ecological history (Omernik 1987, 1995). The Pacific Northwest (Fig. 1a) includes either all or portions of 12 ecoregions in the United States (Fig. 1b).

Forests of large, coniferous trees (red cedars, Douglas-firs, firs, pines, spruces, and others) dominate most of the Pacific Northwest landscape. Coniferous forests cover about 80% of western Oregon and Washington (Tesch 1995). The number of conifer species in this region is unequaled, and several are the tallest and most massive trees in the world (Franklin et al. 1981). Cool, wet winters and warm, dry summers (largely a result of oceanic influence) favor evergreen species, whereas mild temperatures and rich soils promote fast and prolonged growth (Waring and Franklin 1979).

Although conifers predominate in many areas, the Pacific Northwest landscape is highly complex (Franklin and Dyrness 1973; Barbour and Billings 1988; Tesch 1995). The ocean and mountains are the principal factors responsible for the complexity. At lower elevations west of the Olympic Mountains and Coast Range (Fig. 1b), temperatures remain consistently mild and summer fog reduces moisture stress during an otherwise dry season. Aridity and temperatures progressively increase farther inland, especially east of the Cascade Range, because of rainshadow effects caused by mountains. The warmest and driest habitats in this region occur at low elevations in the Snake River Basin–High Desert ecoregion (Fig. 1b).

Regional variation in climate, soils, and topography contributes to differences in vegetation that distinguish each ecoregion. Dense, moist forests of primarily western hemlock and Douglas-fir predominate west of the Cascades (Cascades, western North Cascades, and Coast Range ecoregions). However, the Klamath Mountains ecoregion supports a diverse mixture of drought-resistant conifers and hardwoods, a result of lower precipitation and a complex geological and ecological history. In addition, the lowland river valleys of western Oregon and Washington support extensive oak woodlands, grasslands, and wetlands composed of herbaceous plants (Willamette Valley and Puget Lowland ecoregions). On the eastside, increased aridity and frequent fires promote open, parklike stands of ponderosa pine, lodgepole pine, and western larch in montane areas (eastern North Cascades, Eastern Cascades Slopes and Foothills,

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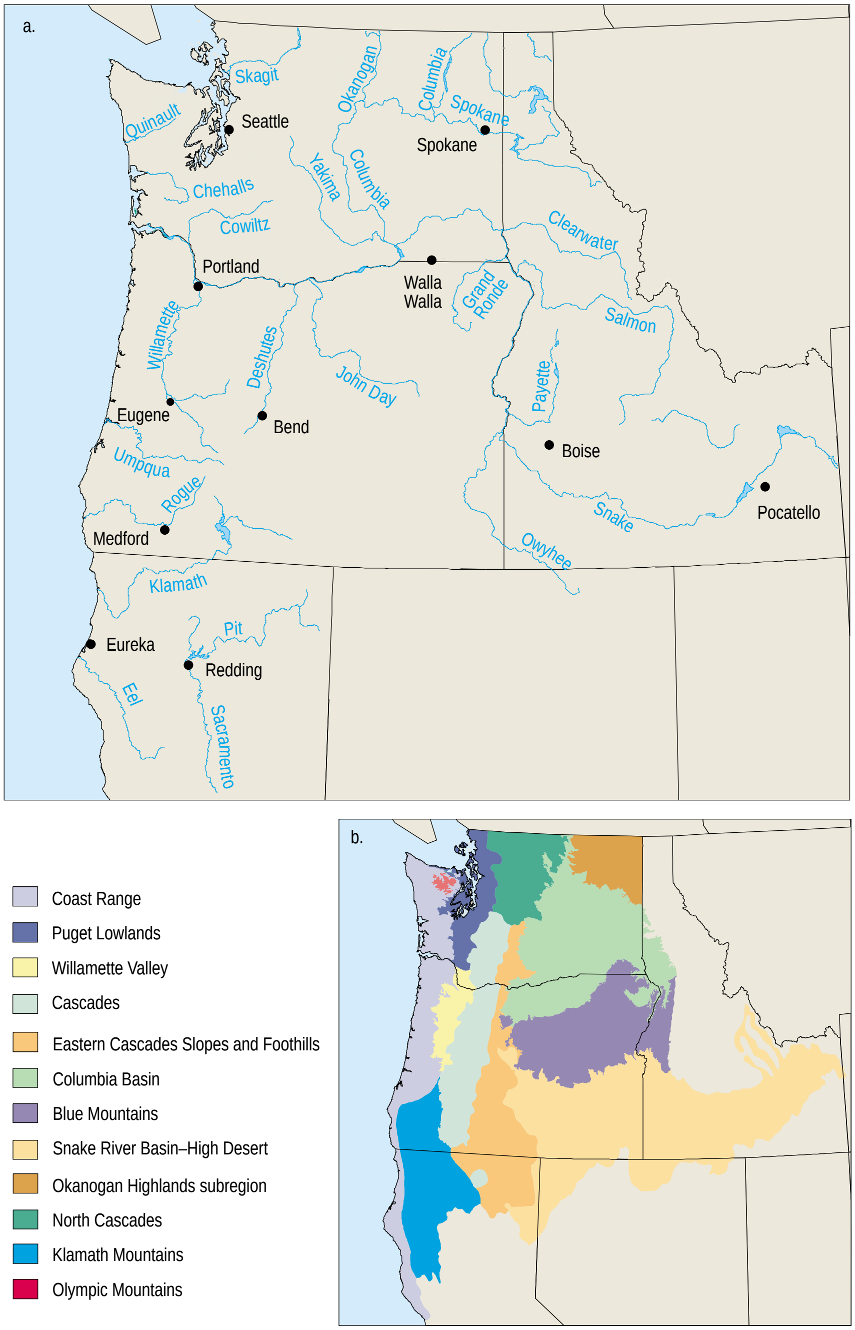

Fig. 1. a) The Pacific Northwest (rivers in blue); b) Pacific Northwest ecoregions (after Omernik 1987 © Blackwell Scientific Publishers; current version provided by S. Azevedo, U.S. Environmental Protection Agency, Corvallis, Oregon).

and Blue Mountains ecoregions, and the Okanogan Highlands subregion) and juniper woodlands, sagebrush–steppe, and grasslands at lower elevations (Columbia Basin and Snake River Basin–High Desert ecoregions).

Status and Trends of Major Ecosystems

Westside Forests

A complex history of disturbances from natural and Native American-induced fires complicates assessments of the typical pre-European settlement in the westside landscape (Johannessen et al. 1971; Agee 1991, 1993). Scientists generally agree, however, that most presettlement forests included diverse mixtures of conifers of different age and size classes, with each class occurring in large patches (Ripple et al. 1991; Ripple 1994; Spies et al. 1994).

Fifty years of even-age timber management by clear-cut logging and replanting greatly altered the structure of forests in the region (Franklin and Forman 1987; Spies and Franklin 1988, 1991; Morrison and Swanson 1990; Ripple 1994; Spies et al. 1994). Today's forests are composed primarily of intermixed patches of stands less than 50 years old with small trees (average diameter at breast height less than 51 centimeters) and older stands with much larger trees (average diameter greater than 102 centimeters, height greater than 70 meters). Forests classified as old-growth (Fig. 2) are generally at least 200–250 years old (Old-Growth Definition Task Force 1986).

Scientists estimate that about 17% of the old-growth Douglas-fir forests that existed in the early 1800's remained in 1988 (Spies and Franklin 1988; Marcot et al. 1991) and that 96% of the original coastal rain forests in Oregon and 75% in Washington had been logged by 1988 (Kellogg 1992). About 51% (2,383,624 hectares) of the federal lands in western Oregon


Courtesy T. B. Thomas, U.S. Forest Service

Fig. 2. Old-growth Douglas-fir forest in the Bull Run watershed, Mount Hood National Forest, Oregon.

and Washington currently supports older forests (average tree diameter greater than 51 centimeters; Forest Ecosystem Management Assessment Team 1993), and about 56% (1,333,049 hectares) of these older stands (28% of total forest cover on federal lands) is classified as old-growth (Bolsinger and Waddell 1993).

Forest fragmentation (Fig. 3) is an important factor to consider when estimating remaining old-growth. Morrison (1988) estimated that 37% of the old-growth in the national forests of western Oregon and Washington occurs in fragmented landscapes (that is, stands of fewer than 162 hectares surrounded by clear cuts, young plantations, and nonforest habitats). The distribution and viability of some wildlife and plant species may be adversely affected by forest fragmentation (Harris 1984; Franklin and Forman 1987; Lehmkuhl and Ruggiero 1991). For species that depend on habitat characteristics that are unique to old-growth forests, a patchwork of small, disjunct stands of old-growth may not be equivalent to one solid patch of equal area.

Eastside Forests

In the past, wildfire, pathogens, and periodic droughts shaped the eastside forest landscape, which was much different from today's landscape (Mutch et al. 1993; Agee 1994; Arno and Ottmar 1994; Lehmkuhl et al. 1994). Open, parklike, old-growth stands of ponderosa pine (Fig. 4), western larch, and lodgepole pine with grassy understories once dominated eastside forests at low and moderate elevations. Frequent, low-intensity fires maintained these forests. The typical landscape pattern was a fine-scale mosaic of stands of varying ages and stages of development, with young stands a result of infrequent, stand-replacing fires. A long history of selective harvesting of mature pines and larches, intensive grazing, and fire suppression greatly altered this forest landscape, however.

Sixty years ago, 74% of the commercial forests in the region was classified as ponderosa pine timber, much of which was old-growth (Cowlin et al. 1942). Recent estimates suggest that 92%–98% of the old-growth ponderosa pine that once existed in the Deschutes, Fremont, and Winema national forests has been logged or lost (Henjum et al. 1994). Stands classified as mixed-conifer timber, frequently overstocked with second-growth pines and firs tolerant of crowding, now cover most of the eastside forest landscape (Mason and Wickman 1994).

The current focus on assessments of forest health and options for restoring old-growth stands reflects concern that more than a century of human disturbance now threatens the stability and sustainability of eastside forest ecosystems (Everett et al. 1994; Tesch 1995). Large areas of dead trees exist now because of past harvest practices and fire suppression that led to overcrowding, epidemic outbreaks of insects, and unusually intense and extensive wildfires (Fig. 5).

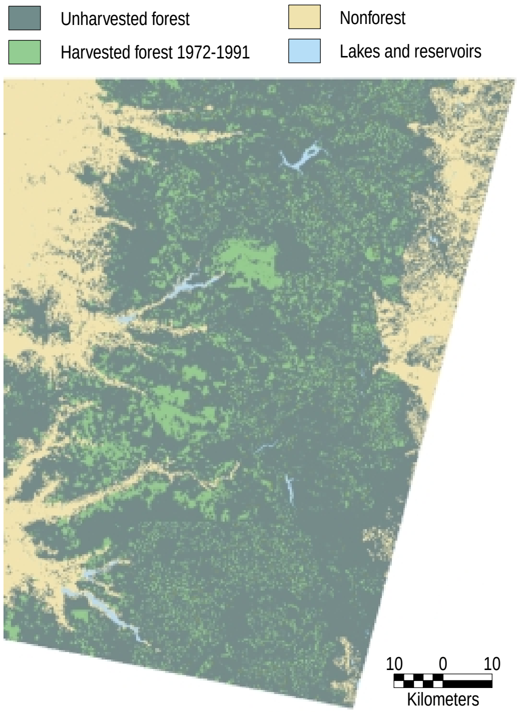

Fig. 3. Forest fragmentation in the central Oregon Cascades (image processing by W. B. Cohen, U.S. Forest Service, Corvallis, Oregon).

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Fig. 4. Classic old-growth ponderosa pine forest with open, grassy understory near Bend, Oregon.

Courtesy D. W. Scott, U.S. Forest Service

Fig. 5. Examples of unhealthy forests in the Blue Mountains ecoregion: a) overstocked firs (brown, dead, and dying trees) are susceptible to defoliation by insects such as the western spruce budworm; these insects do not feed on ponderosa pine and western larch (green trees); b) close-up of understory with overstocked grand firs that were killed by western spruce budworm—healthy, sparsely stocked, mature western larch remain in the overstory; c) combined mortality caused by attacks of budworms and bark beetles leaves a dead, fire-susceptible forest.

Suppression of low-intensity fires and selective harvesting of large, old trees have generally homogenized the eastside landscape, especially in mixed-conifer forests at middle elevations (Lehmkuhl et al. 1994). Unnaturally large, adjoining areas of densely stocked and stressed trees provide an increased food base for defoliating insects (Mason and Wickman 1988; Gast et al. 1991; Hessburg et al. 1994) and are more favorable to the growth of parasitic plants (Zimmerman and Laven 1984; Gast et al. 1991) and fungal pathogens (Filip and Schmitt 1990). The western spruce budworm is native to North America, but extensive, prolonged outbreaks of the intensity illustrated in Figure 6 were not recorded before the late 1940's (Gast et al. 1991). Historically, defoliating insects (for example, western spruce budworm, bark beetles, and mountain pine beetle) affected only small patches of forest, but such insects now tend to occupy large areas at periodic outbreak levels (Hessburg et al. 1994). From 1986 to 1991, for example, bark beetles killed an estimated 1.5 million cubic meters of timber in northeastern Oregon. Similarly, in 1991 western spruce budworms defoliated about 1,618,760 hectares of forest in the same region (Oester et al. 1992).

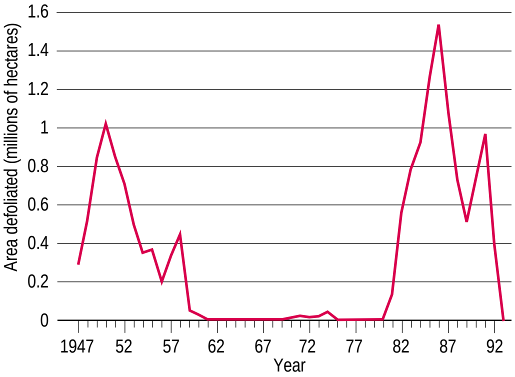

Fig. 6. Defoliation by western spruce budworms in the Blue Mountains ecoregion (data provided by D. Scott, U.S. Forest Service, LaGrande, Oregon).

Fire suppression is a principal cause of current problems with forest health in the region. The threat of extreme fire is now a serious problem because widespread tree mortality due to insect feeding and prolonged drought resulted in large accumulations of fuel. Wildfires are now more often of stand-replacing intensity and burn larger areas than they did before European settlement (Arno and Ottmar 1994). Thus, although the return of a more natural disturbance regime including frequent, low-intensity fires is the key to restoring forest health in the region, the reintroduction of fire to produce the desired results is difficult (Mutch et al. 1993; Tanaka et al. 1995).

Eastside Rangelands

Human activities during the past 100–150 years significantly altered most lowland, eastside ecosystems. More than 99% of the fertile Palouse Prairie grasslands of southeastern Washington and adjacent areas of Oregon and Idaho was converted to cropland, primarily for annual wheat (Noss et al. 1995). More than 99% of basin big sagebrush communities on the Snake River plain of Idaho and a total of 10% of the sagebrush–steppe (about 45 million hectares; Fig. 7) in the Intermountain West (that part of the United States between the Rocky Mountains and the coastal mountains), were converted to agriculture (Hironaka et al. 1983; Noss et al. 1995; West 1996). Livestock altered nearly all of the remaining sagebrush–steppe; about 30% was heavily grazed (West 1996). Because vegetation in this region did not coevolve with large herbivores, it is sensitive to grazing by domestic livestock (Daubenmire 1970). Considerable expanses (2–2.5 million hectares) of grassland and sagebrush–steppe have been replaced by invasive, nonindigenous annual vegetation, primarily because of overgrazing (Pellant 1990; Whisenant 1990; Pyke and Borman 1993; Noss et al. 1995).

Livestock grazing pressure and rangeland condition vary depending on who owns or manages the land. About 70% of nonfederal rangelands and 65% of Bureau of Land Management rangelands in the Pacific Northwest were in fair to poor condition in the mid-1980’s (Joyce 1989). A similar regional rating for U.S. Forest Service lands was not available; however, a national assessment showed that 80% of these lands was in satisfactory condition for livestock in 1986 (Joyce 1989). From 1953 to 1986, grazing increased about 25% on U.S. Forest Service lands but remained at constant levels on Bureau of Land Management lands in the Pacific Northwest (Joyce 1989). These trends coincided with a 15%–20% decrease in total pasture and rangeland area in the three Pacific Coast states (Joyce 1989). Broader, integrated assessments of the health of public and private rangeland have been attempted (Society for Range Management 1989) but suffer from a lack of standardized surveys and common assessment criteria (National Research Council 1994).

Successional relations in grassland and sagebrush–steppe communities are more complex than formerly thought (Laycock 1991). The mere removal of disturbances such as grazing does not ensure the return of original plant communities (Anderson and Holte 1981; Anderson 1986). About 9% (2.8 million hectares) of the public land administered by the Bureau of Land Management in the region is sufficiently degraded so that changes in land management alone will not significantly improve rangeland quality (Pyke and Borman 1993).

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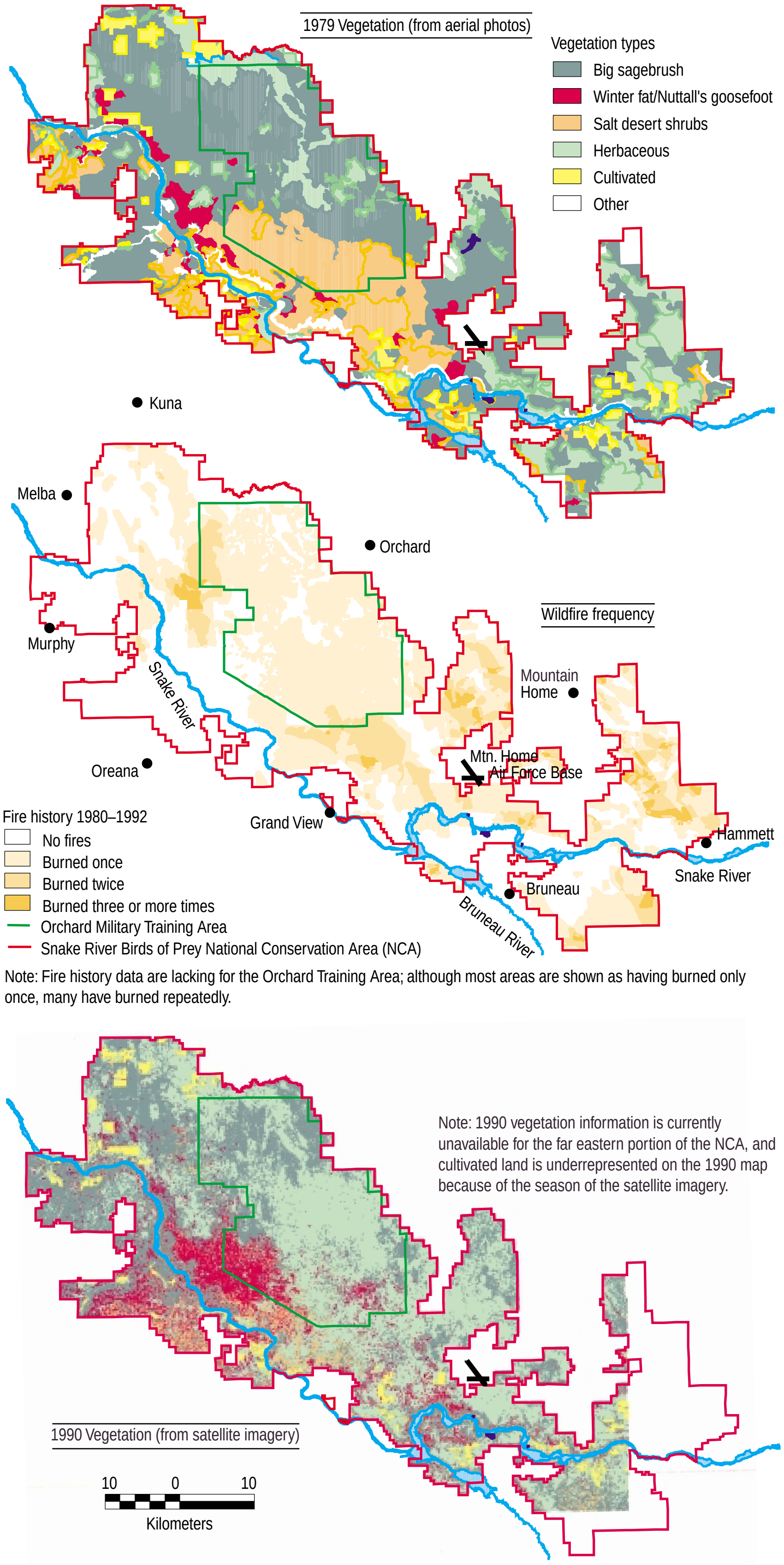
Fig. 7. Sagebrush–steppe near Fish Fin Rim, Lake County, Oregon.

Invasion and expansion of nonindigenous plants are major concerns in rangeland ecosystems of the Pacific Northwest (Pyke and Borman 1993). The introduction and initial spread of nonindigenous annual grasses (primarily cheatgrass [Fig. 8] and medusahead) occurred from the late 1800’s to the mid-1900’s during a period of severe overgrazing (Mack 1986). The competitive abilities of these nonindigenous grasses allow them to invade even areas that are not grazed, especially after wildfires (West and Hassan 1985; Whisenant 1990; Kindschy 1994). From 1981 to 1987, 202 fires burned 88,322 hectares in the Snake River Birds of Prey National Conservation Area in Idaho and converted a considerable area of a native shrub–steppe into sites dominated by nonindigenous grasses, primarily cheatgrass (Pellant 1990; Zarriello et al. 1994; Fig. 9). Cheatgrass is dominant on about 6.8 million hectares of sagebrush–steppe in the Intermountain West and could eventually invade an additional 25 million hectares (Pellant and Hall 1994).

The intentional introduction of nonindigenous perennial grasses such as crested wheatgrass is another problem. This species is widely

Courtesy D.A. Pyke, USGS

Fig. 8. Nonindigenous cheatgrass (short, bright-green grass in foreground) invading native sagebrush–steppe near Orchard, Idaho.



Note: Fire history data are lacking for the Orchard Training Area; although most areas are shown as having burned only once, many have burned repeatedly.

Note: 1990 vegetation information is currently unavailable for the far eastern portion of the NCA, and cultivated land is underrepresented on the 1990 map because of the season of the satellite imagery.

Fig. 9. Shifts from native shrub–steppe (big sagebrush and salt desert shrub) to primarily nonindigenous grasslands (herbaceous cover) between 1979 and 1990 in areas burned by wildfire in the Snake River Birds of Prey National Conservation Area (NCA), Idaho (maps prepared with the help of T. Zarriello, USGS, Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon).

planted during revegetation projects because it is desirable as livestock forage and grows faster than most native species (Pellant and Monsen 1993). Even when planted as a mixture with native species, crested wheatgrass often dominates the site and thereby further reduces habitat diversity (DePuit and Coenenberg 1979; Schuman et al. 1982; Redente et al. 1984).

Juniper woodlands are also rapidly expanding, to the detriment of preferred rangeland vegetation (Miller and Wigand 1994; Fig. 10). The range of western juniper has expanded and contracted several times during the past 30,000 years. These shifts can largely be explained by changes in the global climate (Miller and Wigand 1994); however, the recent, accelerated increase in juniper coverage is a result of a combination of favorable climate, livestock grazing, and a lack of fire (Eddleman 1987; Miller and Rose 1995).

Riparian and Aquatic Ecosystems

The Pacific Northwest includes a diverse network of rivers and streams (Fig. 1a). The Columbia River is one of the largest rivers in North America, and several of its tributaries (for example, the Snake, Salmon, and Willamette rivers) are among the largest rivers in the conterminous United States. These river systems are major sources of natural resources; however, competing developmental interests, associated disturbances, and unsustainable resource extraction have led to widespread degradation of most of the river and stream networks in the Pacific Northwest.

In 1988, 95% (23,174 kilometers) of streams surveyed throughout Oregon had been moderately or severely degraded because of excessive sedimentation, high water temperatures, bank instability, or other problems with water quality related primarily to logging and removal of large woody debris from stream channels (Forest Ecosystem Management Assessment Team 1993). In 1992, 4,828 kilometers (54%) of rivers surveyed in Washington were classified as not fully supporting designated beneficial uses because of various types of pollution and degradation (Forest Ecosystem Management Assessment Team 1993). In the north coast and Klamath River basin regions of California, 51% of surveyed streams failed to meet requirements for compliance with the Clean Water Act (Forest Ecosystem Management Assessment Team 1993). About 83% of the riparian habitat on lands administered by the Bureau of Land Management was in need of extensive restoration in the late 1970's (Almand and Krohn 1979); a more recent assessment showed that this was still true in Idaho in 1991 (U.S. General Accounting

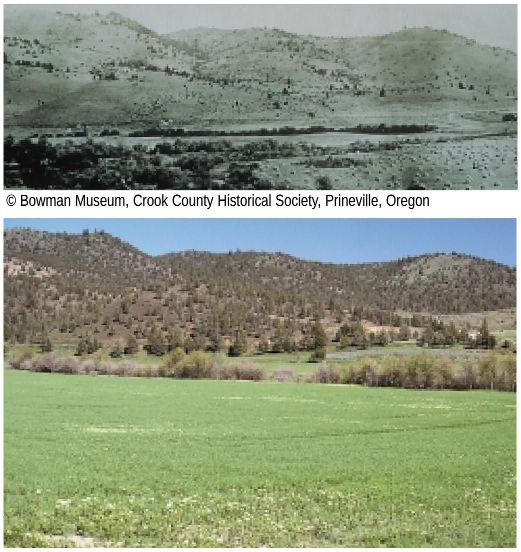


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Fig. 10. Change in coverage of juniper woodland on hillsides above Keystone Ranch near Prineville, Oregon, between 1910 (top) and 1991.

Office 1988). Degradation of these streams was mostly due to grazing-related damage to riparian vegetation, bank stability, and water quality (Kauffman and Krueger 1984; Platts 1991; Wissmar et al. 1994). Thus, throughout the Pacific Northwest, most riparian ecosystems are at least moderately if not severely degraded because of logging, grazing, mining, water diversions, hydroelectric dams, and other human activities.

