Research Contribution 32

The Effects of Silvicultural Activities on Wildlife and Fish Populations in Oregon and the Pacific Northwest:

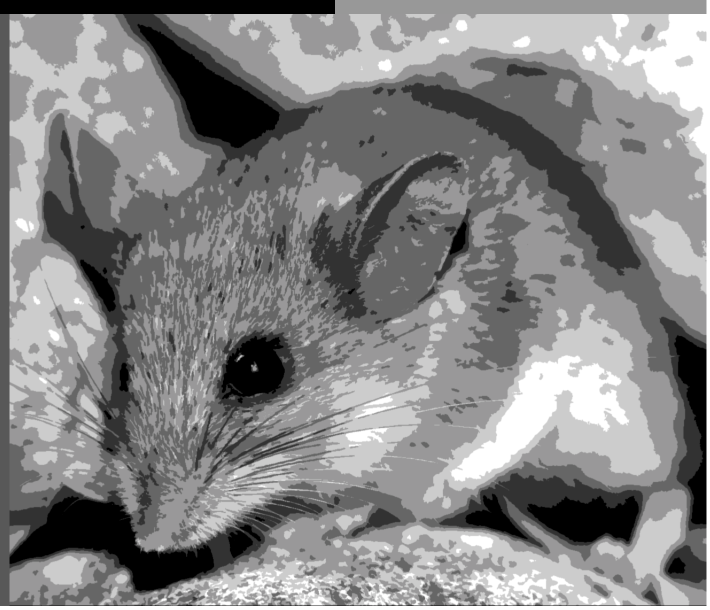
An Annotated Bibliography from 1960 to 1999

by

Kathleen G. Maas-Hebner

Barbara A. Schrader

May 2001



Oregon State University
College of Forestry

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ABSTRACT

Maas-Hebner, KG, and BA Schrader. 2001. The Effects of Silvicultural Activities on Wildlife and Fish Populations in Oregon and the Pacific Northwest: An Annotated Bibliography from 1960 to 1999. Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 32.

This annotated bibliography was compiled to provide forest managers with a comprehensive list of sources on the potential effects of silvicultural activities on wildlife and fish populations in Pacific Northwest forests. The bibliography emphasizes publications directly examining silvicultural activities and responses by these populations. Abstracts from 296 publications are indexed by geographic area, forest type, wildlife or fish species, silvicultural activity, and author. In addition, the appendices list 29 general resource references and 70 World Wide Web links. Forest management activities covered in this bibliography include even- and uneven-aged harvesting systems, site preparation, vegetation management, pest control, fertilization, and road construction and use. The focus of this bibliography is the interface between silviculture and management of wildlife and fish habitat in Oregon; however, applicable literature is included from other regions in western North America.

Contents

*I*NTRODUCTION

Forest management in the Pacific Northwest has become increasingly complex in recent years, and it promises to remain challenging into the 21st century. Timber harvest activities are frequently in conflict with protection of wildlife and fisheries habitat. Public interest in biological conservation demands that protection and enhancement of habitat be integrated with silvicultural prescriptions. During timber harvest activities, current state and federal regulations dictate minimum requirements for retaining habitat features and riparian buffer strips. These regulations currently focus on the number and size of live and dead trees and decaying logs to be left at each site, as well as the width of vegetated zones surrounding salmonid-bearing streams, the maximum harvest unit size, and required rates of reforestation. Although current policies and regulations set minimum requirements across a broad spectrum of wildlife habitats, land managers need better information on the response of wildlife to a variety of forest management techniques.

Our goal in compiling this bibliography was to highlight existing studies of the effects of silvicultural activities on wildlife and fish populations and habitat. The focus, therefore, is the *interface* between silviculture and wildlife and fisheries habitat management in Oregon. In compiling this bibliography, we hope to supply needed information to managers, researchers, and land owners, to foster applied research in forest management, and to promote partnerships between federal and private land owners and the scientific community.

We began assembling this bibliography by identifying wildlife and fish species occurring in various Oregon forest types (Bond 1994, Csuti et al. 1997) and conducting an initial search for each species in electronic literature databases (Agricola, Wildlife Worldwide, Aquatic Sciences and Fisheries Abstracts, Fish and Fisheries Worldwide, and UnCover Reveal). Searches were then expanded or limited by adding geographic and forest management terms. Other publications were found through lists of literature citations in publications and unpublished reports. We screened literature from across western North America for appropriate references—that is, references that addressed the response of vertebrates to silvicultural activities in forest types similar to those in Oregon. Since our focus was on silvicultural activities, however, many familiar wildlife and fish habitat publications may not be present. Other works excluded from this bibliography are habitat restoration and enhancement studies not associated with active forest management (such as placement of large woody debris in streams), habitat studies conducted solely in unmanaged forests, and regulatory activities (such as removal of woody debris from streams). In general, the included works are readily available to the public. Only a few theses and dissertations are present; if these studies were later published elsewhere, we favored the more accessible source.

Works included in this bibliography were published between 1960 and 1999. Many of the early studies (1960 to the early 1980s) focus on timber harvest practices employed prior to implementation of the Oregon Forest Practices Act in 1971. Although these studies may not reflect current practices, they involve a management legacy that continues to affect fish and wildlife populations. Not surprisingly, many studies on the effects of silviculture on vertebrate habitat are fairly recent and are concentrated in a few forest types, such as westside Douglas-fir forests. Forest management activities covered in this bibliography include even- and uneven-aged harvesting systems, site preparation, vegetation management, pest control, fertilization, and road construction and use. References on general silvicultural practices, wildlife natural histories and habitat use, or research techniques are not included in this bibliography; however, Appendix C includes selected references that may be of use to those interested in these topics. Both Appendices C and D (World Wide Web resources) include information on other bibliographies related to wildlife and fish in the Pacific Northwest. Currently, a number of new studies in western North America are examining these questions; where possible, we have included preliminary reports and references. Additional information on these studies will be available over the next few years.

How to Use This Bibliography

We have standardized common names to match those in the Atlas of Oregon Wildlife (Csuti et al. 1997) and Keys to Oregon Fishes (Bond 1994). All scientific names listed in the Appendices and Index follow currently accepted taxonomy. Source titles, however, are written as originally published and may include old names. To ease confusion, we include older genus names in the Index, which directs readers to the current genus. We have also attempted to standardize terms used for silvicultural activities according to definitions in the Dictionary of Forestry (Helms 1998); this was not always possible, however, because of the limited descriptions given by the authors. Brief definitions of each activity are given in the Glossary.

All publications are indexed by authors and publication editors, where applicable. The subject index is extensive. Publications are indexed by dominant forest tree species, US state or Canadian province, mountain range (for Oregon studies), silvicultural activity, vertebrate species, and a general grouping (e.g., fish, amphibian, birds, small mammals, salmonids). Herbicides and other chemicals are indexed by active ingredient (e.g., glyphosate, 2,4-D, carbaryl), not by commercial trade names. All vertebrate species with enough data for an author to include them in their statistical analyses are indexed by both common and scientific names. Some of these species may not be mentioned in our annotation, but information about them is included in the original publications. Publications considering landscape level influences are also indexed by forest fragmentation, edge habitat/edge effect, and home range size. Fisheries studies were further indexed by stream water quality, temperature, sedimentation, and large woody debris. Our inclusion or omission of a source is not meant to indicate quality. Appendix D lists several World

Wide Web pages useful for locating the citations in this bibliography; these sites should help those who wish to stay familiar with ongoing research and publications.

Finally, readers are reminded that these annotations are not meant to replace the original documents but rather to serve as a quick overview and guide to available literature. Every attempt has been made to ensure accurate annotation of the articles during the compilation and editing stages. However, if readers are to fully understand the applications and limitations of the material, we strongly encourage them to consult the original sources.

Electronic Database Availability

The bibliography database created in ProCite bibliographic software will be available in 2001 on the College of Forestry's Publications Web Page:

http://www.cof.orst.edu/cof/pub/home/

The files will be downloadable and are fully searchable in ProCite or other bibliographic databases that can use the same format.

Cited References

Bond, CE. 1994. Keys to Freshwater Fishes. OSU Bookstores, Inc., Corvallis, OR.

Csuti, B, AJ Kimerling, TA O'Neil, MM Shaughnessy, EP Gaines, and MMP Huso. 1997. Atlas of Oregon Wildlife: Distribution, Habitat, and Natural History. Oregon State University Press, Corvallis, OR.

Helms, JA. 1998. The Dictionary of Forestry. Society of American Foresters, Bethesda, MD.

ANNOTATED BIBLIOGRAPHY

1. Adams, EM, and ML Morrison. 1993. Effects of forest stand structure and composition on red-breasted nuthatches and brown creepers. *Journal of Wildlife Management* 57(3): 616–629.

   The use of forest resources by brown creepers and red-breasted nuthatches was studied in the California Sierra Nevada Range. The forest was made up of incense-cedar, Douglas-fir, ponderosa pine, sugar pine, white fir, and California black oak. The forest was divided into several management type compartments, including even-aged management, uneven-aged management, and unmanaged forest. A sub-sample of compartments was used for evaluating the effects of stand structure and bark arthropod diversity on creeper and nuthatch behavior. No direct comparisons were made between behavior and type of stand management. The intensity of stand use by the two species was positively correlated with percent basal area of sugar pine. Brown creepers foraged on incense-cedar more than on any other tree species; red-breasted nuthatches were more varied in their use of tree species. The authors suggest that managers should maintain a diversity of stand structures and tree species for year-round use by bark-foraging birds.

2. Anthony, RG, GR Green, ED Forsman, and SK Nelson. 1996. Avian abundance in riparian zones of three forest types in the Cascade Mountains, Oregon. *Wilson Bulletin* 108(2): 280–291.

   Bird abundance was compared in headwater stream riparian zones surrounded by three types of Douglas-fir forests in the Oregon Cascade Range: old-growth (400–450 years old, unharvested); mature (130–200 years old, unharvested); and young forest (25–35 years old, regenerated after clearcutting). During winter, bird species richness and density did not differ among stand types. Brown creepers, chestnut-backed chickadees, golden-crowned kinglets, evening grosbeaks, and winter wrens were common in each stand type. Summertime abundance of brown creepers, chestnut-backed chickadees, Hammond's flycatchers, and hermit/Townsend's warblers was higher in old-growth and mature stands than in young stands. Overall population densities were highest in old-growth stands during summer and young stands during winter.

3. Anthony, RG, and ML Morrison. 1985. Influence of glyphosate herbicide on small mammal populations in western Oregon. *Northwest Science* 59(3): 159–168.

   Small mammals were trapped on two recent clearcuts to determine the effects of glyphosate herbicide use on small mammal populations. The study sites, in the central Oregon Coast Range, had been planted with conifers but were dominated by salmonberry. One site was treated with glyphosate for brush control; the other site was not sprayed. Glyphosate application defoliated about half of the salmonberry and thimbleberry. Two years after spraying, shrub cover was similar to cover before treatment. Small mammal communities increased in abundance, diversity, and biomass 1 year after spraying but returned to pre-spray levels 2 years after treatment. Deer mice populations did not appear to be influenced by the vegetative changes. Creeping vole populations increased in the first year after spraying but declined by 2 years afterward. Townsend's chipmunk populations fluctuated within the treated site but remained relatively constant on the untreated site. The authors conclude that the temporary effects from glyphosate treatments on the clearcuts had no detrimental effects on small mammal populations.

4. Armleder, HM, MJ Waterhouse, RJ Dawson, and KE Iverson. 1998. *Mule Deer Response to Low-Volume Partial Cutting on Winter Ranges in Central Interior British Columbia*. Research Report 16, Research Branch, B.C. Ministry of Forests, Victoria, B.C. 11 pp.

   Mule deer winter use of partially cut Douglas-fir forest was studied in interior British Columbia forests. Study plots were selectively logged in 1984, with low volumes of timber removed. Harvested blocks were compared with unharvested controls of similar size. Deer tracks were surveyed 2–3 days after snowfall of 6 cm or more from 1984 through 1991. The mean number of tracks per 50 m per week did not significantly differ between harvested and unharvested treatments. Increased snow depths did not appear to affect the number of tracks in either treatment. The authors suggest that low-volume selective harvesting may be used in interior Douglas-fir forests and still maintain winter habitat for mule deer.

5. Artman, VL. 1990. *Breeding Bird Populations and Vegetation Characteristics in Commercially Thinned and Unthinned Western Hemlock Forests of Washington*. MS thesis, University of Washington, Seattle.

   To assess the effects of thinning on bird populations and vegetation composition, Artman compared commercially thinned and unthinned 45- to 50-year-old western hemlock stands in the Washington Cascades. Thinned stands had lower tree densities, more open overstory canopies, more understory growth, and higher bird species diversity than unthinned stands. Total bird density did not appear to be affected by thinning and was positively correlated with the presence of deciduous trees and shrubs in the thinned stands. Artman concludes that vegetation diversity in thinned stands benefited bird populations, and that commercial thinning appears to be an appropriate method for enhancing breeding bird habitat.

6. Au, DWK. 1972. *Population Dynamics of the Coho Salmon and its Response to Logging in Three Coastal Streams*. PhD dissertation, Oregon State University, Corvallis.

   The ecology and population dynamics of coho salmon in logged watersheds was studied to evaluate the processes that stabilize and regulate populations. Three Oregon Coast Range watersheds were used; one was clearcut with no riparian buffers, the second was patch clearcut with buffers, and the third was left undisturbed as a control. Logging was done in 1966, and sampling occurred in 1968. The author concentrated on coho salmon year classes from 1963 to 1968. The natural variability of stream-flow-related conditions that influence the magnitude and pattern of coho recruitment increased after logging. In the clearcut watershed, peak storm flows increased and intragravel dissolved oxygen decreased. Increased stream temperatures and fish mortality in this watershed did alter the post-recruitment life conditions of the coho; however, final smolt yield was not significantly affected, perhaps because the instream conditions after logging fell within the environmental variations normally experienced by coho. Au also concludes that riparian buffer strips are an effective way of protecting aquatic resources.

7. Balfour, PM. 1989. *Effects of Forest Herbicides on Some Important Wildlife Forage Species*. FRDA Report 020, Canadian Forestry Service and B.C. Ministry of Forests, Victoria, B.C. 58 pp.

   This paper consolidates information about the effects of using forest herbicide on plant species used as forage by elk, deer, and grizzly bears. Studies took place in British Columbia, Alberta, Saskatchewan, Oregon, Washington, and Idaho; herbicides included glyphosate, hexazinone, 2,4-D, and triclopyr. Damage to forage plants varied depending on season of application. Forage species discussed included true firs (*Abies* spp.), Douglas-fir, western redcedar, western hemlock, birches (*Betula* spp.), cottonwood/aspens (*Populus* spp.), vine maple, western serviceberry, redstem ceanothus, snowbrush, salal, ocean spray, cherries (*Prunus* spp.), willows (*Salix* spp.), roses (*Rosa* spp.), thimbleberry, salmonberry, trailing blackberry, elderberries (*Sambucus* spp.), blueberries/huckleberries (*Vaccinium* spp.), grasses, and sedges.

8. Bart, J, and ED Forsman. 1992. Dependence of northern spotted owls *Strix occidentalis caurina* on old-growth forests in the western USA. *Biological Conservation* 62(2): 95–100.

   Results from three surveys were pooled to determine the types of forest habitats used by northern spotted owls. Survey data came from the Coast and Cascade Ranges in Oregon, Washington, and northern California. Spotted owls were rare or absent in areas made up predominantly of young stands nearing rotation age (< 80 years old). Owls were also rare in areas in which small amounts of old-growth forest had been left after timber harvest. Old-growth stands in designated Wilderness Areas supported sparse owl populations; their reproductive success was considerably lower than that for populations in high-quality old-growth habitat that was not in Wilderness Areas. Wilderness Areas and National Parks tend to be at the upper edge of the owl's elevational range, possibly contributing to their lower reproductive success. The results indicate that current timber harvest practices will lead to declines in owl numbers, and that currently protected old-growth stands are unlikely to provide habitat of high enough quality to maintain self-supporting owl populations.

9. Beese, WJ, and AA Bryant. 1999. Effect of alternative silvicultural systems on vegetation and bird communities in coastal montane forests of British Columbia, Canada. *Forest Ecology and Management* 115: 231–242.

   The authors assessed the effects of silvicultural systems on vegetation and bird communities in coastal montane forests of British Columbia. Stands were dominated by Pacific silver fir and western hemlock, with overstory trees ranging from 200 to 800 years old. Stand treatments included clearcut, clearcut with reserves, shelterwood cut, patch clearcut, and uncut forest. Understory plant cover, species number, and frequency decreased after all harvesting treatments, but the shelterwood treatment retained the greatest diversity of understory trees and shrubs. The different levels of canopy retention showed dramatically different effects on breeding birds. Species richness and abundance was greater 3 years after the shelterwood treatment than before the treatment. Bird species richness and abundance decreased after harvesting in all treated stands, and most of the commonly recorded species exhibited population declines. Most winter birds were concentrated in the uncut old-growth and the unlogged portions of patch-cut blocks.

10. Berrill, M, and S Bertram. 1997. Effects of pesticides on amphibian embryos and larvae, pp. 233–245 in *Amphibians in Decline: Canadian Studies of a Global Problem*, DM Green, ed. *Herpetological Conservation* 1.

    Laboratory trials were used to determine the possible effects of forest- and agricultural-use pesticides on amphibian embryos and larvae. Embryo hatching rates did not appear to be affected by insecticides (permethrin, fenvalerate, and fenitrothion) or herbicides (hexazinone, triclopyr, glyphosate, triallate, trifluralin, and bromoxnil). Newly hatched tadpoles were paralyzed after exposure to pesticides but slowly recovered once exposure ended. Pesticide concentrations higher than those inducing paralysis caused death. Some species were more sensitive to pesticide exposure than others.

11. Beschta, RL. 1978. Long-term patterns of sediment production following road construction and logging in the Oregon Coast Range. *Water Resources Research* 14(6): 1011–1016.

    Three watersheds in the Oregon Coast Range were used to determine long-term patterns of sediment production following road construction, clearcut logging, and slash burning. In one watershed, 82% of the area was clearcut (no riparian buffers); 5% of this area was in roads and landings. In the second watershed, 25% of the area was clearcut in three patch cut units (with riparian buffers in two units); 4% was in roads and landings. Slash was burned in both watersheds. A third watershed, used as a control, had no roads or harvesting. In the clearcut watershed, sediment production increased during 5 of the 8 post-treatment years and was attributed to surface erosion from a severe slash burn. In the patch-cut watershed, sediment increased during 3 of the 8 years and was primarily due to mass soil erosion from roads.

12. Beschta, RL, RE Bilby, GW Brown, LB Holtby, and TD Hofstra. 1987. Stream temperature and aquatic habitat: Fisheries and forestry interaction, pp. 191–232 in *Streamside Management: Forestry and Fishery Interactions*, EO Salo and TW Cundy, eds. Contribution no. 57, Institute of Forest Resources, College of Forest Resources, University of Washington, Seattle.

    This paper reviews stream temperature, its regulation by environmental variables, and potential adverse effects of timber harvesting activities that remove riparian vegetation along the stream channel. Temperature requirements for salmonids are also discussed. The authors suggest using riparian buffer strips to minimize the effects of logging on temperatures. They conclude that although increased stream temperatures do not usually kill fish in the Pacific Northwest, temperature changes can influence salmonid egg development rates, rearing success, and species competition, as well as invertebrate populations and algae production.

13. Beschta, RL, and RL Taylor. 1988. Stream temperature increases and land use in a forested Oregon watershed. *Water Resources Bulletin* 24(1): 19–25.

    Summer stream water temperatures were monitored over a 30-year period (from 1955 to 1984) in the Salmon Creek watershed in the Oregon Cascades; extensive road construction and clearcutting of mature Douglas-fir forests also occurred during this period. Over the 30 years, average daily maximum and minimum temperatures increased, and regression analysis indicated a significant relationship between an index of cumulative harvesting effects (the relative amount of stream area potentially disturbed by logging and road building) and maximum stream temperatures. Maximum temperatures were also higher for several years following major flood events. The authors note, however, that maximum stream temperatures were lower during the last few years of monitoring, which probably reflected a decrease in road construction and logging since 1972, a lack of major flooding after 1971, and changes in management practices during the previous 20 years.

14. Bilby, RE, and PA Bisson. 1992. Allochthonous versus autochthonous organic matter contributions to the trophic support of fish populations in clear-cut and old-growth forested streams. *Canadian Journal of Fisheries and Aquatic Sciences* 49(3): 540–551.

    Rates of annual organic matter input and fish production were compared for a 7-year-old clearcut headwater tributary (no riparian buffers) and an undisturbed old-growth forest tributary. The riparian area along the clearcut stream was dominated by willows (*Salix* spp.) and red alder; the area along the old-growth stream was dominated by Douglas-fir, western hemlock, and western redcedar. Autochthonous organic matter (of instream origin) dominated inputs to the clearcut stream; allochthonous organic matter (terrestrial origin) dominated inputs to the old-growth stream. Although combined autochthonous and allochthonous inputs were almost twice as high in the old-growth stream as in the clearcut stream, fish production was greatest in the clearcut stream. Coho salmon and shorthead sculpin production during early summer explained most of the difference between the streams. On the basis of coho stomach content analysis and the similar ratios of autochthonous inputs to fish production in the two streams, the authors suggest that fish populations may depend on autochthonous material in spring and summer regardless of forest canopy cover.

15. Bilby, RE, and PA Bisson. 1987. Emigration and production of hatchery coho salmon (*Oncorhynchus kisutch*) stocked in streams draining an old-growth and a clearcut watershed. *Canadian Journal of Fisheries and Aquatic Sciences* 44: 1397–1407.

    Two streams in the Washington Cascades were stocked with hatchery coho salmon fry in a study of emigration and summer production differences in old-growth and clearcut forested streams. One stream was in an undisturbed old-growth forest dominated by Douglas-fir, western hemlock, and western redcedar; the other was in a watershed where most of the forest had been clearcut and planted with Douglas-fir during 1974 to 1976. Coho fry were released in 1982 and 1983 in both streams. Downstream movement of fry occurred in three phases: 1) brief but heavy emigration immediately after stocking; 2) little emigration during the summer; and 3) intermittent heavy emigration during early fall freshets. Fry production in the clearcut watershed was greater than in the old-growth watershed. Proportionally fewer fish emigrated from the old-growth stream, but when high populations occurred, higher mortality occurred than in the clearcut stream. The authors suggest that greater emigration occurred in the clearcut stream because of the low occurrence of pools.

16. Binkley, D, and TC Brown. 1993. Forest practices as nonpoint sources of pollution in North America. *Water Resources Bulletin* 29(5): 729–740.

    This paper looks at information from North America on how forest management practices may affect stream water quality (temperature, dissolved oxygen, nitrate-nitrogen concentrations, and suspended sediments). A large proportion of studies are from the Pacific Northwest. Forest practices do have the potential to degrade stream water quality, but the authors conclude that prevention measures can minimize the effects. Riparian buffer strips can prevent unacceptable increases in stream temperatures. Current practices do not usually put large quantities of fine organic material into streams, so oxygen depletion is not a serious problem; however, the authors suggest that sedimentation of gravel streambeds may reduce oxygen diffusion into fish spawning beds. Nitrate-nitrogen concentrations typically increase after timber harvest but rarely affect drinking water quality. Suspended sediment also typically increases after road construction and timber harvesting, but levels vary by region. Although the best management practices usually prevent unacceptable increases in suspended sediment concentrations, large sediment inputs in conjunction with intense storms are not unusual.

17. Binkley, D, H Burnham, and HL Allen. 1999. Water quality impacts of forest fertilization with nitrogen and phosphorus. *Forest Ecology and Management* 121: 191–213.

This paper reviews worldwide studies of potential water quality degradation related to forest fertilization involving nitrogen and phosphorus (as urea, ammonium nitrate, or diammonium phosphate). The authors evaluate information on water quality criteria, responses of stream water to fertilization, buffer strips, water nitrate concentrations related to different fertilizer forms and rates, and the response of soil drainage water to fertilization. They conclude that forest fertilization commonly leads to moderate increases in concentrations of nutrients in water, with the greatest increases resulting from direct application of fertilizers to streams, the use of ammonium nitrate, and high-dosage or repeated applications. No direct evidence relates changes in stream community composition or productivity to forest fertilization, but few studies have directly examined the response of aquatic organisms to fertilization of adjacent forests. There is little current information on the effects of repeated fertilization within short-rotation plantations or fertilization of large areas rather than small stands.

18. Bisson, PA, GG Ice, CJ Penin, and RE Bilby. 1992. Effects of forest fertilization on water quality and aquatic resources in the Douglas-fir region, pp. 179–193 in *Forest Fertilization: Sustaining and Improving Nutrition and Growth of Western Forests*, HN Chappell, GF Weetman, and RE Miller, eds. Institute of Forest Resources, College of Forest Resources, University of Washington, Seattle.

The potential effects of urea fertilizer on stream water quality and aquatic biota are discussed in this paper. After urea is applied to forests, three kinds of dissolved nitrogen are found in stream surface waters: 1) urea-N, which is present for only a few days; 2) ammonia-N, which may have concentrations that are elevated for several weeks to several months; and 3) nitrate-N, which may have elevated concentrations for up to a year or more. Dissolved nitrogen levels are affected by drainage density, urea application rate, precipitation, riparian buffer strip size, and the area of the watershed that is fertilized. Ammonia-N concentrations can also be influenced by temperature and soil chemistry. Nitrogen concentrations do not usually exceed drinking water standards and aquatic toxicity thresholds under normal fertilizing operations. In nitrogen-poor aquatic systems, the increased nitrogen levels have the potential to promote algae growth and production of aquatic invertebrates and fish, although enhancement of fish production has not been clearly demonstrated in the Pacific Northwest. The authors conclude that when reasonable precautions are taken to minimize direct entry of urea into streams, stream water quality should not be compromised.

19. Bisson, PA, and JR Sedell. 1984. Salmonid populations in streams in clearcut vs. old-growth forests of western Washington, pp. 121–129 in *Fish and Wildlife Relationships in Old-Growth Forests*, WR Meehan, TR Merrell, Jr., and TA Hanley, eds. American Institute of Fishery Research Biologists, Morehead City, NC.

Streams in the Washington Coast and Cascade Ranges were surveyed to compare salmonid populations in old-growth forests (75–330 years old) and recent clearcuts with no riparian buffer strips (1–11 years old). Riparian zones in the unlogged forests were dominated by Douglas-fir, western hemlock, and western redcedar. Red alder had begun to grow in some of the older clearcut riparian areas. Salmonids were sampled during the summer low-flow period. Total salmonid biomasses were twice as large, on average, in logged stream sections as in unlogged sections. Streams in logged watersheds contained higher percentages of age-0+ steelhead and cutthroat trout than unlogged sections, but lower percentages of age-0+ coho salmon and age-1+ and -2+ cutthroat trout. Shifts in species and age composition were related to habitat changes resulting from clearcutting and removal of stream channel debris. More large, stable woody debris was present in unlogged than in logged sections. In streams in logged sections, the frequency and size of pools decreased; riffle volume and length increased, but their frequency decreased. The authors suggest that the increases in the proportional abundance of underyearling steelhead and cutthroat trout in logged sections may be due to their preference for riffle habitat; the relative decline of coho salmon and older cutthroat trout may be related to the loss of pool volume and large, stable woody debris that serves as cover.

20. Blake, JG. 1982. Influence of fire and logging on nonbreeding bird communities of ponderosa pine forests. *Journal of Wildlife Management* 46(2): 404–415.

    After a wildfire and salvage logging in northern Arizona ponderosa pine stands, birds were censused to determine the influence of fire and logging intensity on nonbreeding bird communities. Logging intensity included no cutting, partial cutting, and clearcutting. The study compared burned and logged sites with unburned and logged sites that had similar harvest levels; birds were surveyed during fall, winter, and spring. Although species numbers and abundance rates showed no clear trends related to burning, the burned areas tended to support more individuals but fewer species; this pattern, however, was not conclusively demonstrated. Species composition appeared to be related to the availability of foraging substrate. Habitat alterations caused by fire and by logging appeared to have similar influences on nonbreeding bird communities.

21. Borrecco, JE, HC Black, and EF Hooven. 1972. Response of black-tailed deer to herbicide-induced habitat changes, pp. 437–451 in *Western Proceedings, Fifty-Second Annual Conference of the Western Association of State Game and Fish Commissioners*, July 16–19, 1972. Portland, OR.

    The authors looked at western Oregon clearcuts (8–12 years old) to compare black-tailed deer use in untreated plots and plots where vegetation competing with Douglas-fir seedlings was controlled with herbicide (a combination of 2,4-D and atrazine). Treated plots were sprayed in two consecutive spring periods. Surveys of deer use (determined by pellet-group counts) and browse damage to seedlings were conducted during the growing seasons directly following each herbicide application and during the dormant period between the two applications. In the growing season, deer use was higher in sprayed plots than in untreated plots; in the dormant season, use in control and treated plots was similar. Browse damage on seedlings in both treated and untreated plots did not vary by season. The authors conclude that using herbicides in clearcuts can increase the quality of deer habitat without increasing damage to seedlings.

22. Borrecco, JE, HC Black, and EF Hooven. 1979. Response of small mammals to herbicide-induced habitat changes. *Northwest Science* 53(2): 97–106.

    Changes in small mammal populations were studied on western Oregon clearcuts (8–12 years old) sprayed with herbicides (combination of 2,4-D and atrazine) to control vegetation competing with Douglas-fir seedlings. Sprayed plots were compared with untreated plots. Treated plots were sprayed in the spring of 2 consecutive years, and small mammals were trapped each summer following spraying. Creeping vole, vagrant shrew, and Pacific jumping mouse populations decreased after herbicide applications, while deer mouse and Trowbridge's shrew populations increased. Population differences between treatments were most pronounced after the herbicides had had sufficient time to damage or kill vegetation.

23. Bosakowski, T. 1997. Breeding bird abundance and habitat relationships on a private industrial forest in the west-

ern Washington Cascades. *Northwest Science* 71(3): 244–253.

Breeding bird abundances were determined in a private industrial forest under intensive silvicultural management in the Washington Cascades. The forest included large blocks of commercially mature conifer forest (>45 years old), poletimber (27–44 years), sapling (6–26 years), clearcut (0–5 years), and hardwood stands (all ages). Stands were dominated by Douglas-fir and western hemlock. Multiple regression analysis showed that 61 bird species were positively correlated with different habitat types: with mature conifers (for 32 species), poletimber (27 species), sapling stage (38 species), clearcut (32 species), nonforested land (20 species), and hardwood habitat (19 species). Bosakowski concludes that all successional stages on this industrial forest are important to different groups of breeding bird species, and that industrial forests can contribute to the regional biodiversity of breeding birds.

24. Brawn, JD, and RP Balda. 1988. The influence of silviculture activity on ponderosa pine forest bird communities in the southwestern United States. *Bird Conservation* 3: 3–21.

Bird communities in southwestern ponderosa pine stands were censused to describe the communities over a gradient of habitat types resulting from silvicultural activities, and to describe the effects of fire on bird populations. Plots censused included clearcut, moderately thinned, severely thinned, second-growth, and old-growth forests. The clearcut plots had considerably less species richness than any of the other plots. Overall, silvicultural treatments had a more pronounced effect on species composition than on species richness. The clearcut had the fewest breeding pairs, while the old-growth stand had the most. Silvicultural activity, in general, had a negative effect on breeding bird density on the forested plots. The authors suggest that habitat modification related to silvicultural treatments can influence the avian community structure in ponderosa pine, but the influence may be moderate since most of the core species breed within a variety of habitat types.

25. Brown, GW. 1970. Predicting the effect of clearcutting on stream temperature. *Journal of Soil and Water Conservation* 25: 11–13.

This paper presents an equation for predicting stream temperature changes in small streams crossing clearcuts. Using the equation involves estimating maximum heat input into streams; the paper explains how this is done in the field. The equation is based on the assumption that the stream surface is completely exposed to direct sunlight. Shading by overhanging vegetation or topographic features will lead to overestimation of temperature changes. Brown concludes that this problem and other such limitations are not likely to restrict the application of the prediction technique.

26. Brown, GW. 1983. *Forestry and Water Quality*. Second Edition. Oregon State University Bookstores, Inc., Corvallis.

This is an introductory text on how forest management activities and site conditions (e.g., soil type, topography, climate, stream channel characteristics) interact to affect soil erosion, sediment production and transport, mass soil movement, dissolved nutrients and oxygen in stream water, water temperature, and channel morphology. Management practices discussed include roads, logging, fires, grazing, and site preparation, along with preventative measures that can minimize negative effects on stream water quality. The book also discusses the use of herbicides, insecticides, and fire retardants, along with their behaviors in the forest and stream environment. Examples come mainly from the Pacific Northwest.

27. Brown, GW, and JT Krygier. 1970. Effects of clear-cutting on stream temperature. *Water Resources Research* 6(4): 1133–1139.

Three streams in the Oregon Coast Range were monitored to determine the effect of clearcut logging on stream temperatures. One watershed was clearcut without buffer strips, a second was clearcut in patches (patch cut) with buffer strips, and a third was left undisturbed as a control. Logging roads were constructed in the two logged watersheds.

The clearcut watershed was burned to reduce slash, but only the lower unit of the patch cut watershed was partially burned. Logging occurred in 1966; streams were monitored from 1965 through 1968. The average monthly maximum temperatures increased by 14°F; by 1 year after logging in the clearcut watershed, annual maximum temperatures had increased from 57°F to 85°F. No temperature changes attributable to clearcutting were observed in the patch cut watershed.

28. Brown, GW, and JT Krygier. 1971. Clear-cut logging and sediment production in the Oregon Coast Range. *Water Resources Research* 7(5): 1189–1198.

Three streams in the Oregon Coast Range were monitored to determine the effects of roads, clearcut logging, and prescribed burning on suspended sediment yields. One watershed was clearcut without buffer strips, a second was clearcut in patches (patch cut) with buffer strips, and a third was left undisturbed as a control. Logging roads were constructed in the two logged watersheds. The clearcut watershed was burned to reduce slash, but only the lower unit of the patch cut watershed was partially burned. Annual sediment yields before treatment were highly variable in each watershed. Sediment yields doubled in the patch cut watershed after road construction and tripled in the clearcut watershed after cutting and burning. Felling and yarding of trees alone did not produce statistically significant changes in sediment yields. On the undisturbed watershed, there were large variations in sediment concentration related to water discharge.

29. Bryant, MD. 1985. Changes 30 years after logging in large woody debris, and its use by salmonids, pp. 329–334 in *Riparian Ecosystems and Their Management: Reconciling Conflicting Uses—First North American Riparian Conference*, April 16–18, 1985, RR Johnson, CD Ziebell, DR Patton, PF Ffolliott, and RH Hamre, tech. coords. General Technical Report RM-120, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 523 pp.

Changes in the number of large woody debris (LWD) accumulations in fourth and fifth order streams 30 years after logging were examined on Prince of Wales Island, Alaska. The streams were in two watersheds that had been completely logged down to the stream banks, a partially logged watershed including stream bank, an extensively logged watershed with some small-treed riparian buffers, and an unlogged old-growth watershed. The streams had been mapped before logging, starting in 1949, and after logging through 1960. They were remapped in 1983 and 1984. Maps included stream course, LWD, bedrock, gravel bars, and pools. LWD accumulations were categorized for analysis as 1–4 pieces, 5–10 pieces, and 10+ pieces. In the completely logged watersheds, the number of LWD accumulations increased after logging began and had doubled by 1960. By 1984, however, these LWD accumulations had decreased to below pre-harvest levels. In harvested watersheds with no riparian buffers, removal of streamside timber effectively eliminated the source of replacement LWD. Large woody debris pieces that were left after logging moved around in streams more than they did in the unlogged watershed. The amount of LWD in unharvested areas remained fairly stable over the 30-year period. Juvenile coho salmon densities were similar among the LWD accumulation categories, but densities decreased where LWD was absent.

30. Buchanan, JB, RW Lundquist, and KB Aubry. 1990. Winter populations of Douglas' squirrels in different-aged Douglas-fir forests. *Journal of Wildlife Management* 54(4): 577–581.

Winter populations of Douglas' squirrels were monitored in different aged stands dominated by Douglas-fir and western hemlock in the southern Washington Cascades. All stands had regenerated naturally after catastrophic fires, and none had undergone extensive silvicultural treatments. The stands were in two regions, northern and southern. Young stands were 60–165 years old (northern region) and 42–140 years old (southern region). Old-growth stands were 250–730 years old (northern region) and 350 years old (southern region). Mean squirrel counts in old growth were higher in the southern than northern stands. Squirrel populations were three times as high in old-growth stands as in young-growth stands. Populations varied from year to year and appeared to be in synchrony with variations in the annual production of conifer cones. Old-growth forests appeared to provide higher quality habitat (more cones) than younger forests. The authors suggest that converting old-growth forests to even-aged Douglas-fir plantations would most likely result in fewer Douglas' squirrels. They also suggest that silvicultural practices that stimulate cone production may improve habitat quality in young stands.

31. Buck, SG, C Mullis, AS Mossman, I Show, and C Coolahan. 1994. Habitat use by fishers in adjoining heavily and lightly harvested forest, pp. 368–376 in *Martens, Sables, and Fishers: Biology and Conservation*, SW Buskirk, AS Harestad, MG Raphael, and RA Powell, eds. Comstock, Ithaca, NY.

    Habitat use by fishers was studied in heavily and lightly harvested forests in northern California. Differences between the two sites included total length of roads and amount of forest harvested by pre-salvage logging (selective harvest). Forests were dominated by Douglas-fir and white fir. Habitat was divided into four types: open (no trees), brush/poletimber, hardwoods, and mature closed-canopy conifer forest. Within the heavily harvested sites, fishers used timber types differently, with use affected by timber harvest. In contrast, fishers in the lightly harvested forests used timber types in proportion to their availability, and timber harvest did not appear to affect use. The authors suggest that fisher populations are unlikely to be maintained when forest management leads to open stands, large numbers of hardwoods, and dry stand conditions.

32. Bull, EL. 1994. Effect of logging on tailed frog populations in northeastern Oregon. *Northwest Science* 68(2): 117.

    This abstract reports preliminary information from a study that looked at logging in eastern Oregon watersheds and how it affects tailed frog populations. Thirty streams were categorized into one of three categories: $\leq$20% of the watershed logged; 21%–50% logged; and >50% logged. Streams with extensive logging and no riparian buffers had few larvae or adults.

33. Bull, EL, and AK Blumton. 1999. *Effect of Fuels Reduction on American Martens and Their Prey*. Research Note PNW-RN-539, USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 9 pp.

    Changes in small mammal abundance in Oregon's Blue Mountain forests were determined before and after harvests aimed at reducing fuel levels. The authors looked at two stand types, lodgepole pine and mixed conifer.

    Three harvest treatments were used in the lodgepole pine stands: control (no harvest), island (20% of the area left in 1-acre unharvested patches), and scatter (40 downed logs per acre left scattered throughout the unit); the two harvest treatments removed most understory trees and logs and a small portion of overstory trees. Chipmunks (*Tamias* spp.) increased in all treatments. Southern red-backed voles increased in the control and island treatments and declined in the scattered treatment. Deer mice numbers decreased in the two harvest treatments. Winter track surveys suggested that snowshoe hares decreased in all stands after harvesting activities ended. Red squirrel track numbers decreased in the two harvest treatments; coyote tracks remained the same in the harvest treatments and increased in the control.

    Mixed conifer stands (subalpine fir, western larch, grand fir, Engelmann spruce, and Douglas-fir) were either left unharvested or harvested (all standing or down dead material less than 15 inches diameter removed). More southern red-backed voles and fewer chipmunks were present in unharvested stands than in harvested stands. More snowshoe hare tracks were present in unharvested stands, and no differences were seen in the number of coyote or red squirrel tracks.

34. Bull, EL, and BE Carter. 1996. *Tailed Frogs: Distribution, Ecology, and Association with Timber Harvest in Northeastern Oregon*. Research Paper PNW-RP-497, USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 11 pp.

    Forested streams in the Wallowa and Blue Mountains of Oregon were surveyed to determine the possible effects of

timber harvest on tailed frog populations. Timber harvesting around these streams included clearcuts, shelterwood cuts, overstory removals, partial overstory removals, and no harvesting. Numbers of larvae or adults showed no significant differences in streams with heavy, moderate, or low amounts of timber harvesting, although numbers tended to increase as harvesting intensity decreased. The authors suggest that timber harvesting may not significantly influence tailed frog populations in northeastern Oregon as long as riparian buffers and stream structure integrity are retained.

35. Bull, EL, and RS Holthausen. 1993. Habitat use and management of pileated woodpeckers in northeastern Oregon. *Journal of Wildlife Management* 57(2): 335–345.

Home ranges and habitat use for pileated woodpeckers in Oregon's Blue Mountains were determined in forests composed of ponderosa pine, Douglas-fir, western larch, grand fir, and lodgepole pine. Logged and unlogged old-growth areas varied across these stands; logged areas included clearcuts, shelterwoods, and partial overstory removals. Mated pairs had smaller home ranges than single birds whose mate had died within 3 months of radio tagging. Habitat use was greatest and home ranges smallest in areas with old-growth stands, grand fir, no history of logging, and more than 60% canopy closure. Home ranges increased as the area of ponderosa pine increased. Live Douglas-fir and western larch trees were favored for foraging; lodgepole pine was avoided. Ponderosa pine, Douglas-fir, and western larch snags were preferred over snags of other species. For the management of pileated woodpeckers in northeastern Oregon, the authors recommend increasing snag and downed log densities and increasing management areas from 121 ha to 364 ha of forest, of which 75% should be the grand fir forest type, with 25% to be old-growth and the remainder mature forests. At least 50% of the area should have greater than 60% canopy closure, and at least 40% should be unlogged.

36. Bunnell, FL, and GW Jones. 1984. Black-tailed deer and old-growth forests: A synthesis, pp. 411–420 in *Fish and Wildlife Relationships in Old-Growth Forests*, WR Meehan, TR Merrell, Jr., and TA Hanley, eds. American Institute of Fishery Research Biologists, Morehead City, NC.

The authors synthesized and evaluated research on black-tailed deer on northern Vancouver Island, British Columbia. The studies indicated that the value of old-growth forests for deer increases with the frequency of deep snowfalls. Looking at results for clearcuts, young second-growth forests, and old-growth forests, the authors discuss differences in foliage quality, forage intake, and energy output by deer; they conclude that reduction of old-growth forests in areas with high snowfall will reduce deer numbers.

37. Bunnell, FL, LL Kremsater, and RW Wells. 1997. *Likely Consequences of Forest Management on Terrestrial, Forest-Dwelling Vertebrates in Oregon: A Sudy Commissioned by the Oregon Forest Resources Institute*. Report M-7, Centre for Applied Conservation Biology, University of British Columbia, Vancouver, B.C. 130 pp.

This report evaluates the possible consequences of current forest practices for terrestrial vertebrates in Oregon's industrial private forests. The authors considered about 300 native forest-breeding vertebrates and looked at forest practices in both eastern and western Oregon, basing their evaluations on reviews of recent literature, observations from the air and on the ground, and their experiences in other Pacific Northwest forests. Discussions include potential effects of forest practices on riparian species, species associated with snags and large downed wood, hardwood associates, late-successional species, and forest fragmentation.

One hundred vertebrate species are considered "at risk" in Oregon. Of those species, the authors suggest that 45 are potentially influenced by current forest practices, but most are at risk from agricultural activities and urbanization rather than from forestry. Much of the report is based on the assumption that current practices on federal lands will continue similarly through time, maintaining late-successional forests. Federal lands are currently helping to meet regional habitat requirements (such as requirements for large live trees, large snags, and large downed wood) for

wildlife species associated with old-growth forest in Oregon; these habitat conditions are poorly met on private industrial lands. When federal lands are included, the authors conclude that there is no evidence that current forest practices immediately threaten any terrestrial vertebrate; current conservation measures appear adequate for species known to be vulnerable to specific forest practices (e.g., northern spotted owl, marbled murrelet), but the authors caution that current practices may not be adequate for maintaining the present range of these species in the future.

38. Burns, JW. 1972. Some effects of logging and associated road construction on northern California streams. *Transactions of the American Fisheries Society* 101(1): 1–17.

The effects of clearcut logging and construction of logging roads on stream habitat and salmonid populations were studied in four streams in the California Coast Range. Streams were in drainages forested with redwood and Douglas-fir, and each stream was monitored for three summers to include data before, during, and immediately after logging or road construction. The study examined coho salmon, steelhead trout, and cutthroat trout, along with stream bed sediment, water quality, fish food abundance, and habitat rearing capacity. Logging was compatible with salmonid production when the stream and channel were protected during stream cleaning. In some streams, the carrying capacity for salmonid juveniles increased after logging, as long as logging did not increase temperatures, lower dissolved oxygen concentrations, or increase sedimentation. Sedimentation was extensive, however, when bulldozers were used on steep slopes for road construction or in stream beds for removal of debris.

39. Bury, RB. 1983. Differences in amphibian populations in logged and old-growth redwood forest. *Northwest Science* 57(3): 167–178.

Bury compared amphibian populations in old-growth redwood forests and clearcuts in northern California. Perennial vegetation on old-growth plots included more plants and greater cover than in clearcuts, which had been logged 6–15 years prior to the study. In old-growth forests, amphibian populations had more individuals, greater biomass, and greater species diversity than populations in clearcuts. Clearcutting appeared to have a long-term negative effect on amphibians in redwood forests. Although creating openings by logging favored a few species (e.g., clouded salamander and northern salamander), it was detrimental to several others (e.g., Pacific giant salamander, ensatina, and California slender salamander).

40. Bury, RB, and PS Corn. 1988. Responses of aquatic and streamside amphibians to timber harvests: A review, pp. 165–181 in *Streamside Management: Riparian Wildlife and Forestry Interactions, Symposium Proceedings*, K Raedeke, ed. Institute of Forest Resources, College of Forestry, University of Washington, Seattle.

This paper first reviews the general life histories, ranges, and habitats of the tailed frog, Olympic salamander, Pacific giant salamander, and Dunn's salamander, as well as the short- and long-term effects of logging on these species. In a case study in the Oregon Coast Range, all four species occurred more often in streams in unlogged forests than in those in logged stands. Species richness was also higher in unlogged areas. A model for predicting amphibian populations during the first 50 years following clearcutting is presented, as well as a series of management suggestions.

41. Campbell, TM, III, and TW Clark. 1980. Short-term effects of logging on red-backed voles and deer mice. *Great Basin Naturalist* 40(2): 183–189.

The short-term effects of selective harvesting on southern red-backed voles and deer mice were studied in western Wyoming. High-elevation forests were dominated by Engelmann spruce and subalpine fir, and low-elevation forests by lodgepole pine. Selective harvesting removed 34%–74% of the trees on each site. The abundances were similar on logged and unlogged sites for both voles and deer mice. One year after logging, selective harvesting did not appear to have reduced populations of either species.

42. Carey, AB. 1995. Sciurids in Pacific Northwest managed and old-growth forests. *Ecological Applications* 5(3): 648–661.

Carey compared results from companion studies of northern flying squirrels and Douglas' squirrels in managed and old-growth forests in Oregon and Washington. In the first study, more squirrels were present in Douglas-fir forests in the Oregon Cascades than in western hemlock forests in the Washington Cascades. Flying squirrels were more abundant in old-growth forests than in young, managed stands with no old-growth legacies, but when such legacies were included in the young stands, flying squirrel abundance was similar to that in old-growth stands.

The second study, on Washington's Olympic Peninsula, showed that flying squirrel abundance could be predicted from the densities of large snags and ericaceous shrubs. Douglas' squirrel abundance, on the other hand, reflected the size of dominant trees and the amount of understory development. The distribution pattern of squirrels in managed and old-growth forests suggests that where old-growth forests are lacking, silvicultural manipulation of vegetation and snags or management of den trees could be used as a management strategy to accelerate development of habitat for spotted owls (which depend on squirrels for food).

43. Carey, AB, SP Horton, and BL Biswell. 1992. Northern spotted owls: Influence of prey base and landscape character. *Ecological Monographs* 62(2): 223–250.

Home ranges of northern spotted owl pairs and populations of their prey species were studied in relationship to landscape patterns in forests of Washington's Olympic Peninsula and Oregon's southern Coast Range and Klamath Mountains. The Olympic Peninsula study area consisted of old-growth forests dominated by western hemlock and Sitka spruce and young forests that regenerated after clearcutting, fire, or windstorms. The Oregon sites were either Douglas-fir or mixed conifer with Douglas-fir and grand fir, in a mixture of old-growth forest, pole-timber, sapling stands, and clearcuts.

Spotted owls used larger home ranges in Washington than in Oregon. In Oregon, their home ranges were larger in Douglas-fir forests than in mixed conifer forests. The most common prey species in both states was the northern flying squirrel. In heavily fragmented areas, owls traversed 85% more Douglas-fir forest and three times more mixed conifer forest than in lightly fragmented areas. In the most fragmented landscape, social structure appeared to be abnormal as judged by the proportion of adult–subadult pairs, instances of adult nomadism, and overlapping of pair home ranges. Although the pattern of fragmentation affected the owls' ability to find concentrations of old-growth forest, they still consistently selected old forests for foraging and roosting.

44. Carey, AB, and ML Johnson. 1995. Small mammals in managed, naturally young, and old-growth forests. *Ecological Applications* 5(2): 336–352.

Small mammal communities were compared in managed second-growth, unmanaged mixed-aged, and unmanaged old-growth forests on the Olympic Peninsula. Managed second-growth stands (44–67 years old) were dominated by either Douglas-fir or western hemlock and had regenerated by seeding or planting after the previous forests had been clearcut. Two of the seven managed stands had been thinned; the other five had not been thinned but varied in overstory density. Two unmanaged mixed-aged stands were examined: one stand (100–250 years old), dominated by Douglas-fir, red alder, and western hemlock, had developed after fire; the second stand (66–300 years old) was dominated by western hemlock and had developed after windstorm disturbance. The five old-growth stands ranged from 250 to 400 years old and were dominated by either western hemlock or Sitka spruce.

Small mammal communities showed no significant differences in species evenness, richness, or order of numerical abundance between stand types. Ranked by abundance, the eight species most frequently caught were forest field mouse, southern red-backed vole, creeping vole, Trowbridge's shrew, montane shrew, shrew-mole, deer mouse, and vagrant shrew. Communities in managed and mixed-aged stands were similar in composition to those in old-growth forests, but old-growth supported 1.5 times as many individuals and 1.5 times as much biomass as managed stands. The authors also discuss environmental predictors for species abundance and make management suggestions for streamside forests, large woody debris, clearcutting, site preparation and planting, and rotation age.

45. Carey, AB, JA Reid, and SP Horton. 1990. Spotted owl home range and habitat use in southern Oregon Coast Ranges. *Journal of Wildlife Management* 54(1): 11–17.

    Northern spotted owls were radio-tracked in the southern Oregon Coast Range to determine home-range areas and habitat use. Forests were dominated by Douglas-fir and western hemlock, with incense-cedar in some areas. Owls selected home ranges that were largely made up of old-growth forest. Home ranges increased in size as the area of available old growth decreased. Old-growth forests were used for roosting and foraging. Owls did not use clearcuts; early- to mid-successional forests were used either less than or in proportion to their availability.

46. Cederholm, CJ, and LM Reid. 1987. Impact of forest management on coho salmon (*Oncorhynchus kisutch*) populations of the Clearwater River, Washington: A project summary, pp. 373–398 in *Streamside Management: Forestry and Fishery Interactions*, EO Salo and TW Cundy, eds. Contribution no. 57, Institute of Forest Resources, College of Forest Resources, University of Washington, Seattle.

    This paper summarizes a project on Washington's Olympic Peninsula that aimed to determine factors limiting each life stage of coho salmon, to examine the controls for each factor, and to evaluate the effects of management practices on each control. In the basin used for the project, about 60% of the old-growth western hemlock forests had been clearcut, with buffer strips left along streams larger than third order. Forestry-related salmon mortality was primarily due to increased stream sediment load and a reduction of refuge habitat during winter storms. Increased sediment loads originated from landslides and erosion from heavily used logging roads. Field and laboratory experiments showed that 1) survival of eggs and alevins decreases as fine sediments in spawning gravels increase, 2) suspended sediments cause stress to juvenile salmon during summer, 3) blockages or alterations of small winter refuge channels can reduce smolt survival, 4) aggradation of coarse sediments can destroy summer rearing habitat, and 5) removal of large woody debris can reduce streambed stability.

47. Cederholm, CJ, LM Reid, and EO Salo. 1981. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington, pp. 38–74 in *Proceedings from the Conference: Salmon-Spawning Gravel: A Renewable Resource in the Pacific Northwest?* October 6–8,1980. Report no. 39, State of Washington Water Research Center, Pullman.

    Sediment production from logging roads and its effects on salmonid spawning success were studied in the Clearwater River drainage basin on the Olympic Peninsula in Washington. During the study, the basin had 40% of its forested area clearcut and two-thirds of the planned roads completed. Significant amounts of fine sediment accumulated in spawning gravels of some heavily roaded tributary sub-basins, with accumulations highest in sub-basins with road areas exceeding 2.5% of the basin area. The survival to emergence of salmonids decreased rapidly with each 1% increase in fine sediment above natural levels of 10%.

48. Chamberlin, TW. 1987. *Proceedings of the Workshop: Applying 15 Years of Carnation Creek Results,* January 13–15, 1987, Pacific Biological Station, Nanaimo, B.C.

    An intensive 15-year study examining the effects of clearcut logging on stream habitats and fish populations was conducted on the Carnation Creek watershed in coastal British Columbia. The watershed was dominated by western hemlock and western redcedar. Treatments were 1) intensive treatment (logged 1976–1977): trees were clearcut down to the stream bank, including some trees that were felled and yarded across the channel; 2) careful treatment (logged 1978–1979): trees were clearcut down to the stream bank, but other vegetation was left, causing no damage to the bank, and few trees were felled into or yarded across the channel; and 3) leave strip treatment (logged in three openings, 1975–1976, 1978–1979, 1980–1981): the surrounding stand was clearcut, but a variable-width buffer was left along the channel. Sampling was done during the 5 years before road construction and logging began, during the 5-year logging period, and during the 5-year period after logging was completed. This workshop proceedings summarizes preliminary results from the post-logging period. Topics discussed in the papers include changes in watershed hydrology, stream channel morphology, and large woody debris; changes in sediment loads and streambed composition; changes in dissolved ions and stream temperature; effects of logging on terrestrial vegetation; responses of stream invertebrates and autotrophs to logging; and the effects of logging on juvenile coho salmon and cutthroat trout.

49. Chamberlin, TW. 1982. *Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America. No. 3. Timber Harvest*. WR Meehan, tech. ed. General Technical Report PNW-136, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 30 pp.

This is a general review of the effects of clearcut harvesting on salmonid stream habitat. It includes generalized discussions of the effects of harvesting on water depth and velocity, suspended sediments, stream temperature, dissolved oxygen, nutrients, streambed material, stream banks, large woody debris, and riparian vegetation. Chamberlin concludes that water quality problems are directly related to the amount of harvested area within a basin, and that direct impacts on stream habitat can be minimized by leaving riparian buffer strips or through careful design and execution of logging.

50. Chamberlin, TW, RD Harr, and FH Everest. 1991. Timber harvesting, silviculture, and watershed processes, pp. 181–205 in *Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitat*, WR Meehan, ed. American Fisheries Society, Bethesda, MD.

This book chapter is a comprehensive review of how forest management activities can affect watershed processes. Activities discussed include timber felling and yarding, site preparation, stand regeneration, vegetation management, thinning, and final harvest. Timber management interactions with salmonid habitat in small streams are presented first, followed by the possible effects of management activities on watershed hydrologic processes (stream flow, water balance, evapotranspiration, soil water, soil structure, water quality, temperature, suspended sediment, dissolved oxygen, and nutrients). Other topics include the effects of timber harvest on erosion, sedimentation, stream channel form, and geomorphic processes, as well as the possible cumulative effects of timber management on biophysical processes and fish habitats. The authors conclude the chapter with suggestions for altering timber management schemes to minimize negative effects on watersheds.