The landscape along the largest river in Oregon, the Willamette River, has been drastically altered by a long history of agricultural development, channelization, and diking to control flooding (Sedell and Froggatt 1984). The southern half of the river was once a braided system with a diverse network of oxbows, small side channels, ponds, and sloughs that supported extensive marshlands and riparian gallery forests, but the river landscape is much simpler today. Moreover, large deposits of organic wastes from agricultural and urban operations greatly reduced water quality in the river until the 1950's, when secondary sewage treatment began (Hughes and Gammon 1987). These physical and biological changes have profoundly altered the associated riparian and aquatic communities along the river (Dimick and Merryfield 1945; Sedell and Froggatt 1984; Hughes and Gammon 1987; Farr and Ward 1993).

Widespread removal of large woody debris from streams (Fig. 11), lack of recruitment of new woody debris, and increased sedimentation caused by logging and other land uses have reduced the structural diversity of instream habitats for fishes and other aquatic organisms in many of the region's streams. The abundance of large, deep pools—essential components of high-quality fish habitat that frequently form behind large logs—declined in streams throughout the region during the past 50–60 years, in some areas by as much as 50%–60% (Forest Ecosystem Management Assessment Team 1993; McIntosh et al. 1994).

In the past, the status of small headwater springs, seeps, and creeks received little attention in the timber, management, and scientific communities, but this is not as true today (Johnson et al. 1991; Forest Ecosystem Management Assessment Team 1993; Thomas et al. 1993; Henjum et al. 1994; U.S. Forest Service and Bureau of Land Management 1994a). Although small and often ephemeral headwater streams typically do not support fishes, the integrity of these watershed areas is a critical determinant of water and habitat quality in downstream areas where fishes do occur (Vannote et al. 1980; Swanson et al. 1982; Naiman et al. 1992). Logging, mining, grazing, or road building in headwater areas may alter downstream flow regimes, increase sediment loads, and reduce recruitment of woody debris and nutrients to fish-bearing streams. Moreover, small headwater seeps and creeks are habitats for many amphibians (Bury 1988) and may be important water sources for other forest wildlife (Brown 1985).

Many eastside river systems (for example, the John Day, Grand Ronde, Yakima, Wenatchee, Entiat, and Methow rivers) were recently studied to assess the effects of logging, grazing, and mining on riparian habitat and aquatic communities (Mullan et al. 1992; Li et al. 1994; McIntosh et al. 1994; Wissmar et al. 1994). Substantial portions of many of these forested river systems were badly degraded by a long history of logging and grazing (Henjum et al. 1994; U.S. Forest Service and Bureau of Land Management 1994b). Degradation of the rivers, creeks, and lakes in the Goose Lake–Pit River and Klamath basins of southern Oregon and northern California is also a problem because these systems harbor many endemic species and subspecies of fishes (Puchy and Marshall 1993), including two suckers (Lost River sucker and shortnose sucker) on the U.S. List of Endangered and Threatened Wildlife (U.S. Fish and Wildlife Service 1995).

Courtesy G. H. Reeves, U.S. Forest Service

Fig. 11. A healthy stream ecosystem in the Siskiyou National Forest, Oregon, with ample large woody debris that enhances habitat diversity for fishes and other aquatic organisms.

Eastside lowland ecoregions include the primary stretches of the extensive Columbia and Snake river systems. The main-stem and major tributary sections of these two rivers contain several large hydroelectric dams. Large dams create barriers to salmon and white sturgeon movements and alter river flow rates and patterns to the detriment of many fish populations (Northwest Power Planning Council 1986, 1994; Beamesderfer and Nigro 1993). In addition, most riparian cottonwood forests in Idaho are no longer self-sustaining because dams have eliminated the spring flooding that exposed the mineral soil needed for seed germination (Noss et al. 1995).

The Pacific Northwest contains more than 8,000 lakes, ponds, and reservoirs. However, aside from recent intensive research in North Cascades National Park Service Complex, Mt. Rainier National Park, and Crater Lake National Park (Liss et al. 1995; other unpublished work by W. J. Liss, Oregon State University, and G. L. Larson, U.S. Geological Survey, Corvallis, and their colleagues) and some work in Lake Lenore, Washington (Luecke 1990), these water bodies have not been well studied (Bahls 1992).

Status and Trends of Fungi, Plants, and Animals

Fungi

The wet, temperate, locally variable forest environment and high richness of plant species in the western Pacific Northwest are highly conducive for growth of a wide variety of fungi. Forest fungi are ecologically important to the region, because of their important role in forest food webs (Forest Ecosystem Management Assessment Team 1993); some species are eaten by small mammals such as western red-backed voles and northern flying squirrels (Maser et al. 1978, 1985; Maser and Maser 1988; Fig. 12), which, in turn, are primary prey species for northern spotted owls (Forsman et al. 1984). Moreover, 234 rare and endemic species of fungi are identified in the Northwest Forest Plan (Forest Ecosystem Management Assessment Team 1993; U.S. Forest Service and Bureau of Land Management 1994a) as associates of mature and old-growth forests. These concerns challenge resource managers to integrate fungal productivity, diversity, and conservation into strategies for ecosystem management in the region. The status and biology of most fungal species are poorly known, however.

Fig. 12. Truffles, the belowground reproductive structures of many mycorrhizal fungi, are favored foods of small mammals such as this northern flying squirrel.

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Courtesy J. E. Smith, U.S. Forest Service

Fig. 13. This delicate coral fungus is a mycorrhizal species associated with Douglas-fir and other conifers in the Oregon Cascades.

Mycorrhizal and Old-Growth Forest Fungi

Many commercially harvested mushrooms (aboveground) and the truffles (belowground) favored by small mammals are the reproductive structures of mycorrhizal fungi (Fig. 13). These fungi are particularly important components of forests in the region because they form beneficial, mutualistic symbioses with roots of most conifers (Trappe and Luoma 1992). Recent research has revealed that the diversity and productivity of mycorrhizal fungi are higher in mature stands of Douglas-fir than in young or clear-cut stands (Amaranthus et al. 1994; R. Molina, J. E. Smith, and M. A. Castellano, U.S. Forest Service, Corvallis, Oregon, unpublished data).

Scientists have identified 527 species of fungi that are closely associated with mature and old- growth forests in the Pacific Northwest (Forest Ecosystem Management Assessment Team 1993). About 150 of these species are mycorrhizal fungi that were found in the H. J. Andrews Experimental Forest in the Oregon Cascades, and 109 species are regional endemics that may be sensitive to alteration of the forest environment. One endemic species that may be an important indicator of old-growth forest conditions in the Cascade Range is *Piloderma fallax* (Smith, Molina, and Castellano, unpublished data; Figs. 14 and 15), an unusual fungus that does not produce fleshy reproductive structures (mushrooms or truffles).

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Fig. 14. The golden-yellow threads running through a patch of forest soil are hyphae of the fungus *Piloderma fallax*, which is strongly associated with old-growth forests in the Oregon Cascades.

Scientists have conducted considerable research focused on inoculating tree seedlings used in forest regeneration with spores of mycorrhizal fungi to improve tree growth (Castellano and Molina 1989). Natural mycorrhizal inoculum potential declines when live trees remain absent from harvested sites for several years (Perry et al. 1987). Retention of some live host trees and abundant woody debris on harvested sites promotes forest tree and fungal regeneration (Amaranthus et al. 1994). Maintenance of mycorrhizal fungi on harvested sites also may depend on recovery of nontimber, pioneer trees, and shrubs that are normally eliminated by forest management procedures (Perry et al. 1987; Amaranthus and Perry 1989).

Pathogenic Fungi

The biological diversity of microfungi (molds, mildews, rusts, and smuts) is not well known; however, some fungal pathogens have been extensively studied because of the economic consequences of timber loss. For instance, Douglas-fir is highly susceptible to the fungal infection called laminated root rot (Gast et al. 1991; Thies and Sturrock 1995).

The distribution of pathogenic fungi in eastside forests expanded as forest density and fire suppression increased. In 1986 and 1987, a minimum of 2%–20% of the trees (variable depending on the species; highest incidence among Douglas-fir) on managed stands in the Wallowa–Whitman National Forest was infected with some form of fungal pathogen (Schmitt et al. 1991). Trees weakened by fungal pathogens may be more susceptible to insect attack, and vice versa. Gast et al. (1991) discussed the biology, incidence, and effects of 11 different fungal diseases that are now widespread in the Blue Mountains ecoregion.

Fungal pathogens and forest insects reduce the growth and survival of trees; however, weakened live trees and standing or downed dead trees and snags are important habitats for many invertebrate and vertebrate species (Thomas 1979; Brown 1985). In addition, the patchy pattern of tree death and subsequent distribution of canopy gaps caused by root fungi could be a key landscape feature that enhances species and habitat diversity in mature forests (Gast et al. 1991; J. C. Tappeiner III, U.S. Geological Survey, Corvallis, Oregon, personal communication). Landscape-scale studies of the ecological roles and importance of fungi have only recently become a focus of attention, however (Amaranthus and Perry 1994).

Plants

Bryophytes and Lichens

The moist, low-elevation forests of the Pacific Northwest support a variety of plants, but they are particularly rich in bryophytes (mosses, liverworts, and hornworts) and lichens (Brinkley and Graham 1981; McCune 1993). Lobaria lichens (Fig. 16) are some of the few species of plants strongly associated with mature forests in the Cascades and Coast Range of Oregon (Spies 1991). The abundance of many mosses and liverworts is closely correlated with the abundance of coarse woody debris (Lesica et al. 1991), a primary distinguishing characteristic of mature forests. Thus, although systematic population surveys are not common, the regional abundances of lichens and bryophytes probably declined as old-growth forests were extensively clear-cut (Forest Ecosystem Management Assessment Team 1993; McCune 1993).

Relatively few species of bryophytes and lichens occur in eastside rangelands, but these plants are major components of many arid ecosystems. Mixtures of bryophytes, lichens, fungi, algae, bacteria, and cyanobacteria, collectively called cryptobiotic crusts, fill the spaces between shrubs and bunchgrasses in many steppe ecosystems (see box on Soils and Cryptobiotic Crusts in Southwest Chapter). Crusts may improve soil fertility and stability, influence water infiltration, interfere with establishment of nonindigenous plants such as cheatgrass, and improve seed germination for various native plant species (St. Clair and Johansen 1993). In some areas, crusts may constitute 70%–80% of the living cover (Belnap 1990).

The area covered by cryptobiotic crusts in the United States is much smaller now than in the past (McCune and Rosentreter 1992). The survival of cryptobiotic crusts in the Pacific Northwest is threatened by three major factors: invasions of nonindigenous annual grasses and subsequent increases in fire frequency, the conversion of rangelands to agriculture and suburban developments, and livestock trampling (Belnap 1990; West 1990; Johansen et al. 1993; St. Clair and Johansen 1993; St. Clair et al. 1993). One cryptobiotic crust species, the woven-spored lichen, is particularly uncommon; it is listed by the Bureau of Land Management as a sensitive species in Idaho (McCune and Rosentreter 1992; Conservation Data Center 1994).

Vascular Plants

Accurate, comprehensive information on the status and population trends of most species of nontimber trees, shrubs, and herbs is lacking. The status of most species can only be inferred from studies of associations with broad forest types. One such study revealed that the relative abundance of most (80%) understory plant species does not differ among young, mature,

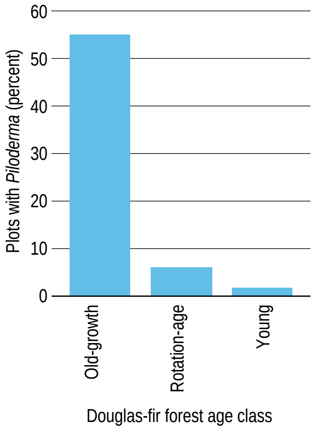

Fig. 15. Frequency distribution of the fungus *Piloderma fallax* in three age classes of Douglas-fir forest in the western Oregon Cascades.


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Fig. 16. Lobaria lichens are characteristically most abundant in cool, moist, old-growth forests in the Pacific Northwest.

and old-growth Douglas-fir forests in the Cascades and Coast Range (Spies 1991).

Nine species of vascular plants in this region are on the U.S. List of Endangered and Threatened Plants (Table 1); however, many more species are candidates for federal listing (for example, 26 species in Oregon and 15 species in Washington; U.S. Fish and Wildlife Service 1993a) or are assigned special status in states where they occur (Fig. 17). In addition, state listings are increasing (Table 2). Most of these sensitive plant species are local or regional endemics with populations that are small, scattered, or highly restricted in distribution. The most commonly identified cause of declining populations is habitat loss caused by urban or agricultural development; however, the status of many of these plants is poorly known.

As of 1992, the Bureau of Land Management listed 144 plants in Oregon and Washington as special status species, but only 8% of these species had been monitored regularly (Willoughby et al. 1992). Among candidates for federal listing that occur in Oregon and Washington, 12 species have declining populations, 16 species have stable populations, and 11 species are listed with unknown status because of insufficient information (Category 1 species in U.S. Fish and Wildlife Service 1993a).

MacFarlane's four-o-clock (Fig. 18) is one example of an endangered plant whose status is well known and for which intensive management has proven successful. This plant occupies open rangeland and canyon habitats near the Snake River drainage in the Blue Mountains ecoregion. Since the plant was listed as an endangered species in 1979, the number of known individuals of MacFarlane's four-o-clock has increased from 25–30 individuals to around 8,600 (U.S. Fish and Wildlife Service 1993b). Efforts by government agencies and private landowners to restrict grazing during critical growing seasons are the keys to expansion of this species (U.S. Fish and Wildlife Service 1992).

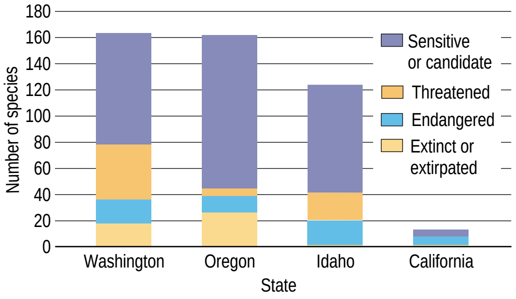
Table 1. Vascular plants in the Pacific Northwest on the U.S. List of Endangered and Threatened Plants (U.S. Fish and Wildlife Service 1995).

Species	Federal or state status[a]					Distribution	Population trend	References[b]
	Federal	California	Oregon	Washington	Idaho			
Applegate's milk-vetch	E	—	E	—	—	Klamath Basin	Downward	
Bradshaw's desert-parsley	E	—	E	E	—	Willamette Valley	Stable	
MacFarlane's four-o-clock	E	—	E	—	S1	Blue Mountains, Western Rockies	Stable/upward	U.S. Fish and Wildlife Service 1992, 1993b
Malheur wire-lettuce	E	—	E	—	—	Snake River Basin–High Desert	Downward or stable but near extinction	
Marsh sandwort	E	E	—	ext	—	Puget Lowlands, Southern California	Nearly extinct	Washington Natural Heritage Program 1995
McDonald's rock-cress	E	E	*	—	—	Klamath Mountains	Stable or downward in California, unknown in Oregon	U.S. Fish and Wildlife Service 1992
Nelson's checker-mallow	T	—	T	E	—	Klamath Mountains, Coast Range, Willamette Valley, Puget Lowlands	Stable or upward in Oregon, upward? in Washington	
Water howellia	T	ext	ext	E	S1	Puget Lowlands, Columbia Basin, Snake River Basin–High Desert	Critically imperiled	Washington Natural Heritage Program 1995
Western lily	E	*	E	—	—	Klamath Mountains, Coast Range	Stable in California, downward? in Oregon	

[a] — = does not occur in state, * = no special status, E = endangered, T = threatened, ext = extirpated, S1 = critically imperiled. References: Oregon Natural Heritage Program 1993; Conservation Data Center 1994; Washington Department of Natural Resources 1994; California Department of Fish and Game 1995a; U.S. Fish and Wildlife Service 1995.

[b] Other comprehensive references: California Department of Fish and Game 1992; Skinner and Pavlik 1994; Oregon Natural Heritage Program 1995; Washington Natural Heritage Program 1995.

Fig. 17. Numbers of vascular plant species in the Pacific Northwest on state lists of extinct or extirpated, endangered (including Idaho Native Plant Society Category 1 species), threatened (including Idaho Native Plant Society Category 2 species), and sensitive (designated rare in California) or candidate species (Oregon Natural Heritage Program 1993; Conservation Data Center 1994; Skinner and Pavlik 1994; Washington Department of Natural Resources 1994; tallies for California and Idaho are based on county occurrences).



About 25% of all the rare and sensitive vascular plant species in Oregon and 34% in Idaho occur in arid lowlands (Oregon Natural Heritage Program 1993; Conservation Data Center 1994). Many sensitive, lowland plant

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Fig. 18. MacFarlane's four-o-clock, an endangered plant that occupies open rangeland and canyon habitats near the Snake River, has benefited from restriction of grazing during critical growing seasons.

species that occur in Idaho (13% of all such species) and Oregon (23%) are milk-vetches. Several such species are the focus of ongoing research by the U.S. Geological Survey on maintaining and restoring native plant communities on eastside rangelands (Pyke and Borman 1993).

Terrestrial Invertebrates

Mollusks

More than 150 species of terrestrial snails and slugs have been identified in moist forests of the Pacific Northwest (Forest Ecosystem Management Assessment Team 1993), and scientists are still discovering new species (Frest and Johannes 1993; Roth 1993). Of the 45 species and subspecies closely associated with mature westside forests, 17 snails and 7 slugs are given special consideration in the Northwest Forest Plan. Most mollusks have limited geographic ranges and narrow ecological requirements because they are poor dispersers. For these reasons, many species are sensitive to forest fragmentation, other aspects of forest management, and disturbances such as fire and grazing (Forest Ecosystem Management Assessment Team 1993).

Arthropods

The diverse mountains of the Pacific Northwest may support as many as 50,000–70,000 species of arthropods (insects, spiders, and their allies; P. A. Opler, U.S. Geological Survey, Fort Collins, Colorado, personal communication). Nevertheless, scientists have only recently begun to conduct comprehensive surveys of the arthropod fauna to document habitat affinities and community composition and structure. With few exceptions, it is impossible to discuss with certainty the status and trends of specific arthropod species.

Table 2. Status changes from 1990 to 1994 of vascular plant species listed as endangered, threatened, or sensitive in Washington (Washington Department of Natural Resources 1994).

Status category	Number of species in 1994	Number of species whose status was elevated since 1990	Number of species added since 1990	Number of species whose status was downgraded since 1990
Possibly extinct or extirpated	18	1	0	0
Endangered	19	7	1	0
Threatened	41	11	3	1
Sensitive	84	1	13	14
Total	162	20	17	15

Many arthropods in the region complete their long life cycles inside slowly decomposing, coarse woody debris in mature forests (Lattin 1993). The deep, moist, complex litter layers in mature westside forests support an even greater variety of arthropods. Scientists commonly recover 250 species of beetles, flies, bugs, mites, millipedes, centipedes, springtails, and sow bugs from a square meter of undisturbed forest floor (Lattin 1990; Moldenke 1990; Fig. 19). Temperate forest soil and litter layers may contain the greatest number of species and densities of arthropods in the world (Anderson 1975).

Fig. 19. A typical collection of mites extracted from about 25 square centimeters of forest soil (field of view is about 1,500 microns wide, magnified here approximately 27 times).

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The wide variety of soil invertebrates is of scientific interest with regard to quantifying biological diversity. Perhaps more importantly, these tiny organisms play key roles in processing and recycling organic matter into nutrients that become available to trees and other forest vegetation (Maser and Trappe 1984; Moldenke and Lattin 1990; Lattin 1993). More than 200 known species of arthropods are closely associated with mature westside forests in the Pacific Northwest (Forest Ecosystem Management Assessment Team 1993; Thomas et al. 1993; P. A. Opler, U.S. Geological Survey, Fort Collins, Colorado and J. D. Lattin, U.S. Geological Survey, Oregon State University, Corvallis, unpublished manuscript). Accordingly, reduction of arthropod diversity and consequent impairment of forest health caused by extensive logging and other land uses could be significant. Landscape-scale information for the assessment of the extent of this potential problem is scarce, however.

The high species richness of arthropods in several westside areas is particularly interesting. Scientists have identified more than 3,400 species of terrestrial and aquatic arthropods in the H. J. Andrews Experimental Forest in the central Oregon Cascades (Parsons et al. 1991). This tally includes 76 species of butterflies or just under half the total known to occur in Oregon (Miller, unpublished data). The fauna of the Klamath Mountains ecoregion is also particularly diverse; it includes some primitive insects (Wygodzinsky and Stys 1970) and 44 species of butterflies in one township near Mt. Ashland (Miller, unpublished data). Mountain localities in the Coast Range and Olympic

Mountains also harbor rich and unique arthropod assemblages (Forest Ecosystem Management Assessment Team 1993), including many glacial-relict species (Lattin, unpublished data) and a diverse butterfly community around Mary's Peak near Corvallis, Oregon (60–62 species; Miller, unpublished data).

Butterflies are the best-known arthropods. Standardized, annual Fourth of July surveys to monitor populations are conducted in many areas. Fourteen counts are conducted in the Pacific Northwest (one in northern California, four in Oregon, eight in Washington, one in Idaho); however, most of the counts have been conducted for only 2–4 years (the longest for 8 years), which precludes accurate trend analyses (Swengel 1995).


© P. Opler

Fig. 20. The federally threatened Oregon silverspot butterfly inhabits open fields and salt-spray meadows along the northern Pacific Coast.

The Oregon silverspot butterfly (Fig. 20), which occurs along the immediate coast, is the only terrestrial invertebrate in the Pacific Northwest on the U.S. List of Endangered and Threatened Wildlife (U.S. Fish and Wildlife Service 1995). This butterfly inhabits coastal, salt-spray meadow and open-field habitats at the fringes of coastal forests from southwestern Washington to central Oregon, with an additional disjunct population occurring in northern California (Pickering et al. 1992; Washington Department of Wildlife 1993a). The species now occurs in only 7 locations (20 in the past) along the northern Pacific Coast (1 in California, 6 in Oregon). Habitat has been lost to development and is degraded by livestock grazing, recreational disturbance, fire suppression, and invasion of nonindigenous plants (McCorkle et al. 1980; Washington Department of Wildlife 1993a). The species is listed as endangered in Washington, but aggressive management and habitat restoration have been successful in Oregon, where some populations are now stable (Hammond 1993).

The arthropod fauna seems less rich in eastside forests than in westside forests where the climate is milder and plant richness is higher (Horning and Barr 1970; Parsons et al. 1991). Few species occur on both sides of the Cascades; the abundances of those that do occur on both sides may drastically differ from one side to the other (Perry and Pitman 1983). The most current information on eastside arthropods relates to only a few species, primarily butterflies and forest insects of economic concern; thousands of other species are poorly known (Horning and Barr 1970; Cobb et al. 1981).

As previously discussed, the current focus of attention on arthropods in eastside forests is with epidemic outbreaks of defoliating insects and bark beetles rather than with declining populations (Furniss and Carolin 1977; Gast et al. 1991; Hessburg et al. 1994). Some species that now thrive in eastside forests are native to the region (for example, western spruce budworm, Douglas-fir tussock moth, mountain pine beetle), but others were introduced (for example, larch casebearer). Gast et al. (1991) and Hessburg et al. (1994) provide detailed information on the biology, ecology, history, and current status of ecologically and commercially important species.

Eastside lowlands have received limited attention from entomologists. Two examples of efforts to quantify insect diversity in the region are noteworthy. Horning and Barr (1970) catalogued 2,064 species of insects representing 248 families from Craters of the Moon National Monument in south-central Idaho, and Cobb et al. (1981) catalogued 1,055 insect species from the Alvord Desert sand dunes of southeastern Oregon.

The widespread conversion of natural grasslands and sagebrush–steppe to agriculture and pastures of nonindigenous crested wheatgrass greatly altered some components of the arthropod fauna in eastside lowlands. As in eastside forests, some native insects responded favorably to the introduction of new food sources. For example, populations of native black grass bugs expanded to epidemic proportions in habitats densely planted with crested wheatgrass (Lattin et al. 1994). Increasing the number of species in grass plantings, thereby mimicking the original state of the grasslands, helps reduce forage losses to these insects (Araya and Haws 1991).

Grasshoppers also concern agricultural and rangeland managers in the region because of the threat of epidemic outbreaks and widespread damage to crops and range grasses. Grasshopper outbreaks occur every 5–10 years and seem correlated with rainfall amounts (Fielding and Brusven 1996). Heavily disturbed sites that are dominated by nonindigenous annual vegetation typically support higher densities but fewer species of grasshoppers than sites with native shrubs and grasses (Fielding and Brusven 1993, 1994). The abundances of some native grasshoppers declined because of habitat conversion to nonindigenous vegetation; for example, the Idaho pointheaded grasshopper is one of only three species of terrestrial insects in Idaho that is listed as sensitive by the Bureau of Land Management (Otte 1981; Conservation Data Center 1994).

The conservation of arthropods has generally received little attention, but ensuring diverse and healthy insect populations could ultimately prove essential for maintaining the integrity of forest and lowland ecosystems (Moldenke and Lattin 1990; Lattin 1993). Successful conservation and restoration depend on accounting for the location of remaining healthy populations. For example, in western Oregon and

Washington, valley landscapes are so highly altered and overrun with nonindigenous insects (Asquith and Lattin 1991; Lattin 1994) that the greatest richness and abundance of native insect species now seem concentrated at higher elevations in adjacent foothill and montane regions (Lattin, unpublished data).

Aquatic Invertebrates

A variety of environmental factors influence the abundance, species richness, and distribution of stream invertebrates. The distribution of benthic (bottom-dwelling) species may depend on substrate characteristics (Minshall 1984), particularly fine sediment concentration (Richards and Bacon 1994), which is often high in logged or grazed areas. Disturbance of riparian vegetation by logging or grazing affects the distribution of functional feeding groups by changing light levels, algal growth rates, and deposition rates of organic debris from riparian vegetation (Vannote et al. 1980; Hawkins and Sedell 1981; Murphy and Hall 1981; Murphy et al. 1981; Hawkins et al. 1982; Gregory et al. 1991). Removal of woody debris from streams during logging reduces the supply of food and stable substrates for benthic organisms and reduces retention of the detritus that other invertebrates eat (Gregory et al. 1991). Nutrient or toxic pollution in urban and agricultural areas can also lead to drastic shifts in community composition (Wiederholm 1984; Li and Gregory 1993).