51. Chambers, CL, and WC McComb. 1997. Effects of silvicultural treatments on wintering bird communities in the Oregon Coast Range. *Northwest Science* 71(4): 298–304.

The authors assessed the responses of wintering birds to three silvicultural treatments in Oregon Coast Range Douglas-fir forests. Stands were 80–120 years old at the time of harvest. Harvest treatments included 1) small-patch group selection, 2) two-story cut, and 3) clearcut with reserves. Harvested stands were compared with an unharvested control. Winter bird abundance was highest in small-patch group harvest stands and lowest in clearcuts. Species richness was highest in small-patch treatments and lowest in control and clearcut stands. Steller's jays and golden-crowned kinglets were most abundant in control and small-patch stands. Spotted towhees were most abundant in two-story stands. Dark-eyed juncos were more abundant in harvested stands than in unharvested stands. Winter wren and song sparrow abundances were similar in all stands. The authors conclude that more winter bird species will be found in stands receiving silvicultural treatments that retain structural and vegetation composition complexity, or in stands that quickly develop late-successional characteristics, than in those that regenerate after traditional clearcutting.

52. Chambers, CL, WC McComb, and JC Tappeiner II. 1999. Breeding bird responses to three silvicultural treatments in the Oregon Coast Range. *Ecological Applications* 9(1): 171–185.

The authors assessed bird responses to three silvicultural treatments in Oregon Coast Range Douglas-fir stands. Stands were 80–120 years old at time of harvest. Harvest treatments included 1) small-patch group selection, 2) two-story cut, and 3) clearcut with reserves. Harvested stands were compared with an unharvested control stand. Small-patch stands and control stands were similar in bird species composition and abundance; two-story and clearcut stands were also similar to each other.

Birds that remained abundant in the small-patch group and control stands but declined in the two-story and clearcut harvests were chestnut-backed chickadees, brown creepers, Steller's jays, red-breasted nuthatches, winter wrens, golden-crowned kinglets, Swainson's thrushes, hermit warblers, Wilson's warblers, and western tanagers. Birds that increased in response to harvesting, on the other hand, included willow flycatchers, house wrens, MacGillivray's warblers, spotted towhees, white-crowned sparrows, American goldfinches, olive-sided flycatchers, brown-headed cowbirds, and purple finches. Birds that showed no detectable response to harvesting treatment were rufous hummingbirds, northern flickers, red-breasted sapsuckers, hairy woodpeckers, Pacific-slope flycatchers (western flycatchers), gray jays, bushtits, American robins, orange-crowned warblers, black-throated gray warblers, black-headed grosbeaks, and dark-eyed juncos. The authors conclude that silvicultural treatments imitating low-intensity disturbances were most effective in retaining bird communities associated with mature forest, whereas high-intensity disturbances such as the two-story and clearcut with reserves treatments greatly altered bird community composition.

53. Cheng, C, JP Kimmins, and TP Sullivan. 1996. Forest fertilization with biosolids: Impact on small mammal population dynamics. *Northwest Science* 70(3): 252–261.

This study examined fertilization of British Columbia forests with sewage sludge (biosolids) and the potential effects of this fertilization on small mammals. Fifteen-year-old Douglas-fir stands were fertilized with sludge and compared with similar unfertilized stands. Small mammals were trapped 6 months before fertilization and 1 year afterwards. Fertilized and unfertilized sites showed no detectable differences in the abundances of deer mice, Townsend's chipmunks, or creeping voles; other species were caught too infrequently for analysis. There were no differences in recruitment, survival, mean body weight, or species diversity among the three main species. The authors caution that other wildlife groups may show more sensitivity to sludge applications than these species, and that more research is needed before sludge is applied on a larger scale.

54. Cole, EC, WC McComb, M Newton, CL Chambers, and JP Leeming. 1997. Response of amphibians to clearcutting, burning, and glyphosate application in the Oregon Coast Range. *Journal of Wildlife Management* 61(3): 656–664.

After selected red alder stands were logged in the Oregon Coast Range, the authors examined the effects of clearcutting and site preparation on small mammal capture rates. Treatments on each site included an unharvested red alder stand, a clearcut followed by broadcast burning, and a clearcut followed by broadcast burning and late-summer application of glyphosate herbicide. After site preparation, clearcuts were planted with Douglas-fir seedlings. All sites included uncut riparian buffers. Amphibians were sampled within each treatment unit and within the buffers. Two years after treatment, logging did not appear to have affected capture rates of rough-skin newts, Dunn's salamanders, or red-legged frogs. Capture rates of ensatinas and Pacific giant salamanders decreased after logging and burning, while rates for western redback salamanders increased. Herbicide applications did not affect capture rates for any species on the logged and burned units. On the basis of available studies, the authors suggest that retaining riparian buffer strips may be necessary for maintaining Pacific giant salamander populations. When red alder stands are converted to Douglas-fir, some alder should be left adjacent to streams to provide long-term habitat for rough-skin newts, red-legged frogs, and other hardwood associates.

55. Cole, EC, WC McComb, M Newton, JP Leeming, and CL Chambers. 1998. Response of small mammals to clearcutting, burning, and glyphosate application in the Oregon Coast Range. *Journal of Wildlife Management* 62(4): 1207–1216.

The authors captured small mammals at three sites in the Oregon Coast Range and assessed the effects of logging red alder and site preparation on these capture rates. Treatments were an unharvested red alder stand, clearcut followed by broadcast burning, and clearcut followed by broadcast burning and a later summer application of glyphosate herbicide. All sites included uncut riparian buffers. Small mammals were trapped in the three treatments and the riparian buffers. Two years after treatment, creeping vole and vagrant shrew captures increased on the logged treatments, while Pacific shrew and Trowbridge's shrew captures decreased. Townsend's chipmunk capture rates increased in the buffers bordering the logged units. Overall capture rates of deer mice were similar in all treatments. In the logged and burned areas, capture rates for the six species did not differ between areas with and without glyphosate applications.

56. Connolly, PJ, and JD Hall. 1999. Biomass of coastal cutthroat trout in unlogged and previously clear-cut basins in the central Coast Range of Oregon. *Transactions of the American Fisheries Society* 128: 890–899.

Resident cutthroat trout populations were sampled in previously clearcut basins in the Oregon Coast Range to characterize the populations and habitats of age-1 or older trout within three forest management types. Headwater streams were either in basins logged 20–30 or 40–60 years prior to the study or in basins with no or very sparse logging (<20%) and covered by 125- to 150-year-old Douglas-fir forests. No streams in the logged basins included riparian buffer strips at the time of harvest. No statistical difference was detected in trout biomass, trout density, or mean weight of individuals. Streams in basins logged 20–30 years ago supported the widest range of trout biomass, including both the lowest and the highest biomasses among all sampled streams. Streams in basins logged 40–60 years ago supported low levels of biomass but an intermediate range of biomass values. Streams in unlogged basins had relatively low levels of biomass and a small range of values. Large woody debris (LWD) was the variable that best explained the differences in trout biomass among the streams. All streams were shaded by mostly closed tree canopies. Deciduous trees were more prominent in canopies over harvested streams, while conifers were more prominent in unlogged basins. The authors suggest that trout production in basins extensively clearcut 20–60 years ago may generally decrease or remain low over the next 50 or more years because of the decreasing amounts of remnant LWD, persistent low recruitment potential for new LWD, and persistent heavy shading by conifers.

57. Corn, PS, and RB Bury. 1989. Logging in western Oregon: Responses of headwater habitats and stream amphibians. *Forest Ecology and Management* 29(1/2): 39–57.

The authors compared the occurrence and abundance of four amphibian species in streams surrounded by uncut or clearcut Douglas-fir forests in the Oregon Coast Range. Uncut forests had naturally regenerated after fires and ranged from 60 to >400 years old. Clearcuts were logged 14–40 years before the study. Species richness was highest in streams surrounded by uncut forest. Density and biomass of each species (Pacific giant salamander, Olympic salamander, Dunn's salamander, and tailed frog) were also higher in uncut forested streams. Past logging upstream from an uncut forest did not appear to affect the presence, density, or biomass of any of the amphibian species. The authors were unable to determine whether populations currently in logged areas are those that were there before clearcutting or are the results of recolonization. They suggest that tailed frogs and Olympic salamanders may be extirpated from headwater streams traversing clearcuts, and that recolonization may be poor because the species are not capable of long-distance terrestrial travel, suggesting a need for protecting headwater streams in management plans.

58. Crocker-Bedford, DC. 1990. Goshawk reproduction and forest management. *Wildlife Society Bulletin* 18(3): 262–269.

This study assessed the adequacy of leaving timber harvest buffer zones around northern goshawk nests to maintain nest fidelity and reproduction. Nests were located in an Arizona ponderosa pine forest that had been partially cut 30–40 years prior to the study. The area was scheduled for partial harvesting again in the early 1980s. During the pre-sale period, all current and historic goshawk nests were found, and small (1.2–2.4 ha) or large (16–200 ha) buffer zones were marked. Afterwards, goshawk nest reoccupancy was monitored from 1985 to 1989 and compared with surveys conducted in the same stands during 1973–1978 and 1981–1984. Reproduction success in the harvested areas and unharvested control stands was determined during 1989. Regardless of size, the buffer zones did not maintain goshawk reproduction; occupancy rates were 75%–80% lower in harvested areas than in controls, and nestling production was 94% lower. Other raptors (red-tailed hawks, great horned owls, long-eared owls, Cooper's hawks) replaced goshawks in most of the logged goshawk territories. Where logged territories remained occupied by goshawks, much less canopy volume had been removed than in the abandoned areas, and the goshawk pairs also had other nests available in nearby unharvested forest tracks.

59. Cross, S. 1985. Responses of small mammals to forest riparian perturbations, pp. 269–275 in *Riparian Ecosystems and Their Management: Reconciling Conflicting Uses—First North American Riparian Conference*, April 16–18, 1985, RR Johnson, CD Ziebell, DR Patton, PF Ffolliott, and RH Hamre, tech. eds. General Technical Report RM-120, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 523 pp.

This paper reviews three different trapping studies examining the responses of small mammals to disturbances in southwestern Oregon forests. The Soda Creek study in the southwestern foothills of the Cascades compared small mammal abundance, community composition, and diversity in a conifer-dominated riparian zone (Douglas-fir, bigleaf maple, and white alder), the riparian–upland transition zone (Douglas-fir, grand fir, western redcedar, and bigleaf maple), and the upland zone (Douglas-fir, western redcedar, and Pacific madrone). Small mammal species richness was greatest in the riparian zone and least in the upland zone.

The Louis Creek study, also in the Cascades, compared small mammal populations in old-growth riparian (western hemlock), transition (western hemlock, western redcedar, grand fir, and Douglas-fir), and upland (Douglas-fir and grand fir) zones. These old-growth areas were compared with a nearby clearcut with riparian zones that was logged in 1977 and sprayed with herbicides annually from 1978 to 1981. Trapping was done in 1981. Species richness in the old-growth area was higher in the riparian and transition zones than in the upland zone. In the clearcut area, species richness, abundance, and diversity were highest in the riparian zone. Species richness was higher in the old-growth riparian zone than in the clearcut riparian zone.

The Middle and Sourgrass Creek study in the Klamath Mountains assessed the effect of leaving a riparian buffer strip and transition zone vegetation alongside a clearcut. Middle Creek old-growth forests were dominated by Douglas-fir and grand fir, and the buffer strips were dominated by Oregon ash, vine maple, and red alder. Forests at Sourgrass Creek were dominated by Douglas-fir and western hemlock, with some red alder in the understory of the buffer strip. The buffer strips were compared with old-growth forests; the clearcuts themselves were not sampled. One year after logging, small mammal frequencies, species diversity, and species evenness were similar in the buffer strips and the old-growth forests at both sites.

On the basis of these three studies, the author concludes that riparian zones support a more diverse small mammal fauna than adjacent forested habitats. Severe disturbances in riparian habitats such as clearcutting may radically affect the presence and abundance of many species. Small mammal communities in riparian buffer strips are similar to those in undisturbed forests.

60. Crouch, GL. 1985. *Effects of Clearcutting a Subalpine Forest in Central Colorado on Wildlife Habitat*. Research Paper RM-258, USDA Forest Service, Rocky Mountain

Forest and Range Experiment Station, Fort Collins, CO. 12 pp.

This study examined the effects of creating 3-acre patch clearcuts on wildlife habitat in the Rocky Mountains of central Colorado. Subalpine old-growth forests consisting of Engelmann spruce, subalpine fir, and lodgepole pine were patch-clearcut in 1977 to enhance water flow in the watershed. Cut units were compared with adjacent uncut units; within each unit, dry areas were compared with moist areas (seeps, springs, or shallow drainages). Ground vegetation cover, forage production, and herbivore activity (elk, mule deer, snowshoe hares) were monitored from 1976 through 1982. After logging, understory plant production on the drier sites generally increased; it increased greatly on moist sites. Big game forage quality also improved after logging. Elk activity did not appear to change on either type of unit, but mule deer activity increased on both. Snowshoe hare activity decreased on the cut unit but remained the same on the uncut unit. Crouch considers the patch-cuts beneficial to big game and other species favoring open forest habitat; because the blocks were small and relatively few, they were neutral or only mildly negative for species favoring closed forest conditions.

61. Crouch, GL. 1986. *Effects of Thinning Pole-Sized Lodgepole Pine on Understory Vegetation and Large Herbivore Activity in Central Colorado*. Research Paper RM-268, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 10 pp.

Dense 65-year-old lodgepole pine stands were thinned to determine potential understory forage production and stand use by elk and mule deer. Stands were thinned to three different growing stock levels (GSL) and compared with an unthinned control (154 ft^2/ac basal area). Thinning treatments were GSL 120 (73 ft^2/ac basal area), GSL 80 (58 ft^2/ac), and GSL 40 (30 ft^2/ac). During the first 5 years after thinning, understory vegetation biomass, cover, and forage quality (moisture content, crude protein, and digestibility) increased substantially in the GSL 40 and GSL 80 treatments but not in the control or the GSL 120 treatment. Herbivore activity, based on fecal pellet group counts, was very low in the first 2 years after thinning but increased in the thinned stands during the following 3 years. Deer preferred the heavily thinned plots, but elk showed no preferences among the different thinning treatments.

62. Davis, PR. 1977. Cervid response to forest fire and clearcutting in southeastern Wyoming. *Journal of Wildlife Management* 41(4): 785–788.

Davis studied the responses of mule deer and elk to forest fires and clearcutting in the Wyoming Rocky Mountains. Study areas consisted of lodgepole pine and small patches of subalpine fir. Burned areas and clearcuts were of similar age since disturbance (5–10 years) and were compared with undisturbed natural openings dominated by grasses and forbs. Fecal pellet-group counts indicated that both mule deer and elk used burned plots, which had standing timber, more than they used clearcuts, which had none. Deer used the natural openings as much as or more than they used clearcuts, while elk used the natural openings more than clearcuts. There was a positive relationship between deer and elk use and the number of plant species in the plots. Davis suggests, however, that cover may be a more important factor than forage variety for predicting deer and elk use of recently burned or clearcut areas.

63. Davis, TM. 1998. Terrestrial salamander abundance in successional forests of coastal British Columbia. *Northwest Science* 72 (Special Issue No. 2): 89–90.

This paper briefly summarizes preliminary results of a study of the abundance of western redback and clouded salamanders in forests of different successional stages on Vancouver Island, British Columbia. Stands sampled included clearcuts (no age given) and young (25–45 years), mature (65–85 years), and old-growth (>200 years) forests. Salamander abundances were lowest in clearcuts but similar in young, mature, and old-growth stands.

64. DellaSala, DA, JC Hagar, KA Engel, WC McComb, RL Fairbanks, and EG Campbell. 1996. Effects of silvicultural modifications of temperate rainforest on breeding

and wintering bird communities, Prince of Wales Island, southeast Alaska. *Condor* 98: 706–721.

Breeding and wintering birds were inventoried in young and old-growth forests in southeastern Alaska to determine the effect of silvicultural treatments on bird communities. Young-growth stands were 20 years old and had naturally reseeded to western hemlock and Sitka spruce after the previous forest was clearcut; these stands were unmodified, precommercially thinned, or patch cut to create canopy gaps. Old-growth stands were >150 years old and dominated by western hemlock, Sitka spruce, and western redcedar; they were not modified. Stand vegetation was characterized after treatment. Total breeding bird and wintering bird abundance and species richness did not differ among the young stand types. Breeding bird abundance was lower in old-growth than in young stands, but species richness did not vary. Wintering bird abundance and species richness, on the other hand, were greater in old-growth stands. In young-growth stands, the authors recommend using variable spaced thinning instead of uniform thinning to create multiple canopy layers for the benefit of bird communities. Residual old-growth clumps should be retained to lessen the negative impact of thinning on forest canopy birds. Old-growth forests may also serve as important winter refugia for some species. The authors note that the Pacific-slope flycatcher and golden-crowned kinglet should be used as indicator species along with the currently used brown creeper and red-breasted nuthatch.

65. deMaynadier, PG, and ML Hunter, Jr. 1995. The relationship between forest management and amphibian ecology: A review of the North American literature. *Environmental Review* 3: 230–261.

The authors review North American literature examining the relationships between amphibian species and forest harvest practices, including several studies from the Pacific Northwest. Their review shows that some amphibian groups (such as salamanders) appear to be more sensitive to clearcutting than other groups (such as anurans). In most situations, clearcutting has negative short-term impacts on amphibian populations, especially salamanders. Research on the influence of forest age on amphibian populations suggests that the long-term impacts of clearcutting are variable; for many species, effects may be mitigated if forest regeneration practices leave adequate microhabitat structures, such as large woody debris, intact. Few studies have examined the effects of broadcast burning during site preparation on amphibians. Studies from the southeastern US suggest that amphibian species in ecosystems naturally disturbed by frequent fires may be at least behaviorally adapted to survive fire, but more rigorous research is needed. Forest roads may directly affect amphibians through road kill, particularly where roads cross dispersal and migration routes. Forest roads may also present a physical or psychological barrier to amphibian movements. Continuous populations that have become reduced in size and isolated by barriers may have higher extinction rates. The authors conclude by discussing problems often encountered in amphibian studies and listing areas of amphibian–forestry relationships needing research.

66. DeWeese, LR, CJ Henny, RL Floyd, KA Bobal, and AW Schultz. 1979. *Response of Breeding Birds to Aerial Sprays of Trichlorfon (Dylox) and Carbaryl (Sevin-4-oil) in Montana Forests*. Special Science Report 224, USDI Fish and Wildlife Service, Washington, DC. 29 pp.

The response of breeding birds to spraying of insecticides for the control of western budworms (*Choristoneura occidentalis*) was studied in Montana. The study area consisted of Douglas-fir and lodgepole pine forests intermixed with areas of grassland and sagebrush. Three treatments were used and replicated: no spraying (control), or aerial applications of insecticide (trichlorfon or carbaryl). After spraying, there was a slight decline in bird numbers on sprayed plots, although the change was not significant. Nesting success appeared similar in control and sprayed forests. No sick or dead birds were found, even though collected bird specimens had budworms in their stomachs and marker dye from the insecticides on their feathers and feet. Bird species residing in the forest canopies encountered the insecticides more often than those residing under the canopy or on the ground. The authors suggest that trichlorfon has more potential for negative effects on birds than carbaryl has, but neither compound posed a threat that was detectable for the application rates and field conditions used in this study.

67. Diller, LV, and RL Wallace. 1999. Distribution and habitat of *Ascaphus truei* in streams on managed, young growth forest in north coastal California. *Journal of Herpetology* 33(1): 71–79.

Tailed frog larvae were surveyed in first and second order streams to determine landscape variables affecting their distribution and habitat use in managed, young Douglas-fir/redwood forests in the northern California Coast Range. The stands within the study area ranged from 0 to 80 years old, and all had regenerated after extensive clearcutting. Stand age distribution was 0–9 years, 13%; 10–20 years, 16%; 21–60 years, 60%; and 61–80 years, 11%. Streams within stands harvested prior to 1973 were not protected during logging. Seventy-five percent of streams surveyed contained tailed frog larvae; geologic formation was the only landscape variable that predicted their presence in a stepwise logistic regression model.

A second survey was conducted to further define the microhabitat used by tailed frog larvae. Occurrence of larvae was positively associated with stream gradient and cobble, boulder, and gravel substrates with lower embeddedness, but there were negative associations with percent fine sediments and water temperature. Only stream gradients differed significantly between stream reaches; canopy cover, water temperature, and forest age did not. The presence of tailed frogs was closely tied to geology, with frogs found most often in streams with unconsolidated formations. Although the authors found an inverse relationship between larvae presence and forest age rather than the direct relationship reported by other authors, they believe this relationship may be a result of past harvesting patterns rather than a favoring of young forest landscapes by tailed frogs. They suggest that the coastal forests where unconsolidated geologic formations are likely to be encountered were harvested first in the region (late 1880s to early 1900s), so they now have the oldest second-growth forests. The more interior forests that are generally on consolidated geologic formations have been harvested within the last 30 years. The authors believe that geologic formation has such a profound effect on stream substrate condition that it may counteract the negative effect of young stand age on the presence of tailed frogs.

68. Diller, LV, and RL Wallace. 1994. Distribution and habitat of *Plethodon elongatus* on managed, young growth forests in north coastal California. *Journal of Herpetology* 28(3): 310–318.

Del Norte salamander distribution was studied on cut banks along forested roads on private timberland in northwestern California. Forests were dominated by redwood and Douglas-fir stands ranging from 0 to 90 years old. Del Norte salamanders were found most frequently in talus, in rocky substrate with an organic surface layer, and on northern slopes. They were negatively associated with mineral soils, exposed rocky substrates, southern slopes, and conifer/tanoak cover types. There was no relationship between forest age or canopy cover and salamander density or presence. The data indicated that the salamanders colonize roadside areas from the adjacent forest and that talus and rocky substrates are very important to the species.

69. Diller, LV, and RL Wallace. 1996. Distribution and habitat of *Rhyacotriton variegatus* on managed, young growth forests in north coastal California. *Journal of Herpetology* 30(2): 184–191.

The authors examined the distribution and habitat of southern torrent salamanders in streams flowing through young managed forests on private timber lands in northern California. Forests were dominated by both coast redwood and Douglas-fir, with Douglas-fir predominating on the drier sites. Forests were 0- to 80-year-old second- and third-growth stands that included clearcuts, sapling/poletimber, small sawtimber, and large sawtimber. The only landscape variable that predicted the presence of southern torrent salamanders was geological formation. Stream surveys indicated that reaches with torrent salamanders had steeper slopes, more small boulders, and less sand than reaches without salamanders. Because the consequences

of past harvesting activities were unknown, the authors were unable to directly relate the presence or absence of torrent salamanders to the surrounding forests or to management practices. Previous unregulated timber harvest practices probably reduced the number of individuals in most headwater streams in consolidated geologic areas.

70. Doerr, JG, CL Barescu, JM Brighenti, Jr., and MP Morin. 1984. Use of clearcutting and old-growth forests by male blue grouse in central southeast Alaska, pp. 309–313 in *Fish and Wildlife Relationships in Old-Growth Forests*, WR Meehan, TR Merrell, Jr., and TA Hanley, eds. American Institute of Fishery Research Biologists, Morehead City, NC.

Habitat use by male blue grouse in southern Alaska was compared in clearcuts and adjacent old-growth forests. Forests were dominated by western hemlock and Sitka spruce. Clearcut areas had been harvested 1–23 years before the study. There were more male blue grouse in old-growth forests than in clearcuts. Grouse territories in forests did not appear to be related to the distance from clearcuts or other stand openings.

71. Doerr, JG, and NH Sandburg. 1986. Effects of precommercial thinning on understory vegetation and deer habitat utilization on Big Level Island in southeast Alaska. *Forest Science* 32(4): 1092–1095.

Twelve years after treatment, the authors studied the effects of precommercial thinning on understory vegetation development and habitat use by Sitka black-tailed deer in stands of Sitka spruce and western hemlock in southeastern Alaska. All unthinned portions of the stands had dense overstory canopy cover, low understory cover, and low deer use. The thinned areas had significantly more deciduous browse cover and more deer use than the unthinned areas. The authors recommend that future thinnings should be done in the precommercially thinned stands to prevent the canopy from closing and reducing understory growth.

72. Duncan, JR. 1997. Great gray owls (*Strix nebulosa nebulosa*) and forest management in North America: A review and recommendations. *The Journal of Raptor Research* 31(2): 160–166.

Information about the effects of forest management on great gray owls in the Pacific Northwest is limited. This paper reviews North American information on great gray owl population trends, habitat use, and nest site and foraging habitat availability. Duncan discusses the effects of forest harvesting (including clearcut size, shape, and residual trees) on owl populations and makes recommendations regarding these practices.

73. Dupuis, LA. 1997. Effects of logging on the terrestrial amphibians of coastal British Columbia, pp. 185–190 in *Amphibians in Decline: Canadian Studies of a Global Problem*, DM Green, ed. *Herpetological Conservation* 1.

Amphibian abundance was compared in old-growth, commercially mature (54–72 years old), and young (17–18 years old) Douglas-fir/western hemlock forests on Vancouver Island, British Columbia. The mature and young stands had regenerated after clearcutting. The western redback salamander was the most abundant species caught; infrequently caught species included roughskin newts and northwestern, ensatina, and clouded salamanders. More salamanders were found in old-growth than in managed stands. However, densities of salamanders in managed stands within 10 m of streams were similar to those in old-growth stands. Low amphibian densities in managed stands indicate unfavorable conditions and may be related to moisture stress. Managed stands lacked large pieces of downed wood that could provide favorable microclimates for salamanders. Managed stands that were isolated from old-growth stands had fewer salamanders than stands adjacent to old growth.

74. Dupuis, LA, and FL Bunnell. 1999. Effects of stand age, size, and juxtaposition on abundance of western redback salamanders (*Plethodon vehiculum*) in coastal British Columbia. *Northwest Science* 73(1): 27–33.

Western redback salamanders were studied in British Columbia to determine the potential effects of stand age, stand size, and proximity to favored habitat on their populations.

Stands were dominated by Douglas-fir and western hemlock and included old-growth (>330 years), managed mature (54–77 years), managed young (17–18 years), and clearcut (5 years) forests. Western redback salamanders were more abundant in large old-growth stands than in other stand types. In mature stands, no relationship was found between stand or patch size and salamander density. Managed stands had more salamanders present when adjacent to old-growth stands. Low juvenile:adult ratios within managed stands not adjacent to old-growth stands suggest poor survival among juveniles in young stands.

75. Dupuis, LA, JNM Smith, and F Bunnell. 1995. Relation of terrestrial-breeding amphibian abundance to tree-stand age. *Conservation Biology* 9(3): 645–653.

Amphibians in old-growth and managed stands were studied to determine possible relationships between stand age and amphibian abundance. Stands were located on Vancouver Island, British Columbia, and were dominated by Douglas-fir and western hemlock. Sites included unmanaged old-growth (>330 years old), managed mature (54–72 years), managed young (17–18 years), and clearcut (5 years) stands. Western redback salamanders were the most abundant species, with densities greatest in old-growth stands. Salamanders decreased with decreasing stand age and were absent from the clearcuts. In managed stands, there were more salamanders near streams than in the interior. The authors recommend that moist microhabitats be promoted in managed stands by leaving large woody debris, shade-producing understory vegetation, and streamside buffers.

76. Easton, WE, and K Martin. 1998. The effect of vegetation management on breeding bird communities in British Columbia. *Ecological Applications* 8(4): 1092–1103.

The authors examined the responses of bird communities to the removal of hardwood trees (stand release) in young conifer plantations in southern British Columbia. Stand treatments included using glyphosate herbicide to kill hardwoods, manually removing hardwood trees, and untreated controls; conifer species and stand ages were not specified. After treatment with glyphosate, the number of bird species decreased but the number of individuals increased. After manual treatment, species numbers, the number of individuals, and species evenness all increased. Bird species turnover was highest in herbicide-treated areas and lowest in untreated controls. Nesting success of open-cup nesting species was significantly lower in herbicide-treated areas than in manually treated areas where hardwoods had resprouted. The authors conclude that the composition of bird communities became more homogenous after herbicide release treatment, whereas communities showed little change after manual release treatment.