Information on the status of aquatic invertebrates is generally limited to assessments of community composition rather than species-specific population trends. Because of the previously described sensitivities, inventories of aquatic invertebrates, primarily insects, are used as indicators of stream health (Anderson 1992; Plotnikoff 1992, 1994). Primary indicators of healthy cold-water streams with good water quality and abundant resources from riparian vegetation include high overall invertebrate richness with a high proportion of mayflies, stoneflies, and caddisflies (Fig. 21). Species from these groups are intolerant of disturbances that yield low oxygen concentrations, high silt loads, and high temperatures. The Oregon Natural Heritage Program (1993) lists the Wahkeena Falls flightless stonefly as threatened with extinction and lists 24 caddisflies as probable sensitive species for which additional information is needed—more evidence that the integrity of many stream ecosystems in the region has been compromised.

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Fig. 21. Mayfly nymphs like this one and other similar stream insects are considered indicators of healthy cold-water streams in the Pacific Northwest because they do not tolerate excessive disturbance.

Aquatic Invertebrates in Westside Rivers and Streams

Undisturbed streams in the Cascades ecoregion support a diverse aquatic invertebrate fauna, including many mayflies, stoneflies, and caddisflies. In Oregon, the diversity of aquatic invertebrates is generally highest in streams in the Cascades (Whittier et al. 1988); these streams also exhibit other faunal characteristics that indicate good-quality habitat (J. Li and A. Herlihy, Oregon State University, Corvallis, unpublished data; Table 3). During one spring–summer period on three streams in the H. J. Andrews Experimental Forest, Anderson (1992) collected more than 256,000 emerging-adult aquatic insects representing more than 250 taxa and 5 orders. In this study, a stream flowing through a 450-year-old conifer forest supported a more diverse insect fauna than streams flowing through a recent clear-cut forest and through a 40-year-old deciduous forest.

The diversity of aquatic insects is naturally low in the glacier-fed streams of the Olympic Mountains (Table 3); however, diversity is reduced further by disturbance. The number of taxa averaged 19 in undisturbed Hoh River tributaries and decreased to 9 where debris torrents occurred (McHenry 1991). Similarly, the number of taxa averaged 18 in undisturbed sections of the Elwha River and decreased to 12 below small dams (Li 1991). Sensitive aquatic insect taxa dominate these systems (Table 3).

Table 3. Characteristics of aquatic macroinvertebrate assemblages in different regions of the Pacific Northwest (averages across several streams).

Region	Density[a]	Total taxa per stream[b]	Intolerant taxa per stream[c] (percent)	Ratio of intolerant taxa to tolerant[d]	Proportion of organisms in most common taxon (percent)
Willamette Valley		29	3		
Puget Lowlands		16			
Mainstem Snake River	49	6	33		70
Western Cascades		60	51		21
Olympic Mountains		9–19	93		
Eastern Cascades	6,707	37	49	8.5	39
Columbia Basin	3,729	27	48		36
Grande Ronde River basin	3,550	42	57	10.5	31
Ochoco Mountains/John Day River basin	3,707	40	60	5.5	28
Oregon high desert	5,936	26	38	5.5	43

[a] Average total number of organisms per square meter.

[b] Typically genera.

[c] Taxa consist of intolerant (to habitat disturbance) mayflies, stoneflies, and caddisflies.

[d] Numbers of intolerant (to habitat disturbance) mayflies, stoneflies, and caddisflies to tolerant chironomid midges.

Streams in the Willamette Valley support fewer aquatic invertebrates (Table 3) and higher proportions of non-insect invertebrate species than streams in adjacent foothills and mountains (Whittier et al. 1988; Li and Herlihy, unpublished data). Similarly, the diversity of aquatic insects is generally lower in streams of the Puget Lowlands than in the Cascades (Plotnikoff 1992, 1994; Table 3). The diversity of freshwater mollusks is also usually highest in montane, spring-fed streams and pools (Forest Ecosystem Management Assessment Team 1993). Thus, decreased habitat diversity and low hydraulic variability in lowland streams seem to support fewer aquatic invertebrate species. However, part of the difference could be that human activities have affected the lowland streams for much longer periods. The number of species increased slowly in the low-gradient Tualatin River as caddisflies, riffle beetles, and mayflies returned after installation of wastewater treatment plants (Li and Gregory 1993).

Aquatic Invertebrates in Eastside Rivers and Streams

Based on regional summaries of insect community characteristics, the health of eastside streams averages fair to good (Li et al. 1995; Table 3). Most subregions, though, contain healthy (mostly at high elevations) and degraded streams (Whittier et al. 1988; Mangum 1992; Wisseman 1992a,b; U.S. Environmental Protection Agency 1994).

Comparative studies in the Ochoco National Forest and John Day River basin revealed that overgrazing, dewatering for irrigation, and loss of riparian vegetation during logging produced high water temperatures and excessive siltation that harmed aquatic invertebrate communities in many streams (Li et al. 1994; Tait et al. 1994). Still, the potential for restoration of degraded streams remains high because some mostly undisturbed streams at higher elevations have well-developed riparian canopies and still support diverse assemblages dominated by sensitive taxa.

On Catherine Creek in the Grand Ronde River basin, 10 years of extensive restoration with grazing exclosures returned the number of aquatic insect taxa (61) and the mayfly–caddisfly–stonefly to chironomid ratio (29:1; midge larvae are considered tolerant species) to high levels (McIntosh 1992). The causes of degradation are not always clear, however; the total number of taxa and the number of mayflies, caddisflies, and stoneflies are low (14 and 7 taxa, respectively), and dominance of the most common taxon is high (56%; lack of numerical or biomass dominance by one or a few taxa is another indicator of healthy communities) at Thirty-mile Creek despite an absence of logging and light grazing by livestock (Carlson et al. 1990).

Benthic insect communities from the lower reaches of the Snake River are particularly depauperate (average 6 taxa) and are dominated by tolerant species (Dorband 1980; Table 3). The reduced fauna in low-elevation rivers and springs of the Columbia and Snake River basins is probably a result of greater human disturbance. Several species of aquatic snails from the Snake River basin (Snake River physa snail, Bliss Rapids snail, Utah valvata snail, Banbury Springs limpet, and Bruneau Hot Springs snail) are on the U.S. List of Threatened and Endangered Wildlife (U.S. Fish and Wildlife Service 1995) because of habitat degradation. In contrast, uniformly low diversity in the high desert region of southeastern Oregon (Robinson and Minshall 1991; U.S. Environmental Protection Agency 1994; M. Vinson, Bureau of Land Management, Logan, Utah, unpublished data) is probably related to the constancy of aridity and high temperatures.

The piedmont-fringe foothills of the Columbia basin ecoregion include spring-fed and seasonally intermittent streams that generally support more diverse aquatic insect communities than systems at lower elevations (Gaines 1987; Whittier et al. 1988; Gaines et al. 1992; Plotnikoff 1992; Wenatchee National Forest 1993; U.S. Environmental Protection Agency 1994). Strong representation of sensitive mayflies, stoneflies, and caddisflies further suggests that these foothill streams are relatively undisturbed natural systems that may provide source populations for restorations at lower elevations.

Aquatic Invertebrates in Lakes

Information on invertebrate communities in lakes is limited, but ongoing studies in North Cascades National Park Service Complex and in Mt. Rainier National Park are beginning to fill the void for montane lakes (Liss et al. 1995; Liss and Larson, unpublished data). The distribution of many benthic and planktonic invertebrates is naturally restricted because of sensitivities to temperature, water chemistry, and substrate type. The distribution of some species, however, is further restricted by the presence of introduced predators such as trout and sockeye salmon (see box on Complex Interactions of Introduced Trout and Native Biota in High-Elevation Lakes; Liss et al. 1995). Most lakes in the Cascades were without fishes before the onset of trout stocking; given that stocking is now widespread (Bahls 1992), the effect on invertebrate communities may be extensive (Anderson 1980; Luecke 1990; Liss et al. 1995).

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Complex Interactions of Introduced Trout and Native Biota in High-Elevation Lakes

Mountain lakes in the West often occur in remote and pristine environments (Fig. 1); nevertheless, they are subject to human-induced disturbances, including global climate change, acid precipitation, ultraviolet radiation, and nonindigenous species. Most mountain lakes in the Pacific Northwest were formed by glacial activity thousands of years ago and do not naturally contain fish. Many, however, are now stocked with trout to provide opportunities for recreational fishing (Bahls 1992). Introduced trout and other nonindigenous fishes may selectively feed upon larger, more visible and active prey (Zaret 1990), and thereby adversely affect the stability of native prey populations. Negative effects include reduced densities, extirpated populations, reduced long-term regional persistence of species, and shifts in community structure toward smaller species. Such effects have been documented for amphibians (Taylor 1983; Bradford 1989; Bradford et al. 1993; Liss et al. 1995) and crustacean zooplankton (Anderson 1971, 1972, 1980; Stoddard 1987; Liss et al. 1995). Zooplankton, in particular, are important ecological components of the pelagic zone of mountain lakes. Recent research in the North Cascades National Park Service Complex in Washington suggests that the effects of trout on native biota may not be uniform on different prey species or in different lakes (Liss et al. 1995).

Salamander larvae are the top vertebrate predator in many North Cascades National Park Service Complex lakes without fishes (Fig. 2). The long-toed salamander is the most common amphibian in high-elevation North Cascade National Park Service Complex lakes. Larvae of the long-toed salamander, which are most abundant in smaller lakes and ponds, seem highly vulnerable to predation by cutthroat trout and rainbow trout (Liss et al. 1995). Snorkeling surveys during the day and at night revealed very few long-toed salamander larvae in lakes with reproducing trout populations. In contrast, larvae of the northwestern salamander (Fig. 3) seem less vulnerable to trout predation; embryo masses and larvae are often abundant in lakes with fish. The northwestern salamander has apparently developed behavioral and morphological adaptations, which may include skin secretions noxious to predators as well as reclusive and nocturnal behavior, that render it more capable of avoiding predation by trout.

Courtesy North Cascades National Park, National Park Service

Fig. 1. Tapto Lakes, typical high-elevation lakes in the Cascade Mountains of Washington.

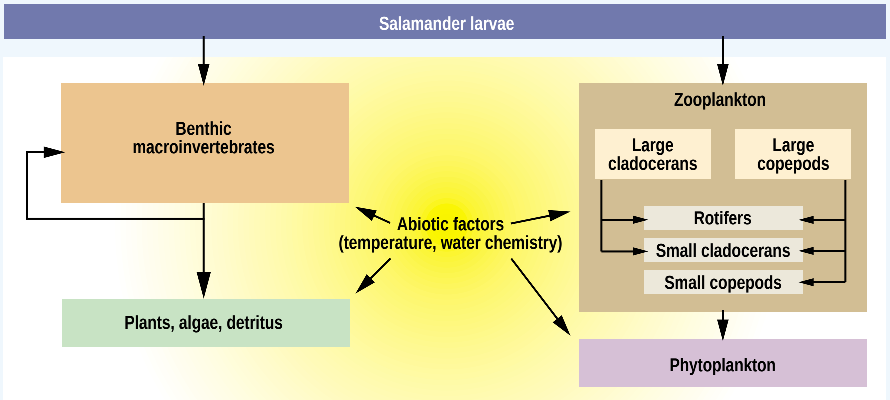

Fig. 2. Diagram of a typical food web in high-elevation lakes without fishes in the Cascade Mountains.

As in most nutrient-poor mountain lakes, North Cascades National Park Service Complex lakes generally contain few species of crustacean zooplankton. Dominance of communities by a single species is common; often one species, usually a large *Diaptomus* copepod (Fig. 4), makes up more than 90% of crustacean zooplankton abundance. Large copepods such as *Diaptomus kenai*, which is the most common species of crustacean zooplankton in this area, are apparently able to feed on a variety of foods including phytoplankton and other zooplankton. Large diaptomid

Fig. 3. Northwestern salamander adult.

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Fig. 4. Large copepods (genus *Diaptomus* [this specimen is about 1.4 millimeters long]) are the dominant pelagic predator in many high Cascade lakes that lack fishes.

copepods are probably the dominant pelagic, invertebrate predator when fish are absent, because other species of predaceous zooplankton (for example, phantom midges and cyclopoid copepods) are not common in North Cascades National Park Service Complex mountain lakes.

Another common species of zooplankton is the small, herbivorous copepod, *Diaptomus tyrrelli*. Whereas *D. kenai* occurs in lakes with a wide range of physical and chemical characteristics, *D. tyrrelli* seems to prefer smaller, shallower (maximum depth 10 meters) lakes with slightly higher nutrient levels (Liss et al. 1995). Apparently, predation by *D. kenai* adults eliminates *D. tyrrelli* from many lakes. Large copepods either do not occur or are uncommon in shallow lakes where the density of reproducing trout is high, whereas small copepods are abundant in these lakes. In contrast, large copepods are often abundant but small copepods are uncommon in lakes where the density of fishes is low.

The effects of introduced trout in North Cascades National Park Service Complex lakes may depend on the size distribution and density of trout, the native prey species present, lake nutrient levels, and the physical characteristics of the lake basin (Liss et al. 1995). The greatest effect of introduced trout may occur when reproducing trout occur at high densities in small, shallow lakes. Many of these lakes are productive for long-toed salamander larvae, and trout seem able to reduce or eliminate larval salamanders and large diaptomid copepods in such lakes. In lakes with higher levels of nutrients, reduced densities of large copepods brought about by fish predation may allow the abundance of smaller copepods to increase. Effects of trout on native biota may be more difficult to detect in larger, deeper lakes with low densities of fish.

See end of chapter for references

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Vertebrate Animals

Fishes

Other fish species may play important roles in aquatic ecosystems of the region, but the fish fauna in the Pacific Northwest is most easily distinguished by an unequaled richness of salmon and trout. With few exceptions, scientists know relatively little about nonsalmonid species in the Pacific Northwest. Thus, our discussion is limited to the status of salmon and trout, except that we also provide a table of current status information (based mostly on literature review) for all species on federal and state sensitive species lists (Table 4).

Salmon and trout predominate in the cold, fast-flowing streams of montane forests. In the past, anadromous salmon and steelhead also filled the waterways at lower elevations as they made their way from ocean habitats to freshwater streams to breed. However, most stocks (genetically distinct, locally adapted, and reproductively isolated populations) of salmon and trout in the Pacific Northwest are now greatly reduced or extirpated (Nehlsen et al. 1991; Wilderness Society 1993; Fig. 22).

The only salmon and trout on the U.S. List of Endangered and Threatened Wildlife (U.S. Fish and Wildlife Service 1995, 1996a,b, 1997) that occur in our region of interest are spring–summer and fall runs of chinook salmon from the Snake River in Idaho, and one stock of sockeye salmon from the Snake River, the Southern Oregon/Northern California Coast stock of coho salmon, and the Umpqua River cutthroat trout. All other species of salmon and trout are given some level of special status in one or more states where they occur, and several stocks of steelhead trout have been proposed for federal listing (Table 4).

In a landmark publication, Nehlsen et al. (1991) identified more than 100 stocks of extinct anadromous salmon and trout, 102 stocks now at high risk of extinction, 58 stocks at moderate risk of extinction, and 54 stocks of

Table 4. Status of fishes on federal and state sensitive species lists.

Species	Federal or state status[a]					Endemic	Anadromous	Range	Population trend	References[b]
	Federal	California	Oregon	Washington	Idaho					
Alvord chub	*	—	S–v	—	—	Yes		Snake River Basin–High Desert	Unknown, locally common	Williams and Bond 1983
Alvord cutthroat trout	*	—	Extinct	—	—	Yes		Snake River Basin–High Desert	Extinct	Miller et al. 1989; Williams and Bond 1983
Bigeye marbled sculpin	*	SC	—	—	—	Yes		Eastern Cascades Slopes and Foothills	Stable or downward	
Borax Lake chub	E	—	E	—	—	Yes		Snake River Basin–High Desert	Stable	U.S. Fish and Wildlife Service 1992; Oregon Natural Heritage Program 1995
Bull trout	C	E	S–c	*	SC–a			All forest ecoregions	Extirpated in California, downward elsewhere	Howell and Buchanan 1992; Washington Department of Wildlife 1992; Mongillo 1993; Rieman and McIntyre 1993
California (Pit) roach	*	SC	S–p	—	—			Snake River Basin–High Desert	Downward in California, stable in Oregon	
Catlow Valley redband trout	*	—	S–v	—	—	Yes		Snake River Basin–High Desert	Stable or downward	
Catlow Valley tui chub	*	—	S–v	—	—	Yes		Snake River Basin–High Desert	Unknown, locally common	
Chum salmon	C	*	S–c	*			Yes	All westside, extirpated in eastside, most of California	Stable or upward only in NW Washington	Frissell 1993; Moyle 1994; Kostow 1997; Mills et al. 1997
Coastal cutthroat trout	E/C[c]	SC	S–c	*	—		Yes	Klamath Mountains, Coast Range, Willamette Valley	Mostly downward	Moyle 1994; Mills et al. 1997; U.S. Fish and Wildlife Service 1996a
Coho salmon	T/C[d]	*	S–c	*			Yes	All westside, extirpated eastside	Stable or upward only in NW Washington	Frissell 1993; Brown et al. 1994; Kostow 1997; Mills et al. 1997; U.S. Fish and Wildlife Service 1996b, 1997
Cowhead Lake tui chub	C	SC	—	—	—			Snake River Basin–High Desert	Downward	
Foskett speckled dace	T	—	T	—	—	Yes		Snake River Basin–High Desert	Upward	Oregon Natural Heritage Program 1995
Goose Lake lamprey	*	SC	S–c	—	—	Yes		Eastern Cascades Slopes and Foothills, Snake River Basin–High Desert	Downward	
Goose Lake redband trout	*	SC	S–v	—	—	Yes		Eastern Cascades Slopes and Foothills, Snake River Basin–High Desert	Downward	
Goose Lake sucker	*	SC	S–c	—	—	Yes		Eastern Cascades Slopes and Foothills, Snake River Basin–High Desert	Stable or downward	
Goose Lake tui chub	*	SC	S–c	—	—	Yes		Eastern Cascades Slopes and Foothills, Snake River Basin–High Desert	Locally common but possibly downward	
Hutton Spring tui chub	T	—	T	—	—	Yes		Snake River Basin–High Desert	Downward	Oregon Natural Heritage Program 1995
Interior redband trout	*	—	S–v	—	SC–a			All eastside	Downward native, upward stocked	
Jenny Creek sucker	*	—	S–p	—	—	Yes		Eastern Cascades Slopes and Foothills	Unknown, highly restricted distribution	
Pitt-Klamath brook lamprey	*	SC	*	—	—	Yes		Eastern Cascades Slopes and Foothills	Downward?	

— continued —

Table 4. Continued.

Species	Federal or state status[a]					Endemic	Anadromous	Range	Population trend	References[b]
	Federal	California	Oregon	Washington	Idaho					
Klamath largescale sucker	*	SC	*	—	—	Yes		Eastern Cascades Slopes and Foothills	Downward	
Lahontan cutthroat trout	T	*	T	—	—	Yes		Eastern Cascades Slopes and Foothills, Snake River Basin–High Desert	Stable or downward	Wood et al. 1993; Oregon Natural Heritage Program 1995 Database
Lahontan shiner	*	*	S–p	—	—	Yes		Snake River Basin–High Desert	Stable or upward	
Lake chub	*	—	—	M	*			Eastern Cascades Slopes and Foothills, Columbia Basin, Okanogan Highlands, Blue Mountains	Unknown	
Leatherside chub	*	—	—	—	SC–c			Snake River Basin–High Desert	Unknown	
Lost River sucker	E	E	E	—	—	Yes		Eastern Cascades Slopes and Foothills	Downward	Coleman et al. 1987; Stubbs and White 1993; Oregon Natural Heritage Program 1995
Lower Columbia River fall chinook salmon	C	—	S–c	*	—	Yes		Cascades, Willamette Valley	Downward	Kostow 1997
Malheur mottled sculpin	*	—	S–c	—	—	Yes		Snake River Basin–High Desert	Unknown	
Margined sculpin	*	—	S–v	C	—	Yes		Columbia Basin, Blue Mountains	Unknown but highly restricted distribution	Lonzarich 1993
McCloud River redband trout	C	SC	—	—	—			Eastern Cascades Slopes and Foothills	Stable or downward	
Miller Lake lamprey	*	—	Extinct	—	—	Yes		Eastern Cascades Slopes and Foothills	Extinct	Miller et al. 1989
Millicoma dace	*	—	S-u	—	—			Coast Range	Unknown, locally common	
Mountain sucker	*	SC	*	M	*			Willamette Valley, Cascades, Eastern Cascades Slopes and Foothills, Columbia Basin, Snake River Basin–High Desert	Downward? in California, unknown otherwise	
Nooksack dace	*	—	—	M	—			Coast Range, Puget Lowlands	Downward in some areas, common in others	McPhail 1994; P. Mongillo, Washington Department of Fish and Wildlife, personal communication
Olympic mudminnow	*	—	—	C	—	Yes		Coast Range, Puget Lowlands	Unknown	P. Mongillo, Washington Department of Fish and Wildlife, personal communication
Oregon chub	E	—	S–c	—	—	Yes		Willamette Valley	Severely reduced range, possibly upward	Markle et al. 1989; Scheerer et al. 1994; Oregon Natural Heritage Program 1995
Oregon Lakes tui chub	*	—	S–v	—	—	Yes		Eastern Cascades Slopes and Foothills, Snake River Basin–High Desert	Unknown, locally common	
Pacific lamprey	*		S–v	*	E		Yes	All ecoregions except Snake River Basin–High Desert	Downward	Moyle 1994; Close et al. 1995
Paiute sculpin	*	*	*	M	*			Willamette Valley, Cascades, all eastside	Stable or upward in California, common in Washington, unknown otherwise	P. Mongillo, Washington Department of Fish and Wildlife, personal communication

— continued —

Table 4. Continued.

Species	Federal or state status[a]					Endemic	Anadromous	Range	Population trend	References[b]
	Federal	California	Oregon	Washington	Idaho					
Pink salmon	*	SC	*	*	—		Yes	All westside, extirpated in California	Downward	Moyle 1994; Mills et al. 1997
Pit sculpin	*	*	S–p	—	—	Yes		Eastern Cascades Slopes and Foothills	Stable or upward in California, downward in Oregon	
Pygmy whitefish	*	—	*	C	*			Coast Range, Cascades, North Cascades, Okanogan Highlands	Unknown	P. Mongillo, Washington Department of Fish and Wildlife, personal communication
Reticulate sculpin	*	SC	*	M	—			All westside	Downward in California, common in Washington, unknown otherwise	
Riffle sculpin	*	*	*	M	—			Coast Range, Willamette Valley, Puget Lowlands, Olympic Mountains	Stable or upward in California, unknown otherwise	
River lamprey	*	SC	*	*	—		Yes	Coast Range, Klamath Mountains, Willamette Valley, Puget Lowlands, Olympic Mountains	Stable or downward	Moyle 1994
Rough sculpin	*	T	—	—	—			Eastern Cascades Slopes and Foothills	Downward?	
Salish sucker	*	—	—	M	—	Yes		Puget Lowlands	Downward?	J. D. McPhail, University of British Columbia, personal communication
Sand roller	*	—	*	M	SC–c			Coast Range, Willamette Valley, Puget Lowlands, Eastern Cascades Slopes and Foothills, Columbia Basin	Stable in Washington, unknown otherwise	P. Mongillo, Washington Department of Fish and Wildlife, personal communication
Sheldon tui chub	*	—	S–c	—	—	Yes		Snake River Basin–High Desert	Unknown, highly restricted distribution	
Shortnose sucker	E	E	E	—	—	Yes		Eastern Cascades Slopes and Foothills	Downward	Coleman et al. 1987; Stubbs and White 1993; Oregon Natural Heritage Program 1995
Shoshone sculpin	*	—	—	—	SC–a	Yes		Snake River Basin–High Desert	Stable or upward	Wallace et al. 1982, 1984; Griffith and Daley 1984; Kuda et al. 1992; Kuda and Griffith 1993
Slimy sculpin	*	—	—	M	*			Columbia Basin, Okanogan Highlands	Common in Washington, unknown otherwise	P. Mongillo, Washington Department of Fish and Wildlife, personal communication
Snake River chinook salmon	T	—	S–c	*	E/T	Yes	Yes	Columbia Basin, Snake River Basin–High Desert	Downward	Hassemer 1993; Hassemer et al. 1997; Kostow 1997
Snake River fine-spotted cutthroat trout	*	—	—	—	SC–a	Yes		Snake River Basin–High Desert	Downward native, upward stocked	
Snake River sockeye salmon	E	—	*	*	E	Yes	Yes	Columbia Basin, Snake River Basin–High Desert	Downward	Hassemer 1993; Hassemer et al. 1997
South coast fall chinook salmon	C	*	S–c	—	—	Yes		Cascades, Klamath Mountains	Downward	Kostow 1997; Mills et al. 1997
Steelhead	PE/PT/C[e]	*	*	*	SC–a		Yes	All ecoregions	Stable or downward	National Marine Fisheries Service 1996

— continued —

Table 4. Continued.

Species	Federal or state status[a]					Endemic	Anadromous	Range	Population trend	References[b]
	Federal	California	Oregon	Washington	Idaho					
Summer Basin tui chub	*	—	S–c	—	—	Yes		Snake River Basin–High Desert	Unknown, probably downward	
Tahoe sucker	*	*	S–p	—	—			Snake River Basin–High Desert	Stable or upward in California, unknown in Oregon	
Tidewater goby	E	SC	—	—	—			Klamath Mountains	Downward	Frissell 1993
Umpqua chub	*	—	S–v	—	—	Yes		Coast Range, Klamath Mountains	Downward	
Warner Basin tui chub	*	—	S–c	—	—	Yes		Snake River Basin–High Desert	Downward?	
Warner sucker	T	—	E	—	—	Yes		Snake River Basin–High Desert	Downward	Williams et al. 1990; Oregon Natural Heritage Program 1995
Warner Valley redband trout	*	*	S–v	—	—	Yes		Snake River Basin–High Desert	Downward	
Westslope cutthroat trout	*	—	S–v	*	SC–a			Eastern Cascades Slopes and Foothills, Columbia Basin, Snake River Basin–High Desert	Downward native, upward stocked	
Wood River sculpin	*	—	—	—	SC–a	Yes		Snake River Basin–High Desert	Stable	

[a] — = does not occur in state, * = no special status, E = endangered, T = threatened, PT = proposed for federal threatened species listing, C = federal candidates for threatened or endangered species listing; California—CT = candidate for threatened status, SC = species of special concern; Oregon—S—c,v,p,u = sensitive species with critical, vulnerable, peripheral, or unknown status; Washington—S = sensitive species, M = monitor species; Idaho—SC–a,b,c = species of special concern category a (priority), b (peripheral), or c (undetermined status). References: Oregon Natural Heritage Program 1993; California Department of Fish and Game 1994, 1995b; Conservation Data Center 1994; U.S. Fish and Wildlife Service 1994, 1995. Washington Department of Wildlife 1994.