77. Edge, WD, CL Marcum, and SL Olson. 1985. Effects of logging activities on home range fidelity of elk. *Journal of Wildlife Management* 49(3): 741–744.

The authors radio tracked cow elk in Douglas-fir/subalpine fir forests in the Garnet Mountains of Montana to determine the effects of logging activities on elk home ranges. Forests covered 85% of the study area. Unforested areas were in pasture, hay fields, clearcuts, riparian areas, meadows, scree, and roads. Timber harvest activities were monitored for intensity from 1977 through 1983. Each elk was tracked for 2 consecutive years. Mean home range area and mean fidelity coefficients were not significantly higher during years with no logging than when logging disturbances occurred in 1 of the 2 tracking years. The authors suggest that cow elk will not abandon traditional home ranges because of logging activities as long as extensive areas of cover remain available; in areas where cover is limited, logging activity may increase home range size and reduce home-range fidelity.

78. Erickson, JL. 1993. *Bat Activity in Managed Forests of the Southwestern Cascade Range*. MS thesis, University of Washington, Seattle.

Bats were surveyed in managed stands in the southwestern Washington Cascade Range to determine their relative use of habitat types. Stands were dominated by western hemlock and Douglas-fir and represented a gradient of forest development including clearcuts (3–7 years), sapling/poletimber (12–20 years), and mature/sawtimber (50–60 years). Except for Townsend's big-eared bat, which was detected equally often in each stand type, bat species or species groups used the different habitat types at different frequencies. Big brown bats and silver-haired bats were detected most often in the clearcut and sometimes in the sapling/pole habitat, but not in the mature/sawtimber. *Myotis* species (long-eared myotis, long-legged myotis, Keen's myotis, small-footed myotis, California myotis, Yuma myotis, and little brown myotis) were detected most often in the mature/sawtimber stands, with fewer detections in the younger stand types. Species richness was highest in the sapling/pole stands. Activity and feeding patterns suggest that clearcuts and sapling/pole stands are used for foraging but not for roosting.

79. Erickson, JL. 1993. Bat activity in managed forests of the western Cascade Range. *Bat Research News* 34(2&3): 56.

Patterns of habitat use by bats were studied in the western Washington Cascade Range. Bats were monitored in three stand types (five stands per type): clearcut (3–7 years old), sapling/poletimber (12–20 years), and commercially mature timber (50–60 years). Results are preliminary; however, the mean number of bat detections per hour was twice as high in clearcut and mature stands as in sapling pole stands.

80. Erickson, JL, and SD West. 1996. Managed forests in the western Cascades: The effects of seral stage on bat habitat use pattern, pp. 215–227 in *Bats and Forests Symposium*, RMR Barclay and RM Brigham, eds. B.C. Ministry of Forests, Victoria, B.C.

Habitat use by bats was assessed across a gradient of intensive forest management conditions to determine the possible effects of these practices on bat populations. The study was conducted in Douglas-fir forests in the Washington Cascade Range. Stands included clearcut (2–3 years old), precommercially thinned (12–20 years), young unthinned (30–40 years), and commercially mature (50–70 years) forests. Overall, the most bat echolocation calls were detected in clearcuts; mature stands had the second highest number of detections, with very few calls detected in precommercially thinned stands, and none in young unthinned stands. The big brown bat, silver-haired bat, and Townsend's big-eared bat were detected most frequently in clearcuts and not at all in unthinned or mature stands. *Myotis* species (California myotis, long-eared myotis, fringed myotis, Yuma myotis, long-legged myotis, and little brown myotis) were detected in all stands except unthinned stands, with most detections in mature stands. The authors conclude that young, unthinned, and precommercially thinned stands are not suitable habitat for forest dwelling bats; high tree densities may impede flight and snags may be too small for use as roosts. Activity levels suggest that clearcuts are used strictly for foraging.

81. Evans, DM, and DM Finch. 1994. Relationships between forest songbird populations and managed forests in Idaho, pp. 308–314 in *Sustainable Ecological Systems: Implementing an Ecological Approach to Land Management*, WW Covington and LF DeBano, tech. coords. General Technical Report RM-247, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 363 pp.

Bird species composition and abundance were compared in managed and unmanaged forested watersheds in west central Idaho. Forests were dominated by Douglas-fir; management techniques were not described. Preliminary results indicated that hermit thrushes, Swainson's thrushes, pileated woodpeckers, and warbling vireos were less abundant in managed than in unmanaged areas. Birds more common in managed watersheds, on the other hand, included northern flickers, olive-sided flycatchers, Hammond's flycatchers, American crows, common ravens, ruby-crowned kinglets, American robins, solitary vireos, yellow-rumped warblers, MacGillivray's warblers, western tanagers, and chipping sparrows. Species that did not differ between the two forest types were dusky flycatchers, Townsend's warblers, brown creepers, golden-crowned kinglets, dark-eyed juncos, brown-headed cowbirds, Cassin's finches, pine siskins, hairy woodpeckers, Steller's jays, mountain chickadees, red-breasted nuthatches, and red crossbills.

82. Everest, FH, RL Beschta, JC Scrivener, KV Koski, JR Sedell, and CJ Cederholm. 1987. Fine sediment and salmonid production: A paradox, pp. 98–142 in *Streamside Management: Forestry and Fishery Interactions,* EO Salo and TW Cundy, eds. Contribution no. 57, Institute of Forest Resources, College of Forest Resources, University of Washington, Seattle.

This paper reviews the role of fine sediment in salmonid streambeds, the effects of forest management activities (road construction, felling, yarding, prescribed burning, site preparation) in causing excess sedimentation, and the way streams move excess sediment. Studies from the Pacific Northwest (including British Columbia) are used as examples, but many of these studies were carried out before the advent of current forest practice regulations. The authors recommend that forest managers should maintain the integrity of stream and streamside zones rather than focusing their attention on one variable such as excessive sedimentation; although water quality has improved under recent forest practices, streamside harvesting and removal of large woody debris from channels have decreased salmonid habitat structure. They also suggest that forest managers use a multi-disciplinary staff to develop site-specific management prescriptions rather than relying on one set of guidelines for all sites.

83. Everest, FH, and RD Harr. 1982. *Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America. No 6. Silvicultural Treatments.* WR Meehan, tech. ed. General Technical Report PNW-134, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 19 pp.

This general report discusses salmonid stream habitat requirements and how silvicultural activities may affect the stream environment. Activities discussed included broadcast burning, mechanical site preparation, and vegetation management. The authors suggest that the impacts associated with these silvicultural activities are generally much lower than those associated with road construction and timber harvest.

84. Everest, FH, and WR Meehan. 1981. Forest management and anadromous fish habitat productivity, pp. 521–530 in *Transactions of the 46th North American Natural Resources Conference,* Wildlife Management Institute, Washington, DC.

This paper reviews information on the interrelationships between salmonid fish habitat and timber harvesting, road construction, and livestock grazing in the Pacific Northwest. Detailed discussions include the effects of organic debris (large wood and fine organic debris from timber harvests) and its removal on fish habitat. The effects of mass soil movements on fish habitat are presented, along with results from a study of debris torrents in Oregon Coast Range streams. Preliminary results from a study examining the relationship between different livestock grazing systems and fish habitat are also presented.

85. Everest, FH, JR Sedell, NB Armantrout, TE Nickelson, SM Keller, JM Johnston, WD Parante, and GN Haugen. 1985. Salmonids, pp. 199–230 in *Management of Wildlife and Fish Habitats of Western Oregon and Washington: Part 1. Chapter Narratives*, ER Brown, ed. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

This paper reviews salmonid species biology, habitat requirements for juvenile and adult anadromous and resident salmon, spawning and egg incubation requirements, and the effects of forest harvesting and road construction on salmonid populations and stream habitat. The paper concludes with some basic management considerations for road construction and maintenance, scheduling and design of timber operations, felling, bucking, yarding, and debris management, and stand regeneration.

86. Fagen, R. 1988. Population effects of habitat change: A quantitative assessment. *Journal of Wildlife Management* 52(1): 41–46.

Fagen used a model based on ecological habitat selection to predict changes in Sitka black-tailed deer populations after clearcutting of old-growth forests in southeastern Alaska. The model indicates that when old-growth conifer forests are replaced by large areas of clearcuts and young, dense second-growth forest, deer populations will be severely impacted, particularly during heavy snowfall years. The deer must expend high amounts of energy to reach forage in snow-covered clearcuts and young open stands where forage availability is often low. The value of old-growth forests to deer increases substantially during such years because the overstory canopy blocks much of the snow and allows for easier movement and increased availability of forage.

87. Feller, MC. 1981. Effects of clearcutting and slashburning on stream temperature in southwestern British Columbia. *Water Resources Bulletin* 17(5): 863–867.

Changes in stream water temperature were examined in watersheds in southwestern British Columbia that had been clearcut with and without burning. Watersheds were dominated by western hemlock, western redcedar, and Douglas-fir. Two watersheds that had regenerated after fires in 1868 were clearcut logged without riparian buffer strips in 1973, and one of them was broadcast burned to reduce slash in 1974. A third watershed, used as a control, had regenerated after logging in the 1920s and was left uncut. Stream temperatures were monitored from 1972 to 1980. Both clearcutting treatments increased mean summer temperatures and summer daily temperature fluctuations. The clearcut/no burn stream returned to pre-treatment temperatures 6–7 years after logging; the clearcut/burn stream still had elevated temperatures 7 years after logging. Winter stream temperatures increased in the clearcut/no burn stream and decreased in the clearcut/burn stream but returned to pre-logging levels after 4 years on both streams. Feller concludes that clearcutting followed by burning has a greater impact on stream temperatures than clearcutting alone.

88. Finley, JRB. 1965. Adverse effects on birds of phosphamidon applied to a Montana forest. *Journal of Wildlife Management* 29(3): 580–591.

Forest areas in Montana were sprayed with the insecticide phosphamidon to determine the chemical's effectiveness in controlling spruce budworms (*Choristoneura fumiferana*) and its possible toxic effects on birds. Forests were dominated by Douglas-fir, western larch, and ponderosa pine. Birds were counted on sprayed and unsprayed areas the week before spraying, the week following spraying, and the fifth week after spraying. Negative effects were immediate. Some birds were killed by the insecticide, and others exhibited signs of nervous system disorders known to occur after exposure. Two sick grouse tested for cholinesterase activity levels showed severe inhibition of cholinesterase. During the first week after spraying, bird activity decreased on the sprayed block but increased on the unsprayed block. In the fifth week after spraying, bird activity on the sprayed block had recovered and was greater than before spraying.

89. Folliard, LB, LV Diller, and KP Reese. 1993. Occurrence and nesting habitat of northern spotted owls in managed young-growth forests in northwestern California. *Journal of Raptor Research* 27(1): 69.

Northern spotted owls were surveyed in managed second-growth Douglas-fir/redwood forests in northern California to determine occurrence and nesting habitat. The relative density of owl sites was influenced by the amount of forest older than 45 years; the median age of stands with nests was 59 years. These conifer nest stands were dominated by trees with diameters ranging from 53 to 90 cm. The authors conclude that the rapid tree growth and abundant prey base of coastal Douglas-fir/redwood forests make them suitable for owl habitat at an early age. They speculate that owl habitat can develop faster after timber harvests in this region than in any other region within the spotted owl's range.

90. Forsman, ED, RB Bruce, MA Walter, and EC Meslow. 1987. A current assessment of the spotted owl population in Oregon. *Murrelet* 68(2): 51–54.

This paper presents summary information on northern spotted owl surveys conducted in western Oregon from 1969 to 1984. Spotted owls were identified in the Coast and Cascade Ranges in several forest types but were confined to mountainous areas characterized by conifer or mixed conifer/hardwood forests. The survey supports the assumption that spotted owls are dependent on older forests and that owl numbers are declining as these older forests are harvested.

91. Forsman, ED, EC Meslow, and MJ Strub. 1977. Spotted owl abundance in young versus old-growth forests, Oregon. *Wildlife Society Bulletin* 5(2): 43–47.

Northern spotted owls were surveyed in second- and old-growth stands in Oregon's Coast and Cascade Ranges to determine their abundance in managed second-growth Douglas-fir stands. Stands sampled were 20–35 years old, 36–45 years, 46–60 years, 61–80 years, and >200 years. Considerably more spotted owl pairs were found in old-growth than in second-growth stands; no owl broods were found in second-growth stands. Owls present in second growth were usually found near adjacent old-growth patches, if patches were present.

92. Franzreb, KE. 1977. *Bird Population Changes After Timber Harvesting of a Mixed Conifer Forest in Arizona*. Research Paper RM-184, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 26 pp.

Franzreb studied the relationship between bird population changes and overstory removal in the mixed conifer forests of the Arizona White Mountains. Stands were dominated by Douglas-fir, subalpine fir, Engelmann spruce, white fir, and quaking aspen. Bird species composition and density differed in harvested and uncut stands. During the summer, total bird densities were higher in uncut stands than in harvested stands. Species that benefited from harvesting were American kestrels, great horned owls, yellow-bellied sapsuckers, olive-sided flycatchers, violet-green swallows, house wrens, American robins, western bluebirds, warbling vireos, and dark-eyed juncos. Species negatively affected were Pacific-slope (western) flycatchers, mountain chickadees, white-breasted nuthatches, red-breasted nuthatches, pygmy nuthatches, brown creepers, hermit thrushes, Townsend's solitaires, golden-crowned kinglets, ruby-crowned kinglets, yellow-rumped warblers, and red-faced warblers. The report also presents individual species preferences for tree species and tree heights.

93. Franzreb, KE, and RD Ohmart. 1978. The effects of timber harvesting on breeding birds in a mixed-coniferous forest. *Condor* 80: 431–441.

Differences in the responses of individual bird species to selective harvesting were determined in a mixed-conifer forest in the White Mountains of Arizona. Forests were dominated by Douglas-fir, ponderosa pine, and southwestern white pine. The harvested stand was compared with an unmanaged forest (no stand ages given). After harvest, birds were more abundant in the unharvested plot than in the harvested plot. Species that foraged by timber-gleaning or foliage-searching were the most adversely affected by logging. The authors note that the number of bird species and population sizes differed more between years than between plots, suggesting that the year (reflecting winter and/or spring conditions) may have influenced bird populations more than timber harvesting did.

94. Fredriksen, RL, DG Moore, and L Norris. 1975. The impact of timber harvest, fertilization, and herbicide treatment on stream water quality in western Oregon and Washington, pp. 283–313 in *Forest Soils and Land Management*, B Bernier and C Winger, eds. Laval University Press, Quebec.

This paper reviews the effects of natural processes and forest management practices on stream water quality in the Douglas-fir region of western Oregon and Washington. Watershed studies in the Coast and Cascade Ranges are used to illustrate soil erosion, stream sedimentation and native nutrient outflow, fertilizers, and herbicides in streams. Forest management practices discussed include road construction, clearcutting, broadcast burning, stand fertilization, and herbicide applications.

95. Gashwiller, JS. 1970. Plant and mammal changes on a clearcut in west-central Oregon. *Ecology* 51(6): 1018–1026.

Plant and small mammal communities were compared between a clearcut and an old-growth Douglas-fir forest in the Oregon Cascade Range. Sites were monitored for 10 years after one site was clearcut harvested and burned.

Ground vegetation was reduced after harvesting and burning but quickly increased so that cover levels and species numbers were higher than those in the old-growth stand. Deer mice, Townsend's chipmunks, creeping voles, and snowshoe hares increased on the clearcut after harvesting. Western red-backed voles, Douglas' squirrels, and northern flying squirrels, however, were found only in the old-growth stand.

96. Gomez, DM, and RG Anthony. 1996. Amphibian and reptile abundance in riparian and upslope areas of five forest types in western Oregon. *Northwest Science* 70(2): 109–119.

The authors examined species composition and relative abundance of amphibians and reptiles in riparian and upslope forested habitats at different seral stages in the Oregon Coast Range. Forest types sampled were shrub/conifer (trees 5–10 years old), open sapling/poletimber (20–35 years), large sawtimber (110–200 years), old growth (>200 years), and deciduous hardwood (no age given). Young conifer stands were dominated by Douglas-fir, old-growth stands by both Douglas-fir and western hemlock, and hardwood stands by red alder and bigleaf maple. Herpetofauna species richness was similar among forest types, but species abundance varied. Total captures of animals were highest in the hardwood forests and lowest in the young conifer stands. Tailed frogs, Dunn's salamanders, roughskin newts, Pacific giant salamanders, and red-legged frogs were captured most often in riparian habitat. Ensatinas were caught most often in upslope conifer habitat. Northern alligator lizards were more abundant in the shrub/sapling habitat than in any other forest type. The authors suggest that tailed frogs, Dunn's salamanders, and roughskin newts are riparian associates, but ensatinas are an upslope forest associate.

97. Gomez, DM, and RG Anthony. 1998. Small mammal abundance in riparian and upland areas of five seral stages in western Oregon. *Northwest Science* 72(4): 293–302.

This paper examines species composition and relative abundance of small mammals in riparian and upslope forest habitats among five seral stages in the Oregon Coast Range. Forest seral stages sampled were shrub/conifer (trees 5–10 years old), open sapling/poletimber (20–35 years), large sawtimber (110–200 years), old-growth (>200 years), and deciduous hardwood (no age given). Young conifer stands were dominated by Douglas-fir, old-growth stands by both Douglas-fir and western hemlock, and hardwood stands by red alder and bigleaf maple. Species richness was similar between riparian and upland habitats and among the five seral stages. However, there were significant differences in abundance for nine species among the seral stages. Total mammal captures were highest in riparian habitat, and among the upland habitats, captures progressively decreased from shrub to old-growth conifer stages. Shrew-moles, water shrews, Pacific shrews, long-tailed voles, Townsend's voles, white-footed voles, and Pacific jumping mice were captured significantly more often in riparian than in upland habitats. Western red-backed voles showed a strong association with upland habitat. The authors suggest that Pacific shrews and long-tailed voles should be considered riparian associates, and that the water shrew should be considered a riparian obligate species. They conclude that small riparian systems (second, third, and fourth order streams) and adjacent upland areas provide important habitat for small mammals in the Oregon Coast Range.

98. Gottfried, GJ, and PF Ffolliott. 1992. Effects of moderate timber harvesting in an old-growth Arizona mixed conifer watershed, pp. 184–194 in *Old-Growth Forests in the Southwest and Rocky Mountain Regions. Proceedings from a Workshop*, March 9–13, 1992, WH Moir, RL Bassett, and RL Kaufman, coords. USDA General Technical Report RM-213, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 201 pp.

A mixed-conifer old-growth watershed in Arizona was harvested to determine the overall effects of moderate harvesting on stand structure, stream function, and wildlife populations. The watershed consisted of uneven-aged forests dominated by Engelmann spruce, blue spruce, Douglas-fir, white fir, subalpine fir, ponderosa pine, southwestern white pine, and quaking aspen. Sections of the watershed were either left unharvested or harvested as group selection, single tree selection, or patch clearcut. Timber harvesting was done in 1978 and 1979, with monitoring occurring from 1974 through 1986. The overall harvesting system (all areas) resulted in increased residual tree growth while the forest retained its uneven-aged structure and relative tree species composition. The treatment also resulted in significant increases in mean annual water yield and in herbaceous forage yields for livestock and wildlife, with only small, short-term changes in bird populations; total estimated bird numbers decreased slightly after timber harvest, but the number of species increased. There were no significant differences when bird numbers were analyzed by nesting or feeding guilds. Ruby-crowned kinglets were the only major species to show a significant decline.

99. Grindal, SD. 1996. Habitat use by bats in fragmented forests, pp. 260–272 in *Bats and Forests Symposium,* RMR Barclay and RM Brigham, eds. Research Branch, B.C. Ministry of Forests, Victoria, B.C.

Grindal monitored bats to determine their commuting and foraging activities in undisturbed forests, clearcuts, forest/clearcut edges, and riparian/lake habitats in interior forests in British Columbia. Forest and clearcut ages and tree species compositions were not specified. Although bat species were not identified from echolocation calls, they were expected to include California myotis, long-eared myotis, little brown myotis, long-legged myotis, Yuma myotis, big brown bat, silver-haired bat, and hoary bat. Foraging activity was higher in the edge habitat than in either the forest or clearcut. The least amount of foraging occurred in the forest, but bats did show commuting activity there, suggesting that the forest may be important for roosting rather than foraging. Total insect biomass was greater at edges and in the forest than in the clearcut; this difference may explain the greater activity in the edge habitat, but it does not explain the decreased foraging activity in the forest. Lake/riparian areas, which had more foraging activity than the forest/clearcut area, appear to be a primary foraging area for bats. Grindal suggests that forest harvesting creates favorable habitat for foraging bats, particularly large bats that may be restricted to open areas, but forested areas may be an important prey source and roosting habitat.

100. Grindal, SD. 1998. Habitat use by bats in second- and old-growth stands in the Nimpkish Valley, Vancouver Island. *Northwest Science* 72 (Special Issue No. 2): 116–118.

The author surveyed bats in second-growth (50–80 years) and old-growth (140–350 years) conifer forests on northern Vancouver Island, British Columbia. Forest types, dominant tree species, and timber harvesting methods were not described. Bats were surveyed in forested areas, cutblocks (patch cut), and roaded areas. Bat species captured or identified by echolocation calls included the little brown myotis, California myotis, Yuma myotis, long-eared myotis, long-legged myotis, hoary bat, big brown bat, silver-haired bat, and Townsend's big-eared bat. Commuting activity by bats was higher in old-growth than in second-growth forests. Bat activity was highest in riparian areas and much lower in forests, cutblock edges, and roaded areas. Roosts were found more often in old-growth than in second-growth stands.

101. Grindal, SD, and RM Brigham. 1998. Short-term effects of small-scale habitat disturbance on activity by insectivorous bats. *Journal of Wildlife Management* 62(3): 996–1003.

The authors monitored changes in bat activity after creation of cutblocks (patch cuts) and roads in mature western redcedar and western hemlock forests in British Columbia. Bat echolocation calls were monitored before and after cutblock harvests (0.5, 1.0, and 1.5 ha) and also before and after construction of one access road; individual bat species, however, were not identified. After harvest, there was more bat activity in cutblock areas than in uncut forested areas, but activity in cutblocks appeared to decrease as the size of the cutblocks increased. Bat activity also increased after completion of the access road. The authors caution that increased bat activity in small cutblock areas does not necessarily mean that activity will increase in larger harvest areas.

102. Gunther, PM, BS Horn, and GD Babb. 1983. Small mammal populations and food selection in relation to

timber harvest practices in the western Cascade Mountains. *Northwest Science* 57(1): 32–44.

Small mammal populations were compared in a mature conifer forest (110 years old), a burned clearcut, and two unburned clearcuts in the Washington Cascade Range. The forest was dominated by western redcedar, western hemlock, and Douglas-fir. Clearcut areas were harvested in the fall and spring prior to sampling. Animal trapping occurred during the following summer/fall period. One clearcut was burned mid-summer during the trapping season. Stomach contents of all species trapped were sampled and analyzed. Small mammal populations were lowest in the forest and highest in the unburned clearcuts. Southern red-backed voles, deer mice, and Trowbridge's shrews were most abundant in unburned clearcuts. In the forest and burned clearcuts, small mammals consumed more invertebrates than any other food type; in the unburned clearcuts, the major food sources were fungi, epiphytic lichens, and conifer seeds.

103. Gutierrez, RJ, JE Hunter, G Chavez-Leon, and J Price. 1998. Characteristics of spotted owl habitat in landscapes disturbed by timber harvest in northwestern California. *Journal of Raptor Research* 32(2): 104–110.

Northern spotted owls were surveyed in two northwestern California forested landscapes with different amounts of mature and old-growth Douglas-fir forest and harvested land. One area was dominated by previously harvested forests with small, scattered patches of remnant forest. The second area was dominated by larger, less isolated mature and old-growth forests than the first, but it had interspersed patches of previously harvested forests. In both landscapes, northern spotted owls appeared to select the most complex older forests available for nesting and roosting. Owls in the second (least harvested) area chose forests that were older and structurally more complex than the habitat that owls in the first area were able to select.

104. Hacker, AL, and BE Coblentz. 1993. Habitat selection by mountain beavers recolonizing Oregon Coast Range clearcuts. *Journal of Wildlife Management* 57(4): 847–853.

The authors examined the distribution and relative abundance of mountain beavers recolonizing 1-year-old and 4- to 5-year-old clearcuts in the Oregon Coast Range. Site preparation on the clearcuts included slash burns and complete removal of all mountain beavers by trapping before the sites were planted with Douglas-fir. By the time of sampling, all clearcuts had been recolonized by mountain beavers. Mountain beavers selected areas with high quantities of small- and large-diameter woody debris, forage plants, uprooted stumps, soft soils, and areas in drainages. The authors suggest that a possible method for decreasing recolonization by mountain beavers would be to reduce favorable habitat features; however, these features may be desired for encouraging other species. They also recommend that instead of removing habitat structures, managers could encourage growth of more favorable food to discourage mountain beavers from damaging tree seedlings.

105. Hagar, DC. 1960. The interrelationships of logging, birds, and timber regeneration in the Douglas-fir region of northwestern California. *Ecology* 41(1): 116–125.

This study monitored changes in bird populations in northwestern California forests immediately after harvest and during the first few years after the original forests were cut. Sites included 1- to 2-year-old weed-stage clearcuts, 3- to 7-year-old shrub-stage clearcuts, and uncut old-growth Douglas-fir forests; clearcuts were naturally regenerating by seed. Hagar also studied the diets of birds in relation to clearcut age and vegetation composition. The dark-eyed junco was the most numerous species on all sites. The number of juncos on recent clearcuts was similar to that in uncut forests, but in older, more shrubby clearcuts, juncos were two to three times as numerous as in uncut forests. Varied thrushes were more frequent on clearcut edges and brush thickets than in uncut forests. Mountain quail and spotted towhees were absent from uncut forests but increased on clearcuts as shrub communities developed. Steller's jays were more abundant in uncut forests, but numbers increased on clearcuts as they entered the shrub stage. Winter wrens were present at higher densities on clearcuts than in forests. Birds more abundant in uncut forests than in clearcuts included

chestnut-backed chickadees, red-breasted nuthatches, pine siskins, evening grosbeaks, purple finches, Cassin's vireos, and golden-crowned kinglets.

106. Hagar, JC. 1999. Influence of riparian buffer width on bird assemblages in western Oregon. *Journal of Wildlife Management* 63(2): 484–496.

The author surveyed bird diversity and abundance in logged and unlogged riparian areas in the Oregon Coast Range to determine the influence of riparian buffer strip width on bird populations. Sites were along headwater streams and were classified by buffer width categories: 1) unlogged sites; 2) buffers <18 m wide; 3) buffers 20–30 m wide; and 4) buffers 40–70 m wide. Four species—Hammond's flycatchers, golden-crowned kinglets, varied thrushes, and hermit warblers—were found on unlogged sites but were rarely observed on logged sites even where buffers were wide. Four other species of forest-associated birds—Pacific-slope (western) flycatchers, brown creepers, chestnut-backed chickadees, and winter wrens—were most abundant on unlogged sites, but abundance increased on logged sites as buffer width increased. Birds found only on logged riparian sites were house wrens, orange-crowned warblers, MacGillivray's warblers, spotted towhees, white-crowned sparrows, and American goldfinches. Hagar concludes that headwater stream riparian buffers will not support all species found in unlogged areas, but they are likely to provide the most benefit for forest-associated birds if they are wider than 40 m and retain large trees.

107. Hagar, JC, WC McComb, and WH Emmingham. 1996. Bird communities in commercially thinned and unthinned Douglas-fir stands of western Oregon. *Wildlife Society Bulletin* 24(2): 353–366.