[b] Comprehensive references: general — Williams et al. 1989; California — McGinnis 1984; Moyle et al. 1989; Moyle and Williams 1990; California Department of Fish and Game 1992; Oregon — Puchy and Marshall 1993; Marshall et al. 1996; Washington — Wydoski and Whitney 1979; Rodrick and Milner 1991; Idaho — Simpson and Wallace 1982; salmon and trout — Konkel and McIntyre 1987; Nehlsen et al. 1991; Behnke 1992; Nickelson et al. 1992; Washington Department of Fisheries et al. 1993; Huntington et al. 1994; U.S. Fish and Wildlife Service 1994; National Marine Fisheries Service 1997.

[c] Umpqua River cutthroat trout is endangered; all other sea-run stocks are candidates.

[d] The Southern Oregon/Northern California Coast stock is threatened; the Oregon Coast stock is a candidate subject to additional review in 2000.

[e] The Upper Columbia River stock is proposed for endangered status; Snake River Basin, Lower Columbia River, Oregon Coast, Klamath Mountains Province, and Northern California stocks are proposed for threatened status; the Middle Columbia River stock is a candidate.

special concern because of low numbers or restricted distributions. Since then, researchers from Washington (Washington Department of Fisheries et al. 1993), Oregon (Nickelson et al. 1992; Kostow 1997), California (Higgins et al. 1992; Moyle 1994; Mills et al. 1997), and Idaho (Hassemer 1993; Hassemer et al. 1997) have conducted their own intensive assessments of stocks in their states. These more recent assessments resulted in subdivisions of some stocks and other additions to the list initiated by Nehlsen et al. (1991). In the Forest Ecosystem Management Assessment Team (1993) report, 314 out of a total of about 400 stocks that occur in the range of the northern spotted owl are identified as at risk.

In another effort, the Wilderness Society (1993) compared the past ranges with the current ranges of the 10 species and major races (for example, spring, summer, and winter runs of chinook salmon) of anadromous salmon and trout. The society determined that all species and races except the pink salmon are extinct or at risk of extinction over most of their former ranges (also see McIntosh et al. 1994; Fig. 23).

Most recently, Huntington et al. (1994) released a report on healthy native stocks in the Pacific Northwest and California. They classified 121 stocks as healthy and another 59 as marginally healthy (disputed health status); however, they cautioned that 95% of these

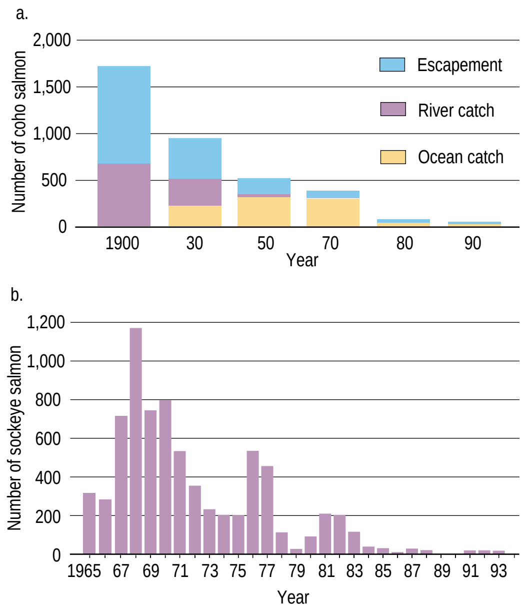

Fig. 22. Examples of declining populations of anadromous salmon: a) estimated abundance of coho salmon on the north coast of Oregon (adapted from Kostow 1997) and b) counts of sockeye salmon at upper dams on the lower Snake River in Idaho (adapted from Hassemer et al. 1997).

stocks are threatened by some form of habitat degradation and that without increased conservation efforts these stocks may not remain healthy.

Remaining healthy stocks of anadromous salmon and trout are most concentrated in the upper tributaries of the Puget Sound drainage in Washington and in coastal drainages of the middle and northern Oregon Coast Range (Wilderness Society 1993; Huntington et al. 1994; Fig. 23). Few anadromous stocks from Idaho and California are healthy (Huntington et al. 1994); however, many northern coast, winter-run populations of California steelhead are still widely distributed (Mills et al. 1997), and six stocks of summer-run steelhead in Idaho are at least marginally healthy (Hassemer et al. 1997). Most anadromous stocks in the mid-Columbia basin are also relatively stable (Mullan et al. 1992; Wilderness Society 1993); however, spring runs of chinook salmon in the Grand Ronde and John Day river basins are rapidly dwindling in size (Li, personal communication), and dams eliminated all anadromous stocks from large sections of the upper Columbia and Snake river drainages (Fig. 23). Stocks that inhabit the western slope of the Cascade Range and interior drainages are at greater risk because of greater logging and grazing, both past and current (Wilderness Society 1993; McIntosh et al. 1994; Wissmar et al. 1994). Principal human-caused factors that harm salmon and trout are listed in Table 5.

Documenting changes in the status of anadromous salmon and trout is complicated because obtaining accurate indexes of abundance is difficult and because population sizes may naturally fluctuate from year to year depending on oceanic and freshwater environmental conditions (Platts 1988; Lawson 1993; Washington Department of Fisheries et al. 1993; Botkin et al. 1994). For instance, the El Niño phenomenon was linked to changes in ocean productivity (Mysak 1986) that probably affected the growth and productivity of anadromous species for multiyear periods (Nickelson and Lichatowich 1983; Nickelson 1986; Lawson 1993). Factors such as these mean that managers must have long-term (10–20 years or more) information on which to base status assessments. Some long-term data sets on commercial harvest and other indirect measures of abundance are available, but the accuracy of these indexes has been questioned (Botkin et al. 1994), and data on many watersheds and stocks do not exist.

The northern squawfish is not a member of the salmon family but is of interest with regard to management of anadromous salmon and trout. Unlike sturgeon (Beamesderfer and Nigro 1993) and anadromous salmon, the northern

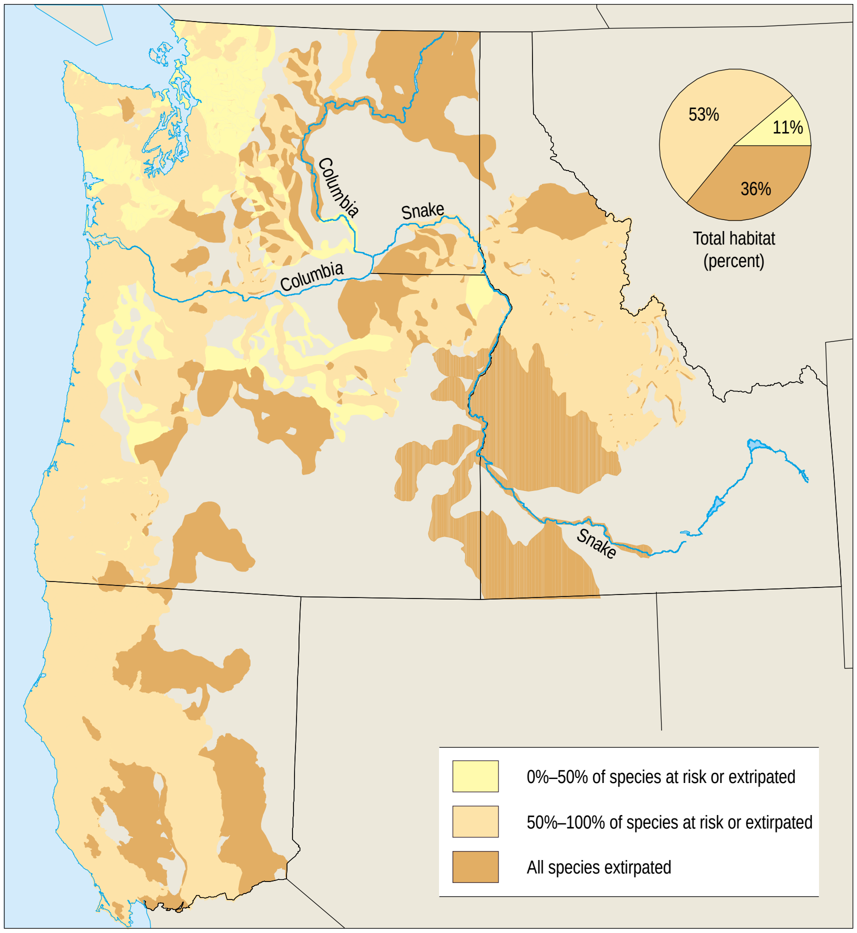

Fig. 23. Relative levels of endangerment of anadromous salmon and trout in the Pacific Northwest (adapted from Wilderness Society 1993).

Table 5. Human-caused adverse effects on salmon and trout in the Pacific Northwest.

Factor	Effects	References[a]
Hydroelectric dams	Impede migratory passage; aid predation by squawfish and sea lions	Northwest Power Planning Council 1986, 1994; Willis et al. 1994
Changes in water flow from hydroengineering, agriculture, and forest management	Alter habitat structure and water quality	Hicks et al. 1991
Siltation from logging, grazing, mining, and other land uses	Clogs spawning gravels; reduces habitat diversity	Everest et al. 1987; Bjornn and Reiser 1991; McIntosh et al. 1994
Removal of large woody debris and lack of accumulation of new debris after logging	Reduces habitat diversity, detritus and nutrient retention, and substrates for invertebrate prey	Anderson et al. 1978; Everest et al. 1985; Harmon et al. 1986; Bisson et al. 1987; Sedell et al. 1988; Bilby and Ward 1991; Reeves et al. 1993; McIntosh et al. 1994
Removal of riparian vegetation by logging or grazing	Increases water temperatures; reduces nutrient additions and sediment filtration; destabilizes stream banks	Kauffman and Krueger 1984; Beschta et al. 1987; Platts and Nelson 1989; Beschta 1991; Platts 1991; Li et al. 1994
Hybridization and competition with hatchery fish and nonindigenous species	Eliminate and reduce vigor of native stocks	Rieman and McIntyre 1993; Reisenbichler 1997
Excessive fishing	Reduces recruitment	Pacific Fishery Management Council 1992

[a] Other comprehensive references: Salo and Cundy 1987; Nehlsen et al. 1991; Meehan 1991; Bisson et al. 1992; Higgins et al. 1992; Naiman et al. 1992; Frissell 1993; Kaczynski and Palmisano 1993; Palmisano et al. 1993; Washington Department of Fisheries et al. 1993; Wilderness Society 1993; Botkin et al. 1994; Moyle 1994.

squawfish seems to have benefited from habitat changes caused by large Columbia River dams. Fast-flowing stretches of stream immediately downstream of the dams, commonly referred to as tailrace sections, are favored habitats for young salmon. Squawfish eat these young salmon and seem to benefit by congregating in tailrace areas (Rieman and Beamesderfer 1990). Because of this effect, squawfish are a concern for managers of salmon fisheries and hydroelectric facilities and are the focus of extensive predator control (Northwest Power Planning Council 1986, 1994; Willis et al. 1994).

All native trout species have populations or subspecies on federal or state lists of sensitive species (Table 4), but among resident species the bull trout (Fig. 24) is most recognized as a species in trouble. In the past, bull trout were widely distributed in cool mountain streams of the Pacific Northwest, southeastern Alaska, British Columbia, and Montana. This species, though, has been extirpated from California and from several streams in the Pacific Northwest and northern Rocky Mountains, and now occurs primarily as scattered local populations, many of which are declining in size (Howell and Buchanan 1992; Mongillo 1993; Rieman and McIntyre 1993). The U.S. Forest Service considers bull trout an indicator species because the fish is unusually sensitive to disturbances that degrade the quality of forested mountain streams. The integrity of many bull trout populations is further compromised by hybridization with nonindigenous brook trout and by competition with expanding and introduced populations of rainbow trout, brown trout, and lake trout (Rieman and McIntyre 1993). Accordingly, the bull trout is a species of concern throughout its range in the United States (U.S. Fish and Wildlife Service 1994).

Fig. 24. Bull trout are considered indicators of healthy cold-water streams in the mountains of the Pacific Northwest.

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Amphibians

Amphibians flourish in the cool, wet forests of the western Pacific Northwest and are dominant vertebrates in many stream and upland habitats (Murphy and Hall 1981; Bury 1988; Welsh and Lind 1988; Bury et al. 1991a). Of the 33 species of amphibians that occur in the region, 15 salamanders and 2 frogs are endemic to the Pacific Northwest (Nussbaum et al. 1983; Leonard et al. 1993; Bury 1994; Table 6). Amphibians in this region have more unique and geographically isolated species than any other vertebrate group in the Pacific Northwest (Bury 1994).

An apparent global decline in the abundance of amphibians is generating considerable concern among scientists (Hayes and Jennings 1986; Blaustein and Wake 1990; Welsh 1990; Wyman 1990; Griffiths and Beebee 1992; Vial and Saylor 1993) and attention often focuses on western North America (Corn 1994). Only one Pacific Northwest amphibian is a candidate for federal listing: the Oregon spotted frog (Table 6). Many more species of salamanders and frogs are listed as sensitive species in states where they occur (Table 6). Widespread declines are of concern because amphibians are functionally significant components of the region's forest and aquatic ecosystems (Walls et al. 1992; Forest Ecosystem Management Assessment Team 1993).

Amphibians in Westside Forests

Seventeen species of salamanders, including 14 endemic species, and the tailed frog (Fig. 25) are closely associated with mature and old-growth westside forests (Forest Ecosystem Management Assessment Team 1993). Tailed frogs and 12 species of salamanders are obligate riparian species, whereas the other species are largely terrestrial. Four of the riparian species (Van Dyke's salamander, Cascade torrent salamander, southern torrent salamander, and tailed frog) and four of the terrestrial species (Del Norte salamander, Siskiyou Mountains salamander, Larch Mountain salamander, and Oregon slender salamander) are listed as sensitive, candidate, or monitor species in the states where they occur (Table 6). Several studies revealed changes in the sizes of local populations in the wake of logging and other disturbances, and repetitive sampling revealed

Fig. 25. The tailed frog is a primitive amphibian that is closely associated with cool mountain streams in the Pacific Northwest.

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Table 6. Status and habitat associations of amphibians in the Pacific Northwest. Ranges in parentheses indicate that the species' occurrence in the province is highly restricted.

Species	Endemic	Range	Federal or state status[a]					Population trend[b]	Habitat associations[c]
			Federal	California	Oregon	Washington	Idaho		
Black salamander		Klamath Mountains	*	*	S–p	—	—	Unknown	Large woody debris in forest; talus
California slender salamander		Klamath Mountains	*	*	S–p	—	—	Unknown	Woody debris and moist forest litter
Cascade torrent salamander	Yes	Cascades	*	—	S–v	M	—	Unknown	Seeps, springs, creeks in mature conifer forest
Cascades frog	Yes	Cascades, North Cascades, Eastern Cascades Slopes and Foothills	*	SC	S–v	*	—	Downward	Alpine and subalpine pools near streams and wet sphagnum moss
Clouded salamander		Coast Range, Klamath Mountains, Cascades	*	*	S–u	—	—	Unknown	Large Douglas-fir logs with intact bark in moist forest; talus
Columbia torrent salamander	Yes	Coast Range	*	—	S–v	M	—	Unknown	Seeps, springs, creeks in mature conifer forest
Cope's giant salamander	Yes	Coast Range, Cascades	*	—	S–u	M	—	Unknown	Riparian habitats in mature conifer forest
Del Norte salamander	Yes	Klamath Mountains	*	SC	S–v	—	—	Unknown	Talus and adjoining areas in mature conifer forest
Dunn's salamander	Yes	Coast Range, Klamath Mountains, Cascades	*	*	*	C	—	Stable?	Talus and rubble in riparian areas in mature conifer forest
Ensatina		All westside	*	*	*	*	—	Unknown	Coarse woody debris in forests
Foothill yellow-legged frog		Coast Range, Klamath Mountains, Cascades, Willamette Valley	*	SC	S–v	—	—	Downward	Warm streams and rivers
Great Basin spadefoot		Columbia Basin, Snake River Basin–High Desert	*	*	*	*	*	Downward in Idaho	Open, arid grass and shrub–steppe and pine forest
Larch Mountain salamander	Yes	Cascades	*	—	S–v	S	—	Unknown	Talus and woody debris in mature conifer forest
Long-toed salamander		All ecoregions	*	*	*	*	*	Downward in Idaho and high Cascades	Streams, ponds, lakes
Northern leopard frog		Okanogan Highlands, Columbia Basin, Snake River Basin–High Desert	*	SC	S–v	*	SC–a	Downward	Ponds, lakes, sluggish streams
Northern red-legged frog		All westside	*	SC	S–u	*	—	Downward	Ponds and other shallow, quiet waters
Northwestern salamander	Yes	All westside	*	*	*	*	—	Unknown	Streams, ponds, lakes
Olympic torrent salamander	Yes	Olympic Mountains	*	—	—	M	—	Unknown	Seeps, springs, creeks in mature conifer forest
Oregon slender salamander	Yes	Cascades, Eastern Cascades Slopes and Foothills	*	—	S–v	—	—	Unknown	Large woody debris in moist forest
Pacific chorus frog		All ecoregions	*	*	*	*	*	Downward in Idaho	Shrubby habitats
Pacific giant salamander	Yes	All westside, (Columbia Basin)	*	*	*	*	—	Stable?	Moist litter, riparian areas, and lakes in mature conifer forest
Rough-skinned newt		All westside, Eastern Cascades Slopes and Foothills, (Columbia Basin)	*	*	*	*	—	Unknown	Moist forest
Shasta salamander	Yes	Klamath Mountains	*	T	—	—	—	Stable or downward	Moist limestone formations
Siskiyou Mountains salamander	Yes	Klamath Mountains	*	T	S–v	—	—	Unknown	Talus and adjoining areas in mature conifer forest
Southern torrent salamander	Yes	Coast Range, Klamath Mountains, Cascades	*	CT	S–v	—	—	Downward ?	Seeps, springs, creeks in mature conifer forest
Spotted frog[d]		All ecoregions except Klamath Mountains	C	SC	S–c; S–u	*	SC–a	Downward	Marshy fringes of sluggish streams, lakes, and ponds
Striped chorus frog		Snake River Basin–High Desert	*	—	—	—	*	Downward	Marshy riparian, damp shrub, and woodland habitats
Tailed frog	Yes	Coast Range, Klamath Mountains, Cascades, North Cascades	*	SC	S–v	M	*	Downward	Cool, rocky streams in mature conifer forest
Tiger salamander		Eastern Cascades Slopes and Foothills, Okanogan Highlands, Columbia Basin, Snake River Basin–High Desert	*	*	S–u	M	*	Stable or upward	Lakes, ponds, reservoirs in grass and shrub steppe
Van Dyke's salamander	Yes	Coast Range, Cascades	*	—	—	C	—	Unknown	Moist litter, talus, riparian areas in mature conifer forest
Western toad		All ecoregions	*	*	S–v	*	SC–b	Locally variable	Marshes, ponds, humid terrestrial with moderate vegetative cover
Western red-backed salamander	Yes	All westside	*	—	*	*	—	Unknown	Coarse woody debris in young forest
Woodhouse's toad		Columbia Basin, Snake River Basin–High Desert	*	*	*	M	*	Stable or upward	Grass and shrub–steppe, riparian areas

[a] — = does not occur in state,* = no special status, C = candidate for federal threatened or endangered species listing; California — CT = candidate for threatened status, SC = species of special concern, T = state-threatened; Oregon — S–c,v,p,u = sensitive species with critical, vulnerable, peripheral, or unknown status; Washington — S = sensitive species, C = candidate for sensitive species status, M = monitor species; Idaho — SC–a,b = species of special concern category a (priority) or b (peripheral). References: Oregon Natural Heritage Program 1993; California Department of Fish and Game 1994, 1995b; Conservation Data Center 1994; U.S. Fish and Wildlife Service 1994; Washington Department of Wildlife 1994.

[b] Primary comprehensive references: Rodrick and Milner 1991; Groves and Peterson 1992; Marshall et al. 1996; see text for others.

[c] Primary comprehensive references: Nussbaum et al. 1983; Leonard et al. 1993; see text for others.

[d] Recently split into two species, Oregon and Columbia spotted frogs; both species show evidence of decline (see box on spotted frogs in the Western Pacific Northwest).

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some large-scale extirpations; however, little quantitative data exist to accurately document regional population trends (Corn 1994).

Undisturbed streambeds in Pacific Northwest forests include mostly sediment-free gravel and large woody debris that provide vital cover and breeding substrates for stream amphibians (Bury and Corn 1988; Bury et al. 1991a). Woody debris in streams also provides substrate and food for invertebrate prey (Anderson et al. 1978). Land uses that remove riparian vegetation and woody debris and increase water temperatures and sedimentation in streams are detrimental to many amphibians (Murphy and Hall 1981; Welsh and Lind 1988; Corn and Bury 1989; Welsh 1990; Bull 1994). The number of species, the density, and the biomass of amphibians range from two to seven times higher in streams flowing through natural forests than in streams flowing through logged areas in the Coast and Cascade ranges of Oregon (Corn and Bury 1989).

The negative effect on amphibians of large-scale habitat modification and chronic sedimentation in streams may persist for decades (Corn and Bury 1989). Logging, though, is not always detrimental to stream productivity. In high-gradient streams where sedimentation is less of a problem, larvae of the Pacific giant salamander are often more abundant in streams that flow through clear-cuts than in streams that flow through intact forests. The salamanders respond to the greater primary productivity and abundance of invertebrate prey that result from increased insolation after removal of riparian vegetation (Murphy and Hall 1981; Murphy et al. 1981; Hawkins et al. 1983).

Forest fragmentation from clear-cutting, excessive thinning of stands, and removal of woody debris desiccate forest floors and harm amphibians. Southern torrent salamanders and tailed frogs often occur as isolated populations because they are unable to disperse across dry forests (Bury and Corn 1988; Bury et al. 1991a). Ensatinas, five endemic species of woodland salamanders, Oregon slender salamanders, clouded salamanders, and black salamanders are closely associated with woody debris and moist microhabitats in the riparian and forest-floor areas they prefer (Herrington and Larsen 1985; Aubry et al. 1988; Bury and Corn 1988; Raphael 1988; Welsh 1990; Bury et al. 1991b; Corn and Bury 1991; Gilbert and Allwine 1991a; Washington Department of Wildlife 1993b). In the Klamath Mountains ecoregion, in particular, the richness and abundance of terrestrial salamanders are generally higher in older and more mesic forests than in younger and drier forests (Welsh and Lind 1988).

Widespread Declines of Ranid Frogs

Much of the concern over global amphibian declines is focused on frogs, which may be particularly sensitive to a variety of modern environmental disturbances. Evidence suggests that every species of ranid frog in the western United States has experienced local or regional population declines (Hayes and Jennings 1986). The reasons for the declines vary depending on the species and locale; however, the reasons also often remain obscure (Corn 1994). Widespread loss and degradation of permanent and ephemeral waterways are common causes of amphibian declines. One probable threat to aquatic frogs may be a worldwide problem—increasing ultraviolet-B radiation caused by the thinning of the ozone layer could be causing widespread mortality of frog eggs (Blaustein et al. 1994a).

Large populations of foothill yellow-legged frogs and northern red-legged frogs still occur in parts of the Klamath Mountains ecoregion; however, most populations farther south are extirpated or declining (Blaustein and Wake 1990; Fellers and Drost 1993; Corn 1994; Jennings and Hayes 1995; Marshall et al. 1996), and northern red-legged frogs have disappeared from much of the Willamette Valley (Blaustein et al. 1994b). Population sizes of Cascades frogs are declining throughout the Cascades (Blaustein and Wake 1990; Marshall et al. 1996), and 24 of 30 populations monitored since the 1970's in Lassen Volcanic National Park in California are almost extirpated (Blaustein and Wake 1990; Fellers and Drost 1993). The spotted frog (now reclassified as two species, the Oregon spotted frog and Columbia spotted frog) was once widespread in a variety of low and high-elevation habitats on both sides of the Cascades. Now this species is almost extirpated west of the Cascades (see box on Spotted Frogs in the Western Pacific Northwest), and populations are declining in many other areas (Nussbaum et al. 1983; Hayes and Jennings 1986; McAllister et al. 1993; Hayes 1994).

Surveys in the late 1950's, 1970's, and early 1980's revealed robust populations of northern leopard frogs in several areas of eastern Washington (Metter 1960; Leonard and McAllister 1996). More recently, however, biologists from the Washington Department of Fish and Wildlife and Department of Natural Resources failed to find leopard frogs in most of these historical localities (Leonard and McAllister 1996). Introduced bullfrogs were usually abundant in areas without northern leopard frogs and absent in areas with leopard frogs (also see Bury and Whelan 1984).

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Spotted Frogs in the Western Pacific Northwest

Before the turn of the century, most zoological collections were concentrated near forts and the early precursors of today's major cities. The spotted frog (Fig. 1) was first described from specimens collected by scientists based at Fort Steilacoom near present-day Tacoma, Washington (Baird and Girard 1853). Early naturalists also wrote about spotted frogs near Seattle and Portland (Dickerson 1906; Jewett 1936). Between 1850 and 1940, specimens were deposited in herpetological collections across the country. These specimens provide the primary evidence of the species's formerly broad distribution in western Washington and Oregon.


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Fig. 1. Oregon spotted frog.

After 1940 the decline of spotted frog populations in western Oregon and Washington was probably well under way. During the 1950's and 1960's, researchers in western Washington and western Oregon had difficulty finding animals for their studies (Dumas 1966; Storm 1966). In the last several years, scientists expanded their searches for spotted frogs in the western halves of both states, but with few positive results. A single population near Olympia, Washington (discovered in 1990), is the last known population in the heavily developed lowlands of the Puget Lowland and Willamette Valley ecoregions (McAllister et al. 1993; Hayes 1994; Fig. 2).

Recent genetic investigations demonstrated significant differences between the spotted frogs of western Oregon and Washington and those from other parts of the species' range, which includes much of eastern Washington and Oregon and parts of Idaho (Leonard et al. 1993). These results warranted recent reclassification of the Oregon spotted frog and the Columbia spotted frog as distinct species (Green et al. 1996, 1997; Fig. 2). The Oregon spotted frog is now rare. In addition to the population near Olympia, these frogs are still found in northwestern Klickitat County in Washington, in several lakes and marshes in the Oregon Cascades (Hayes 1994), and at one site in southern British Columbia.

Nonindigenous bullfrogs are probably a primary cause of declining populations of spotted frogs (Storm 1966; Nussbaum et al. 1983; McAllister et al. 1993). Bullfrogs were brought into Washington and other western states to be farmed for culinary purposes. By the mid-1900's, breeding populations of bullfrogs were well established in the Puget Lowland and Willamette Valley ecoregions (Slater 1939; Nussbaum et al. 1983; Bury and Whelan 1984). Bullfrogs, though, are probably not the only cause of declining populations of spotted frogs. Introduced fishes, particularly warm-water species such as largemouth bass, sunfishes, perch, and bullhead catfishes, could also be involved because these species prey on both spotted frog tadpoles and adults (Hayes and Jennings 1986). In addition, human developments have altered or eliminated wetlands and introduced a wide array of contaminants to many aquatic systems.

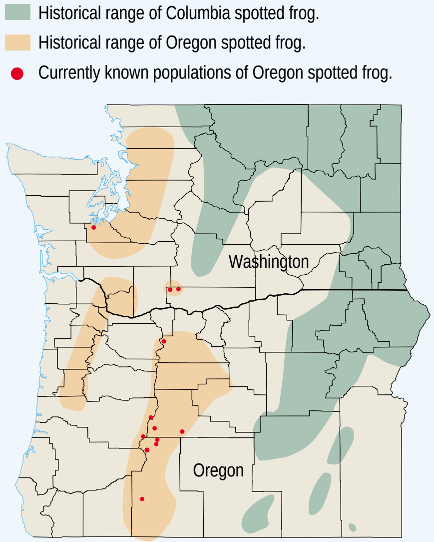

Fig. 2. Historical and current range of the Oregon spotted frog, and historical range of the Columbia spotted frog in the United States.

The means for conservation of remaining populations of spotted frogs are not readily apparent. If nonindigenous species are the primary problem, some spotted frog populations remain vulnerable. Scientists continue to discover bullfrogs in new localities in Washington and Oregon. Habitat alterations from human activities also continue in most areas. Detailed knowledge of the effects of various habitat alterations and contaminants on spotted frogs is lacking.

See end of chapter for references

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Other Eastside Amphibians

A recent survey of experts in Idaho provides information about the possible status of some eastside amphibians (Groves and Peterson 1992; Table 7), including additional evidence of declines among spotted frogs and northern leopard frogs. Other sources suggest that some populations of Great Basin spadefoots (Fig. 26) benefited from increased irrigation (Nussbaum et al. 1983), whereas other populations suffered when breeding habitats in sagebrush were

Table 7. Population trends of amphibians in Idaho based on a 1990 mail questionnaire sent to regional experts (Groves and Peterson 1992).

Species	Number of responses	Percent stable or upward	Percent downward
Great Basin spadefoot toad	4	0	100
Long-toed salamander	7	43	57
Northern leopard frog	9	22	78
Pacific chorus frog	12	33	67
Spotted frog	4	25	75
Striped chorus frog	5	20	80
Tailed frog	4	75	25
Tiger salamander	4	75	25
Western toad	14	50	50
Woodhouse's toad	1	100	0

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Fig. 26. Great Basin spadefoot.
© D. Quinney, State of Idaho, Military Division

replaced with grainfields and altered by hydroelectric development (Leonard et al. 1993). Otherwise, accurate status information and quantitative data on populations of eastside species are lacking (Groves and Peterson 1992).

Reptiles

The greatest richness of reptiles occurs in drier, warmer habitats on the eastside and in the mixed evergreen forests and oak woodlands of the Klamath Mountains ecoregion. Northwestern garter snakes and Oregon garter snakes are the only two species of reptiles endemic to the cool, moist forests of the Pacific Northwest (Nussbaum et al. 1983; Stebbins 1985). Populations of garter snakes (including those of three other species) are secure throughout the region (Marshall et al. 1996).

Sharp-tailed snakes (a sensitive species in Oregon), ring-necked snakes, western rattlesnakes, and common kingsnakes are largely extirpated from their former ranges in the southern Willamette Valley. Common causes for these declines include urban and agricultural development, removal of woody debris during logging, and loss or degradation of oak woodland habitats (Puchy and Marshall 1993; Marshall et al. 1996). Similarly, the California mountain kingsnake is listed as sensitive in Oregon and is a candidate for sensitive species status in Washington because of possible associations with coarse woody debris and sensitivities to disturbances from logging (Washington Department of Wildlife 1994; Marshall et al. 1996).

Many other reptiles that occur in the region, especially lizards, seem to respond positively to the opening of forests by logging, at least until the canopy closes in 10–30 years (Bury and Corn 1988; Raphael 1988). This is consistent with the trend of increasing diversity in warmer, drier habitats. No lizards that occur in the western Pacific Northwest are on state or federal lists of endangered, threatened, or sensitive species, but the actual status of these species is poorly known.

The western pond turtle (Fig. 27) is the only nonmarine reptile listed as endangered or threatened in Washington (Washington Department of Wildlife 1994), and it is one of only two reptiles listed as sensitive with critical status in Oregon (Oregon Natural Heritage Program 1993). Western pond turtles are abundant in parts of the Klamath Mountains ecoregion, but they have been extirpated or are rare from Seattle south through the Willamette Valley where threats from agriculture, pollution, and urbanization are greater (Holland 1991; Washington Department of Wildlife 1993c; Marshall et al. 1996; Holland and Bury 1997). Because these turtles do not reproduce until they are 8–11 years old and then lay small clutches of eggs, depleted populations rebound slowly, if at all (Holland and Bury 1997).

Fig. 27. Western pond turtle.
© D. Holland, Camp Pendleton Amphibian and Reptile Survey, Fallbrook, California

Eastside lowlands support the highest richness of reptiles in the Pacific Northwest, including several species that reach their northernmost range limits in southern Oregon and Idaho. The status of these species is poorly known, but reptiles are functionally important in arid steppe ecosystems. Striped whipsnakes, long-nosed snakes, ground snakes, desert collared lizards, and desert horned lizards are afforded some level of special status in Oregon, Washington, or Idaho. All of these species are widespread in the Great Basin (Stebbins 1985); the listings primarily reflect concern for local, peripheral populations that may be particularly susceptible to habitat degradation or other disturbances. However, desert collared lizards and desert horned lizards may be threatened by excessive collecting for the pet trade (Idaho Department of Fish and Game 1994; Marshall et al. 1996). In addition, large-scale changes in the structure and distribution of shrub–steppe vegetation and related habitats may adversely affect reptiles (Werschkul 1982); however, conservation is greatly hampered by the general lack of information on the status of reptilian populations.

Birds

The assessment of population trends of birds has been more successful than that for other vertebrate groups because the North American Breeding Bird Survey conducted by the U.S. Geological Survey provides long-term (1968–97 in the Pacific Northwest) abundance data for many species (Robbins et al. 1986; Peterjohn and Sauer 1993; Peterjohn 1994; Peterjohn et al. 1995). Breeding Bird Survey methods, though, do not adequately account for sparsely distributed, secretive, or nocturnal species. Consequently, Breeding Bird Survey data exist for only about 64% of the bird species that occur in westside forests (a total of about 140 species), and similar or more severe limitations apply to other regions. Moreover, the reliability of the data available for assessing trends in particular regions is highly dependent on the number of routes (25-kilometer segments along roads) surveyed each year. For the purpose of this report, we consider only species with sample sizes of at least 20 routes, and consider data for species with samples sizes between 20 and 40 routes only marginally reliable. In most eastside regions, in particular, many bird species are sparsely distributed and the survey effort was limited until just recently. In some cases, other survey data and information help fill the gaps in knowledge and increase the reliability of the indicated trends.

The proportion of species for which raw or modified Breeding Bird Survey data (modified data after Carter and Barker 1993; discussed further in eastside sections below) indicate significant population trends varies across regions of the Pacific Northwest (Fig. 28). Most important, the proportion of species with downward trends in population sizes is greatest in low- to moderate-elevation westside forests (in the South Pacific Rainforest region). Probable causes for this trend include widespread loss and degradation of mature riparian woodlands and extensive replacement of structurally diverse coniferous forests with early-seral vegetation because of clear-cutting (Mannan and Meslow 1984; Rosenberg and Raphael 1986; Raphael et al. 1988; Lehmkuhl et al. 1991; McGarigal and McComb 1993; Hejl 1994). This regional comparison may be misleading, however, because the proportion of species for which no data are available (many of which may have declining population sizes) is high in all regions.

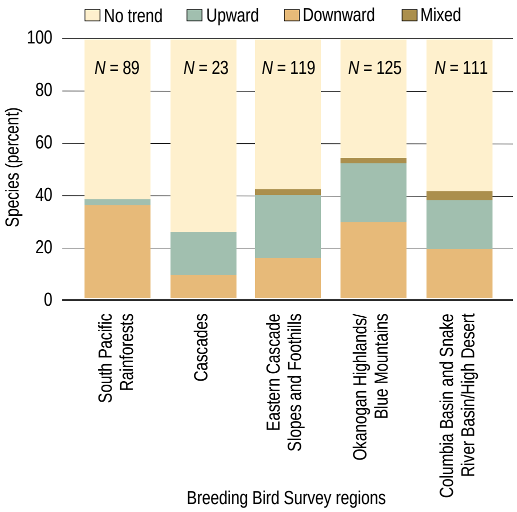

Fig. 28. Regional variation in proportions of bird species for which raw (westside forests) and modified (eastside habitats; after Carter and Barker 1993) Breeding Bird Survey data (U.S. Geological Survey, Washington, D.C.) indicate significant population trends (mixed means that the trends reversed during the past decade or so) since the late 1960's. (*N* = sample size. The South Pacific Rainforests region includes the Klamath Mountains, Coast Range, and low- to moderate-elevation western Cascades and North Cascades ecoregions. Cascades region includes the higher-elevation Cascades).

Birds in Westside Ecosystems

The only birds on the U.S. List of Endangered and Threatened Wildlife (U.S. Fish and Wildlife Service 1995) that nest and regularly occur in westside forests are bald eagles, northern spotted owls, and marbled murrelets. Each of these threatened species depends on habitat resources that occur mostly in mature conifer or riparian forests (Brown 1985; Thomas et al. 1993; Ralph et al. 1995; see box on Northern Spotted Owl). Several other species that state governments list as sensitive (for example, northern goshawk, harlequin duck, black-backed woodpecker, pileated woodpecker [Fig. 29], and Vaux's swift) also usually find optimal habitat in such mature forests (Brown 1985; Thomas et al. 1993). Breeding Bird Survey data indicate no significant population trends for pileated woodpeckers and Vaux's swifts in westside forests since 1968, but plots of annual abundance indexes show slight nonsignificant declines (Fig. 30). Breeding Bird Survey data on the other species are not available.


Courtesy E. L. Bull, U.S. Forest Service

Fig. 29. Pileated woodpecker at its nest cavity.

Other survey data show that the number of breeding attempts by bald eagles in Oregon steadily increased and that productivity (young per successful territory) remained stable from 1979 to 1994 (Fig. 31). Still, the productivity of some populations along the Columbia River may yet be compromised by waterborne toxins (C. J. Henny, U.S. Geological Survey, Corvallis, Oregon, personal communication).

Bird populations of westside forests are often affected by direct physical changes to their habitat. Widespread logging of marbled

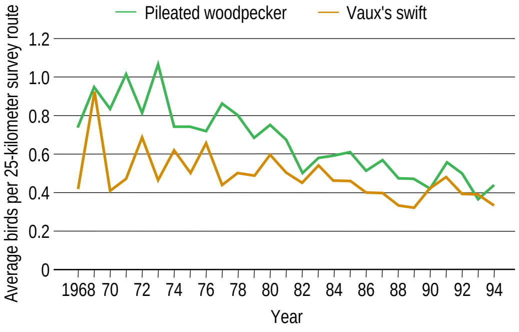

Fig. 30. Trends in the annual abundance indexes of pileated woodpeckers and Vaux's swifts in the western Pacific Northwest (Breeding Bird Survey data for the South Pacific Rainforest region, U.S. Geological Survey, Washington, D.C.).

Northern Spotted Owl

The northern spotted owl (Fig. 1) is an inconspicuous, medium-sized, dark brown owl that inhabits forests of the Pacific Coast region from southwestern British Columbia to central California (Fig. 2). It has been the centerpiece of debate regarding forest management on federal lands in the Pacific Northwest because of its apparent preference for large tracts of old-growth forest (Thomas et al. 1990, 1993; Forest Ecosystem Management Assessment Team 1993). In 1990 the species was federally listed as threatened.

Spotted owls are primarily nocturnal and normally spend their days perched in a protected roost. They nest in cavities or on platforms in large trees in nests built by other species (Forsman et al. 1984). Established pairs normally remain in the same territories from year to year; annual foraging areas may exceed 1,000 hectares (Forsman et al. 1984; Thomas et al. 1990; Carey et al. 1992a). Spotted owls eat a broad range of


Courtesy Bureau of Land Management

Fig. 1. Northern spotted owl adult and nestlings on nest in old-growth snag.

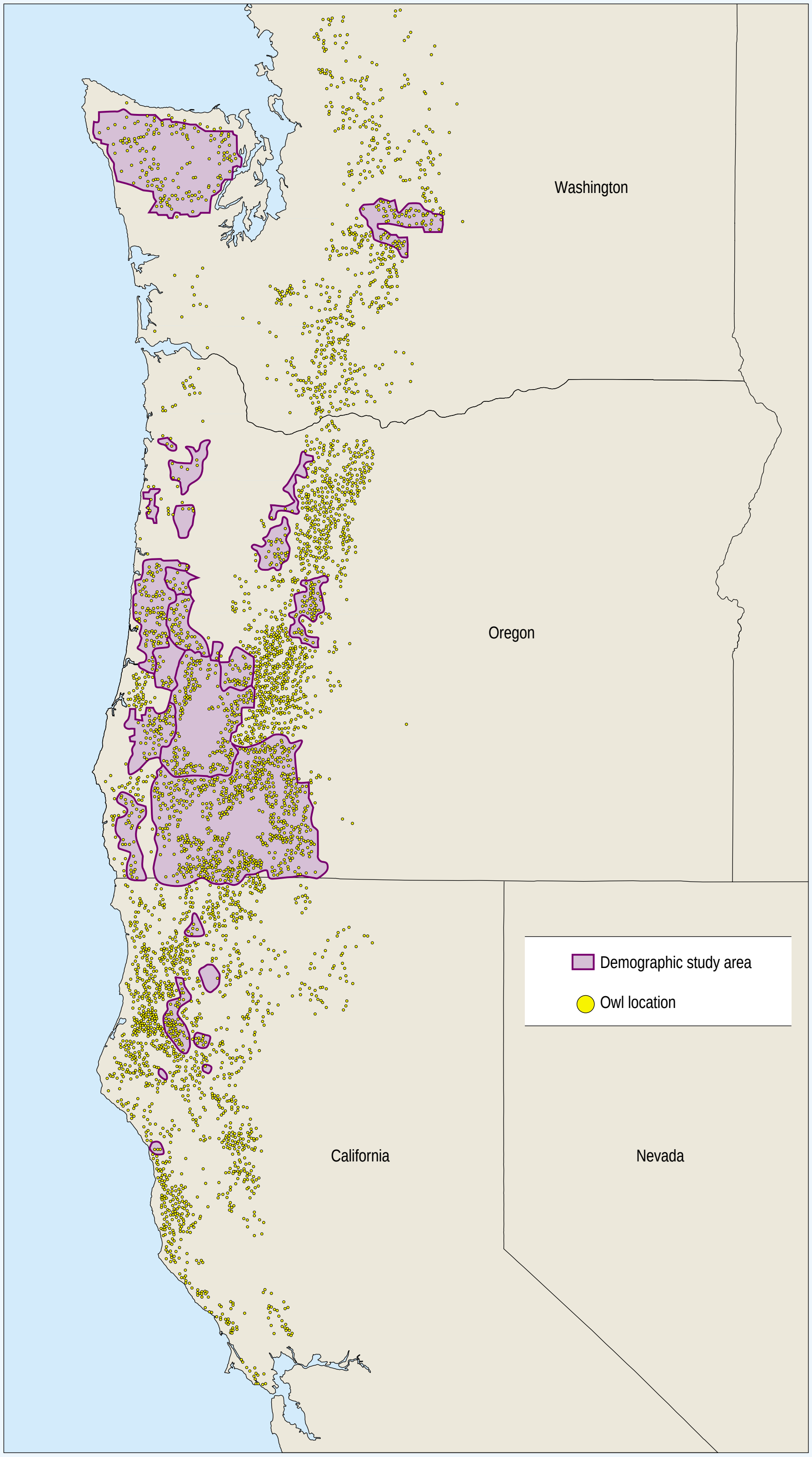

Fig. 2. Current demographic study sites for northern spotted owls and the distribution of all owl pairs located in California, Oregon, and Washington between 1986 and 1994 (map prepared by the U.S. Forest Service, Olympia Forestry Sciences Laboratory, Washington).

mammals, birds, insects, amphibians, and reptiles, but northern flying squirrels, voles, mice, and woodrats are their primary prey (Forsman et al. 1984; Thomas et al. 1990; Carey et al. 1992b). Predators of spotted owls include great-horned owls and northern goshawks.

Spotted owls occur in many types and age-classes of forests, but most occur in older forests, and most scientists believe that young forests are marginal habitat for spotted owls. Studies of habitat use (Forsman et al. 1984; Carey et al. 1992b) and of landscape features around nest sites of spotted owls (Ripple et al. 1991; Lehmkuhl and Raphael 1993) confirm selection of older forests for nesting and foraging. Nevertheless, most landscapes occupied by spotted owls include diverse mixtures of old and young forest patches that are created by natural disturbances and timber harvest.

An intensive and extensive survey by many federal and state agencies, consulting firms, and private landowners revealed that moderately large populations of northern spotted owls still exist (Thomas et al. 1993). The number of known or suspected pairs is approximately 30 in British Columbia, 860 in Washington, 2,900 in Oregon, and 2,300 in northern California (E. D. Forsman, U.S. Forest Service, Corvallis, Oregon, unpublished data). Studies of banded birds, however, suggested that adult survival has declined in recent years and has caused the population size of territorial owls to dwindle at an accelerating rate (Burnham et al. 1994). Population assessments based on studies of banded birds are controversial (Thomas et al. 1993), but the reliability of such indexes should increase as more years of data are included.

Population assessments are further complicated by the fact that responses by spotted owls to forest management seem to vary from region to region. For example, in some portions of northwestern California, spotted owls are relatively common in forests aged 60–100 years (L. V. Diller, Simpson Timber Co., Korbel, California, personal communication), whereas few owls occur in such forests in the central Oregon Coast Range (Forsman, unpublished data). Differential use of young forests by spotted owls probably depends on regional differences in prey populations, forest structure, and climate.

Because spotted owls use a wide range of forest types, managers have had difficulty developing a simple description of owl habitat that can be applied to all areas. This has led to considerable debate over how much habitat is still available for spotted owls. More is known about the distribution and abundance of the northern spotted owl than about any other owl in the world, but the status of the species is still hotly debated.

The productivity and occurrence of spotted owls also are affected by expanding populations of barred owls. The range of barred owls has been expanding from the eastern United States since the early 1900's and now includes western Canada, the Pacific Northwest, and northern California (Taylor and Forsman 1976; Hamer et al. 1994). Barred owls have invaded many forest areas that were previously occupied by spotted owls. In some cases, barred owls seemed to displace resident spotted owls. In other cases, individuals of the two species hybridized. The long-term effects of the barred owl invasion on spotted owl populations will probably remain unclear for many decades.

Current studies of spotted owls are many and diverse, including studies of population dynamics, diet, habitat, prey, dispersal, behavior, physiology, and genetics. Several large-scale demographic studies (Fig. 2) designed to monitor the survival and rates of reproduction of spotted owls are the most controversial (Burnham et al. 1994). These demographic studies cover a large portion of the owl's range and are the source of most of the current information on population trends. Despite this large investment in research and monitoring, spotted owl population trends are still not fully understood, especially in relation to changing habitat conditions.

Because spotted owls are a focus of debate about forest management practices in the Pacific Northwest, surveying and monitoring these owls will probably remain a high priority on federal forest lands. Although most current monitoring involves long-term studies of banded birds, other less costly methods of population assessment (for example, transect surveys of calling birds or habitat-based monitoring) are needed (U.S. Fish and Wildlife Service 1992). The ultimate objective of regional monitoring of a species such as the spotted owl is to learn if implementation of proposed management plans maintains viable populations. A meaningful effort will require extensive tracking of owl and prey populations and habitat changes for several decades.

See end of chapter for references

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murrelet nesting habitat in coastal old-growth forests probably has depleted this species' populations and reduced its range in the Pacific Northwest (Ralph 1994; Ralph et al. 1995). The U.S. Forest Service considers northern goshawks an indicator of old-growth forest conditions, and goshawks seem sensitive to forest fragmentation (Reynolds 1989; Marshall et al. 1996). Harlequin ducks nest in riparian areas in mature forests where disturbance is minimal, where abundant woody debris provides loafing areas and shelter for nests, and where healthy streams provide adequate macroinvertebrate prey (Rodrick and Milner 1991; Marshall et al. 1996). Black-backed woodpeckers and other woodpeckers may be adversely affected by current efforts to eliminate insect-occupied, diseased, and cavity-bearing trees and snags from timber stands (Bull et al. 1986; Goggans et al. 1989; Marshall et al. 1996). Despite knowledge of these sensitivities, quantitative population data for these species are scarce.

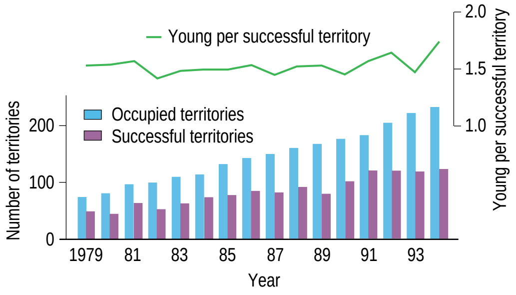

Fig. 31. Trends in the population size and productivity of nesting bald eagles in Oregon (adapted from Isaacs and Anthony 1994).

Thomas et al. (1993) listed 38 species of birds closely associated with mature and old-growth westside forests. Breeding Bird Survey data for 17 of these species (including Vaux's swifts and pileated woodpeckers) are at least marginally reliable. Three of the 17 species show significant long-term or recent downward population trends (winter wren, golden-crowned kinglet, and Wilson's warbler; Table 8; Fig. 32); none show significant upward trends. Nine other species that often forage or nest in mature conifer or riparian forests, but which may also find suitable habitat in younger forests, also show downward trends (Table 8). For instance, rufous hummingbirds occur in a variety of shrub and forest habitats but are often most abundant around older forests (Gilbert and Allwine 1991b; Ralph et al. 1991). These downward trends are consistent with evidence of large-scale shifts in habitat availability from old-growth to young forests.

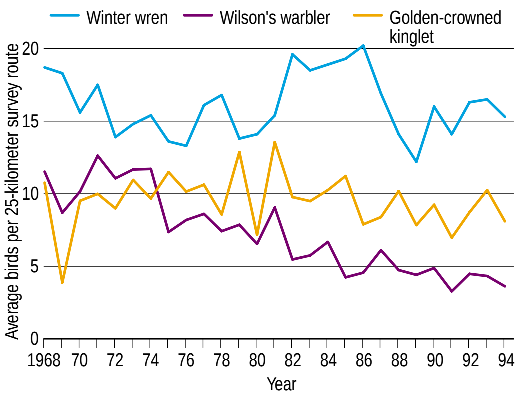

Fig. 32. Examples of downward trends in the annual abundance indexes of bird species that occur in mature and old-growth forests in the western Pacific Northwest (Breeding Bird Survey data for the South Pacific Rainforest region, U.S. Geological Survey, Washington, D.C.).

About one-third of the species that occur in westside forests use cavities in primarily large trees and snags for nesting and roosting (Brown 1985). Reliable Breeding Bird Survey data are available for 19 of these species. Winter wrens, which nest in a variety of cavities, crevices, and brush piles in mature forests, and four species that nest in residual, old-forest snags in open young-forest, early-seral, or riparian habitats (Bewick's wren, black-capped chickadee, western bluebird, American kestrel) show long-term or recent downward population trends (Table 8). Breeding Bird Survey data indicate no significant trends for five species of woodpeckers—

Table 8. Population trends (Breeding Bird Survey data, U.S. Geological Survey, Washington, D.C.) and habitat associations of bird species with significant long-term (1968–1994) or recent (1980–1994) downward abundance trends in westside forests.

Species	Trends by region[a,b]		Habitat associations[c]						
	South Pacific Rainforests (long-term/recent)	Cascade Mountains (long-term/recent)	Old-growth forest	General forest	Shrub/ early seral forest	Meadow/ grassland	Riparian woodland	Herbaceous wetland	Cavity-nesting
American kestrel	D*/NS*		P		P		P		P
Band-tailed pigeon	D/D		P	P			P		
Barn swallow	D/D					P		P	
Bewick's wren	D/NS			S	P		P		S
Black-capped chickadee	NS*/D*		S	P			P		P
Brown-headed cowbird	D/NS	NS*/ND		P	P		P		
Bullock's oriole	D*/NS*						P		
Bushtit	D/D*			S	P				
Chipping sparrow	D/D*	NS*/ND	P	P	P		P		
Common nighthawk	D*/ND				P	P			
Dark-eyed junco	D/NS	NS*/NS*	P	P	P				
Golden-crowned kinglet	D/NS	NS*/D*	P	P					
Killdeer	D/D					P		P	
Lazuli bunting	D*/NS*			S	P		P		
Lesser goldfinch	D*/NS*			S	P		P		
MacGillivray's warbler	D/NS	NS*/NS*					P		
Mourning dove	D/D			P			P		
Olive-sided flycatcher	D/D	D*/NS*	P	S					
Orange-crowned warbler	D/D			P	S		P		
Pine siskin	D/D	NS*/NS*	P	S			P		
Rufous hummingbird	D/D*	NS*/ND	P	P	P		P		
Song sparrow	D/D	NS*/ND		S	P		P		
Western bluebird	D*/D*				P		S		P
Western meadowlark	D/D*					P		S	
Western tanager	D/NS	NS*/NS*	P	S					
Western wood-pewee	D/NS		P	S			P		
White-crowned sparrow	D/D			S	P	P	P		
Wilson's warbler	NS/D		P	S			P		
Winter wren	NS/D		P				P		S
Wrentit	NS*/D*				P				
Yellow-rumped warbler	NS*/D*	NS*/ND	P	P			P		
Total downward	31	2	14	21	15	5	21	3	5

[a] Breeding Bird Survey regions: South Pacific Rainforests equals the Coast Range, Klamath Mountains, low- to moderate-elevation western Cascades and North Cascades ecoregions; Cascade Mountains equals high-elevation Cascades.