Breeding bird and wintering bird abundance and diversity were compared in thinned and unthinned Douglas-fir stands (40–55 years old) in the Oregon Coast Range. Stands were thinned from below (removing suppressed and intermediate crown classes) 5–15 years prior to sampling. During the breeding season, bird species richness did not appear to be affected by thinning. Species richness was positively related to the densities of hardwoods 31–43 cm DBH, conifers greater than 56 cm DBH, and snags greater than 53 cm DBH, but it was negatively related to distance to patch edges. Winter bird abundance did not differ between thinned and unthinned stands, but species richness was marginally greater in unthinned stands. Hairy woodpeckers, red-breasted nuthatches, Hammond's flycatchers, warbling vireos, dark-eyed juncos, and evening grosbeaks were consistently more abundant in thinned than in unthinned stands. Pacific-slope (western) flycatchers, on the other hand, were consistently more abundant in unthinned stands. Birds inconsistently associated with the two stand types included gray jays, brown creepers, western tanagers, winter wrens, golden-crowned kinglets, and black-throated gray warblers. Species that were not specifically associated with either thinned or unthinned stands were Swainson's thrushes, Hutton's vireos, Wilson's warblers, chestnut-backed chickadees, and hermit warblers. The authors include a fairly in-depth discussion of these birds and the habitat variables they appear to be associated with, as well as management suggestions.

108. Hall, JD, GW Brown, and RL Lantz. 1987. The Alsea watershed study: A retrospective, pp. 399–416 in *Streamside Management: Forestry and Fishery Interactions*, EO Salo and TW Cundy, eds. Contribution no. 57, Institute of Forest Resources, College of Forest Resources, University of Washington, Seattle.

The Alsea watershed study (Oregon Coast Range) monitored three streams during a 15-year logging study (1959–1973) to determine the effects of clearcutting on fish and the stream environment. One watershed was clearcut without buffer strips, a second was patch clearcut with buffer strips, and a third was left undisturbed. This study was used as a basis for many current Oregon regulations aimed at protecting stream habitat and water quality during logging operations. The authors compare the original Alsea study with more recent studies in the Douglas-fir region, assessing applications of its findings and suggesting directions for future work. For a more detailed summary of the Alsea watershed study, see Moring and Lantz (1975, citation 187).

109. Hall, JD, and RL Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams, pp. 355–375 in *Symposium on Salmon and Trout in Streams,* TG Northcote, ed. HR MacMillan Lectures in Fisheries, Institute of Fisheries, University of British Columbia, Vancouver.

The effects of clearcut logging on stream water quality and salmonid habitat were studied in three Oregon Coast Range watersheds. One watershed was clearcut without buffer strips, a second was clearcut in patches (patch cut) with buffer strips, and a third was left undisturbed as a control. Logging roads were constructed in the two logged watersheds. The clearcut watershed was burned to reduce slash, but only the lower unit of the patch cut watershed was burned (and only partially). Pre-logging monitoring in all watersheds began in 1958, prior to road construction in the logged watersheds in 1969, and continued during logging in 1966 and for the year following logging in 1967. Dissolved oxygen concentrations in surface and intragravel water decreased in the clearcut watershed during logging. Stream temperature increased significantly in the clearcut watershed after logging ended. Survival of coho salmon and cutthroat trout in the clearcut watershed was affected by logging, but the effects could not be fully evaluated at the time of this study. No significant changes in fish population or habitat were seen in the patch cut watershed during logging or the first year after logging.

110. Hanley, TA. 1983. Black-tailed deer, elk, and forest edge in a western Cascade watershed. *Journal of Wildlife Management* 47(1): 237–242.

Hanley studied the use of forest edges, clearcuts, and uncut old-growth forests by Columbian black-tailed deer and Rocky Mountain elk in the Washington Cascades. Forests were 450–550 years old and dominated by Pacific silver fir and western hemlock. Clearcuts ranging from 0 to 20 years old dominated the study area. Deer and elk (four animals each) were monitored by radiotelemetry. Interpretation of the data was limited, but the author concludes that there was a pattern of decreasing habitat use within both forest and clearcut with increasing distance from the forest edge.

111. Hansen, AJ, SL Garman, JF Weigand, DL Urban, WC McComb, and MG Raphael. 1995. Alternative silvicultural regimes in the Pacific Northwest: Simulations of ecological and economic effects. *Ecological Applications* 5(3): 535–554.

The authors used the ZELIG forest model to perform a simulation experiment on long-term responses of ecological and economic variables to different retention levels and rotation lengths in Pacific Northwest Douglas-fir forests. Canopy tree retention levels simulated were 0, 5, 10, 15, 20, 30, 50, and 150 trees per hectare. Simulated rotation lengths were 40, 80, 120, and 240 years. Each scenario was run for a 240-year time period. Following each harvest, the simulated stands were thinned 15 and 30 years after sites were planted with Douglas-fir seedlings. The simulated stand data were linked with regression equations to predict the densities of 17 bird species as a function of tree size class distribution. Results indicated that when trees were retained (at any level), stand structure was more similar to pre-treatment natural forests than when no trees were retained. Variation in tree size under intermediate levels of retention did not reach the level of the natural forest during the simulation period. Tree species composition was related to retention level and rotation age. Bird responses to retention level and rotation age were species-specific. The authors conclude that these factors strongly influence ecological and economic (not presented here) responses in Pacific Northwest forests, and that more research is needed to reduce the uncertainty about these effects.

112. Hansen, AJ, and P Hounihan. 1996. Canopy tree retention and avian diversity in the Oregon Cascades, pp. 401–421 in *Biodiversity in Managed Landscapes: Theory and Practice*, RC Szaro and DW Johnson, eds. Oxford University Press, New York, NY.

Breeding bird abundance and habitat structure associations were studied to determine the possible effects of overstory tree retention on bird communities in managed conifer stands in the Oregon Cascades. Stands were 100–150 years old at the time of harvest and dominated by Douglas-fir, western hemlock, grand fir, and noble fir. Stands represented a gradient of canopy tree retention and included clearcuts, clearcuts with reserves, shelterwoods, and commercial thinnings. The density of retained canopy trees strongly influenced breeding bird abundance and diversity. Total bird abundance increased proportionally with tree density. Bird diversity was lowest in clearcuts and highest in shelterwoods and commercial thinnings. Species requiring open canopy habitat (American robin and dark-eyed junco) were negatively associated with tree density, while species requiring closed canopy habitat (hermit/Townsend's warbler, golden-crowned kinglet, Hammond's flycatcher, and red-breasted nuthatch) were positively associated with tree density.

113. Hansen, AJ, WC McComb, R Vega, MG Raphael, and M Hunter. 1995. Bird habitat relationships in natural and managed forests in the west Cascades of Oregon. *Ecological Applications* 5(3): 555–569.

The authors integrated data from five previous studies conducted in the Oregon Cascades to quantify bird abundance across broad gradients of forest age and management histories. Bird species abundances were compared in recent clearcuts, canopy retention sites, closed canopy plantations, mature stands, and old-growth forests. Stands were dominated by Douglas-fir, western redcedar, and western hemlock. Relationships between bird abundance and stand level characteristics were also studied. Analysis showed that 18 of 23 bird species examined differed significantly in abundance among stand types, with some species primarily associated with each type of stand. Significant habitat functions were generated for 17 of the 23 species. The authors suggest that the habitat functions can be used to predict bird abundance based on habitat measurements derived from field data, remote sensing data, or computer model output.

114. Hargis, CD, and JA Bissonette. 1997. Effects of forest fragmentation on populations of American marten in the intermountain west, pp. 437–451 in Martes: *Taxonomy, Ecology, Techniques, and Management*, G Proulx, HN Bryant, and PM Woodward, eds. Provincial Museum of Alberta, Edmonton.

The effects of forest fragmentation on American marten populations were studied in Engelmann spruce/lodgepole pine forests in Utah. Martens were trapped in forests with no logging, forests with up to 42% logging (in areas infested with mountain pine beetle, *Dendroctonus ponderosae*), and clearcuts (more than 5 years old). Marten captures decreased as the percentage of area in clearcuts and forest openings increased. Small mammal densities were greater in clearcuts than in forests, but martens were not correlated with the increase in number or biomass of prey species associated with clearcuts. The southern red-backed vole was the dominant prey species caught in forests, whereas the deer mouse and least chipmunk were the most frequent prey species caught in clearcuts. The authors conclude that stands with desired habitat features such as coarse woody debris and mature conifer stand structure may be unsuitable for the American marten if they occur in a highly fragmented landscape.

115. Hargis, CD, JA Bissonette, and DL Turner. 1999. The influence of forest fragmentation and landscape pattern on American martens. *Journal of Applied Ecology* 36: 157–172.

The authors examined the effects of forest fragmentation and landscape pattern on American martens in the Uinta Mountains, Utah. Eighteen sites were selected in mature forests containing Engelmann spruce, lodgepole pine, and scattered subalpine fir. Non-forested areas covered 2%–42% of each site; natural openings in the form of meadows and boulder fields covered 2%–12%, and clearcuts covered 0%–42%. Clearcutting on most sites had occurred at least 5 years before the study began. Martens were live-trapped at eighteen sites. The sites were sampled at various frequencies between 1991 and 1993. Small mammals were trapped separately to estimate prey densities. Martens appeared to respond negatively even to low levels of habitat fragmentation; they were nearly absent from landscapes with more than 25% non-forest cover, although forest connectivity was still present. Marten capture rates were negatively correlated with increasing proximity to open areas and increasing extent of high-contrast edges. Forested landscapes appeared unsuitable for martens when the average nearest-neighbor distance between non-forested patches was less than 100 m. Small mammal densities were higher in clearcuts than in forest, but marten captures were not correlated with prey abundance or biomass associated with clearcuts.

116. Harr, RD, and RL Fredriksen. 1988. Water quality after logging small watersheds in the Bull Run Watershed, Oregon. *Water Resources Bulletin* 24(5): 1103–1111.

Changes in stream water quality after 25% of a watershed was clearcut and burned were studied in the Oregon Cascade Mountains. Two watersheds were patch cut and a third was left uncut as a control. One watershed was logged in 1969 and burned to decrease slash in 1970; the second was logged in 1971–1972 and slash was allowed to decay. Construction of roads in the two logged watersheds began in 1964 and ended in 1965. Stream water quality was monitored from 1970 through 1981. Suspended sediment concentrations were slightly higher where roads were constructed. Logging and slash disposal led to changes in nutrient cycling in both logged watersheds. Nitrate-nitrogen concentrations increased in both logged watersheds but increased the most where slash was left to decompose, remaining very high during the first 7 post-logging years; in the burned watershed, concentrations decreased after 6 years. No apparent changes in the outflow of other anions or cations were seen. Annual maximum temperatures increased 2°C–3°C after logging but decreased within 3 years as vegetation began shading the streams.

117. Harris, LD, C Maser, and A McKee. 1982. Patterns of old growth harvest and implications for Cascades wildlife. *Transactions of the North American Wildlife Natural Resources Conference* 47: 374–392.

This paper reviews old-growth harvesting trends and old-growth reserves in the Oregon and Washington Cascades, along with possible impacts on amphibian, reptile, and mammal populations. The authors used data from several surveys and studies to determine the species potentially present in Cascade forests at different elevations and seral stages. They point out that vertebrate species diversity decreases as elevation increases, yet most old-growth reserves and wilderness areas are at high elevations. Vertebrate species diversity is high in very early and late stages of Douglas-fir succession, although species composition varies. The authors suggest that placing long-rotation management areas adjacent to old-growth stands may minimize the acreage of actual old-growth needed to provide habitat for some species. The relationship between island biogeography and old-growth reserves and parklands such as Mt. Rainier National Park is also discussed.

118. Hartman, GF. 1982. *Proceedings of the Carnation Creek Workshop: A Ten-Year Review*, February 24–26, 1982. Pacific Biological Station, Nanaimo, B.C.

An intensive 15-year study examining the effects of clearcut logging on stream habitats and fish populations was conducted in the Carnation Creek watershed in coastal British Columbia. This workshop proceedings presents preliminary results from the first 10 years of the study, including 5 pre-logging years and 5 years during logging. The watershed was dominated by western hemlock and western redcedar. There were three treatments: 1) In the intensive treatment (logged 1976–1977), trees were clearcut down to the stream bank, with trees and logs felled or yarded across and into the channel; the stream bank was damaged in the process. 2) In the careful treatment (logged 1978–1979), trees were clearcut down to the stream bank, but other vegetation was left, causing no damage to the bank; few trees were felled into or yarded across the channel. 3) In the leave strip treatment (logged in three openings 1975–1976, 1978–1979, and 1980–1981), the surrounding stand was clearcut, but a variable-width buffer was left along the channel. Individual proceedings papers discuss preharvest vegetation, soils, and changes that occurred during logging; silvicultural programs for the watershed; logging impacts on the hydrologic regime; impacts on stream temperature, dissolved ions, large woody debris, and spawning gravel quality; effects on primary producers and invertebrates; impacts on sculpins; effects on juvenile coho salmon from exposure to short-term pulses of suspended sediment; and population changes in juvenile coho during the logging phase.

119. Hartman, GF, LB Holtby, and JC Scrivener. 1984. Some effects of natural and logging-related winter stream tem-

perature changes on the early life history of coho salmon (*Oncorhynchus kisutch*) in Carnation Creek, British Columbia, pp. 141–149 in *Fish and Wildlife Relationships in Old-Growth Forests*, WR Meehan, TR Merrell, Jr., and TA Hanley, eds. American Institute of Fishery Research Biologists, Morehead City, NC.

The effects of logging-related winter stream temperature changes on juvenile coho salmon were studied in the Carnation Creek watershed. This coastal British Columbia watershed was dominated by western hemlock and western redcedar. Extensive clearcut logging began during the winter of 1976–1977 and continued through 1980–1981, by which time 41% of the watershed had been logged. Some sections were logged to the stream bank, but in others, variable-width buffers were left. Coho were sampled before and during the logging operations. Winter stream temperatures increased after logging began as a result both of logging activities and of a climatic amelioration that began in 1976. As a result of the higher winter stream temperatures, coho salmon fry emerged earlier in the spring than before logging. Early emerging fry that did not move downstream during spring freshets had an earlier start to growth and more rapid growth, resulting in larger fish in the autumn. Winter survival of juvenile coho also increased with the larger sizes, which led to more 1-year smolts and an increased proportion of 1-year versus 2-year smolts.

120. Hartman, GF, and JC Scrivener. 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. *Canadian Bulletin of Fisheries and Aquatic Sciences* 223. 148 pp.

This book presents results from the first 17 years of a multidisciplinary study of the effects of clearcut harvesting and regeneration activities on a stream ecosystem in coastal British Columbia. The Carnation Creek watershed was dominated by western hemlock and western redcedar. Prelogging monitoring occurred from 1970 to 1975, logging during the winters of 1976–1977 and 1979–1980, and post-logging monitoring from the spring of 1981 to spring 1986. Forest practices that increased stream insolation, water temperature, and nutrient levels increased the numbers, growth period, and size of coho salmon fry; these same environmental factors, however, reduced the ocean survival of chum salmon fry. Growth period and growth rate of steelhead and cutthroat trout fry also increased, but growth decreased among the older age groups of coho salmon and trout. Streamside logging decreased stream channel stability and amounts of large woody debris. Negative effects from logging required more time to manifest themselves than positive effects. Influences of the negative and positive freshwater impacts continued into the marine life history stages of both coho and chum salmon. The authors also discuss applications of the results for land use planning.

121. Hartman, GF, JC Scrivener, and MJ Miles. 1996. Impacts of logging in Carnation Creek, a high-energy coastal stream in British Columbia, and their implication for restoring fish habitat. *Canadian Journal of Fisheries and Aquatic Sciences* 53 (Suppl. 1): 237–251.

A small drainage basin in coastal British Columbia was studied intensively for more than 20 years to examine the impacts of clearcut harvesting on stream conditions and fish populations. The Carnation Creek basin was logged in two phases; during the first phase (1976–1981), 41% of the basin was clearcut, and in the second phase, an additional 42% was cut. A total of 61% of the length of the headwater stream had been logged, requiring 38.5 km of roads and 21 crossings of hillslope channels. Landslides and debris torrents modified steep slope tributaries and the creek mainstem. Bank erosion also altered the stream channel on the alluvial flood plain. These effects were additive in the system and reduced the quality of spawning and rearing habitat for juvenile salmonids (mainly coho salmon, cutthroat trout, and steelhead trout). Salmonid production was limited by combinations of processes and conditions that were different for each species and life-history stage. The authors suggest that in streams similar to Carnation Creek, it will be necessary to restore some stability to the hill slopes and gullies before attempting fish habitat improvements in the main channel; improvement work must be based on knowledge of the processes that limit fish production if projects are to succeed.

122. Hartman, G, JC Scrivener, LB Holtby, and L Powell. 1987. Some effects of different streamside treatments on physical conditions and fish population processes in Carnation Creek, a coastal rain forest stream in British Columbia, pp. 330–372 in *Streamside Management: Forestry and Fishery Interactions*, EO Salo and TW Cundy, eds. Contribution no. 57, Institute of Forest Resources, College of Forest Resources, University of Washington, Seattle.

This study describes the effects of streamside logging treatments on stream habitat and salmonid populations in a long-term study in the Carnation Creek watershed. The coastal British Columbia watershed was dominated by western hemlock and western redcedar. There were three treatments: 1) In the intensive treatment (logged 1976–1977), trees were clearcut down to the stream bank, with trees and logs felled or yarded across and into the channel; the stream bank was damaged in the process. 2) In the careful treatment (logged 1978–1979), trees were clearcut down to the stream bank, but other vegetation was left, causing no damage to the bank; few trees were felled into or yarded across the channel. 3) In the leave strip treatment (logged in three openings 1975–1976, 1978–1979, and 1980–1981), the surrounding stand was clearcut, but a variable-width buffer was left along the channel.

In the intensive treatment, the volume and stability of large woody debris (LWD) decreased immediately after logging; in the careful treatment, LWD decreased a few years after logging. An increase in stream bank erosion (accompanied by the decrease in LWD volume and stability) decreased instream gravel quality in the intensive and careful treatments. LWD remained most stable in the leave strip treatment. The numbers of steelhead trout smolts decreased after logging; coho salmon smolts increased for a few years but later fell back to pre-logging numbers. Since logging, the physical conditions of the stream and the coho populations have shown greater annual variations than before logging.

123. Hauer, FR, GC Poole, JT Gangemi, and CV Baxter. 1999. Large woody debris in bull trout (*Salvelinus confluentus*) spawning streams of logged and wilderness watersheds in northwest Montana. *Canadian Journal of Fisheries and Aquatic Sciences* 56: 915–924.

Changes in characteristics of large woody debris (LWD) in bull trout spawning streams were examined in forests in northwestern Montana. The authors did not specify forest type or time since logging for the study areas. Streams were in unlogged wilderness forest, clearcuts with riparian buffer strips, or clearcuts with no riparian buffer strips. Large-diameter short pieces of LWD attached to the stream bank were most likely to be perpendicular to stream flow. Large-diameter long pieces either were parallel to the flow or were likely to extend across the channel thalweg (if attached to the bank). The majority of pools were formed as scour pools created either by large LWD pieces perpendicular to stream flow or by multi-piece LWD aggregates. Stream reaches in wilderness watersheds had relatively constant ratios of large to small LWD, attached to unattached LWD, and LWD with and without rootwads. The ratios in stream reaches in logged watersheds, however, varied substantially. The authors conclude that logging can alter the delivery, storage, and transport of LWD in Rocky Mountain streams and may cause substantial changes in stream habitat.

124. Hayes, JP, and MD Adam. 1996. The influence of logging riparian areas on habitat utilization by bats in western Oregon, pp. 228–237 in *Bats and Forests Symposium*, October 19–21, 1995, RMR Barclay and RM Brigham, eds. Research Branch, B.C. Ministry of Forests, Victoria, B.C.

Bat activity was monitored in riparian areas to determine the effect of logging on habitat utilization. Sites were located in the central Oregon Cascade and Coast Ranges. Riparian areas were either clearcut logged or left wooded. Wooded areas were dominated by red alder. More bat echolocation calls were recorded in the wooded habitat than in the clearcut habitat; most calls in the wooded areas were identified as *Myotis* species. The decrease of *Myotis* activity in clearcut patches may be due to differences in prey insect populations. The authors conclude that logging in riparian areas can have substantial impacts on bat activity.

125. Hayes, JP, SS Chan, WH Emmingham, JC Tappeiner, LD Kellogg, and JD Bailey. 1997. Wildlife response to thinning young forests in the Pacific Northwest. *Journal of Forestry* 95(8): 28–33.

This paper presents a current review of information on thinning Douglas-fir stands in western Oregon and Washington, possible effects of thinning on wildlife, and the potential for using thinning to create late-successional stand characteristics similar to those of old-growth forests. The authors suggest using relative density diagrams when managing forests to meet timber and wildlife objectives.

126. Hayes, JP, EG Horvath, and P Hounihan. 1995. Townsend's chipmunk populations in Douglas-fir plantations and mature forests in the Oregon Coast Range. *Canadian Journal of Zoology* 73(1): 67–73.

Townsend's chipmunk population density patterns and habitat associations were examined in western hemlock/Douglas-fir stands in the Oregon Coast Range. Chipmunks were trapped in 10- to 15-year-old plantations, 20- to 25-year-old plantations, 30- to 35-year-old plantations, and mature fire-regenerated stands (>140 years old) dominated by western hemlock and Douglas-fir. Plantations were dominated by Douglas-fir and had regenerated after clearcutting. Chipmunk population densities and sex ratios were similar in plantations and mature stands. Mean body mass was greater in mature stands than in young stands during autumn, but not during spring. Population density was correlated with the percent of salal present. The authors suggest that stand structure plays an important role in determining habitat quality for Townsend's chipmunks.

127. Hayward, GD. 1997. Forest management and conservation of boreal owls in North America. *The Journal of Raptor Research* 31(2): 114–124.

Hayward reviews the status of boreal owls in North America, discussing trends in forest management and current understanding of potential responses of boreal owls to forest management. He presents hypotheses about how stand replacement harvest, partial cutting, and uneven-aged management practices may influence boreal owls on temporal and geographic scales. Components such as cavities in large snags and trees and abundance of prey species in mature and older forests are important to boreal owl habitat quality. Hayward suggests that timber harvests that provide diverse stand structure and components of mature forests may be compatible with boreal owl conservation, but implementing stand replacement harvests over an entire watershed through large clearcuts is not compatible with conservation of these owls.

128. Hayward, GD, and J Verner. 1994. *Flammulated, Boreal, and Great Gray Owls in the United States: A Technical Conservation Assessment*. General Technical Report GTR-253, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 213 pp.

This is a technical review of information available on flammulated, boreal, and great gray owls in the western U.S. The report discusses the status of populations (range, distribution, abundance), habitat preferences and requirements, migrations, home ranges, feeding habits, life history, and responses to logging, fire, forest fragmentation, and human/mechanical disturbance. It also includes discussion of pre- and post-settlement histories, disturbance regimes, and stand dynamics of forest types inhabited by the owls, along with conservation, management, and information/research needs.

129. Heifetz, J, ML Murphy, and KV Koski. 1986. Effects of logging on winter habitat of juvenile salmonids in Alaskan streams. *North American Journal of Fisheries Management* 6(1): 52–58.

Eighteen southeastern Alaskan streams were compared to determine the effects of clearcut logging and buffer strips on the winter habitat of juvenile salmonids. The stream reaches were in clearcut areas with logging down to at least one bank, clearcut areas with buffer strips along both banks, or undisturbed old-growth Sitka spruce/western hemlock forest. Fish and habitat were surveyed 1–12 years after logging. Most winter coho salmon, Dolly Varden, and steelhead trout juveniles occupied deep pools with cover provided by upturned tree roots, log accumulations, or cobble substrate; most pools were formed by large woody debris. Riffles, glides, and pools without cover were not used. Stream reaches in clearcuts without buffer strips had significantly less pool habitat than old-growth reaches. Leaving buffer strips in clearcut areas protected winter habitat by maintaining pool area and cover. Tree blowdown from buffer strips also provided additional large woody debris in some reaches.

130. Hejl, SJ, RL Hutto, CR Preston, and DM Finch. 1995. Effects of silvicultural treatments on forest birds in the Rocky Mountains, pp. 220–244 in *Ecology and Management of Neotropical Migratory Birds: A Review and Synthesis of the Critical Issues,* TE Martin and DM Finch, eds. Oxford University Press, New York, NY.

This paper reviews information on neotropical migratory birds in the Rocky Mountains of the U.S. and the ways silvicultural treatments may affect them. The first part describes current forest structure in terms of floristic composition, natural disturbance, and human-induced disturbances. The paper then discusses bird–habitat relationships in natural forests and relative species abundance. The next section compares bird abundance and community structure in different logging treatments (clearcuts, shelterwood cuts, overstory removals, and group selection) and discusses the possible effects of these treatments. The authors point out that their synthesis is limited because of the small number of available studies and because most studies were restricted to timber harvesting and did not include other management activities.

131. Hershey, TJ, and TA Leege. 1982. *Elk Movements and Habitat Use on a Managed Forest in North-Central Idaho.* Wildlife Bulletin 10, Idaho Department of Fish and Game, Boise. 24 pp.

The effects of forest harvesting on elk populations were studied in Idaho old-growth grand fir forests interspersed with clearcuts. Elk were monitored by radio telemetry, visual sightings, and hunter surveys. The elk used old-growth grand fir stands with cool, moist, poorly drained areas in late summer and early fall. They used clearcuts most often in spring, early summer, and late fall, selecting areas where slash had been removed or reduced by broadcast burning. Elk temporarily left areas during logging, hunting, or motor vehicle activities, and the degree of displacement appeared to be related to proximity, intensity, and duration of the disturbance. The authors recommend that forest harvest activities should not be conducted during periods when elk are present, particularly during calving season and peak migration periods. Undisturbed areas adjacent to logging or road building activities should be made available for elk use

132. Hicks, BJ, JD Hall, PA Bisson, and JR Sedell. 1991. Responses of salmonid populations to habitat changes caused by timber harvest, pp. 483–518 in *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats*, WR Meehan, ed. American Fisheries Society, Bethesda, MD.

This chapter reviews changes in stream environments, salmonid habitat quality, and salmonid growth and survival that may result from forest management activities. Forest practices discussed include streamside timber harvest, upslope timber harvest, road construction, and site preparation. Potential stream environment changes include increased temperature, decreased supply of large woody debris, increased fine and coarse sediments, and altered nutrient supply. The authors discuss current limits in knowledge and suggest future studies.

133. Hollstedt, C, and A Vyse. 1997. *Sicamous Creek Silvicultural Systems Project: Workshop Proceedings,* April 24–25, 1996, B.C. Ministry of Forests, Research Branch, Victoria, B.C.

This proceedings presents study information and preliminary results from the Sicamous Creek Silvicultural Project in a British Columbian subalpine forest. The multi-disciplinary study examines the effects of several silvicultural treatments on birds, mammals, and the forest ecosystem. The study was installed in a subalpine fir/Engelmann

spruce old-growth forest with overstory trees ranging from 25 to 325 years old; most were 100–125 years. Five overstory treatments were used: 1) uncut control; 2) single-tree selection; 3) 0.1-ha patch cuts; 4) 1.0-ha patch cuts; and 5) 10-ha clearcuts. Four soil disturbance treatments were applied in each overstory treatment: 1) no site preparation; 2) mechanical site preparation by scalping; 3) mechanical site preparation by mounding; and 4) broadcast burning. Pre-treatment collection of data began in 1994, followed by logging in winter 1995. Post-treatment monitoring began in 1995 after logging ceased. Wildlife studies include 1) effects of alternative silvicultural practices on song bird communities; 2) effects of silvicultural systems on habitat and landscape relationships of mice and voles, small carnivores, cavity-nesting birds, and spruce grouse; and 3) persistence rates of snags and relationships between small mammals and downed wood.

134. Holt, DW. 1997. The long-eared owl (*Asio otus*) and forest management: A review of the literature. *The Journal of Raptor Research* 31(2): 175–186.

This paper reviews information on long-eared owls in North America and discusses population trends and potential effects of forest management on the owl; no direct evidence suggests that long-eared owls would respond either negatively or positively to forest harvesting. Holt also addresses concerns about whether the owl should be considered a forest species.

135. Holtby, LB. 1988. Effects of logging on stream temperatures in Carnation Creek, British Columbia, and associated impacts on the coho salmon (*Oncorhynchus kisutch*). *Canadian Journal of Fisheries and Aquatic Sciences* 45(3): 502–515.