[b] D = downward, NS = no significant trend, ND = insufficient data, and * = a problem with sample size (number of routes = 20–39).

[c] P = primary, S = secondary. References: Brown 1985; Ruggiero et al. 1991a; Puchy and Marshall 1993; Andelman and Stock 1994a,b.

primary cavity excavators—that occur in westside forests and woodlands (northern flicker, acorn woodpecker, downy woodpecker, hairy woodpecker, and pileated woodpecker). Nest-site availability, though, could become a more important limiting factor for secondary and primary cavity-nesting species unless management aids in recruitment of large snags (Mannan and Meslow 1984).

The reasons for apparent downward trends in westside populations of species such as orange-crowned warblers, MacGillivray's warblers, yellow-rumped warblers, and bushtits (Table 8) are not obvious. These species typically inhabit forest–shrub edge habitats (Brown 1985). Clear-cutting often creates a version of this habitat type; however, natural gaps in older forests and riparian corridors in undisturbed, mature forests—both habitats that have been degraded in many areas—may provide suitable edge habitat without increased risk of exposure to predation by nonforest species or nest parasitism by brown-headed cowbirds (Yahner 1989; Robinson et al. 1992). In addition, all of these species except the bushtit are Neotropical migrants that may be experiencing problems during migration or on wintering grounds (Finch and Stangel 1992).

Only Steller's jays and common yellowthroats show long-term or recent upward population trends in westside forests (Fig. 33). These are widely distributed species with general habitat requirements.

Loss of large, riparian trees and snags along the Willamette River may once have reduced nesting by ospreys, but their local abundance has steadily increased since 1976 when the birds began nesting on utility poles (Henny and Kaiser 1996; Fig. 34). The Breeding Bird Survey does not cover the central Willamette Valley, and data for westside forests reveal no significant trend in osprey population sizes.

The Canada goose is another species that is common in the Willamette Valley, especially during winter. Its populations have increased in abundance during the past two decades (see box on Wintering Canada Geese in the Willamette Valley).

Birds in Eastside Forests

Breeding Bird Survey data for birds that occur in eastside habitats are limited because of the relative rarity and limited distributions of the associated species. Sample sizes for Breeding Bird Survey data on birds in the eastern Cascades (Breeding Bird Survey Pitt–Klamath Plateau region) are all below 40 routes, indicating poor or marginal reliability. More extensive and consistent monitoring of bird populations in eastside forests is needed. However, the reliability of trend interpretation is improved by indexes that incorporate information about the estimated magnitude of trends over time and the accuracy of the data. Carter and Barker (1993) developed such a modified index from Breeding Bird Survey data for Neotropical migrant land birds of the western United States. The trend data given here for birds of the Intermountain West, calculated for long-term (1969–1991) and recent (1982–1991) Breeding Bird Survey periods, were derived in a similar way.

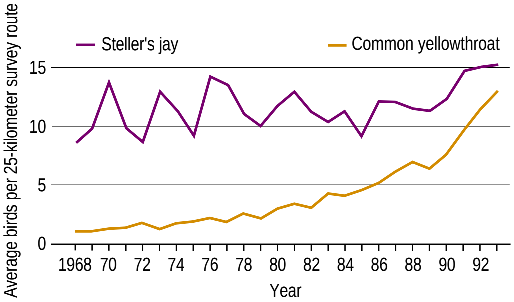

Fig. 33. Upward trends in the annual abundance indexes of Steller's jays and common yellowthroats in the western Pacific Northwest (Breeding Bird Survey data for the South Pacific Rainforest region, U.S. Geological Survey, Washington, D.C.).

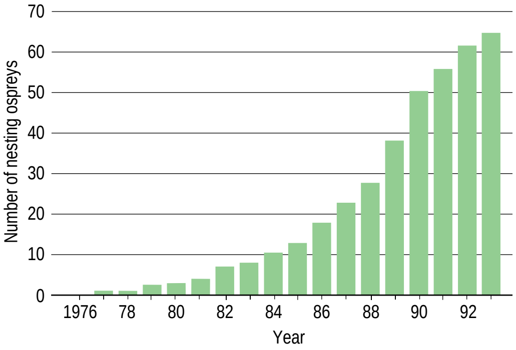

Fig. 34. Osprey abundance along the Willamette River, Oregon (adapted from Henny and Kaiser 1996).

In the Eastern Cascades Slopes and Foothills ecoregion, 29 species show significant upward population trends, whereas only 19 species show significant downward trends (Fig. 28). In contrast, slightly more species show downward trends than upward trends in the combined Okanogan Highlands–Blue Mountains region (Fig. 28). The strongest contrast is evident in recent data; many more species show recent downward trends and fewer species show recent undetermined trends in the Okanogan Highlands–Blue Mountains region than in the eastern Cascades region. A greater proportion of species show significant trends in the Okanogan Highlands–Blue Mountains region than in the eastern Cascades region, but still no trends can be discerned for 46% of the species that occur there (Fig. 28).

Ten species that are primarily associated with old-growth forests and four other species that often use old-growth forests show long-term or recent downward population trends in the eastern Cascades or Okanogan Highlands–Blue Mountains regions (Table 9). Only three

Wintering Canada Geese in the Willamette Valley

Only about 2,500 Canada geese wintered in the southern Willamette Valley between 1938 and 1948 (Gullion 1951), but during the subsequent 20 years, the size of the valley population greatly increased (Fig. 1). The U.S. Fish and Wildlife Service (Region 1, Portland, Oregon) began systematic surveys of wintering Canada geese in 1953 when the peak count was fewer than 10,000 birds. The typical winter population increased to about 20,000 birds by 1967. Throughout this period most of the geese counted were dusky Canada geese (Fig. 2). The southern Willamette Valley was the major harvest area for dusky Canada geese in the early 1950's (Chapman et al. 1969). In the mid-1960's, three national wildlife refuges were established to provide the geese with some refuge from hunting.

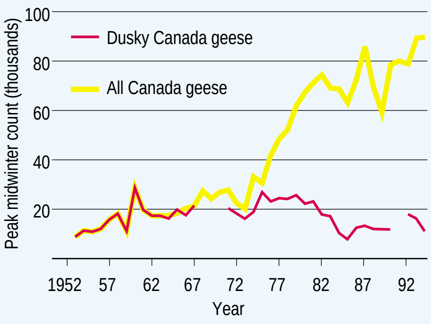

Fig. 1. Trends in winter population sizes of Canada geese in the Willamette Valley, Oregon (data provided by U.S. Fish and Wildlife Service, Portland, Oregon).

The winter abundance of dusky Canada geese in the Willamette Valley began to decline in the 1980's because of long-term ecological changes that occurred on the birds' nesting grounds in Alaska. In 1964 an earthquake on the Copper River Delta lifted the nesting grounds 0.5–2 meters (Shepherd 1965) and caused the habitat to change from tidal wetlands to uplands. Predation of nests by grizzly bears, coyotes, bald eagles, and mew gulls subsequently increased. By the 1980's nest productivity had significantly declined, leading to a population decline that continues today (Campbell 1992).

In the late 1960's, Taverner's Canada goose, a smaller subspecies that nests in arctic Alaska and Canada, began wintering in the Willamette Valley and greatly complicated management of geese in the valley. As the population of dusky Canada geese began to decline, the winter population size of Taverner's Canada geese increased exponentially during the mid-1970's and early 1980's (Jarvis and Cornely 1985). Managers were faced with the dilemma of protecting a declining subspecies threatened by changes on their breeding grounds, while the size of another subspecies population was rapidly expanding to the point of providing a considerable surplus for harvest. Moreover, certain behavioral tendencies of dusky Canada geese make them particularly vulnerable to hunters (Simpson and Jarvis 1979).

Low numbers of a third subspecies, the cackling Canada goose, wintered at the northern end of the Willamette Valley in the mid-1960's (Chapman et al. 1969), but most individuals wintered in the Central Valley of California. The population size of this subspecies subsequently declined precipitously, resulting in a flyway-wide hunting closure from 1984 to 1993. During the mid-1980's, the cackling Canada goose remained an insignificant part of the winter population of Canada geese in the Willamette Valley. The population size of this subspecies greatly increased during the last decade, however; the current winter population is about 60,000 birds. Four other subspecies also contribute to the winter population in the Willamette Valley: Vancouver Canada goose, the federally threatened Aleutian Canada goose, western Canada goose, and lesser Canada goose. Thus, 7 of the 11 recognized subspecies of Canada goose in North America (Delacour 1954) winter in the Willamette Valley. Moreover, the western Canada goose began nesting in the valley about 20 years ago and its nesting population continues to increase.

All subspecies of Canada goose that winter in the Willamette Valley graze on green vegetation. Numerous types of grass and clover are planted by valley farmers. The area planted in grasses for seed in the Willamette Valley changed from limited amounts in the 1950's to about 160,000 hectares in 1993 (Fig. 3). Estimates of grass seed production steadily increased from 13,900 to 243,300 metric tons from 1940 to 1990 (Oregon State University Extension Service, Corvallis, unpublished data). Modern farm practices steadily improved yields and this, in turn, probably resulted in increasing forage potential for wintering

Courtesy C. Stahr, W. L. Finlay, National Wildlife Refuge, Corvallis, Oregon

Fig. 2. Dusky Canada geese.

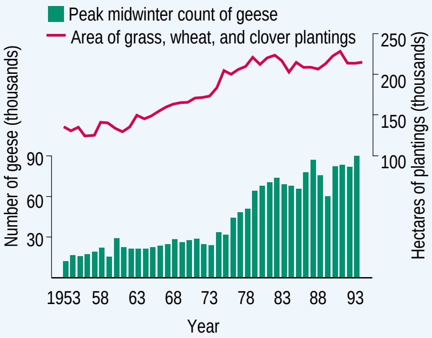

Fig. 3. Changes in the area planted for production of grass seed, wheat, and clover in the Willamette Valley, Oregon, since the 1950's (data provided by Oregon State University Extension Service, Corvallis).

geese. The cultivated grasses grow during the winter and provide fresh green vegetation, whereas most native plants are dormant in winter and do not provide forage for grazing geese.

The fact that Canada geese now winter farther north than before is not unique to the Willamette Valley; similar situations occur in northern portions of the Mississippi and Atlantic flyways. As a consequence, the Willamette Valley now supports about ten times more geese in winter than it did 40 years ago.

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See end of chapter for references

such species (Hammond's flycatcher, hermit thrush, and golden-crowned kinglet) show upward trends in the eastern Cascades region; no such species show upward trends in the Blue Mountains–Okanogan Highlands region. These trends are consistent with evidence of widespread loss and degradation of old-growth forests. The data, however, are insufficient to establish trends for most of the species that are closely associated with old-growth eastside forests. Specialized monitoring that targets specific habitats is needed for these species.

Four species that are closely associated with old-growth eastside forests have been extensively studied: pileated woodpecker (Bull 1987; Bull et al. 1992; Bull and Holthausen 1993), flammulated owl (Goggans 1985; Bull et al. 1990), great gray owl (Bryan and Forsman 1987; Bull et al. 1988; Bull and Henjum 1990; Fig. 35), and Vaux's swift (Bull 1991; Bull and Cooper 1991; Bull and Hohmann 1993). Although these studies were not designed to provide information on population trends, they showed how each species depends on habitat characteristics of old-growth forests (for example, cavities in large trees and snags for nesting and roosting). Because of such requirements, many scientists believe that losses of old-growth roost and nest trees and conversion of structurally complex old-growth pine forest to mostly homogeneous young and fir-dominated forests reduced populations of these species (Bryan and Forsman 1987; Marshall et al. 1996). Vaux's swifts show a significant downward population trend in the Okanogan Highlands–Blue Mountains and Columbia River basin–High Desert regions (Table 9), but the data are not sufficient to confirm trends for Vaux's swifts in the eastern Cascades ecoregion or for the other species in any eastside region.

Six species (house wren, mountain bluebird, tree swallow, violet-green swallow [Fig. 36], northern flicker, and western bluebird) that nest in cavities in the eastern Cascades region show long-term upward population trends. All of the secondary cavity nesters (that is, all of

Courtesy E. L. Bull, U.S. Forest Service

Fig. 35. Adult female and juvenile great gray owls in Oregon.

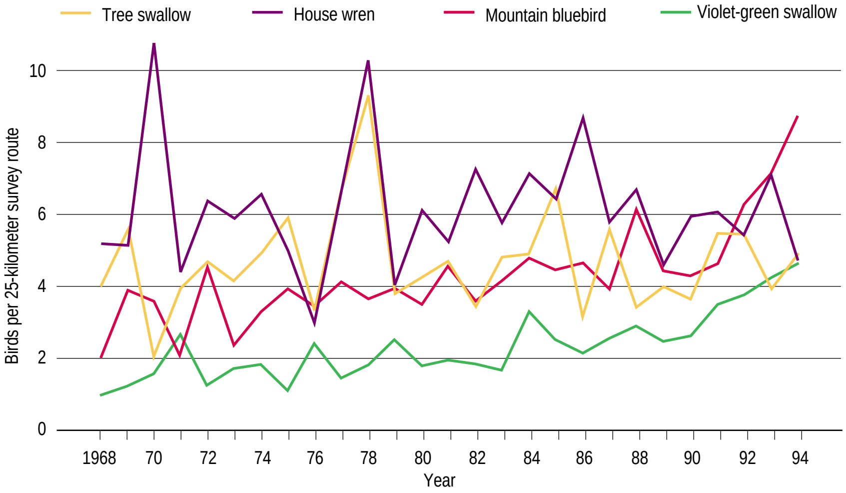

Fig. 36. Examples of upward trends in the annual abundance indexes of bird species that nest in tree cavities in the eastern Cascades (Breeding Bird Survey data for the Pitt–Klamath Plateau region, U.S. Geological Survey, Washington, D.C.).

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Table 9. Population trends (after Carter and Barker 1993) and primary habitat associations of selected land birds with significant long-term (1969–1991) or recent (1982–1991) downward abundance trends in one or more eastside regions.

Species	Trends by region[a,b]			Habitat associations[c]							
	Eastern Cascades Slopes and Foothills (long-term/recent)	Okanogan Highlands and Blue Mountains (long-term/recent)	Columbia Basin and Snake River Basin–High Desert (long-term/recent)	Old-growth forest	General forest	Early seral forest	Riparian woodland	Montane or riparian meadow	Grass or shrub–steppe	Juniper woodland	Cavity-nesting
American goldfinch	D/NS	D/D	NS/NS					X			
American kestrel	NS/D	NS/D	NS/NS				X			X	X
American robin	NS/NS	NS/D	U/U	X	X		X			X	
Bank swallow	U/NS	D/D	U/U					X			
Barn swallow	D/D	NS/D	NS/NS					X			
Brewer's blackbird	U/NS	D/D	NS/D				X	X	X	X	
Brewer's sparrow	NS/NS	D/D	D/D						X	X	
Brown creeper	D/NS	NS/NS	NS/NS	X							
Calliope hummingbird	D/NS	NS/NS	NS/NS					X			
Cassin's finch	NS/NS	NS/D	NS/NS		X					X	
Cedar waxwing	NS/NS	U/D	NS/NS				X				
Chipping sparrow	D/D	D/U	D/D	X	X	X				X	
Common nighthawk	U/U	U/U	U/D							X	
Common yellowthroat	NS/NS	D/D	NS/NS				X	X			
Dark-eyed junco	U/U	D/D	NS/NS			X		X			
Dusky flycatcher	D/NS	U/U	NS/NS				X	X			
Golden-crowned kinglet	U/NS	D/NS	NS/NS	X							
Grasshopper sparrow	NS/NS	D/D	D/D						X		
Gray catbird	NS/NS	NS/D	NS/NS				X				
Green-tailed towhee	U/D	NS/NS	NS/U						X	X	
Hammond's flycatcher	U/NS	D/D	NS/NS	X							
Hermit thrush	U/U	U/D	NS/NS	X							
Horned lark	D/NS	D/D	D/D						X		
Killdeer	D/D	D/D	D/D					X	X		
Lark sparrow	D/D	NS/NS	D/D					X	X	X	
Lewis' woodpecker	D/NS	D/NS	NS/NS	X			X				X
Loggerhead shrike	NS/NS	NS/NS	D/NS						X	X	
Long-billed curlew	NS/NS		NS/D						X		
MacGillivray's warbler	U/U	D/D	NS/NS			X	X				
Mountain bluebird	U/D	U/U	U/U				X			X	X
Mourning dove	D/NS	D/U	D/NS						X	X	
Northern flicker	U/U	D/D	U/U	X			X			X	X
Northern harrier	NS/NS	D/NS	D/NS					X	X		
Northern rough-winged swallow	D/NS	NS/U	U/U					X			
Olive-sided flycatcher	D/NS	D/D	NS/NS	X							
Pine siskin	NS/D	D/NS	NS/NS	X	X						
Prairie falcon	NS/NS	U/NS	D/NS						X	X	
Red-eyed vireo	NS/NS	D/NS					X				
Red-winged blackbird	NS/D	NS/NS	D/U					X			
Rock wren	U/NS	NS/D	D/D			X	X		X	X	
Sage sparrow	NS/NS	NS/NS	D/D						X		
Savannah sparrow	D/NS	NS/D	U/U					X			
Say's phoebe	NS/NS	U/U	NS/D				X				
Short-eared owl	NS/NS	NS/NS	D/D					X	X		
Song sparrow	U/U	D/D	U/U			X	X				
Spotted towhee	U/U	D/D	U/NS			X	X			X	
Swainson's thrush	NS/NS	NS/D	NS/NS	X			X				
Townsend's solitaire	U/D	U/D	NS/NS		X					X	
Townsend's warbler	NS/NS	NS/D		X							
Turkey vulture	NS/NS	D/D	D/D						X	X	
Vaux's swift	NS/NS	D/D	NS/D	X							X
Veery	NS/NS	D/D	NS/NS	X			X				
Violet-green swallow	U/U	U/U	D/U				X	X			X
Western kingbird	D/D	NS/NS	NS/D				X				
Western meadowlark	D/NS	NS/NS	NS/D					X	X	X	
White-crowned sparrow	NS/NS	D/NS	NS/NS					X		X	
Willow flycatcher	NS/NS	U/U	NS/D				X	X			
Wilson's warbler	U/U	NS/D	NS/NS				X	X			
Yellow-headed blackbird	NS/U	U/U	D/D					X			
Total downward	22	39	25	14	5	5	21	21	17	20	6

[a] D = downward, U = upward; NS = no significant trend.

[b] No trend given indicates species does not occur in that region or is not at sufficient level to appear in Breeding Bird Survey records.

[c] X = found in that habitat association; references: Puchy and Marshall 1993; Andelman and Stock 1994a,b; Dobkin 1994a.

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the just-listed species except northern flicker) also show upward trends in the Okanogan Highlands–Blue Mountains region. These population responses may reflect higher densities of small- and medium-sized standing dead trees that resulted from outbreaks of disease and insects.

Eleven species (American kestrel, Brewer's blackbird, cedar waxwing, common yellowthroat, gray catbird, Lewis' woodpecker, MacGillivray's warbler, red-eyed vireo, spotted towhee, song sparrow, and Wilson's warbler) that regularly nest in woody riparian habitats in the Okanogan Highlands–Blue Mountains region show long-term or recent downward population trends (Table 9). Four other species (American robin, northern flicker, Swainson's thrush, and veery) that nest in woody riparian or mature upland forests in the Okanogan Highlands–Blue Mountains region also show downward population trends. These data are generally consistent with evidence that much of the riparian woodland and old-growth habitat in the region has been lost or degraded (Dobkin 1994a).

Wilson's warblers and spotted towhees in the eastern Cascades region, all of the secondary cavity nesters mentioned previously, and 11 more species (cedar waxwing, black-headed grosbeak, dusky flycatcher, lazuli bunting, Bullock's oriole, orange-crowned warbler, warbling vireo, western wood-pewee, willow flycatcher, yellow-breasted chat, and yellow warbler) in the Okanogan Highlands–Blue Mountains region also often nest in woody riparian habitats but show long-term or recent upward population trends (Table 9). Many of these species also will nest in shrub-dominated, early-seral habitats created by clear-cutting. Other such species with increasing populations in the eastern Cascades region include dark-eyed junco, MacGillivray's warbler, Nashville warbler, and song sparrow. In addition, it is probably not simply coincidental that the brown-headed cowbird—an obligate brood parasite of many of these species but a species that avoids large expanses of forest—also shows long-term or recent upward population trends in both eastside forest regions.

Nine species in the eastern Cascades region (barn swallow, calliope hummingbird, dusky flycatcher, killdeer, lark sparrow, northern rough-winged swallow, red-winged blackbird, savannah sparrow, and western meadowlark) and 12 species in the Okanogan Highlands–Blue Mountains region (American goldfinch, bank swallow, barn swallow, belted kingfisher, Brewer's blackbird, common yellowthroat, dark-eyed junco, killdeer, northern harrier, savannah sparrow, white-crowned sparrow, and Wilson's warbler) that nest in montane or riparian meadow habitats show long-term or recent downward population trends (Table 9).

A few species that usually occur in upper-elevation juniper woodlands show long-term or recent downward population trends (Table 9). However, although the trends are not always consistent across the two regions, many more such species in the eastern Cascades (for example, Brewer's blackbird, common nighthawk, gray flycatcher, northern flicker, red-tailed hawk, rock wren, spotted towhee, solitary vireo, and vesper sparrow) and the Okanogan Highlands–Blue Mountains (for example, common nighthawk, golden eagle, mountain bluebird, prairie falcon, red-tailed hawk, ruby-crowned kinglet, solitary vireo, and Swainson's hawk) regions show long-term or recent upward population trends, with no indication of declines in the respective regions. This pattern is consistent with regional expansion of juniper woodlands.

Birds in Eastside Rangelands

As in other eastside habitats, raw Breeding Bird Survey data are not sufficient to confirm population trends for most species that occur in eastside rangelands (Columbia Basin and Snake River–High Desert). Among species for which significant population trends can be confirmed by using the modified index (Carter and Barker 1993), about equal numbers show upward and downward trends (Fig. 28).

Nearly two-thirds of the 25 species that show downward population trends in eastside rangelands are primarily or exclusively associated with grassland and shrub–steppe habitats (Fig. 37; Table 9). Two additional species that show downward population trends (rock wren and chipping sparrow) occur primarily in open

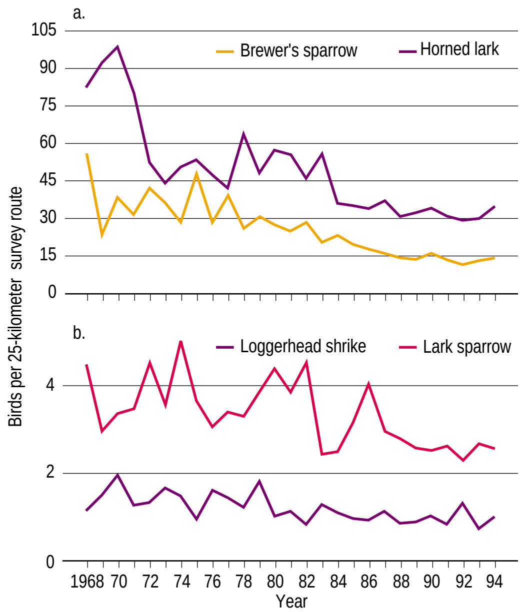

Fig. 37. Examples of downward trends in the annual abundance indexes of bird species that occur in eastside grassland and shrub–steppe habitats (Breeding Bird Survey data for the Columbia Plateau region; U.S. Geological Survey, Washington, D.C.).

juniper woodlands with a sagebrush and bunchgrass understory. Other than some birds of prey, the sage thrasher is the only grassland or shrub–steppe species for which adequate data are available that shows a significant upward population trend. The Columbian sharp-tailed grouse is also intimately tied to native grasslands but was extirpated from Oregon and California by the late 1960's and is declining throughout the remainder of its range (Puchy and Marshall 1993; Tirhi 1995). Similarly, the sage grouse is closely associated with native sagebrush habitats, but its populations have greatly declined in Oregon (see box on Sage Grouse in Oregon). Widespread population declines of grassland and shrub–steppe birds in the western United States have been attributed to conversion of habitat to agriculture and to

Sage Grouse in Oregon

Sage grouse (Fig. 1) were once common in shrub–steppe habitats in central and eastern Oregon (Gabrielson and Jewett 1940), but concern about the status of sage grouse began nearly a century ago. Between 1900 and 1940 the range of sage grouse in Oregon was reduced by approximately 50%, and since 1940 the abundance of birds within the remaining range has declined by at least 60% (Crawford and Lutz 1985; Fig. 2). A reduction in the ability of the bird to nest successfully and to recruit chicks into the fall population seems to be the cause of the decline.

© S. Carlisle, Wild Goose Photos, Kelso, Washington

Fig. 1. Male sage grouse in breeding display.

The key factor that caused the initial decline of sage grouse in Oregon was probably the conversion of sagebrush-dominated lands for agricultural purposes, pastures, or plantings of nonindigenous grasses. These changes, though, do not account for declines in the vast areas of Oregon where sagebrush is still the dominant cover type. Research during the past 10 years revealed much information about the answer to this apparent dilemma. Sagebrush is important to sage grouse; the grouse use it for food during fall and winter and for cover during most of the year (Patterson 1952). Still, other components of the sagebrush ecosystem, such as herbaceous grasses and forbs, may play the key role in determining sage grouse reproductive success (Gregg 1992).

Recent research in Oregon (Barnett 1993; Barnett and Crawford 1994) revealed that hen sage grouse readily consume herbaceous plants, such as clovers, desert parsleys, mountain-dandelions, hawksbeard, and phloxes, immediately before beginning to nest, and that the amount of these highly nutritious foods could be related to reproductive success. Hens also ate sagebrush, but the herbaceous plants contained 2–3 times more protein and much higher levels of other nutrients (Barnett and Crawford 1994).