The effects of logging-related changes in stream temperatures and their possible impacts on juvenile coho salmon were studied in Carnation Creek in coastal British Columbia. The watershed was dominated by western hemlock and western redcedar. Extensive clearcut logging began during winter 1976–1977 and continued through 1980–1981, by which time 41% of the watershed had been logged. Some stream sections had variable-width buffers, while other sections were logged to the stream bank. Clearcutting resulted in year-round increases in stream temperatures. Coho were sampled from 1971 to 1984.

After logging began, coho salmon fry emerged earlier with the increased stream temperature, and their summer growing season was increased by 6 weeks. Fingerlings were significantly larger in the fall after logging than during the years before logging. Increased fingerling size contributed to increased winter survival. Yearling smolt numbers doubled, although 2-year-old smolt numbers decreased. Warmer spring temperatures were associated with earlier seaward migration of smolts, which possibly led to decreased smolt-to-adult survival. Holtby uses models to predict the effects of logging on stream temperatures, discussing the potential effects of these predicted temperatures on critical events in coho life history. The life history model is used to correlate the effects of logging-related stream temperature changes with the population size of adult coho. The model predicted the increased number of adult coho to be a small fraction of the observed increase in smolt numbers.

136. Holtby, LB, and JC Scrivener. 1989. Observed and simulated effects of climatic variability, clear-cut logging and fishing on the numbers of chum salmon (*Oncorhynchus keta*) and coho salmon (*O. kisutch*) returning to Carnation Creek, British Columbia, pp. 62–81 in *Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks*, CD Levings, LB Holtby, and MA Henderson, eds. Canadian Special Publications Fish and Aquatic Sciences no. 105.

Long-term salmon population data from the Carnation Creek watershed study in western British Columbia were used to develop computer models for partitioning the variability in adult chum and coho salmon returns according to effects of climatic variability in the stream and ocean, changes in stream conditions caused by clearcut logging, and fishing mortality. For both chum and coho salmon, most of the observed variation in adult numbers resulted from climatic variability in the stream and ocean. Fishing mortality increased with higher exploitation rates. Chum salmon were adversely affected by observed and simulated logging activity, but coho were unaffected.

137. Hooven, EF. 1973. Response of the Oregon creeping vole to the clearcutting of a Douglas-fir forest. *Northwest Science* 47(4): 256–264.

Population changes in Oregon creeping voles following clearcut logging (with and without controlled slash burning) were examined in the Oregon Cascade Range. Before logging, stands were dominated by 125-year-old Douglas-fir; logged sites were compared with one unharvested stand. More voles were captured on the burned stands than on the unburned clearcut. Substantially more creeping voles were captured in clearcuts than in the unharvested stand, where they were captured only infrequently; numbers in the clearcuts increased during the 3-year period following logging. Hooven suggests that the increase in voles on the clearcuts may have been due to the increase in herbaceous plants after logging.

138. Hooven, EF, and HC Black. 1976. Effects of some clearcutting practices on small mammal populations in western Oregon. *Northwest Science* 50(4): 189–208.

The authors observed changes in vegetation and small mammal populations over a 3-year period on two clearcuts and one uncut stand in the Oregon Cascades. Stands were 125 years old and dominated by Douglas-fir at the time of harvest. Slash was reduced on one clearcut in a controlled burn. The paper discusses the responses of both vegetation and small mammals. Shrews (*Sorex* spp.) and Townsend's chipmunks were adversely affected by logging and were primarily present in the uncut stand. Most of the Trowbridge's shrews were caught in the uncut stand; the fewest were caught on the burned clearcut. Townsend's chipmunk numbers were greatest in the uncut stand and lowest on the unburned clearcut. Deer mouse and creeping vole populations increased after logging and burning. White-footed voles were caught most often in the burned clearcut and least often on the uncut stand. During the first few years following logging, snowshoe hares did not repopulate clearcuts until plant cover increased. Arboreal mammals such as northern flying squirrels, Douglas squirrels, and western red-backed voles were present only in the uncut stand. Pacific jumping mice were more abundant in the burned clearcut than in the uncut stand.

139. Horton, SP. 1996. Spotted owls in managed forests of western Oregon and Washington, pp. 215–231 in *Raptors in Human Landscapes. Adaptations to Built and Cultivated Environments*, DM Bird, DE Varland, and JJ Negro, eds. Academic Press Incorporated, San Diego, CA.

This review of northern spotted owl literature includes information on conservation, habitat use and preferences, home range size, population decline, and forest management. On the basis of the literature, Horton concludes that forests can be managed to provide favorable habitat for owls, and managed stands should contain elements of old unmanaged forests including large live trees, diverse canopies, shade-tolerant conifers, large logs, and large snags.

140. House, RA, and PL Boehne. 1986. Effects of instream structures on salmonid habitat and populations in Tobe Creek, Oregon. *North American Journal of Fisheries Management* 6(1): 38–46.

An Oregon Coast Range stream with a history of splash damming and clearcut logging was studied to determine the effects of instream structures on salmonid habitat and populations. Two stream sections were examined. One section had been clearcut and cleaned of large woody debris (LWD) 20 years earlier and was now dominated by a young red alder stand. The second section was in a mature mixed conifer/bigleaf maple stand and contained large amounts of LWD. The alder section lacked the secondary channels, pools, meanders, and undercut banks produced by LWD in the mature section, which had twice as many pools, 10 times the amount of spawning gravel, and three times as many coho salmon, cutthroat trout, and steelhead fry as the alder section had. In 1982, LWD pieces were placed in the alder section to enhance the stream for salmonid use. One year after placement of the LWD pieces, salmonid biomasses in the two stream sections were similar. There was a positive correlation between coho salmon numbers and the presence of LWD.

141. House, RA, and PL Boehne. 1987. The effect of stream cleaning on salmonid habitat and populations in a coastal Oregon drainage. *Western Journal of Applied Forestry* 2(3): 84–87.

Stream reaches in an Oregon Coast Range drainage basin were surveyed to determine the effects of post-timber harvest stream cleaning on salmonid populations and habitat. Reaches were grouped as high gradient, cleaned, partially cleaned, partially cleaned/partially rehabilitated, and uncleaned. Coho salmon, steelhead and cutthroat trout, and stream habitat characteristics were sampled in each reach. The number of pools was greatest in uncleaned reaches and smallest in cleaned reaches. Similarly, common pool types (lateral scour, plunge, and backwater) were found most frequently in uncleaned reaches and least frequently in cleaned reaches; trench pools were absent from cleaned reaches. Boulders formed most pools in high gradient and cleaned reaches, while large woody debris (LWD) formed most pools in the uncleaned reaches. Uncleaned reaches had the most off-channel habitat. Overall salmonid densities were highest in uncleaned reaches, followed by partially cleaned/partially rehabilitated, partially cleaned, high gradient, and lastly, cleaned reaches. The authors recommend the retention of conifers in riparian zones for creation of future LWD, along with the maintenance of LWD to allow streams to reach their potential for habitat.

142. Huggard, DJ. 1999. *Marten Use of Different Harvesting Treatments in High-Elevation Forest at Sicamous Creek*. B.C. Ministry of Forests Research Report 17, Victoria. 17 pp.

American marten habitat use in several timber harvest treatments, edges, and openings was studied in Engelmann spruce/subalpine fir forests in British Columbia. Harvesting treatments were 10-ha clearcuts, 1.0-ha patch clearcuts (patch cuts), 0.1-ha patch cuts, individual tree selections, and unharvested controls. Marten activity was monitored along winter track transects and by snow-tracking individuals. Harvesting treatments removed about 33% of timber volume but reduced marten use by more than 60% compared with the unharvested control; in the 0.1-ha patch cut, however, use was reduced by only 33%. Martens avoided 1.0-ha and 10-ha openings, but they did use 0.1-ha openings. The different-sized leave strips surrounding the treatments were used equally, but leave strips were used less than contiguous forest. Martens preferred wetter sites and areas with canopy cover greater than 30%.

143. Humes, ML. 1996. *Activity of Bats in Thinned, Unthinned, and Old-growth Forests in the Oregon Coast Range*. MS thesis, Oregon State University, Corvallis.

Humes examined the effects of thinning Douglas-fir stands on bats by comparing thinned, unthinned (each 50–100 years), and old-growth stands (>200 years) in the Oregon Coast Range. Thinning occurred 10–23 years before sampling. Bats detected included Townsend's big-eared bat, big brown bat, silver-haired bat, hoary bat, California myotis, long-eared myotis, little brown myotis, fringed myotis, long-legged myotis, and Yuma myotis. Most bat activity occurred in old-growth stands, followed by thinned and unthinned stands. Thinning stands appeared to increase bat activity. Sampling on one site suggested that bat activity may be greater on limited-use roads than in the interior of thinned and unthinned young stands. Snag diameter, shrub cover, and canopy gaps were correlated with bat activity.

144. Humes, ML, JP Hayes, and MW Collopy. 1999. Bat activity in thinned, unthinned, and old-growth forests in western Oregon. *Journal of Wildlife Management* 63(2): 553–561.

The influence of thinning Douglas-fir stands on bat activity in the Oregon Coast Range was assessed by the authors. Douglas-fir stands were 50–100 years old and thinned 10–23 years prior to sampling. Thinned stands were compared with unthinned stands of comparable age and with nearby old-growth stands (>200 years). The three stand types varied in tree size and density and amount of overstory and understory cover. Bat activity was higher in old-growth stands and thinned stands than in unthinned stands. The authors conclude that structural changes caused by thinning young stands may benefit bats by creating habitat structure that they can use more effectively.

145. Hunter, ML, Jr. 1990. *Wildlife, Forests, and Forestry: Principles of Managing Forest for Biological Diversity*. Prentice Hall, Englewood Cliffs, NJ.

This is a general text on wildlife and forest management that presents a broad overview and discussion of terminology and concepts in a non-technical manner. General discussions include forest biology, succession, down and dead wood, snags, keystone species, and indicator species. From a management point of view, discussions include management of wildlife species with regard to stand diversity and structure, as well as natural disturbances versus harvesting regimes. The book uses examples from various areas of the world, including the northern spotted owl and black-tailed deer.

146. Hutto, RL, SJ Hejl, CR Preston, and DM Finch. 1993. Effects of silvicultural treatments on forest birds in the Rocky Mountains: Implications and management recommendations, pp. 386–391 in *Status and Management of Neotropical Migratory Birds*, September 21–25, 1992, DM Finch and PW Stangel, eds. General Technical Report RM-229, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 422 pp.

This paper compiles information on several bird species found in conifer forests of the Rocky Mountains. Census results from several studies were categorized within the following forest types: ponderosa pine, mixed conifer, lodgepole pine, spruce–fir, Cascadian forest, or aspen. Timber harvest methods were categorized as either clearcut or partially clearcut. Bird species responses from the compiled studies were scored one of three ways: the species declined after harvest, increased after harvest, or was unaffected. Thirteen species were less abundant in clearcuts than in uncut forests, but their abundance was not always lower in partial clearcuts. Ten species, on the other hand, were consistently more abundant in logged areas than in uncut forests. The authors present several management recommendations based on their findings.

147. Irwin, LL. 1978. *Relationships Between Intensive Timber Culture, Big Game Habitats, and Elk Habitat Use Patterns in Northern Idaho*. PhD dissertation, University of Idaho, Moscow.

Irwin used radio tracking to examine elk habitat and forage use (by adult female elk and yearling males and females) in northern Idaho forests dominated by western hemlock and grand fir. The study area consisted of grass/shrub areas, brush fields, clearcuts, poletimber stands, mature timber stands, and old-growth forest. Elk exhibited seasonal and daily habitat preferences. In spring, they preferred shrub and grass/shrub areas during the morning and evening activity periods and timber stands during rests. In summer, elk preferred shrub or brush fields and clearcuts during active periods and dense poletimber stands during rest periods. During fall, elk showed less variation in habitat use, preferring poletimber stands away from roads and hunters. In winter, movement was restricted by deep snow, and the animals tended to use cover provided by timber stands. This dissertation also discusses elk activity in relation to roads and hunting, as well as the relationship between vegetation dynamics and silvicultural activities.

148. Irwin, LL, and JM Peek. 1983. Elk habitat use relative to forest succession in Idaho. *Journal of Wildlife Management* 47(3): 664–672.

Habitat use by elk in successional forests of Idaho was monitored by radiotelemetry. Forests were dominated by western hemlock and grand fir but also included areas dominated by mountain hemlock, subalpine fir, Engelmann spruce, and western white pine. Old-growth forests of western hemlock and western white pine were also present. Successional stages included shrub, grass/shrub, clearcut, poletimber, and mature/old-growth habitat. Habitat use varied by season. In spring, elk preferred grass/shrub and shrub areas for foraging and tall shrub areas and poletimber stands for resting. In summer, they preferred clearcuts for foraging and poletimber stands on ridges for resting. In autumn, elk used poletimber stands on mesic slopes. Elk did not show any habitat selection patterns during the winter. Elk preferred to rest in areas that were more than 400 m away from active roads. Selection of home ranges was related to forage production.

149. Iwanaga, PM. 1971. *Effects of Logging on the Growth of Juvenile Coho Salmon.* MS thesis, Oregon State University, Corvallis.

The effect of increased water temperature after clearcutting on the growth of juvenile coho salmon was studied in the Oregon Coast Range as part of the Alsea watershed study. Fish were sampled in one watershed that was clearcut without buffer strips and in a second that was patch clearcut with buffer strips (used as a control). Iwanaga conducted two separate experiments to compare growth rates in the two kinds of harvest sites, one in streams and one in aquariums; the aquarium study used the temperature fluctuations found in the streams, but the amount of food given to the coho was controlled. Growth rates of juvenile coho in the clearcut watershed were higher than those of coho in the patch cut watershed. Iwanaga suggests that the increased growth seen in clearcut streams may be due to an increase in food availability and a decrease in cutthroat trout populations. In the aquarium study, fish in the cooler tanks (representing the buffered stream) had higher growth rates than those in the warmer tanks. The cooler temperatures appeared to reduce the maintenance requirements of the coho; a reduced basal metabolic demand allowed more of the consumed food to be utilized for growth.

150. Jenkins, K, and E Starkey. 1996. Simulating secondary succession of elk forage values in a managed forest landscape, western Washington. *Environmental Management* 20(5): 715–724.

The authors used a simulation model based on site-specific information on post-harvest forest succession and forage characteristics to evaluate past and future influences of forest management practices on elk forage values in commercially managed Douglas-fir and western hemlock forests in Washington. Future effects were evaluated for 1) clearcut logging harvestable stands every 5 years (0%, 20%, and 40%), 2) thinning 20-year-old Douglas-fir forests, and 3) reducing the harvesting cycle from 60 to 45 years. Simulation results are presented in the paper. The authors conclude that the simulation models are useful for examining changes in forage production related to management strategies on a landscape level, but they caution that the options examined in the paper provide little potential for improving elk forage in the immediate future.

151. Johnson, SW, J Heifetz, and KV Koski. 1986. Effects of logging on the abundance and seasonal distribution of juvenile steelhead in some southeastern Alaska streams. *North American Journal of Fisheries Management* 6(4): 532–537.

Eighteen streams in southeastern Alaska were surveyed to determine the effects of clearcut logging with and without buffer strips on steelhead trout populations. Stream reaches surveyed were in undisturbed old-growth Sitka spruce/western hemlock forest, clearcut areas with logging down to at least one bank, or clearcut areas with buffer strips along both banks. Fish and habitat were surveyed 1–12 years after logging. Few juvenile steelhead were found in reaches where juvenile cutthroat trout were present, and no juvenile steelhead were found in streams with a low-flow discharge. Only two of the six sites (Mitkof Island and Prince of Wales) had steelhead juveniles in each stream type; in these streams, logging appeared to affect the growth of steelhead fry and the abundance and distribution of both fry and parr. The authors note that they could not reliably determine the effects of logging on the fish because seasonal movement and mixing of populations made it difficult to determine where the fish had resided before being collected. In the Prince of Wales Island streams, fry were more abundant and larger in clearcut reaches without buffer strips than in reaches in either old-growth forests or clearcuts with buffers. At both sites, summer parr density was highest in clearcut reaches, but by winter, densities had decreased by 91% in the unbuffered clearcuts and increased by 100% in the forests and 400% in the buffered clearcuts. The authors suggest that the benefits of increased summer growth and juvenile density after canopy removal are offset by the reduction in winter rearing habitat.

152. Jones, JL, and EO Garton. 1994. Selection of successional stages by fishers in north-central Idaho, pp. 377–387 in *Martens, Sables, and Fishers: Biology and Conservation*,

SW Buskirk, AS Harestad, MG Raphael, and RA Powell, eds. Comstock, Ithaca, NY.

Fishers were radio-tracked in northern Idaho to determine responses to stand management. Stands were dominated by either grand fir or subalpine fir. Successional stages in the study area included non-forest, sapling/poletimber, young forest, mature forest, and old growth. Non-forested areas were not used by fishers. Fishers used mature forest most often in the summer and young forests most often in the winter, but the use of the other stands did not differ by season. Most hunting and resting occurred in mature and old-growth forests, although fishers did hunt in all forested stands. The authors suggest that landscape management should include a variety of successional stages to provide a diversity of prey species, but late-successional forests need to be present to provide adequate resting habitat.

153. Kelsey, KA. 1995. *Responses of Headwater Stream Amphibians to Forest Practices in Western Washington*. PhD dissertation, University of Washington, Seattle.

Tailed frogs and Pacific giant salamanders were sampled in headwater streams in the central Washington Cascade Range to determine how timber harvest practices affect stream-breeding amphibian populations. Streams were in second-growth Douglas-fir/western hemlock forests and clearcuts (with variable buffer widths) above fish-bearing reaches. Data suggested that tailed frogs were more vulnerable than Pacific giant salamanders to habitat changes following timber harvest. Streams in unlogged areas had higher densities of second-year tailed frog tadpoles and greater biomass of Pacific giant salamander larvae than the streams in clearcuts. Habitat associations and possible habitat features that support the two species are discussed. Kelsey recommends protecting headwater streams during harvesting to provide breeding areas for tailed frogs. She suggests that if habitat for tailed frogs is maintained, Pacific giant salamanders will also benefit.

154. Kinley, TA, and NJ Newhouse. 1997. Relationship of riparian reserve zone width to bird diversity and density in southeastern British Columbia. *Northwest Science* 71(2): 75–86.

Riparian buffer strip width was evaluated with respect to bird diversity and density in the montane spruce zone of southeastern British Columbia. Riparian forests were hybrid white/Engelmann spruce, and upland forests were lodgepole pine. Control sites had unharvested upland forests; treated sites had upland clearcuts with varying riparian buffer widths: wide (average 70 m), medium (37 m), or narrow (14 m). In control areas, bird species richness was similar in riparian and upland forest, but bird density, species diversity, and equitability (relative species distribution) were highest in the riparian areas. In riparian buffers along clearcuts, bird density increased with buffer width, but species diversity and equitability did not differ. The authors recommend that riparian buffer width be increased from that currently required by British Columbia and the nearby USFS Kootenai National Forest.

155. Kirchhoff, MD, JW Schoen, and OC Wallmo. 1983. Black-tailed deer use in relation to forest clear-cut edges in southeastern Alaska. *Journal of Wildlife Management* 47(2): 497–501.

Winter habitat use by black-tailed deer was determined by examining fecal pellet-groups in 10 old-growth western hemlock/Sitka spruce stands and clearcuts in southeastern Alaska. Pellet-group density was higher in the old-growth forests than in adjacent clearcuts. The authors found no evidence of increased deer use near forest/clearcut edges. Clearcutting may have decreased habitat diversity by removing hardwoods and tall shrubs, whereas old-growth stands provided a mosaic of cover and foraging areas because of natural small-scale disturbances. Old-growth crowns may also lead to areas of shallow snow where forage is still available during the winter.

156. Kremsater, LL, and FL Bunnell. 1992. Testing responses to forest edges: The example of black-tailed deer. *Canadian Journal of Zoology* 70: 2426–2435.

Black-tailed deer response to forest edges was studied on Vancouver Island in British Columbia. Edges were between clearcuts, second-growth, and old-growth stands. Distributions of deer locations around edges were compared with the distributions expected if deer showed no affinity for edge habitat. There was little deer response (affinity for edge habitat) when edge habitat occurred within a fine-grained mosaic of forage and cover (i.e., where forage and cover were available in the same habitat). Where forage and cover occurred in distinctly different habitats, however, the deer were clearly associated with edges. Edges appeared to be less important when forage and cover were interspersed across the landscape.

157. Lautenschlager, RA. 1993. Response of wildlife to forest herbicide applications in northern coniferous ecosystems. *Canadian Journal of Forest Research* 23(10): 2286–2299.

This paper reviews literature concerning the effects of forest-use herbicides on wildlife in North America. The studies used herbicides (2,4,5-T, 2,4-D, glyphosate, and/or triclopyr) to control vegetation in young conifer stands, and most focused on the response of birds or small mammals to changes in vegetation after spraying. These studies have often been limited by lack of replication, limited or no pre-treatment information, and short duration (1 or 2 years after spraying). These problems, along with dissimilar sampling techniques, have often led to contradictory conclusions. It does appear that responses by birds and small mammals are species-specific.

158. Lehmkuhl, JF, SD West, CL Chambers, WC McComb, DA Manuwal, KB Aubry, JL Erickson, RA Gitzen, and M Leu. 1999. An experiment for assessing vertebrate response to varying levels and patterns of green-tree retention. *Northwest Science* 73 (Special Issue): 45–63.

This preliminary paper describes a new study examining vertebrate responses to varying retentions of overstory green trees, presenting an overview of the study areas, experimental and sampling designs, ecology and habitat of targeted vertebrate groups, and hypothetical responses to treatments. Stands were dominated by Douglas-fir and located in the Oregon and Washington Cascades. Six treatments were installed: 100% retention (control), 75% aggregated retention, 40% dispersed retention, 40% aggregated retention, 15% dispersed retention, and 15% aggregated retention. Summaries of pre-treatment data are included, but not post-treatment data. Target vertebrate species include birds, small mammals, bats, reptiles, and amphibians.

159. Levno, A, and J Rothacher. 1967. *Increases in Maximum Stream Temperatures After Logging in Old-Growth Douglas-fir Watersheds*. Research Note PNW-65, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 12 pp.

This study monitored water temperature changes after old-growth watersheds in the Oregon Cascade Range were clearcut. Three watersheds were used: one was left uncut, the second had 25% of its area clearcut, and the third was 100% clearcut over a 4-year period. Neither clearcut basin had riparian buffer strips. Maximum stream temperature in the 25% clearcut basin did not increase after harvesting, broadcast burning, and stream cleaning. After part of the stream channel was scoured during a 1964 flood, however, temperatures did increase. In the 100% clearcut, normal seasonal water temperature fluctuations did not change significantly until 55% of basin had been harvested.

160. Levno, A, and J Rothacher. 1969. *Increases in Maximum Stream Temperatures After Slash Burning in a Small Experimental Watershed*. Research Note PNW-110, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 7 pp.

A 237-acre experimental old-growth watershed in the Oregon Cascade Range was completely clearcut as part of a long-term study. After logging, the watershed was broadcast burned to reduce slash, which removed most of the remaining streamside vegetation; logs were removed from the lower portion of the stream channel. Water temperatures were monitored for 1 year after burning and stream cleaning and were compared with temperatures in an uncut watershed to determine the effects of burning. Stream temperatures rose after logging (reported by Levno and Rothacher 1967, citation 159) and drastically increased again after broadcast burning.

161. Lyon, LJ. 1979. Habitat effectiveness for elk as influenced by roads and cover. *Journal of Forestry* 77: 658–660.

Elk pellet-group counts near forest roads and adjacent habitat were used to determine use of roaded habitats in Montana forests. Roads were single lane with unimproved surfaces. Elk avoided habitat adjacent to these roads; as canopy cover decreased, elk avoided areas further and further from the roads. Lyon concludes that elk use available habitat less effectively when forest roads are open to traffic.

162. Lyon, LJ. 1979. *Influence of Logging and Weather on Elk Distribution in Western Montana.* Research Paper INT-236, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 11 pp.

Elk movement in response to clearcutting and seasonal weather was monitored in a Montana drainage by examining elk pellet-group distributions over an 8-year period beginning in 1970. High-elevation forests were dominated by subalpine fir and lodgepole pine and low-elevation forests by Douglas-fir. One of the drainages was logged from 1971 through 1974, and several smaller areas were logged on or near the study area during the study period. Weather was the most important factor affecting elk distribution, followed by timber harvesting. Elk moved out of areas with active logging operations. The distance they moved and the time until they returned depended on the location and duration of the operation.

163. Lyon, LJ, and CE Jensen. 1980. Management implications of elk and deer use of clear-cuts in Montana. *Journal of Wildlife Management* 44(2): 352–362.

The use of clearcuts in western and eastern Montana by Rocky Mountain elk, mule deer, and white-tailed deer was assessed by counting pellet groups. Pellet-group distribution suggested that elk and deer enter clearcuts to find increased forage. The authors suggest that the willingness of an animal to enter a clearcut depends on cover and whether security requirements for feeding are met. As long as slash did not prevent movement, elk and deer appeared to prefer clearcuts with cover unless the cover inhibited forage growth. Elk appeared to prefer smaller clearcuts than deer and preferred areas away from open roads.

164. Mannan, RW, and EC Meslow. 1984. Bird populations and vegetation characteristics in managed and old-growth forests, northeastern Oregon. *Journal of Wildlife Management* 48(4): 1219–1238.

The authors examined breeding bird populations and the structure and composition of vegetation in managed and old-growth forests in Oregon's Blue Mountains. Managed forests were 85 years old and had been thinned in 1971, and old-growth stands were >200 years old with little to no human disturbance. All stands were dominated by ponderosa pine and Douglas-fir. Stands and birds were sampled during 1978–1980. Managed and old-growth stands differed in tree height diversity and in numbers of large trees, snags, and understory grand firs; mean values for these components were all greater in old-growth stands. Chipping sparrows, ruby-crowned kinglets, and dusky flycatchers were more abundant in managed than in old-growth forests; these birds appeared to be attracted to open stand structure. Red-breasted nuthatches were more numerous in old-growth forests, and their distribution appeared to be related to the abundance of large snags. Townsend's warblers and golden-crowned kinglets were more abundant where grand fir was present in the understory of old-growth forest. The authors suggest that managers should focus on bird species likely to be negatively impacted when old-growth forest is harvested; managed stands should include forest components such as large snags and trees.

165. Marcot, BG. 1985. *Habitat Relationships of Birds and Young-Growth Douglas-fir in Northwestern California*. PhD dissertation, Oregon State University, Corvallis.

The author observed birds in various northern California mountain habitats to determine species distribution and abundance in relation to habitat conditions and even-aged silvicultural treatments. Habitat types studied included five successional stages: grass/forb, early shrub/sapling, late shrub/sapling, poletimber, and sawtimber. Stands were dominated by Douglas-fir. Densities for most of the 73 common bird species differed significantly across the five successional stages. During the breeding season, each successional stage supported high densities of certain species. The grass/forb stage had the least species and the lowest bird density, while the late shrub/sapling stage had the most species and highest bird density. Marcot compared his study with Hagar's study (citation 105), conducted during the mid-1950s in the same areas, and found that band-tailed pigeons, western wood pewees, fox sparrows, dusky flycatchers, western bluebirds, purple finches, and evening grosbeaks had increased with the increase in clearcuts. Species restricted to forested stages had decreased as clearcutting increased; forest species that decreased were brown creepers, golden-crowned kinglets, Hammond's flycatchers, chestnut-backed chickadees, red-breasted nuthatches, and hermit warblers. Marcot also discusses relationships between bird species and habitat variables, as well as seasonal variations in bird populations.

166. Marcum, CL. 1976. Habitat selection and use during summer and fall months by a western Montana elk herd, pp. 91–96 in *Proceedings of the Elk, Logging, Roads Symposium*, December 16–17, 1975. Forest, Wildlife, and Range Experiment Station, University of Idaho, Moscow.

The authors examined summer and fall habitat selection by Rocky Mountain elk in Montana. Habitat included forest (ponderosa pine, Douglas-fir, and subalpine fir types), clearcuts, roads, prairie, and talus. The elk appeared to have a wide tolerance for different environmental situations. Clearcuts and main roads were used proportionally less than their availability. Subalpine fir and Douglas-fir habitat types, riparian areas, shrub/grass, and closed roads were used proportionally more than their availability would suggest. The authors concluded that no measurable benefits to elk would result if high-elevation forests used as summer ranges were logged.

167. Martin, KJ, and RG Anthony. 1999. Movements of northern flying squirrels in different-aged forest stands of western Oregon. *Journal of Wildlife Management* 63(1): 291–297.

Northern flying squirrel home ranges and movements were compared in western Oregon Cascade second-growth and old-growth coniferous forests. Second-growth stands were dominated by 40-year-old Douglas-fir that regenerated after clearcutting, burning, planting, and fertilizing. Old-growth stands were >400 years old, unlogged, and dominated by Douglas-fir, western hemlock, and western redcedar. Flying squirrels were trapped, radio collared, and tracked for two summers. Home range size and squirrel movement did not differ between the two stand types. Squirrel abundance was similar in the two stand types (reported in Rosenberg and Anthony (1992), citation 226).

168. McGarigal, K, and WC McComb. 1995. Relationships between landscape structure and breeding birds in the Oregon Coast Range. *Ecological Monographs* 65(3): 235–260.

The authors examined the relationship between landscape structure (extent of coniferous late-seral forest habitat) and breeding bird abundance in the central Oregon Coast Range. The three basins studied were characterized by steep slopes and deeply cut drainages with forests dominated by Douglas-fir. The Coast Range area had experienced stand replacement fires in the 1880s and extensive clearcutting in a dispersed-patch pattern since the 1950s; this pattern maximized fragmentation. Fifteen relatively common and widespread diurnal breeding bird species were surveyed in each landscape. Landscape structure typically explained less than 50% of the variation in abundance for these species. Species abundances were generally greater in more heterogeneous landscapes; that is, they were associated with the more fragmented distribution of habitat. Only winter wrens showed an association (greater abundance) with the least fragmented landscapes. Relationships to late-seral forest area varied dramatically among bird species. The abundances of birds associated with particular habitat types at patch level showed variation among landscapes that could not be explained by habitat area alone.

169. McGarigal, K, and WC McComb. 1999. Forest fragmentation effects of breeding bird communities in the

Oregon Coast Range, pp. 223–246 in *Forest Fragmentation: Wildlife and Management Implications*, JA Rochelle, LA Lehmann, and J Wisniewski, eds. Brill, Boston, MA.

This study examined the relationship between landscape structure (extent of coniferous late-seral forest habitat) and breeding bird abundance in the central Oregon Coast Range. The three basins studied were characterized by steep slopes and deeply cut drainages with forests dominated by Douglas-fir. This area had experienced stand replacement fires in the 1880s and extensive clearcutting in a dispersed-patch pattern since the 1950s, leading to extensive fragmentation. The authors used analysis of variance and regression procedures to quantify the independent effects of late-seral forest area and configuration on 55 bird species. Landscape structure typically explained less than 50% of the variation in individual bird species abundance among landscapes. Equal numbers of species were positively and negatively associated with late-seral forest area. Species abundances were generally greater in more heterogeneous landscapes. The authors conclude that the area of late-seral forest is likely to be more important than its configuration, and that land owners should first focus on maintaining amounts of sufficient late-seral forest and then consider the arrangement of forest within the landscape.

170. McMahon, TE, and DS deCalesta. 1990. Effects of fire on fish and wildlife, pp. 233–250 in *Natural and Prescribed Fire in Pacific Northwest Forests*, JD Walstad, SR Radosevich, and DV Sandberg, eds. Oregon State University Press, Corvallis.

The authors discuss the potential short-term and long-term impacts of prescribed burning and natural wildfires on fish and wildlife populations and habitat in the Pacific Northwest. They discuss changes in stream habitat—including water temperature, nutrients and food resources, large woody debris, and water sediment and turbidity—and the benefits of leaving riparian buffer strips. The authors include both the direct effects of fire on terrestrial wildlife mortality and the indirect effects (positive and negative) associated with changes in food resources and cover, which provides protection from environmental extremes and predators.

171. Medin, DE. 1985. *Breeding Bird Responses to Diameter-Cut Logging in West-Central Idaho*. Research Paper INT-355, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 12 pp.

Breeding bird response to diameter-limit cutting was studied in Douglas-fir/ponderosa pine forests in Idaho. Stands were cut to a 10-inch minimum diameter at breast height, and logs were yarded by helicopter. Slash was lopped, scattered, and burned. Logged stands were compared with unlogged stands. Birds were surveyed 1 year before logging and for 3 years after logging. Total bird density changed little after logging, but community composition changed markedly in logged stands; species requiring open habitats increased, but those requiring more closed habitats decreased. Species that responded positively to logging and increased in density were *Empidonax* flycatchers, Townsend's solitaires, American robins, chipping sparrows, dark-eyed juncos, and Cassin's finches. Species present in logged stands after but not before logging included house wrens, mountain and western bluebirds, black-backed woodpeckers, olive-sided flycatchers, warbling vireos, and black-headed grosbeaks. Species that responded negatively to logging included mountain chickadees, red-breasted nuthatches, brown creepers, Swainson's thrushes, Townsend's and MacGillivray's warblers, and western tanagers. Species with similar densities on both logged and unlogged plots were calliope hummingbirds, hairy woodpeckers, northern flickers, hermit thrushes, solitary vireos, Nashville and yellow-rumped warblers, and pine siskins. On the basis of patterns in this study and others, Medin concludes that certain breeding bird species show consistent responses to logging in western coniferous forests.

172. Medin, DE. 1986. The impact of logging on red squirrels in an Idaho conifer forest. *Western Journal of Applied Forestry* 1(3): 73–76.

The response of red squirrel populations to diameter-limit cutting of Douglas-fir/ponderosa pine forests was studied in Idaho. Harvested stands were cut to a 10-inch minimum diameter at breast height, and slash was burned. Harvested plots were compared with an uncut control. Logging and burning reduced shrub canopy cover. Squirrel densities dropped sharply after logging and burning. Red squirrel densities on the harvested sites were only one-fifth of densities on the uncut control. Medin speculates that the removal of snags and large woody debris may have reduced suitable habitat for the red squirrel.

173. Medin, DE. 1986. *Small Mammal Responses to Diameter-Cut Logging in an Idaho Douglas-fir Forest*. Research Note INT-362, USDA Forest Service, Intermountain Research Station, Ogden, UT. 6 pp.

Small mammal response to diameter-limit cutting was studied in Douglas-fir/ponderosa pine forests in Idaho. Stands were cut to a 10-inch minimum diameter at breast height, and logs were yarded by helicopter. Slash was lopped, scattered, and burned. Logged stands were compared with unlogged stands. Small mammals were live trapped 1 year before logging and for 3 years after logging. Deer mice populations were similar on the logged and unlogged sites. Yellow-pine chipmunks increased on logged sites, but southern red-backed voles disappeared.

174. Medin, DE, and GD Booth. 1989. *Responses of Birds and Small Mammals to Single-Tree Selection Logging in Idaho*. Research Paper INT-408, USDA Forest Service, Intermountain Research Station, Ogden, UT. 11 pp.

The authors studied changes in bird and small mammal populations after single-tree harvesting in north-central Idaho forests dominated by Douglas-fir and ponderosa pine. Animals were sampled for 2 years before logging began and for 3 years after it ended. Total breeding bird populations changed little after harvesting. Olive-sided flycatcher, Swainson's thrush, yellow-rumped warbler, and chipping sparrow abundance increased after logging, while brown creeper and red-breasted nuthatch abundance decreased. Western tanagers and Townsend's solitaires declined slightly. Birds that did not change after logging were hairy woodpeckers, calliope hummingbirds, northern flickers, *Empidonax* flycatchers, mountain chickadees, golden-crowned kinglets, American robins, solitary vireos, Nashville warblers, Townsend's warblers, MacGillivray's warblers, dark-eyed juncos, Cassin's finches, and pine siskins. Of the mammals, deer mice decreased after logging, yellow pine chipmunks increased, and southern red-backed vole numbers did not change.

175. Meehan, WR, ed. 1991. *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitat*. Special Publication 19, American Fisheries Society, Bethesda, MD.

This book is a compilation of scientific literature and resource agency reports on the potential impacts of land management activities (including habitat restoration and management) on stream ecosystems, salmonid biology, and stream habitat requirements. Land-use activities discussed include timber harvesting and silvicultural activities, chemical applications (herbicides, pesticides, fertilizers, etc.), road construction and maintenance, water transportation and storage of logs, pulp and paper mill processing, livestock grazing, mining, and recreation. Chapters pertaining to silvicultural activities are annotated in citations 50, 132, and 202.

176. Meehan, WR, WA Farr, DM Bishop, and JH Patric. 1969. *Some Effects of Clearcutting on Salmon Habitat of Two Southeast Alaska Streams*. Research Paper PNW-82, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Juneau, AK. 45 pp.

The effects of clearcutting on salmonids and stream habitat were studied from 1949 to 1964 in three southeastern Alaska watersheds. Forests were dominated by western hemlock, Sitka spruce, western redcedar, and Alaskan cedar. Two of the watersheds were extensively clearcut during 1953–1961, while the third was left undisturbed. Stream flow did not appear to increase after logging in the harvested watersheds. Suspended sediment remained at low levels in all streams. Stream temperatures in both logged watersheds increased by 1ºF–4ºF shortly after logging began, but the change varied among streams and with position of clearcuts. Logging debris did not appear to impede salmon migration. Escapement surveys suggested that salmon (mainly pink and chum) increased after clearcutting, but the increase may reflect the removal of

commercial fish traps from nearby waters, masking any changes due to clearcuts.

177. Meehan, WR, FB Lotspeich, and EW Mueller. 1975. Effects of forest fertilization on two southeast Alaska streams. *Journal of Environmental Quality* 4(1): 50–55.

The effect of urea fertilizer on stream water quality was studied on recent clearcuts with no riparian buffer strips in southeastern Alaska. Urea was applied by helicopter to two clearcuts with streams flowing across them. Treated streams were compared with streams in two clearcuts receiving no fertilizer. A short-term increase in ammonia-nitrogen was observed after application; nitrate-nitrogen levels increased and remained high during the year following application. Biomass of periphyton and benthic organisms did not change after application of urea.

178. Mellen, TK, EC Meslow, and RW Mannan. 1992. Summertime home range and habitat use of pileated woodpeckers in western Oregon. *Journal of Wildlife Management* 56(1): 96–103.

Pileated woodpeckers were tracked by radiotelemetry in eight forest vegetation types in the central Oregon Coast Range to determine home range area and habitat use. Forests were dominated by Douglas-fir. Vegetation classes were 1) 0- to 15-year-old managed clearcuts with seedlings and/or saplings, 2) 16- to 40-year-old managed stands with saplings and small poletimber, 3) 41- to 70-year-old managed immature stands with poletimber and/or small sawtimber, 4) 71- to 100-year-old managed and unmanaged mature forest with small and/or large sawtimber, 5) 100- to 200-year-old unmanaged older mature forest with large sawtimber, 6) >200-year-old unmanaged old-growth forest, 7) deciduous riparian areas dominated by red alder and bigleaf maple, and 8) non-forested land including agricultural lands, lakes, and meadows. Home ranges of pairs were larger than home ranges of individuals. Pileated woodpeckers preferred forests that were older than 40 years and deciduous riparian habitats for foraging and other diurnal activities. Nesting and roosting occurred only in stands older than 70 years. The authors suggest that because pileated woodpeckers forage in younger forests, they may not be good indicator species for mature and old-growth forest habitat in western Oregon.

179. Mills, LS. 1995. Edge effects and isolation: Red-backed voles on forest remnants. *Conservation Biology* 9(2): 395–403.

Mills examined the negative effects of habitat edges on western red-backed voles in Oregon's Klamath Mountains. The edges were between isolated remnants of uncut Douglas-fir forest (more than 80 years old) and the surrounding clearcuts (0–30 years old, post harvest age). Trapping data indicated that the red-backed voles were isolated in the remnants and made little use of the regenerating clearcuts or edges. Most voles were captured in the remnant interior rather than on the forest/clearcut edge. Vole density increased with remnant forest size. Vole distribution did not appear to be associated with volume or distribution of logs, which decreased with distance from the edge into the remnant forests; however, distribution was associated with the availability of hypogeous fungi (a major food source) found in the remnant interior.

180. Moore, DG. 1975. *Effects of Forest Fertilization with Urea on Stream Water Quality, Quilicene Ranger District, Washington*. Research Note PNW-241, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 9 pp.

After second-growth conifer stands were fertilized with urea on the Olympic Peninsula, Washington, stream water quality was monitored to determine the amount of fertilizer nitrogen entering adjacent streams. Areas fertilized included a 10-year-old and a 40-year-old Douglas-fir plantation and a 70-year-old Douglas-fir/western hemlock stand. Urea was aerially applied to the stands but not within 60 m of streams. Stream water quality was monitored for 7 months after application. Fertilizer reached the streams in the form of urea-nitrogen, ammonia-nitrogen, and nitrate-nitrogen. Levels were well within acceptable standards for drinking water: urea-N was less than 1.0 ppm, ammonia-N increased slightly above background levels, and nitrate-N reached

0.121 ppm. After the first 3 weeks, only nitrate-N entered the streams. Most (95%) of the nitrogen that entered the streams entered within the first 9 weeks after application. Moore concludes that the small amounts of nitrogen entering the streams after fertilization should have minimal impacts on eutrophication.

181. Moring, JR. 1975. *The Alsea Watershed Study: Effects of Logging on the Aquatic Resources of Three Headwater Streams on the Alsea River, Oregon. Part II: Changes in Environmental Conditions*. Fisheries Research Report 9, Part II, Oregon Department of Fisheries and Wildlife, Corvallis. 39 pp.

Three streams were monitored during a 15-year logging study (1959–1973) in the Oregon Coast Range to determine the effects of logging on salmonids, other fish, and the stream environment. The first watershed was clearcut without buffer strips, the second was patch clearcut with buffer strips, and the third was left undisturbed. The study was reported in three parts (see citations 187 (Part I) and 182 (Part III)). Following logging in the clearcut watershed, stream temperatures and mean monthly stream flow increased, while surface water, intragravel water, dissolved oxygen concentrations, and gravel permeability decreased. The patch cut watershed did not show any significant changes in water temperature, surface or intragravel dissolved oxygen concentrations, or gravel permeability after logging. Both logged watersheds had an increase in suspended sediment after road construction.

182. Moring, JR. 1975. *The Alsea Watershed Study: Effects of Logging on the Aquatic Resources of Three Headwater Streams on the Alsea River, Oregon. Part III: Discussion and Recommendations*. Fisheries Research Report 9, Part III, Oregon Department of Fisheries and Wildlife, Corvallis. 24 pp.

Three streams were monitored during a 15-year logging study (1959–1973) in the Oregon Coast Range to determine the effect of logging on salmonids, other fish, and the stream environment. The first watershed was clearcut without buffer strips, the second was patch clearcut with buffer strips, and the third was left undisturbed. This publication, the third of three parts (see citations 187 (Part I) and 181 (Part II)), includes synopses of the study, the site, and results from Parts I and II. Based on study results, the author makes the following recommendations: 1) the use of riparian buffer strips is necessary to prevent direct physical changes and indirect biological changes to the stream environment; 2) roads should be designed and constructed to minimize erosion potential and excess sediment and mass transport of materials; 3) trees should not be felled across the stream or onto the bank, and logs should not be yarded across the stream; 4) excessive logging debris should be removed from the stream as soon as possible; and 5) state fisheries agencies and/or their biologists should be consulted when headwater streams may be affected by logging operations.

183. Moring, JR. 1981. Changes in populations of reticulate sculpins (*Cottus perplexus*) after clear-cut logging as indicated by downstream migrants. *American Midland Naturalist* 105(1): 204–207.

Changes in downstream migrations of reticulate sculpins after clearcut logging were examined in the Oregon Coast Range. Two headwater streams were monitored for 14 years (1960–1973). One watershed was clearcut in 1966, followed by removal of logging debris from the stream channel and broadcast burning of the site. The second watershed was not logged. Short-term decreases in reticulate sculpin populations persisted for 5 years after logging, as indicated by a reduction in migrating fish. During the same period, the average fish was longer than before logging, which may indicate a decrease in competition. Timing of downstream migrations did not change after logging.

184. Moring, JR. 1982. Decrease in stream gravel permeability after clear-cut logging: An indication of intragravel conditions for developing salmonid eggs and alevins. *Hydrobiologia* 88: 295–298.

Excess sediment can reduce gravel permeability; in turn, the reduction in permeability may adversely affect developing salmonid eggs and alevins. Changes in stream gravel permeability after clearcut harvesting were studied in three Oregon Coast Range drainage basins. In one basin, 82%

of the watershed was clearcut; in the second, 25% was patch clearcut with riparian buffer strips; and the third basin was uncut. One stream in each basin was monitored for 11 years, including 7 years after logging. Pre-logging gravel permeability varied between streams. Average permeability of the 82% clearcut basin decreased significantly after logging, whereas permeability in the uncut and the patch cut streams remained stable throughout the study. Sediment discharge increased significantly with logging activity in the two harvested watersheds (Moring 1975, citation 181; Beschta 1978, citation 11). Moring concludes that increased sediments tend to decrease gravel permeability and emergence survival of salmonids, but natural variation of stream gravel is high. He suggests that monitoring gravel permeability during land-disturbing activities may be a more useful tool than measuring sediment levels for assessing intragravel rearing conditions.

185. Moring, JR, GC Garmon, and DM Mullen. 1994. Effects of logging practices on fishes in streams and techniques for protection: A review of four studies in the United States, pp. 194–207 in *Rehabilitation of Freshwater Fisheries*, IG Cowx, ed. Fishing News Books, Oxford, England.

The authors use four studies to demonstrate the detrimental effects of logging practices on cold water stream fishes and their environment. Two studies were done in the Oregon Coast Range and two in Maine. The Oregon studies examined clearcut logging with and without riparian buffers and partial thinning. The Maine studies examined clearcutting. In areas with no riparian buffer strips, water temperatures rose to more than 30ºC, dissolved oxygen decreased significantly, particulate organic matter increased, bank stability was reduced, and solar radiation to the stream increased. Cutthroat trout and reticulate sculpin numbers decreased after logging in the Oregon studies. Salmonid populations remained similar to natural populations where buffer strips were used or where substantial shading was left intact. The authors conclude that maintaining intact buffer zones is critical for aiding bank stability and reducing erosion, as well as for preventing increased water temperatures in small streams.

186. Moring, JR, and RL Lantz. 1974. *Immediate Effects of Logging on the Freshwater Environment of Salmonids*. Federal Aid Progress Reports: Fisheries. AFS 58, Oregon Department of Fish and Wildlife, Research Division, Portland. 101 pp.

The effects of several logging practices on stream water quality and salmonids were studied in 12 streams in the Oregon Coast Range. Logging methods were clearcutting with and without riparian buffer strips and partial thinning with road construction. Streams were monitored one season before logging and one season after logging. Cutthroat trout populations declined after logging, but coho salmon populations did not appear to be affected. On most streams, water temperature increased after logging, while surface and intragravel dissolved oxygen concentrations decreased. Streambed gravel distributions and composition were more variable after logging. Gravel was less disturbed in streams with buffer strips. Streambed damage varied greatly among streams and was related to type of logging and to the care taken by individual operators conducting tree falling, yarding, and road construction.

187. Moring, JR, and RL Lantz. 1975. *The Alsea Watershed Study: Effects of Logging on the Aquatic Resources of Three Headwater Streams on the Alsea River, Oregon. Part I: Biological Studies*. Fisheries Research Report 9, Part I, Oregon Department of Fisheries and Wildlife, Corvallis. 66 pp.

Three streams were monitored during a 15-year logging study (1959–1973) in the Oregon Coast Range to determine the effects of logging on salmonids, other fish, and the stream environment. The first watershed was clearcut without buffer strips, the second was patch clearcut with buffer strips, and the third was left undisturbed. This report is the first of three parts (see citations 181 (Part II) and 182 (Part III)). In the clearcut watershed (no riparian buffer), cutthroat trout populations decreased after logging, and the migration of juveniles changed after slashburning and clearance of debris from the stream. Coho salmon were less affected, but average length, weight, and condition decreased in juveniles the summer after logging.

Changes in cutthroat trout and coho populations were minimal in the patch clearcut watershed. Later, coho biomass and net production rates increased in both logged watersheds. In the clearcut watershed, the two youngest age classes of reticulate sculpins were almost eliminated, and the number of adult western brook lampreys declined after logging. Sculpin populations remained the same after logging in the patch clearcut watershed, while lamprey numbers increased.

188. Morrison, ML. 1992. Bird abundance in forests managed for timber and wildlife resources. *Biological Conservation* 60(2): 127–134.

Bird abundances and species composition were compared in uneven- and even-aged managed mixed conifer forests in the Sierra Nevada Mountains of California. Stands were comprised of incense-cedar, white fir, Douglas-fir, ponderosa pine, and sugar pine. No descriptions of silvicultural treatments were given. Breeding birds were surveyed during two 2-year periods. Total numbers of breeding bird species were similar between years and stand types, but species abundances varied, leading to few consistent differences between stand types. Hammond's flycatchers and hermit warblers were more abundant in uneven-aged stands, while Nashville warblers and purple finches were more abundant in even-aged stands.

189. Morrison, ML, and RG Anthony. 1989. Habitat use by small mammals on early-growth clear-cuttings in western Oregon. *Canadian Journal of Zoology* 67: 805–811.

Habitat use by small mammals on two Oregon Coast Range clearcuts was studied over a 3-year period. Clearcuts had been harvested, burned, and planted with Douglas-fir 5–6 years before the study began. The deer mouse, a habitat generalist, dominated the small mammal community along with several less frequently caught species that showed varying degrees of habitat specificity (Trowbridge's shrew, creeping vole, Townsend's chipmunk, Pacific jumping mouse, vagrant shrew, and Pacific shrew). Habitat use differences among the seven species were primarily related to the use of grass and forb cover.

190. Morrison, ML, and EC Meslow. 1983. *Avifauna Associated with Early Growth Vegetation on Clearcuts in the Oregon Coast Range*. Research Paper PNW-305, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 12 pp.

The authors surveyed birds nesting in early-growth clearcuts in the Oregon Coast Range. Douglas-fir/western hemlock forests were clearcut, burned, and planted with Douglas-fir. Birds were surveyed 4–9 years after planting during at least one nesting season on each site. Fifty-three bird species were observed, but only 22 species nested; only 11 nesting species were common or abundant, all of which nested and foraged on or near the ground. Cavity-nesting species were rare on all sites. Some species appeared to be related to the density of red alder. The presence of non-nesting species was sporadic. The authors conclude that bird communities associated with clearcuts are characterized by species that prefer shrub-dominated habitat and that can be expected to be regular nesters on clearcuts.

191. Morrison, ML, and EC Meslow. 1983. Bird community structure on early-growth clearcuts in western Oregon. *American Midland Naturalist* 110(1): 129–137.

The structure of bird communities on early-growth clearcuts was studied in the Oregon Coast Range. Twelve clearcuts were logged, burned, and planted with Douglas-fir seedlings 4–9 years before the study began. Ground vegetation was mainly shrubs, with red alder as the predominant overstory tree. Half the sites had been treated with phenoxy herbicides (2,4-D or 2,4,5-T) to control shrubs and red alder 1–4 years before the study. Total nesting bird density on the clearcuts ranged from 326 to 352 birds/40.5 ha. The number of nesting birds varied little among the sites. Predominant birds on all sites were white-crowned sparrows, song sparrows, rufous hummingbirds, and Swainson's thrushes. Species with moderate densities were willow flycatchers, American goldfinches, rufous-sided towhees, and orange-crowned warblers. The total density of nesting birds decreased with increasing conifer height but increased with increasing deciduous tree cover. In addition, bird densities increased where patches of deciduous trees formed breaks in plant communities dominated by shrubs and conifers.

192. Morrison, ML, and EC Meslow. 1983. Impacts of forest herbicides on wildlife: Toxicity and habitat alteration. *Transactions of the North American Wildlife Natural Resources Conference* 48: 175–185.

This paper reviews laboratory and field studies that examined the possible toxicity of herbicides to wildlife. The authors conclude that the herbicides themselves do not pose a direct toxic threat to wildlife. However, possible impurities—such as dioxin in 2,4,5-T—may be a threat; such impurities should be the focus of concern, rather than the actual herbicides. The paper also reviews potential wildlife response to herbicide applications and associated habitat alterations. The authors conclude that the general response of wildlife to herbicide use can be predicted if data are available on the range and habitats occupied by a species and the species' density in those habitats.

193. Morrison, ML, and EC Meslow. 1984. Effects of the herbicide glyphosate on bird community structure, western Oregon. *Forest Science* 30(1): 95–106.

This study examined habitat characteristics used by birds in regenerating clearcuts, along with bird population changes before and after young conifers were released with glyphosate. The two clearcuts were in the Oregon Coast Range and had been planted with Douglas-fir 7 years before the study began. One clearcut was treated with glyphosate herbicide to control shrubs; the other was left untreated. Vegetation decreased the first year after spraying on the treated site, but it increased by 2 years after spraying, so that levels at the two sites were similar. Overall bird density did not change after the herbicide treatment. Species that decreased on the treated clearcut were rufous hummingbirds, MacGillivray's warblers, Wilson's warblers, rufous-sided towhees, and white-crowned sparrows. Species that increased, on the other hand, were willow flycatchers, orange-crowned warblers, dark-eyed juncos, and American goldfinches. At 1 year after treatment, several species decreased their use of shrubs and increased their use of hardwoods, but by 2 years after treatment, many species had returned to pre-spray levels of use. The study indicates that vegetation changes resulting from herbicide applications may affect both the densities and behavior of bird species.

194. Morrison, ML, and EC Meslow. 1984. Response of avian communities to herbicide induced vegetation changes. *Journal of Wildlife Management* 48: 14–22.

Bird responses to brush control with 2,4-D herbicide were studied on clearcuts in the Oregon Coast Range. Clearcuts of two ages were used: those 4–5 years old were sprayed 1 year before sampling, and those 6–8 years old were sprayed 4 years before sampling. Sprayed sites were compared with untreated controls of equivalent age. For both clearcut types, vegetation cover was similar, but slightly higher, on control sites than on sprayed sites; however, hardwood cover (mainly red alder with some bigleaf maple) was significantly greater on the control sites. Bird density and diversity were similar on control and treated sites for clearcuts of both ages, although some birds altered their foraging behavior on treated sites, increasing their use of shrubs instead of hardwood trees. The authors suggest that retaining patches of hardwood trees in clearcuts treated with 2,4-D would maintain the bird communities present in untreated clearcuts.

195. Motobu, DA. 1978. Effects of controlled slash burning on the mountain beaver (*Aplodontia rufa rufa*). *Northwest Science* 52(2): 92–99.

Mountain beavers were trapped on clearcuts near Gray's Harbor, Washington, to determine the possible effects of burning on populations. Slash was burned 1 year after clearcutting. Prior to burning, mountain beavers within the clearcuts were trapped, tagged, and released. Mountain beavers within a wide buffer area surrounding one unit were trapped and removed to determine whether the lack of a nearby population would influence the movement of animals out of the burn area during or after the fire. Units were then broadcast burned, and mountain beavers were retrapped. The fire did not appear to affect the age classes or sex distributions of populations within either clearcut. The fire also did not affect the movement of tagged animals, which were recaptured similar distances apart before and after the fire. Mountain beavers moved into unburned areas if the unburned area was within their normal range. Predator activity within the units increased during the 3 weeks after the fire, particularly activity by coyotes, as shown by evidence of their digging to recover carcasses or live animals in mountain beaver burrows. No digging by coyotes was seen prior to the fire.

196. Murphy, ML, and JD Hall. 1981. Varied effects of clearcut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon. *Canadian Journal of Fisheries and Aquatic Sciences* 38: 137–145.

Aquatic vertebrate and insect predators were inventoried in Oregon Cascade streams to assess the effects of clearcut logging on stream communities. The streams were in clearcuts (5–17 years post-logging), second-growth stands (12–35 years post logging), or old-growth Douglas-fir/western hemlock forests (>450 years old). All logged sites had been clearcut without riparian buffer strips and burned. Aquatic vertebrates present (listed in decreasing order of biomass and frequency) were Pacific giant salamander, cutthroat trout, sculpins (*Cottus* spp.), Olympic salamander, and speckled and longnose daces. Twenty-seven insect taxa were also inventoried. Effects associated with clearcutting depended on stream size, gradient, and time since harvest. Streams in clearcuts still exposed to sunlight had greater biomass, density, and species richness of vertebrate and insect predators than those in old growth. Second-growth stream sections that had been reshaded by hardwood trees had lower biomass of trout and fewer predator taxa than old-growth streams.