The abundance of herbaceous plants influenced patterns of habitat use by hens with broods and by broodless hens (Gregg 1992; Gregg et al. 1993; Drut et al. 1994a; Ramsey et al. 1994). During summer, herbaceous plants are a very important source of nutrition for hens and their chicks. Without adequate amounts of certain forbs, chicks forage largely on nutrient-poor sagebrush and consequently are less likely to survive (Drut et al. 1994b). Important chick foods during the critical period of summer growth include herbaceous plants such as hawksbeard, clovers, mountain-dandelions, milkvetches, and microsteris, and insects such as ants and beetles, which are closely associated with plant stands that are rich in herbaceous plants (Drut et al. 1994b).

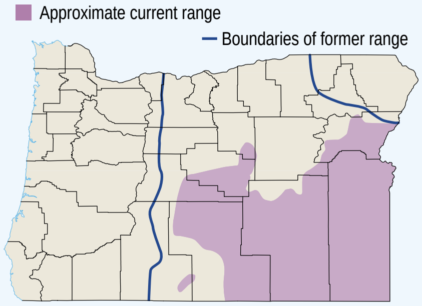

Fig. 2. Comparison of past range with the approximate present range of sage grouse in Oregon (adapted from Crawford and Lutz 1985).

Other research in Oregon revealed the importance of grass cover, in particular residual grass cover with a height of about 20 centimeters or more (Gregg 1992; DeLong 1994; Gregg et al. 1994; Ramsey et al. 1994; DeLong et al. 1995). The amount of tall residual grass cover and medium-height sagebrush were the key factors that determined whether a sage grouse nest was successful. Sagebrush provides overhead concealment from predators and protection from environmental forces, whereas residual grass cover provides ground-level concealment for the hen. Sage grouse nest early in the year (March and April) when new grasses are just beginning to grow. The birds must, therefore, rely on residual cover from the previous year's growth for the protection they need.

In combination, these factors tremendously influence the nesting success of sage grouse and, therefore, sage grouse abundance. Maintenance of diverse herbaceous communities in existing sagebrush habitats and restoration of former sage grouse habitat will be keys to ensuring the continued existence of sage grouse in Oregon and elsewhere. Priorities for sage grouse research, management, and monitoring are outlined in a report derived from a recent conference on comprehensive approaches to sage grouse management and conservation (Dobkin 1995).

See end of chapter for references

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overgrazing by livestock (DeSante and George 1994; Fleischner 1994; Dobkin 1995; Tirhi 1995). Grazing affects fire patterns and aids in invasions of nonindigenous plant species, which in turn alter the structural characteristics of the landscape and reduces the diversity and abundance of native plants to the detriment of these bird species.

As in eastside forest regions, several species that often occur in juniper woodlands show upward population trends in eastside rangelands (American robin, gray flycatcher, green-tailed towhee, house wren, mountain bluebird, northern flicker, and red-tailed hawk). Again, this is consistent with regional expansion of juniper woodlands. The common nighthawk also occurs in juniper woodlands and shows a long-term upward population trend, but the trend seems to have recently reversed (Table 9).

Across the arid lands of western North America, many species of birds occur in riparian habitats (Knopf et al. 1988; Dobkin 1994a). Many bird biologists believe that degradation and elimination of riparian habitats are the most important causes of declining landbird populations in the region (DeSante and George 1994; Ohmart 1994). However, only two exclusively riparian species (willow flycatcher and yellow-headed blackbird) show long-term and recent downward population trends in eastside rangelands. Two other riparian species (violet-green swallow and red-winged blackbird) have long-term downward population trends, but these trends recently reversed. Fourteen riparian species show consistent upward population trends in eastside rangelands (bank swallow, belted kingfisher, black-headed grosbeak, Bullock's oriole, cliff swallow, lazuli bunting, northern rough-winged swallow, savannah sparrow, song sparrow, tree swallow, warbling vireo, western wood-pewee, yellow-breasted chat, and yellow warbler). Several of the species associated with juniper woodlands that show upward population trends also often nest in woody riparian habitats (American robin, house wren, mountain bluebird, northern flicker, and red-tailed hawk). In addition, the abundance of brown-headed cowbirds increased in eastside rangelands as the population sizes of potential host species grew. These upward trends may signal the beginning of riparian habitat recovery in some parts of the region; however, the magnitude of the increases was very small for nearly all of these species.

An ongoing study at Hart Mountain National Wildlife Refuge in southeastern Oregon is assessing the recovery rates of riparian vegetation and bird communities after removal of livestock (Dobkin 1994b; Dobkin et al. 1995a). The riparian avifauna is now characterized by a low number of species and a disproportionate representation of a few abundant and widespread species (principally house wren, American robin, and red-winged blackbird). It is encouraging, though, that two species which usually indicate mature riparian habitat, MacGillivray's warbler and lazuli bunting, began nesting during the third year of recovery.

Eastside rangelands harbor many birds of prey that are often closely associated with riparian habitats in the region (Knight 1988). Several species that occur throughout the arid rangelands of the Pacific Northwest (burrowing owl, red-tailed hawk, Swainson's hawk [Fig. 38], ferruginous hawk, and golden eagle) show long-term or recent upward population trends. This is a particularly positive sign for burrowing owls because their populations are declining throughout much of their western range (DeSante and George 1994).

The Snake River Birds of Prey National Conservation Area in southwestern Idaho and neighboring river canyons support one of the highest nesting densities of noncolonial birds of prey anywhere in the world (Knight 1988; Lehman et al. 1994). Prairie falcons and golden eagles (Fig. 39) have been closely monitored since the 1970's at the Snake River site. The number of nesting territories occupied by prairie falcons has fluctuated around a consistent mean since 1976, whereas the number of nests occupied by golden eagles has declined slightly since 1971; the productivity of both species has been variable (Fig. 40;

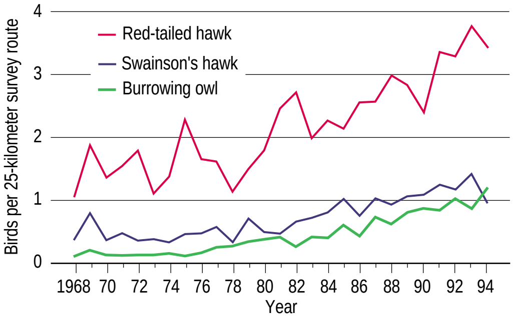

Fig. 38. Examples of upward trends in the annual abundance indexes of birds of prey in eastside lowlands (Breeding Bird Survey data for the Columbia Plateau region, U.S. Geological Survey, Washington, D.C.).


Courtesy M.W. Collopy, USGS

Fig. 39. Golden eagle with nestling in Idaho.

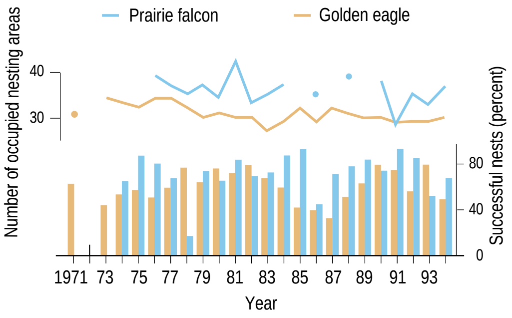

Fig. 40. Trends in the nesting populations and nesting success of prairie falcons (population trends in three regularly monitored 10-kilometer survey units) and golden eagles in the Snake River Birds of Prey National Conservation Area, Idaho (adapted from Lehman et al. 1994).

Lehman et al. 1994). Golden eagles vacated nesting territories in areas that were converted to agriculture or that were taken over by nonindigenous grasses.

Mammals

Carnivores

Several medium to large carnivores are on state lists of sensitive species and have regional populations that are either precariously small and probably nonviable or declining (Table 10). All except the kit fox are primarily forest species, and all have suffered from habitat loss and degradation, excessive hunting, or persecution. Martens (Fig. 41) and fishers are of particular interest because they are two of the most threatened terrestrial mammals closely associated with old-growth forests in the Pacific Northwest (Forest Ecosystem Management Assessment Team 1993; Thomas et al. 1993).

Courtesy J. Hoylan, U.S. Forest Service

Fig. 41. The marten is one of the most threatened species closely associated with undisturbed old-growth forests in the western Pacific Northwest.

The geographic distribution of martens in the three Pacific Coast states markedly decreased during this century primarily because of habitat loss from logging of mature forests (Maser et al. 1981; Buskirk and Ruggiero 1994;

Table 10. Status of terrestrial, carnivorous mammals in the Pacific Northwest that are on federal or state lists of sensitive species.

Species	Federal or state status[a]					Population trend	References
	Federal	California	Oregon	Washington	Idaho		
Fisher	*	*	S-c	C	SC–a	Downward	Maser et al. 1981; Rodrick and Milner 1991; Aubry and Houston 1992; Marshall et al. 1996; Thomas et al. 1993; Powell and Zielinski 1994
Gray wolf	E	ext	E	E	E	Upward? in Washington, unknown otherwise	Laufer and Jenkins 1989; Washington Department of Wildlife 1991; U.S. Fish and Wildlife Service 1992
Grizzly bear	E	ext	ext	E	T	Stable or downward	Almack et al. 1993
Kit fox	*	—	T	—	SC–b	Downward	Keister and Immell 1994
Marten	*	*	S-c	C	*	Downward	Maser et al. 1981; Rodrick and Milner 1991; Marshall et al. 1996; Thomas et al. 1993; Buskirk and Ruggiero 1994; Oregon Department of Fish and Wildlife trapping records
North American lynx	*	—	*	T	SC–b	Downward	Washington Department of Wildlife 1993d; Koehler and Aubry 1994
Wolverine	*	T	T	M	SC–a	Upward? in Idaho, unknown otherwise	Groves 1987; California Department of Fish and Game 1992; Banci 1994

[a] — = does not occur in state, * = no special status, E = endangered, T = threatened, ext = extirpated; Oregon—S–c = sensitive species with critical status; Washington—C = candidate for sensitive species status, M = monitor species; Idaho—SC–a,b = species of special concern category a (priority) or b (peripheral). References: Oregon Natural Heritage Program 1993; California Department of Fish and Game 1994, 1995b; Conservation Data Center 1994; Washington Department of Wildlife 1994; U.S. Fish and Wildlife Service 1995.

Marshall et al. 1996). Accurate, quantitative population data are difficult to obtain, but the number of martens trapped in western Oregon steadily declined during the past 50 years (Fig. 42). The range of fishers in Washington remained constant during the past 40 years, but a scarcity of recent sighting records and incidental trappings suggests that the density of fishers is precariously low in Washington (Aubry and Houston 1992; Powell and Zielinski 1994). Fisher populations are probably also depleted in Oregon, but accurate assessments are unavailable (Maser et al. 1981; Powell and Zielinski 1994; Marshall et al. 1996). Fishers are sensitive to forest fragmentation in northern California (Rosenberg and Raphael 1986), and it is widely believed that martens are also sensitive to alteration of the mature forest environment they prefer (Buskirk and Ruggiero 1994). Current assessments suggest that both species will remain at risk.

In contrast, coyotes, red foxes, and black bears are widespread, and their populations are stable or increasing (Maser et al. 1981; Aubry 1984; MacCracken and Hansen 1987; Vaughan and Pelton 1995). These species easily adapt to the presence of humans and have prospered despite widespread persecution and trapping in many regions because they are highly fecund and readily exploit many habitats and food sources.

The status of large predators is relatively well known because they have concerned ranchers and trappers for decades and will probably always remain concerns of outdoor enthusiasts and inhabitants of rural communities (Laufer and Jenkins 1989; Almack et al. 1993; Washington Department of Wildlife 1993d). However, efforts to forecast population trends and manage even these species suffer from a lack of reliable data on past abundances and population demographics (Washington Department of Wildlife 1993d; North Cascades Grizzly Bear Steering Committee 1994).

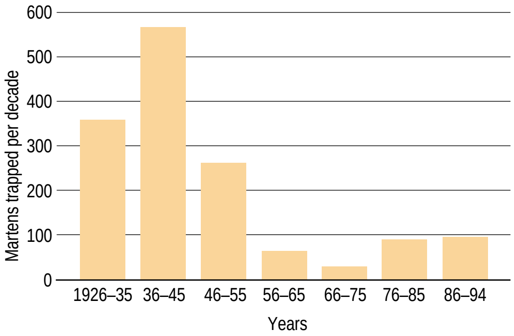

Fig. 42. Average number of martens trapped per decade in western Oregon (based on Oregon Department of Fish and Wildlife fur-trapper records).

Small Mammals in Westside Forests

Accurate population information about rodents, squirrels, and other small mammals is scarce. Eleven species of small mammals are endemic to conifer forests of the Pacific Northwest and northern California, but the status of most is unknown (Table 11).

The endemic red tree vole (Fig. 43) is another threatened species that is closely associated with old-growth forests in the western Pacific Northwest (Forest Ecosystem Management

Table 11. Status, habitat associations, and distributions of small mammals that are endemic to Douglas-fir forests of the Pacific Northwest (based on Ingles 1965; Brown 1985; Puchy and Marshall 1993; Thomas et al. 1993).

Species	State status[a]			Distribution	Habitat association	Population trend
	California	Oregon	Washington			
Baird's shrew	*	*	*	Willamette Valley, Klamath Mountains, Coast Range/ Cascades—Oregon	Generalist	Unknown
Fog shrew	*	*	*	Klamath Mountains, Willamette Valley, Coast Range/Eastern Cascades Slopes and Foothills—Oregon	Generalist	Unknown
Mountain beaver	*	*	*	All westside, Eastern Cascades Slopes and Foothills	Early seral	Upward
Creeping vole	*	*	*	All westside, Eastern Cascades Slopes and Foothills—Washington, Okanogan Highlands	Early seral	Upward
Pacific shrew	*	*	*	Klamath Mountains, Coast Range—Oregon	Riparian	Unknown
Pacific marsh shrew	*	*	M	All westside, Eastern Cascades Slopes and Foothills	Riparian	Unknown
Red tree vole	SC	*	*	Klamath Mountains, Coast Range/Cascades—Oregon	Old-growth	Decreasing?
Shrew–mole	*	*	*	All westside, Eastern Cascades Slopes and Foothills	Riparian	Unknown
Southern red-backed vole	*	*	*	Blue Mountains, Cascades/North Cascades/Eastern Cascades Slopes and Foothills—Washington, Okanogan Highlands	Late seral	Unknown
Western red-backed vole	*	*	*	Klamath Mountains, Coast Range, Cascades, Eastern Cascades Slopes and Foothills	Late seral	Unknown
White-footed vole	SC	S–u	*	Klamath Mountains, Coast Range/Cascades—Oregon	Riparian	Unknown

[a] Status codes: SC = California state species of special concern; S–u = Oregon state sensitive species with unknown status; M = Washington state monitor species. References: Oregon Natural Heritage Program 1993; Washington Department of Wildlife 1994; California Department of Fish and Game 1994; * = no special status.

Translocated Sea Otter Populations off the Oregon and Washington Coasts

The historical distribution of sea otters extended from the northern islands of Japan north and east across the Aleutian chain to the mainland of North America then south along the west coast to central Baja California, Mexico (Riedman and Estes 1990). By the beginning of the twentieth century, after 150 years of being intensively hunted for their valuable fur, sea otters had been extirpated from most of their range (Kenyon 1969). In 1911 sea otters were protected by the passage of the International Fur Seal Treaty. Unfortunately, only 13 remnant populations survived the fur-hunting period, and two of those, British Columbia and Mexico, would also ultimately disappear, leaving only a small group of sea otters south of Alaska, along the rugged Big Sur coast of California (Kenyon 1969).

The earliest attempts to reestablish sea otters to unoccupied habitat were begun in the early 1950's by R. D. (Sea Otter) Jones, then manager of the Aleutian National Wildlife Refuge (Kenyon 1969). These early efforts were experimental, and all failed to establish populations. However, the knowledge gained from Jones's efforts and the seminal work of Kenyon (1969) and others during the 1950's and early 1960's ultimately led to the successful efforts to come.

During the mid-1960's the Alaska Department of Fish and Game began translocating sea otters to sites where the species had occurred before the fur-trade period. The first translocations were restricted to Alaska, but beginning in 1969 and continuing through 1972, the effort expanded beyond Alaska. During this period, 241 sea otters were translocated to sites in British Columbia, Washington, and Oregon (Jameson et al. 1982). The work was done cooperatively between state and provincial conservation agencies, with much of the financial support for the Oregon and Washington efforts coming from the Atomic Energy Commission (now ERDA). Follow-up studies of the Oregon population began in 1971 and continued through 1975. After 1975, surveys in Oregon occurred infrequently. In Washington no follow-up surveys were conducted until 1977, although the population has been monitored closely since then (Jameson et al. 1982, 1986; Jeffries and Jameson 1995).

Oregon

Sea otters were extirpated by fur-trade hunters in Oregon by the early twentieth century. Most of Oregon's sea otter habitat occurs in the southern half of the state, where the only extensive nearshore rocky reef systems are found. Ninety-three translocated sea otters were liberated here: 29 near Port Orford in 1970 and 24 near Port Orford and 40 near Cape Arago in 1971. Counts never reached anywhere near the number of otters released, but from 1972 to 1974 they ranged from 20 to 23 otters. In 1975, however, the population began to decline, and in 1981 only one sea otter could be found (Jameson et al. 1982). By then the population was clearly no longer viable, and no subsequent sightings were made until the summer of 1992, when a single sea otter was observed at Cape Arago. No sea otters have been seen since then. Sea otters are once again extirpated in Oregon, and the translocation should be classed as a failure.

Washington

As in Oregon, the Washington sea otter population had also been extirpated by fur-trade hunting by the early twentieth century. Fifty-nine sea otters were released off the west coast of the Olympic Peninsula of Washington during the summers of 1969 and 1970 (Jameson et al. 1982); all had been translocated from Amchitka Island, Alaska. In 1969, 29 sea otters were released directly to the open ocean near Point Grenville (Fig. 1), with no time to acclimate or to recondition their fur. Sixteen of those 29 translocated sea otters were found dead on beaches near the release site within 2 weeks after translocation. No doubt some carcasses went undiscovered.

In 1970, release procedures and the release site were changed. The release location was changed to La Push (Fig. 1), located within the boundaries of Olympic National Park and near the middle of the best sea otter habitat in Washington. In midsummer, 30 sea otters were flown to La Push and released into holding pens anchored in a protected cove just beyond the La Push harbor entrance. The 30 otters were fed and allowed to acclimate for several days in the pens before release. All were liberated in excellent condition, and known mortality after release was low. Thus, the initial nuclear population in Washington could never have been larger than 43 otters and may have dropped to fewer than 10 individuals by the early 1970's (Jameson et al. 1982). No follow-up surveys of the Washington population were done until 1977 (Jameson et al. 1982, 1986; Table).

All sites within the survey area are located off the west coast of Washington's Olympic Peninsula between Destruction Island and Neah Bay (Fig. 2). From 1977 to 1984, surveys were conducted by U.S. Fish and Wildlife Service biologists (Table). Since 1985 surveys have been conducted cooperatively by the U.S. Fish and Wildlife Service's research division (now the Biological Resources Division of the USGS) and the Washington Department of Fish and Wildlife biologists (Table).

Population Growth

Growth of the population has continued at a finite rate of about 12% per year since 1989, when the current survey method began. From 1977 to 1988 the rate was higher, at 21% per year (R. Jameson, U.S. Geological Survey, Corvallis, Oregon, unpublished data; Fig. 3). Whether the difference between the rates indicates a slowdown of population growth or simply a difference in survey techniques (the method was modified in 1989) is still open to question. Pups were only noted separately from independent otters at ground count locations; thus the number of pups noted in the Table is probably low. However, pup counts at ground stations from 1993 to 1995 averaged 24 pups for every 100 independent otters, which suggests pup production has remained good.

The majority of sea otters in Washington occur between Makah Bay and Destruction Island (Fig. 2). Several significant changes in distribution have occurred recently, however. At the southern end of their range, sea otters now regularly occur inshore from Perkins Reef. As many as 20 sea otters have been counted in this area recently, although no more than one had been seen there before. At the northern end of the range, scattered individuals were regularly seen near Cape Flattery and between there and Neah Bay. In 1995, however, more than 100 otters moved into this area. This appears to be a seasonal phenomenon, occurring during the late winter and early spring. In late 1995, a small group of females rounded Cape Flattery and took up residence near Slant Rock. This area was previously inhabited almost entirely by male sea otters.

In 1988 and again in 1991, the outer coast of the Olympic Peninsula was hit by spills of bunker fuel oil, both from shipping accidents. The 1988 spill occurred in December, the 1991 spill in late July. In both cases about 230,000 gallons were spilled.

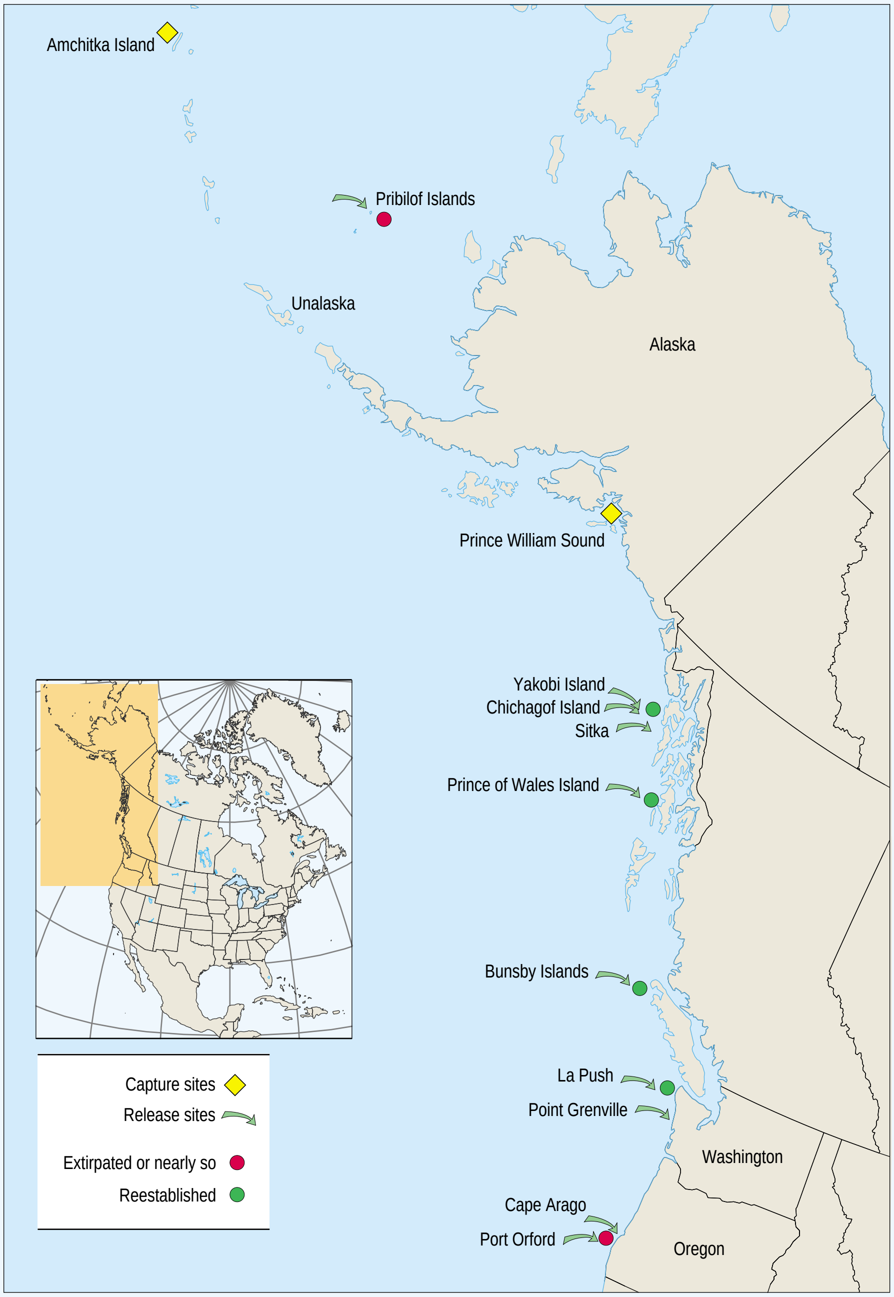

Fig. 1. General locations of capture and release sites and the status of translocated sea otter populations in Oregon and Washington (modified from Jameson et al. 1982).

Table. Results of surveys of the sea otter population in Washington, 1977–1995.

Year	Number of independents (adults and subadults)	Pups	Total
1977	15	4	19
1978[a]	12	0	12
1979	No survey		
1980	No survey		
1981	35	1	36
1982	No survey		
1983	48	4	52
1984	No survey		
1985	60	5	65
1986	No survey		
1987	89	5	94
1988	No survey		
1989	198	10	208
1990	197	15	212
1991 (July)	259	17	276
1991 (October)	242	20	262
1992	283	30	313
1993	283	24	307
1994	325	35	360
1995	341	54	395

[a] The 1978 results are probably not indicative of the actual number of sea otters in the population because inclement weather conditions precluded a thorough survey of the southern portion of the range.

The sea otter population was relatively unaffected by both spills, although thousands of seabirds died in each. No oiled sea otters were found in 1988, and only one was found in 1991. This animal did, however, die of complications caused by oiling (N. J. Thomas, National Wildlife Health Research Center, Madison, Wisconsin, necropsy report).

When we began our surveys in 1977 (Jameson et al. 1982), the sea otter population was distributed between Destruction Island and Cape Alava, a distance of about 60 kilometers. In 1992 the population was distributed between Destruction Island and Makah Bay, a distance of about 80 kilometers. By 1996 the range had increased to more than 110 kilometers, Destruction Island to Neah Bay (Fig. 2). Before 1991 the distribution had changed little from what it was in 1977. Until then all the population growth had taken place within the 1977 boundaries. In 1991 a large group broke away from the main population and established itself in Makah Bay about 15 kilometers north of where they were the previous

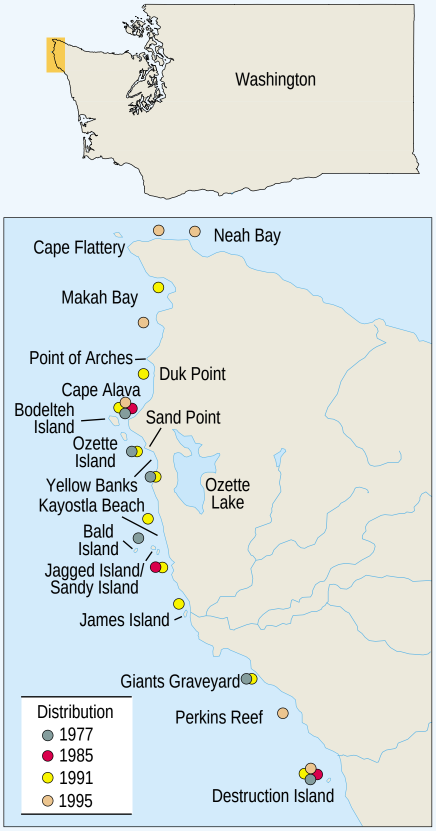

Fig. 2. Distribution of sea otters on the Olympic Peninsula coast, 1977–1995 (area blown up for detail indicated above).

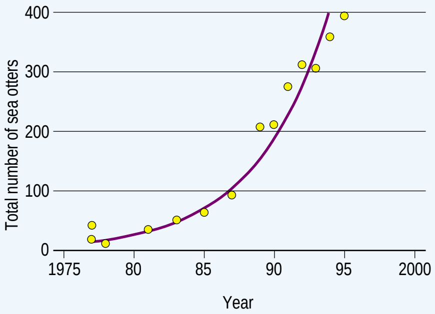

Fig. 3. Growth of the Washington translocated sea otter population, 1977–1995. Circles represent actual survey counts.

year. The distribution in 1992 was similar to 1991. Females with pups now occur from near Cape Flattery to Destruction Island.

Important Surveys

The Washington sea otter population is important because it is the only translocated population having the dual distinction of becoming successfully established and of being intensively monitored. Other translocations have been successful, but few data are available on their patterns of growth. Others that have been intensively monitored, in Oregon (Fig. 1) and San Nicolas Island, California, have failed, or appear to be heading toward failure (Jameson et al. 1982; Rathbun et al. 1990). The Washington sea otter population will continue to be monitored, and in 1994 a project was initiated to collect data on female reproductive rates, pup survival rates, foraging behavior, and activity and time budgets. This information, coupled with the population growth data, will provide a basis for comparison among populations that are either stable, growing at expected rates, or growing at rates below what is expected for populations reoccupying historical habitat.

The southern sea otter (Wilson et al. 1991) population in California, listed as threatened under the Endangered Species Act in 1977, is such a population. Since 1982 this population has grown at about 5% per year (Riedman and Estes 1990), considerably more slowly than the Washington population and slower than most growing sea otter populations (Estes 1990). Contrasting the reproductive and pup survival rates of the Washington and California populations will hopefully provide insight into why the growth rates are so different. Once that point is reached, researchers can attempt to uncover the cause or causes of the differences. Recent information from California and Kodiak Island, Alaska, suggests that preweaning survival of pups may be a quite significant factor in determining rates of sea otter population growth (Riedman et al. 1994; Monson and DeGange 1995).

See end of chapter for references

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Fig. 43. The red tree vole is a mammal closely associated with old-growth forests in the Pacific Northwest.

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Assessment Team 1993; Thomas et al. 1993). The number of species of small mammals may not differ between old-growth and young, managed forests in Oregon and Washington, but old-growth stands with diverse understory vegetation and abundant snags and coarse woody debris typically support 1.5 times more biomass and individuals than do young forests (Carey 1995; Carey and Johnson 1995). Thus, the abundances of these and other sensitive species (for example, Douglas's squirrel, shrew-mole, northern flying squirrel, and western red-backed vole) probably declined in proportion to the loss of old-growth forests during the past 50 years (Thomas et al. 1993). In contrast, mountain beavers and creeping voles are two species endemic to westside forests that are increasing in abundance and seem to thrive in the early-seral habitats that result from logging (Black 1992).

Ungulates

Deer and elk are ecologically and economically important. Elk thrive in undisturbed old-growth forest in Olympic National Park and significantly influence the structure of forest vegetation (see box on Roosevelt Elk and Forest Structure in Olympic National Park). Other long-term ecological studies of elk are ongoing at the Starkey Experimental Forest near LaGrande, Oregon (Skovlin 1991), and on the Arid Land Ecology Reserve administered by the U.S. Department of Energy in south-central Washington (McCorquodale et al. 1988).

The endangered Columbian white-tailed deer has suffered from habitat loss and degradation. These deer were once widespread but now occur only in a small area of island and flood-plain habitat near the mouth of the Columbia River and in the upper Umpqua Valley of Oregon (U.S. Fish and Wildlife Service 1983; Rodrick and Milner 1991). Their preferred habitat is a mosaic of woodlands that provide cover and small- to moderate-sized patches (less than 500 meters wide) of brushland or open pasture that provide food (Suring 1975). The causes of decline are urban and agricultural development, competition with Columbian black-tailed deer (stable populations in western Oregon during the past 20 years; Fig. 44) in remaining habitat, and avoidance of pastures occupied by cattle (Rodrick and Milner 1991). However, habitat enhancement and protection allowed populations to rebound from 300 to 400 individuals in 1976 to 6,000–7,000 individuals in 1992. The U.S. Fish and Wildlife Service (1992) is considering a reclassification from endangered to threatened, and the Oregon Department of Fish and Wildlife recently removed the species from the state's list of endangered species because of these successes.

Small Mammals in Eastside Rangelands

Small mammals can be very abundant in eastside shrub–steppe and grassland ecosystems; total biomass ranges from 650 grams per hectare in bunchgrass stands of south-central Washington (French et al. 1976) to as high as 5,000 grams per hectare in southeastern Idaho

Roosevelt Elk and Forest Structure in Olympic National Park

Roosevelt elk occur along the Pacific Coast of North America from Vancouver Island to northern California. Large populations occupy Washington's Olympic Peninsula (1.38 million hectares); the 5,000 or so elk in Olympic National Park (370,000 hectares) represent the last large population in mostly undisturbed natural habitat, which includes old-growth forests (Houston et al. 1990; Fig. 1).

The elk of Olympic National Park include year-round residents and populations that migrate to high elevations during summer. From 3,000 to 4,000 elk reside entirely in the park along drainages on the north and west sides, including the Elwha, Hoh, Queets, and Quinault rivers. Winter densities are around 6–7 elk per square kilometer. Censuses revealed that subpopulations on the west side of the park remained stable during the 1980's (Houston et al. 1990). Old-growth forests of massive western hemlock, Sitka spruce, western red-cedar, and Douglas-fir provide much of the habitat used by these subpopulations.

Scientists study elk–vegetation relations in the park, primarily in forests on the west side, to increase understanding of the long-term effects of native ungulates in forest communities. Elk consume ferns, shrub foilage, and coniferous foilage during fall and winter, and grasses and herbaceous plants during spring and summer. Seasonally important dietary items include western hemlock, sword fern, red alder, and oxalis. Digestible energy in these foods is usually low, indicating that elk densities may be limited by the quality and quantity of winter forage (Leslie et al. 1984).

Twenty-five ungulate exclosures were established in Olympic National Park (23) and the surrounding Olympic National Forest (2) in the 1930's and 1950's. Woodward et al. (1994) recently (1987–1990) resampled vegetation inside and adjacent to the original exclosures. When past vegetation was compared with present vegetation on either side of the exclosures, scientists learned that ungulates, mainly elk, are a powerful force shaping plant communities (Fig. 2). Ungulate


Courtesy National Park Service, Olympic National Park

Fig. 1. A bull Roosevelt elk in characteristic old-growth habitat in Olympic National Park, Washington.


Courtesy National Park Service, Olympic National Park

Fig. 2. Comparison of vegetation inside an ungulate exclosure (background) with vegetation outside (foreground) the exclosure near old-growth forest in Olympic National Park.

herbivory influenced the species composition, morphology, and standing crop of forest vegetation at all structural layers (herbaceous understory, shrubs, lower tree canopy, and overstory canopy). In communities on valley floors initially dominated by grasses, exclusion of ungulates resulted in decreased cover of grasses and usually forbs, decreased species richness of forbs, and sometimes increased height and abundance of ferns. Shrub size and density also increased in the absence of herbivory, and ungulates influenced the recruitment and morphology of vine maple in the lower forest canopy. Ungulates had variable effects on the establishment of overstory species; browsing seemed to affect recruitment of Pacific silver fir and western redcedar on Olympic National Forest after clear-cut logging, but effects on other tree species outside and inside the park were unclear.

The intensity of ungulate herbivory varies in time and space, and the effects on vegetation are complex. As in other recent studies, the Olympic National Park studies show that mammalian herbivores strongly interact with vegetation and are not just passive components of the ecosystems they occupy.

See end of chapter for references

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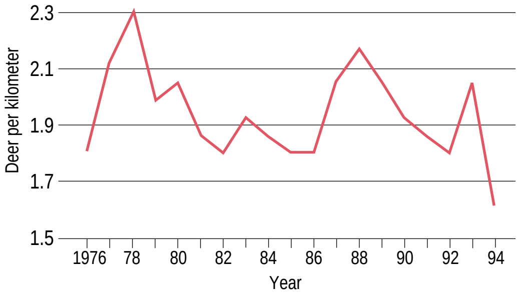

Fig. 44. Average number of Columbian black-tailed deer spotlighted per kilometer of road in western Oregon from 1976 to 1994 (data provided by the Oregon Department of Fish and Wildlife, Corvallis).

(Groves and Keller 1983). Livestock grazing and widespread seeding of ranges with nonindigenous crested wheatgrass have drastically altered small mammal habitats throughout the region, however (Boula and Sharp 1985). Livestock grazing may reduce the number of species but increase the total biomass of small mammals in rangeland habitats (Medin and Clary 1990). In contrast, small mammal biomass typically decreases after replacement of native shrubs with crested wheatgrass (Boula and Sharp 1985; Koehler and Anderson 1991). Small mammals also may be adversely affected by changes in fire frequency and intensity that drastically alter habitats (Groves and Steenhof 1988).

As elsewhere, the regional population status of most eastside small mammals is unknown. Still, Bureau of Land Management and U.S. Geological Survey biologists have been studying populations of Townsend's ground squirrels (Fig. 45) in the Snake River Birds of Prey National Conservation Area in Idaho for more than a decade as part of a landscape-scale study of golden eagles and other birds of prey (Smith and Johnson 1985; Yensen et al. 1992). The abundance and size of squirrels are generally greater on sites with native shrubs than on recently burned or grassy sites, and squirrels on undisturbed shrubby sites are more likely to survive drought (Groves and Steenhof 1988; Yensen et al. 1992; Van Horne et al. 1993a). Burned sites, however, may provide a rich supply of succulent forage during wet years (Van Horne et al. 1993a,b), and the open habitat may aid in the ability of small mammals to be vigilant against birds of prey (Sharpe et al. 1994). Obtaining accurate population estimates has been problematic because of seasonal and annual variation in the squirrels' use of complex burrow networks that lead to various habitats (Knick 1993). Unraveling these complexities requires long-term data sets and careful, comprehensive analyses. The same applies to other mammals, including black-tailed jack rabbits, whose population sizes dramatically fluctuate on cycles of 10–12 years (Fig. 46).

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Fig. 45. Townsend's ground squirrels have been a focus of long-term studies in the Snake River Birds of Prey National Conservation Area in Idaho.

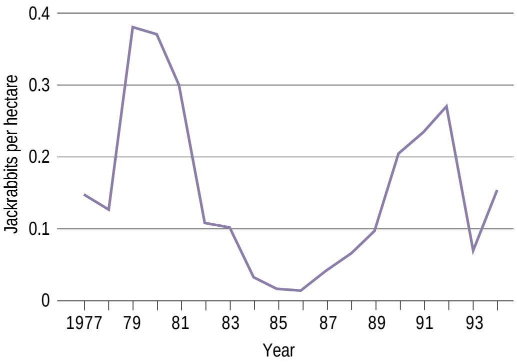

Fig. 46. Estimated density of black-tailed jack rabbits during spring in the Snake River Birds of Prey National Conservation Area, Idaho (adapted from Watts and Knick 1994).

Townsend's ground squirrels and black-tailed jack rabbits are common and thriving, but Washington ground squirrels, Idaho ground squirrels, and pygmy rabbits are not faring as well. The distribution of the Washington ground squirrel, once a widespread inhabitant of native grasslands in the Columbia River basin, is now greatly reduced (Betts 1990). Incompatible farming practices, livestock grazing, and limited distribution are factors responsible for its decline (Marshall et al. 1996) and those of the Idaho ground squirrel, which inhabits sagebrush–steppe along the middle portion of the Snake River. Because of similar factors, the pygmy rabbit has been eliminated from most of its former range in Washington (Washington Department of Wildlife 1993e); the decline of this species is coincident with estimates of a 60% reduction in shrub–steppe habitat (Dobler 1992).

Bats

Bats make up a unique group of small mammals because of their ability to fly, their nocturnal habits, and their insectivorous diet. Bats naturally contribute to regulation of insect populations and may contribute to nutrient cycling, especially in riparian–upland ecotones (Cross 1988; Christy and West 1993). Twelve species of bats occur in Douglas-fir forests (Christy and West 1993), and the diversity of bats is even higher in some eastside regions. Life-history details and the status of most species are poorly known, however.

Assessment of bat population trends is difficult because of variation in life-history strategies and a consequent lack of standardized monitoring. One large, summer-resident colony of Brazilian free-tailed bats (200,000 or more, the largest known congregation of bats on the Pacific Coast) at the Lava Beds National Monument in northern California has been monitored since 1988 (Cross 1991; B. Stoffel, Lava Beds National Monument, Tule Lake, California, personal communication), and populations of several species have been monitored at the Oregon Caves National Monument in the Klamath Mountains ecoregion since the mid-1970's (Cross 1977; Cross and Schoen 1989). Populations at both sites have remained stable during the periods of record.

In contrast, the abundance of Townsend's big-eared bats has declined by 58% west of the Cascades and 16% east of the Cascades since 1975–1985 because of habitat alteration and human disturbance (Perkins 1990). Populations of other species associated with forests also seem to be declining.

Nine forest-dwelling bats, including Townsend's big-eared bat, are assigned some level of special status in states where they occur (Table 12). Most of these species also were targeted for special consideration in the Northwest Forest Plan. Most common bat species in the Washington Cascades and Oregon Coast Range are more abundant (2.5–9.8 times) in old-growth forests than in younger forests (Thomas and West 1991). Several species are closely associated with old-growth forests because they roost in large trees and snags with deeply furrowed bark and cavities (Perkins and Cross 1988; Thomas 1988; Thomas and West 1991; Cross 1993; Cross and Waldien 1994, 1995; Perkins 1994). Definitive studies are scarce, but timber harvest substantially reduces activity levels of the little brown bat (Lunde and Harestad 1986) and probably those of other forest species of bats (Thomas and West 1991).

In eastside rangelands, bats typically roost in rock crevices or caves and therefore are not limited by the availability of trees and snags. Most of the remaining 3,000 or so Townsend's big-eared bats roost in lava tubes in central and southeastern Oregon (Perkins and Levesque 1987; Dobkin et al. 1995b). Restricted water availability may be as important a limiting

Table 12. Status and habitat associations of bats in the Pacific Northwest that are on state sensitive species lists.

Species	State status[a]				Habitat associations[b]	Population trend[c]
	California	Oregon	Washington	Idaho		
Fringed myotis	*	S–v	M	SC–c	Forest, clearings	Downward? in Oregon
Keen's myotis	—	—	M	—	Forest	Unknown
Long-eared myotis	*	S–u	M	*	Forest, clearings, steppe	Unknown
Long-legged myotis	*	S–u	M	*	Forest, clearings, meadows, steppe	Unknown
Pallid bat	SC	S–v	M	*	Forest, steppe	Downward? in Oregon
Red bat	*	*	M	—	Forest	Unknown
Silver-haired bat	*	S–u	*	*	Forest	Unknown
Spotted bat	SC	*	—	SC–c	Steppe	Unknown
Townsend's big-eared bat	SC	S–c	C	SC–c	Forest, steppe	Downward
Western pipistrelle	*	*	M	SC–c	Steppe	Unknown
Western small-footed myotis	*	S–u	M	*	Steppe	Unknown
Yuma myotis	*	S–u	*	*	Forest, steppe	Unknown

[a] — = does not occur in state, * = no special status; California—SC = species of special concern; Oregon—S–c,u,v = sensitive species with critical, vulnerable or unknown status; Washington—C = candidate for sensitive species status, M = monitor species; Idaho—SC–c = species of special concern category c (undetermined status). References: Oregon Natural Heritage Program 1993; California Department of Fish and Game 1994; Conservation Data Center 1994; Washington Department of Wildlife 1994, Marshall et al. 1996.

[b] References: Brown 1985; Christy and West 1993; Puchy and Marshall 1993; Thomas et al. 1993.

[c] References: Perkins and Levesque 1987; Rodrick and Milner 1991; Marshall et al. 1996; U.S. Fish and Wildlife Service 1994.

factor as roost availability in this region. Maintenance of healthy open-water habitats is important because all Pacific Northwest bats need water for drinking, and many species concentrate their feeding in such areas because insects are plentiful there (Whitaker et al. 1977; Christy and West 1993).

Knowledge Gaps, Current Efforts, and Prospects for the Future

Westside Forests

One of the most highly coordinated wildlife research and monitoring efforts in the country exists in the western Pacific Northwest. The Northwest Forest Plan and the Old-Growth Forest Wildlife Habitat Research and Development Program (Ruggiero et al. 1991b) are virtually unprecedented. In addition, long-term research on the northern spotted owl, although highly controversial, has enhanced the understanding of forest structure and stimulated interest in species that otherwise would have been largely ignored (for example, fungi and small mammals).

Forest management to aid in the creation of old-growth characteristics requires an understanding of functional processes in existing old-growth forests (Forest Ecosystem Management Assessment Team 1993). Managers, therefore, require information on a diverse array of species and functional relations rather than on only a few endangered species, which have been the focus in the past. The Survey and Manage category of species listed in the Northwest Forest Plan is a response to this gap in knowledge. Most of these species are fungi, lichens, bryophytes, mollusks, and arthropods that researchers believe are functionally significant associates of old-growth forests, but for which little or no information exists.

Eastside Forests

The extensive loss of parklike old-growth forests and unprecedented increases in insect and disease epidemics in eastside forests spurred scientists to develop strategies for restoring past ranges of variability in species composition and structure (Gast et al. 1991; Mutch et al. 1993; U.S. Forest Service 1993; Tanaka et al. 1995; Tesch 1995). Reducing stand density to minimize moisture and nutrient stress for individual trees and reintroducing fire—the natural thinning agent—are primary objectives, but both these actions are controversial (Agee 1994; Arno and Ottmar 1994). Scientists emphasize that restoration efforts must be focused at the landscape level to ensure the restoration of a mosaic of forest types that will, in turn, reduce the continuity of food sources for defoliating insects (Mason and Wickman 1994) and provide natural fuel breaks (Arno and Ottmar 1994). Without a dynamic, landscape-level effort to restore a balanced mosaic of healthy trees, insect and disease outbreaks will continue to increase in frequency, severity, and length (Lehmkuhl et al. 1994), and wildfires will continue to be large and difficult to control (Arno and Ottmar 1994).

Eastside Rangelands

Restoration of diverse mixtures of native plants on sites dominated by nonindigenous species is a great challenge facing rangeland managers (Pyke and Borman 1993). As in eastside forests, reestablishing a natural fire regime is often emphasized, but additional research is needed to determine how fire can be effectively reintroduced without exacerbating problems with nonindigenous species. Natural, often unpredictable weather cycles may determine the short-term success of restoration projects; large-scale annual and seasonal variation in the size and activity patterns of wildlife populations are common. Therefore, unraveling the complex dynamics of these arid ecosystems and generating accurate assessments of the success of restoration efforts will require heretofore uncommon intensive and long-term research and monitoring.

Riparian and Aquatic Ecosystems

Several major studies were recently initiated in the Pacific Northwest to expand our understanding of riparian ecosystems and the ecology of salmon and trout. The congressionally appointed Northwest Power Planning Council (1986, 1994) developed an early comprehensive management plan for the Columbia River and associated hydroelectric dams. The development of a regionwide strategy for managing watersheds and fishery resources in the Pacific Northwest began with the Gang-of-Four Report (Johnson et al. 1991), which formed the basis for the Aquatic Conservation Strategy in the Northwest Forest Plan (also see Reeves and Sedell 1992). The Aquatic Conservation Strategy identifies key watersheds with good water quality, good fish habitat, and populations of threatened or endangered stocks of anadromous salmon and trout, and prescribes undisturbed forest buffer zones along streams to protect stream integrity (that is, to ensure low sediment loads, adequate shade, continued recruitment of woody debris and nutrients, and so on). Other scientists suggested revised criteria for

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selecting watersheds for conservation (Nickelson et al. 1992; American Fisheries Society 1993; Pacific Rivers Council 1994), but the essential common theme is that to ensure protection of multiple scales of biological diversity and landscape-level ecological processes, the minimum scale of attention must be entire watersheds rather than single stream reaches (Naiman et al. 1992; Reeves and Sedell 1992).

The U.S. Forest Service and Bureau of Land Management (1994a) are also conducting a joint study commonly called PACFISH. The goal of this study is to develop “an ecosystem-based, aquatic habitat and riparian-area management strategy” for lands the agencies administer outside the range of the northern spotted owl in the Pacific Northwest and California. The PACFISH effort is an analog of the Aquatic Conservation Strategy in the Northwest Forest Plan.

Two major efforts were recently commissioned by the Oregon state legislature to synthesize information and to develop a comprehensive plan for coordinating restoration efforts in the state. The first was designed to assess the effects of forestry practices on anadromous fishes in western Oregon and northern California. It resulted in recommendations about how forest management could help restore anadromous fish populations (Botkin et al. 1994; Cummins et al. 1994). The intent of the second study, commonly known as the Bradbury Commission and recently transformed into a cooperative venture called For the Sake of the Salmon (B. Bradbury, executive director, Portland, Oregon), is to develop a management framework to “protect and restore native fishes by focusing on strategies that provide the greatest ecological benefits for native fishes and ecosystems (with priority given to anadromous salmonids)” (W. Nehlsen, Pacific Rivers Council, Portland, Oregon, unpublished report). Two key principles guide this study: protection of relatively intact ecosystems must be the first priority because such areas provide source populations for recovery of nearby degraded systems (Pacific Rivers Council 1994), and conservation must accommodate biological diversity at several spatial scales (landscape, river basins, and individual watersheds).

Specific Biota

Information about most species, particularly at the level of landscape ecology and population dynamics, is incomplete. Scientists are beginning to achieve this level of understanding for closely monitored vertebrate species such as northern spotted owls and some forest trees such as Douglas-fir and ponderosa pine. Many other species, though, are important links in critical ecosystem processes but are poorly known beyond information from small-scale studies.

Key examples of species for which there are obvious gaps in knowledge include fungi, arthropods, small mammals, and nongame fishes. Fungi are biologically and ecologically diverse and functionally significant to food webs, nutrient cycles, and plant productivity in forest and lowland ecosystems (Trappe and Luoma 1992). The number of species of arthropods is far greater than the number of all other species combined, and scientists know that arthropods are functionally important in many aquatic (Anderson et al. 1978; Anderson and Sedell 1979) and terrestrial (Mattson 1977; Moldenke and Lattin 1990; Miller 1993) ecosystems. Moreover, diverse fungal and arthropod communities could be important hallmarks of old-growth forest structure (Forest Ecosystem Management Assessment Team 1993). Nevertheless, little is known about the ecology of most fungal and arthropod species. Similarly, small mammals and fishes are important links in terrestrial and aquatic food webs that support many of the larger vertebrates that so often garner public attention, yet many species are poorly known. If the goal is to maintain healthy, functioning ecosystems, the well-being of these less obvious and perhaps ultimately more important elements of the systems must be ensured.

Many different species have shown signs of decline from human-caused disturbances such as logging; however, the apparent widespread decline of amphibians is especially noteworthy, and the Pacific Northwest is increasingly a focus of attention in this regard. Recent studies have revealed localized declines of aquatic and terrestrial amphibians because of logging and riparian habitat alterations. Similarly, extensive and intensive surveys left little doubt that the ranges of some species (for example, spotted frog and northern leopard frog) are greatly reduced. Nevertheless, regional and landscape-level information about most species is unavailable. The status of entire species or subspecies cannot be adequately assessed from responses of a few local populations to management (Corn 1994).

These examples emphasize particularly obvious gaps of knowledge that should receive attention. However, our intent is not to suggest that these subjects should necessarily become top-priority foci of concern at the expense of current emphases. In fact, many scientists may argue that a taxonomic focus should be avoided in favor of a process-oriented focus on, for example, the landscape-level dynamics and

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effects of natural disturbances (Perry 1988; Agee 1993; Swanson et al. 1994).

The accounts presented in this regional report provide only a glimpse of the depth and breadth of research that has taken place in the Pacific Northwest. For decades, federal and state agencies and private industry have supported considerable research on a wide array of organisms, communities, and ecosystems. Today, some of the best long-term, ecological data sets come from this region. Nevertheless, our knowledge remains grossly incomplete for numerous species, and we have only begun to unravel the ecological complexities of most regional ecosystems.

Acknowledgments

Numerous people from the following state agencies provided valuable assistance with identifying key contacts, issues, and research programs, and with securing data and graphics: Idaho Department of Fish and Game; California Department of Fish and Game; Washington Department of Natural Resources; Washington Department of Fish and Wildlife; Oregon Department of Fish and Wildlife; Oregon Department of Agriculture; Oregon, Washington, and California natural heritage programs; Idaho Conservation Data Center; and the California Native Plant Society. Many other people contributed to the development of the chapter; the following were particularly instrumental in this regard: R. Anthony, H. Li, and J. Tappeiner III, U.S. Geological Survey, Corvallis, Oregon; B. Peterjohn, U.S. Geological Survey, Laurel, Maryland; S. Knick and T. Zarriello, U.S. Geological Survey, Boise, Idaho; G. Lienkaemper, D. Olson, G. Reeves, and T. Spies, U.S. Forest Service, Corvallis, Oregon; K. Aubry and M. Raphael, U.S. Forest Service, Olympia, Washington; L. Jurs, Bureau of Land Management, Spokane, Washington; J. Lint, Bureau of Land Management, Roseburg, Oregon; M. Borman, S. Gregory, B. McIntosh, and A. Moldenke, Oregon State University, Corvallis; S. Balakoff, The Wilderness Society, Seattle, Washington; B. Hughes, U. S. Environmental Protection Agency, Corvallis, Oregon; and J. E. Smith, Pacific Watershed Institute, Seattle, Washington. Constructive reviews of earlier drafts by E. Multer, U.S. Geological Survey, Corvallis, Oregon; J. E. Williams, Bureau of Land Management, Boise, Idaho; and two anonymous reviewers improved the quality of the manuscript.

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