197. Murphy, ML, CP Hawkins, and NH Anderson. 1981. Effects of canopy modification and accumulated sediment on stream communities. *Transactions of the American Fisheries Society* 110(4): 469–478.

Oregon Cascade stream reaches were compared in logged and forested areas to determine the effects of accumulated fine sediment on stream communities. Three stages of forest development were studied: recent clearcut (5–10 years since logging) with no forest canopy over streams; second-growth stands (30–40 years since clearcutting) with deciduous forest canopy over streams; and old-growth Douglas-fir/western hemlock forest (>450 years old). The authors compared one stream with mostly coarse sediment and one with more fine sediment for each forest development stage. Steams traversing clearcuts had higher microbial respiration rates and more aufwuchs (periphyton, bacteria, fungi, and associated organic matter on rock surfaces), benthic and drifting invertebrates, salamanders, and trout. Five species of aquatic vertebrates were caught, but there were no consistent differences in numbers or relative dominances of species among forest ages or between low- and high-gradient streams. Pacific giant salamanders were more abundant in high-gradient than in low-gradient streams. Cutthroat and rainbow trout were more abundant in clearcut sites than forested sites. Tailed frogs and reticulate sculpins were present on some of the sites. The authors conclude that changes in trophic status and increased primary productivity resulting from shade removal may mask or override effects of sedimentation in small Cascade Range streams.

198. Murphy, ML, J Heifetz, SW Johnson, KV Koski, and JF Thedinga. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. *Canadian Journal of Fisheries and Aquatic Sciences* 43(8): 1521–1533.

Eighteen southeastern Alaskan streams were compared to determine the short-term effects of clearcut logging with and without buffer strips on juvenile salmonid density and habitat. The stream reaches were in clearcuts with logging down to at least one bank, clearcuts with buffer strips along both banks, or undisturbed old-growth Sitka spruce/western hemlock forests. Fish and habitat surveys were done 1–12 years after logging. Clearcut reaches without buffer strips had more periphyton, lower channel stability, and less canopy cover, pool volume, and large woody debris than old-growth reaches; buffered reaches did not consistently differ from old-growth reaches. For streams with

underlying limestone, summer levels of periphyton, benthos, and coho salmon fry were higher in clearcut reaches without buffers and in buffered reaches with canopy openings than in old-growth reaches. In winter, parr abundance depended on the amount of large woody debris. Parr were scarce when debris had been removed from clearcut reaches. The authors conclude that clearcutting and removal of the canopy from the stream bank may increase fry abundance in summer by increasing primary reduction, but it may reduce parr abundance in winter if large woody debris is removed. Buffer strips appear to maintain and sometimes increase large woody debris, protecting stream habitat while allowing increased primary production and juvenile salmonid abundance.

199. Newton, M, KM Howard, BR Kelpsas, R Danhaus, CM Lottman, and S Dubelman. 1984. Fate of glyphosate in an Oregon forest ecosystem. *Journal of Agricultural and Food Chemistry* 32: 1144–1151.

Residues and metabolites from glyphosate herbicide sprayed aerially on a hardwood/shrub ecosystem were determined in the Oregon Coast Range. Coho salmon fingerlings were released into a stream crossing the study site prior to spraying. Vegetation, soil, litter, water, small mammals, and coho were sampled on the day of spraying and 1, 2, 3, 6, 7, 14, 28, and 55 days afterward. Nearly all the herbicide was intercepted by vegetation, with only small amounts reaching the ground. The half life of glyphosate was twice as long in soil as in vegetation and litter. Concentrations in stream water peaked the day spraying occurred and decreased quickly. Stream sediments picked up residues more slowly than water did, but residues reached higher concentrations. Coho fingerlings did not accumulate detectable amounts of glyphosate. Small mammal exposure appeared to be dependent on food preferences, and tissue concentrations were low. The authors conclude that glyphosate does not accumulate in organisms at higher trophic levels.

200. Niederleitner, JF. 1987. Use of early successional, midsuccessional, and old-growth forests by breeding blue grouse (*Dendragapus obscurus fuliginosus*) on Hardwick Island, British Columbia. *Canadian Journal of Zoology* 65(1): 151–155.

Blue grouse habitat use was studied for one season in three forest types in British Columbia. Stands were predominantly western hemlock with some clearcuts planted with Douglas-fir. Transects were laid out in two clearcuts (3–13 years old), one second-growth stand (59 years old), and one old-growth stand (>250 years old). There were more blue grouse males and more broods on clearcuts than in the second- or old-growth stands. Niederleitner suggests that herbaceous cover may be an important component of preferred habitat.

201. Norris, LA, HW Lorz, and SV Gregory. 1983. *Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America. No. 9. Forest Chemicals*. WR Meehan, tech. ed. General Technical Report PNW-GTR-149, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 95 pp.

This chapter reviews the use of herbicides, insecticides, fertilizers, and fire retardants in the forest environment and their potential effects on salmonids and their habitat. This is an earlier version of the paper written by Norris et al. that was published in 1991 (citation 202). Potential direct effects of using forest chemicals on fish and prey are evaluated on the basis of data concerning chemical movement, persistence, and toxicity. Chemicals discussed include herbicides (2,4-D, picloram, atrazine, MSMA, fosamine ammonium, glyphosate, dinoseb), insecticides (malathion, carbaryl, azinphos-methyl, carbofuran, acephate), urea fertilizer, and fire retardants. Based on available information, the authors present hazard assessments for forest chemicals at the organism level (acute toxicity and chronic toxicity) and at the ecosystem level. The chapter concludes with a discussion of research needs.

202. Norris, LA, HW Lorz, and SV Gregory. 1991. Forest Chemicals, pp. 207–296 in *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitat*, WR Meehan, ed. American Fisheries Society, Bethesda, MD.

This chapter reviews the use of chemicals in the forest environment and the potential effects on salmonids and their habitat. This is an updated and expanded version of a report published by Norris et al. in 1983 (citation 201). Detailed discussions on the use of chemicals and their behavior in the forest environment, as well as chemical toxicity to fish and invertebrates, are given for herbicides (2,4-D, picloram, hexazinone, atrazine, triclopyr, MSMA, fosamine ammonium, glyphosate, dalapon, and dinoseb), insecticides (malathion, carbaryl, azinphos-methyl, carbofuran, acephate, *Bacillus thuringiensis* (*B.t.*), and nuclear polyhedrosis virus (NPV)), urea fertilizer, and fire retardants. Based on available information, the authors present risk assessments for forest chemicals at the organism level (acute toxicity and chronic toxicity) and at the ecosystem level. The chapter concludes with a discussion of research needs.

203. Norris, LA, and WL Webb. 1989. Effects of fire retardant on water quality, pp. 79–86 in *Proceedings of the Symposium on Fire and Watershed Management*, October 26–28, 1988, NH Berg, tech. coord. General Technical Report PSW-109, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.

The authors studied the entry, fate, and impact of ammonium-based fire retardants on five forest streams in the western U.S. The first two streams were in the Oregon Coast Range in forests dominated by Douglas-fir, western hemlock, Sitka spruce, and red alder. The third stream was in the Oregon Cascades with surrounding forests dominated by Douglas-fir and red alder. The fourth was in an Idaho ponderosa pine forest, and the fifth was in southern California chaparral. The fire retardant was applied across segments of four of the streams and parallel to the fifth. Streamwater samples were taken up to 13 months after application at locations up to 2700 m downstream from the point of entry. The retardant did not kill or incapacitate fish in the first 24 hours or affect the density or diversity of stream invertebrates in the first year after application. Retardant dispersal model simulations suggest that fish mortality could occur anywhere from 0 to more than 10,000 m below the entry point, depending on application parameters and stream characteristics. The authors present guidelines for minimizing impacts of fire retardants on streams.

204. Osborn, JG. 1981. *Effects of Logging on Cutthroat Trout* (Salmo clarki) *in Small Headwater Streams*. MS thesis, University of Washington, Seattle.

The effects of clearcut logging on resident and anadromous cutthroat trout in headwater streams were studied in old-growth watersheds on Washington's Olympic Peninsula. The old-growth forests adjacent to the study streams included Sitka spruce, western hemlock, Douglas-fir, and western redcedar. Objectives were to assess changes in trout populations, biomass, and densities, as well as to compare survival and growth in different kinds of streams. Two streams were used for an intensive study and three for an extensive study.

The streams in the intensive study had been part of an earlier woody debris removal study in which most large woody debris had been removed from one stream; the other was left as an untreated control. This control stream was clearcut to the bank in the spring of 1978, and afterwards, the stream was cleaned of logging debris. Sampling occurred after the 1978 logging operations and during 1979. The amount of habitat in the clearcut stream was drastically reduced, while habitat in the unlogged stream remained unchanged over the course of the study. Trout population size, biomass, and density were similar in the two streams. Logging did not appear to affect sculpins.

Streams in the extensive study were surrounded by clearcuts of different ages (1, 5, or 18 years since cutting). Clearcut streams were compared with an uncut control stream. All clearcut streams except the one on the 18-year site had been cleaned of woody debris after harvest. Stream habitat was similar in the three streams, and the streambeds did not appear to be disturbed by logging activities. The streams also supported good populations of trout and sculpins.

Differences between the intensive and extensive studies were due to instream structure. The intensive streams were

dependent on large woody debris for structure, and supply was affected by clearcutting, whereas structure in the extensive study streams was provided primarily by large boulders and cobble.

205. Patton, DR. 1974. Patch cutting increases deer and elk use of a pine forest in Arizona. *Journal of Forestry* 72(12): 764–766.

Patton studied the effects of patch cutting on forage production and use by mule deer and elk in two Arizona ponderosa pine forest watersheds. One watershed was left uncut. The second was patch clearcut during 1966–1967; 12 patches ranged from 2 to 32 acres, and the remaining area had patches of less than 2 acres. Forage production was measured before and after logging, in 1964 and 1968. Deer and elk fecal pellets were counted to estimate activity levels during 1964–1966 (before harvesting began) and 1967–1972 (after harvesting ended). Forage production increased after timber harvesting in the cut watershed. Stems of both quaking aspen and gambel oak also increased after harvest. Deer used the logged watershed more than the uncut watershed, but activity peaked 3 years after harvest and then declined. Elk activity was very low before harvesting began and increased in the cut watershed after logging, but values varied considerably.

206. Patton, DR. 1976. *Timber Harvesting Increases Deer and Elk Use of a Mixed Conifer Forest*. Research Note RM-329, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 3 pp.

The potential effects of timber harvesting on forage production and big game use were studied in two Arizona watersheds. One watershed was left uncut, and the other was partitioned into two areas, with one area selectively cut and the other cut as an overstory removal. Logging occurred in 1972. Vegetation and mule deer and elk activity (as indicated by fecal pellet counts) were monitored during 1969–1971 before logging and 1973–1975 after logging ended. Understory forage production and the number of quaking aspen stems increased in the 3 years following logging. Deer use increased in the logged watershed after harvesting. Elk activity was low in both watersheds throughout the study but increased slightly on both watersheds after logging occurred.

207. Pedersen, RJ, AW Adams, and JM Skovlin. 1980. *Elk Habitat Use in an Unlogged and Logged Forest Environment*. Wildlife Research Report 9, Oregon Department of Fish and Wildlife, Portland. 121 pp.

The objectives of this study were to determine the relationships between elk populations and habitat use before, during, and after road construction and timber harvesting. The study area, in the Blue Mountains of Oregon, included areas of upland mixed conifer, old-growth grand fir, grasslands, riparian forest, old clearcuts, and recent clearcuts created by salvage logging. Elk were trapped, radio collared, and followed over an 8-year period. Elk preferred riparian habitat to all other types. They also preferred mixed conifer "stringers" (narrow forested valleys separated by grassy ridges), as well as the small amount of remaining old-growth grand fir. Elk did not use recent clearcuts (within the first year after harvesting), but use increased as the clearcuts aged. The authors also discuss management recommendations for the various habitat types.

208. Perry, C, and R Overly. 1976. Impact of roads on big game distribution in portions of the Blue Mountains of Washington, pp. 62–68 in *Proceedings of the Elk, Logging, Roads Symposium,* December 16–17, 1975. Forest, Wildlife, and Range Experiment Station, University of Idaho, Moscow.

Elk activity was examined in relation to logging road use, road type, and adjacent vegetation type in the Blue Mountains of Washington. Vegetation types included grassland/meadow, open forest, and closed forest. Forest types included ponderosa pine, grand fir, subalpine fir, and lodgepole pine. Roads included main (improved gravel with oil base), secondary (semi-improved gravel and dirt), and primitive (unimproved gravel and dirt) roads. The authors found that when roads were in use, elk activity declined significantly in adjacent areas up to 800 m away. As road

quality and human and vehicular traffic decreased, nearby elk activity increased. Impact on elk was greatest along main roads with adjacent open vegetation types. All road types reduced elk activity in adjacent grassland/meadow areas. The authors suggest that if roads are not properly buffered, they can negatively affect more than 160 ha of elk habitat per km of road.

209. Postovit, HR. 1976. The potential effects of urea fertilization on *Peromyscus maniculatus* in northwest forests. *Northwest Science* 50(2): 87–96.

The effects of urea fertilization of forests on deer mice were examined in lab and field trials on the Olympic Peninsula, Washington. In lab trials, mice ingested urea only when there was no alternate food or water source available. Ingested urea caused loss of vigor or death. Dissipation of urea was examined in a forest dominated by Douglas-fir and in a disturbed field used to simulate clearcut conditions. Urea applied to both areas dissipated quickly with rain and dew. Postovit concludes that deer mice are unlikely to experience urea poisoning in forests because of the presence of alternative uncontaminated water and food sources.

210. Putnam, BJ. 1983. *Songbird Populations of Precommercially Thinned and Unthinned Stands of Ponderosa Pine in East-Central Washington*. MS thesis, Oregon State University, Corvallis.

Breeding bird populations were compared in precommercially thinned and unthinned uneven-aged ponderosa pine stands in east-central Washington. Bird species composition, total species density, and species richness were similar in the thinned and unthinned stands. Species diversity and species evenness were higher in thinned stands than in unthinned stands. Birds with higher densities in thinned stands were American robins, black-backed woodpeckers, hairy woodpeckers, house wrens, western bluebirds, and western wood-pewees. Those with higher densities in unthinned stands were Hammond's flycatchers, hermit thrushes, red-breasted nuthatches, and solitary vireos. Birds with similar densities in both stand types were northern flickers, dusky flycatchers, mountain chickadees, white-breasted nuthatches, Townsend's solitaires, yellow-rumped warblers, rufous-sided towhees, chipping sparrows, dark-eyed juncos, brown-headed cowbirds, purple and Cassin's finches, and red crossbills.

211. Ramirez, P, Jr., and M Hornocker. 1981. Small mammal populations in different-aged clearcuts in northwestern Montana. *Journal of Mammalogy* 62(2): 400–403.

Small mammal populations were compared in different-aged clearcuts in two subalpine fir forest types in Montana. Clearcuts (5, 11, and 15 years since harvest) were compared with uncut forests. Stands were dominated by western larch, subalpine fir, and Douglas-fir. Columbian ground squirrel densities were higher in clearcuts than in uncut forests, but southern red-backed vole densities were higher in forests. Deer mice densities were higher in 5-year-old than in 15-year-old clearcuts, with populations peaking 2–5 years after clearcutting and gradually declining as plant succession advanced.

212. Raphael, MG. 1988. Long-term trends in abundance of amphibians, reptiles, and mammals in Douglas-fir forests of northwestern California, pp. 23–31 in *Management of Amphibians, Reptiles, and Small Mammals in North America: Proceedings of a Symposium*, July 19–21, 1988, RC Szaro, KE Severson, and DR Patton, eds. General Technical Report RM-166, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 458 pp.

This study compared abundances of several amphibian, reptile, and mammal species in relation to stand age in northern California Douglas-fir forests. Forest understories contained tanoak and Pacific madrone. Site choice was based on stand age; stands represented several seral stages including early clearcut/brush and sapling (<10 years), late clearcut/brush and sapling (10–20 years), poletimber (20–50 years), sawtimber (50–150 years), mature (150–250 years), and old-growth forest (>250 years). Amphibians were more abundant in forested stands than in clearcuts, but reptiles were more abundant in clearcuts. Mammals

exhibited a greater variety of response to seral stage than either amphibians or reptiles. Species that were more abundant in early seral stands than in forest were the western toad, Pacific treefrog, western fence lizard, sagebrush lizard, western skink, southern and northern alligator lizards, piñon mouse, western red-backed vole, creeping vole, and gray fox. Species less abundant in early seral stands were the Del Norte salamander, black salamander, clouded salamander, Pacific shrew, Douglas' squirrel, northern flying squirrel, dusky-footed woodrat, western red-backed vole, and fisher. Species similar across seral stages were the Pacific giant salamander, roughskin newt, ensatina, Trowbridge's shrew, shrew-mole, Allen's chipmunk, western gray squirrel, deer mouse, brush mouse, red tree vole, black bear, ringtail, and western spotted skunk.

213. Raphael, MG, KV Rosenberg, and BG Marcot. 1988. Large-scale changes in bird populations of Douglas-fir forests, northwestern California. *Bird Conservation* 3: 63–83.

The authors surveyed Douglas-fir forests of different seral stages in the California Coast Range to determine how forest harvesting has influenced the bird community; seral stages included brush/sapling (0–20 years after logging, fire, windthrow, or landslide), poletimber/sawtimber (80–150 years old), and mature (>100 years old). They also describe the likely composition of historical (pre-European settlement) bird communities and predict future community composition. The authors estimate that before commercial logging began, 74% of the land was mature/old-growth forest, with 13% of the land in each of the brush/sapling and pole/sawtimber stages. On the assumption that half of the mature/old-growth forest has been cut and is now in the brush/sapling stage, they suggest that in the future, 11% of the forest will be in mature/old-growth stands, with most of the rest as pole/sawtimber. The authors present the estimated densities in each seral stage for 60 bird species, along with estimated historical populations and the percentage of change from historical time to the present and future. They conclude that none of the bird species analyzed will be extirpated from the Douglas-fir region because of the continued shifts from forest to open shrubland, but they caution that none of the species analyzed are restricted to mature forest. Among the species studied, 14 are likely to decline by 50% or more and 10 are likely to increase by at least 50% as mature/old-growth forest is harvested and replaced by younger stands.

214. Reeves, GH, FH Everest, and JR Sedell. 1993. Diversity of juvenile anadromous salmonid assemblages in coastal Oregon basins with different levels of timber harvest. *Transactions of the American Fisheries Society* 122(3): 309–317.

Salmonid community and stream habitat diversity were studied in drainage basins with variable amounts of clearcut harvesting in the Oregon Coast Range. Basins were chosen based on relative amounts of timber harvest. Half of the basins had low harvesting levels (25% or less of the watershed logged), and the other half had high harvesting levels (more than 25% logged). These percentages were seen as indicators of disturbance intensity from road construction, timber harvesting, and site preparation. Salmonid assemblage diversity was greater in basins with low harvest levels than in those with high harvesting, where a single salmonid species tended to dominate assemblages. Assemblage diversity was more strongly associated with percent of basin harvested than with basin area or gradient. Stream habitat was most complex (as measured by large woody debris) in basins where timber harvesting was low. The authors conclude that a fish-community and basin-level approach must be taken if the effects of human activities on stream fish populations are to be fully assessed.

215. Reeves, GH, JD Hall, and SV Gregory. 1997. The impact of land-management activities on coastal cutthroat trout and their freshwater habitats, pp.138–144 in *Sea-Run Cutthroat Trout: Biology, Management, and Future Conservation*, JD Hall, PA Bisson, and RE Gresswell, eds. Oregon Chapter, American Fisheries Society, Corvallis.

The authors review studies examining the impact of land management activities, particularly timber harvesting, on coastal cutthroat trout populations and stream habitat. In general, these studies show that cutthroat trout populations are susceptible to land management activities. Juvenile and smolt numbers decline after timber harvesting and may remain depressed for extended periods of time. These responses may be due to changes in pool depth and complexity, which may reduce habitat suitability. Further, stream carrying capacity or trout survival may be reduced if juveniles are forced to compete with other species. The authors recommend that policies address the ecosystem level of organization to protect freshwater habitat and to restore and create new habitat for salmonids and other freshwater organisms.

216. Reynolds, HG. 1962. *Effect of Logging on Understory Vegetation and Deer Use in a Ponderosa Pine Forest of Arizona.* Research Note RM-80, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 7 pp.

The potential effects of selection cutting on forage production and deer use were studied in ponderosa pine forests in Arizona. Logging began in 1951, and one or more ridges were logged annually. Understory vegetation and deer use (measured by fecal pellet groups) were monitored between1951 and 1961 in logged and unlogged forests. Vegetation production increased after logging, with the greatest increases seen 4–6 years after harvest. After the sixth year, forage production declined but still remained higher than pre-logging levels. Deer use decreased on logged sites during the first 2 years after logging but increased to levels higher than those on uncut areas in the following years.

217. Reynolds, J. 1994. Martens and fishers: Habitat use in managed forests, pp. 147–153 in *Proceedings, 15th Annual Forest Vegetation Management Conference.* Forest Vegetation Management Conference, Redding, CA.

This proceedings paper presents preliminary information on a study examining habitat use by American martens and fishers in managed forests in the northern California Cascade Mountains. Forests were mixed conifers, predominantly white fir and true fir (species not specified), and ranged from young to mature ages. Two study areas were used. Stands in the marten study had been harvested at least once since the 1950s; logging activities included overstory removal, commercial thinning, selection harvest, and clearcutting. The fisher study area was first logged in the 1880s for the railroad; the author estimates that half of the 8,000-acre area was logged between 1880 and 1961. Martens and fishers were trapped and radio collared to determine home ranges and rest and den sites. Habitat typing was being completed at the time of writing, but some preliminary information is presented.

218. Reynolds, PE. 1989. *Proceedings of the Carnation Creek Herbicide Workshop,* FRDA Report 063. B.C. Ministry of Forests, Research Branch, Victoria, B.C. 349 pp.

Short-term direct impacts of the herbicide glyphosate on stream water quality, stream biota, vegetation, and soil were assessed in a logged western hemlock/redcedar watershed in coastal British Columbia. Portions of the Carnation Creek watershed were logged from 1976 through 1981. Glyphosate was applied aerially to a logged portion of the watershed in September 1984 to control brush species. A 10-m pesticide-free zone was maintained along the stream, but two tributary swamps were also sprayed (referred to as oversprayed by authors) as part of the study design. Post-treatment monitoring began immediately after spraying and continued for 2 years. This workshop proceedings presents results from each of the herbicide studies. Papers include 1) changes in dissolved stream ions following logging, slash burning, and herbicide application; 2) changes in the temperature regime of an oversprayed valley-bottom tributary; 3) effects of glyphosate on periphyton, stream invertebrates, and coho salmon fingerlings; 4) litter-fall and decomposition rates in an oversprayed tributary; and 5) salmonid toxicity studies with glyphosate.

219. Reynolds, PE, JC Scrivener, LB Holtby, and PD Kingsbury. 1993. Review and synthesis of Carnation Creek herbicide research. *Forestry Chronicle* 69(3): 323–330.

The effects of aerially applied glyphosate herbicide on stream water quality and fish populations were studied on

Vancouver Island, British Columbia, in young conifer stands. Glyphosate was applied annually over a 3-year period to control hardwoods and shrubs competing with crop trees (Sitka spruce, western hemlock, and western redcedar). The maximum recommended label rate was applied in the fall before seasonal storms began. Streams sprayed with herbicide were considered to have had acceptable impacts on coho salmon and other aquatic organisms. Glyphosate residues had dissipated and degraded rapidly in the environment; after 1 year the remaining residues had been adsorbed to organic matter, soil particles, and/or the stream bottom and appeared to be inactive and immobilized.

220. Richardson, JS, and WE Neil. 1998. Headwater amphibians and forestry in British Columbia: Pacific giant salamanders and tailed frogs. *Northwest Science* 72 (Special Issue No. 2): 122–123.

Pacific giant salamanders and tailed frogs were surveyed in managed and unmanaged forest headwater streams in British Columbia. Study sites were in clearcut (<10 years old), second-growth (25 years), and old-growth stands (>250 years); dominant tree species were not specified. Age of the surrounding forest did not significantly affect the presence of larvae of either species. For both amphibians, larvae density was slightly higher in clearcuts than at old-growth sites, but average individual larvae weight was lower in the clearcuts. The authors suggest several interpretations for their findings and present additional hypotheses.

221. Richmond, ML, CJ Henny, RL Floyd, RW Mannan, DM Finch, and LR DeWeese. 1979. *Effects of Sevin-4-oil, Dimlin, and Orthene on Forest Birds in Northeastern Oregon*. Research Paper PSW-148, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. 19 pp.

Three insecticides used to control Douglas-fir tussock moth outbreaks were applied to forest plots in the Blue and Wallowa Mountains of Oregon to determine possible effects of spraying on forest birds. The insecticides acephate (Orthene), carbaryl (Sevin-4-oil), and diflubenzuron (Dimlin) were applied to several forest types (grand fir, ponderosa pine, hardwoods, lodgepole pine, Douglas-fir, and subalpine fir). Birds were collected on plots treated with acephate or carbaryl to determine brain cholinesterase (ChE) levels. Birds were not collected on the diflubenzuron plots, since diflubenzuron is not known to inhibit ChE. Acephate caused extensive inhibition of brain ChE activity for more than 1 month after spraying. In contrast, the authors found no major effects from carbaryl, and no adverse effects on birds related to the application of diflubenzuron. The long-term effect of acephate on breeding bird populations was not fully evident from this study.

222. Ringler, NH, and JD Hall. 1975. Effects of logging on water temperature and dissolved oxygen in spawning beds. *Transactions of the American Fisheries Society* 104(1): 111–121.

The effects of clearcut logging on streamwater temperature and dissolved oxygen in salmonid spawning beds were examined in three small headwater streams in the Oregon Coast Range. One watershed was completely clearcut, the second was clearcut in a staggered pattern, and the third was left unlogged. Prior to logging, the forests were dominated by Douglas-fir with varying amounts of red alder. Logging led to increased temperatures and decreased dissolved oxygen concentrations in the intragravel water in spawning beds. The changes were related to a decrease in forest cover over the stream surface and deposition of fine sediment in the gravel. Although there were changes in temperature and dissolved oxygen, survival-to-emergence rates for coho salmon were not seriously reduced. The decrease in the resident population of cutthroat trout after logging, however, may have been related to these changes.

223. Ringler, NH, and JD Hall. 1988. Vertical distribution of sediment and organic debris in coho salmon (*Oncorhynchus kisutch*) redds in three small Oregon streams. *Canadian Journal of Fisheries and Aquatic Sciences* 45(4): 742–747.

The authors studied the vertical distribution of fine sediment and organic debris in coho salmon redds in three Oregon Coast Range streams associated with varying amounts of clearcutting. One watershed was clearcut without buffer strips, a second was clearcut in patches (patch cut) with buffer strips, and a third was left undisturbed as a control. Logging roads were constructed in the two logged watersheds. The clearcut watershed was burned to reduce slash, but only the lower unit of the patch cut watershed was burned, and only partially. Logging occurred in 1966. In 1967 and 1968, after coho salmon had completely emerged, cores were taken in redds to determine gravel composition, which varied significantly among redds in the two logged streams. Fine sediment content appeared to decrease with depth in the logged streams, but variability in composition of stream gravel obscured depth-related differences. Organic content in the gravel made up less than 2.8% of the core samples by weight and was directly related to the quantity of sediment in the stream bed. The vertical distribution pattern of organic debris in the clearcut stream differed significantly from that in the other streams. Patterns of distribution and variability in gravel composition were consistent with post-logging changes in gravel permeability and in coho salmon's survival to emergence.

224. Ritchie, DC, AS Harestad, and R Archibald. 1987. Glyphosate treatment and deer mice in clearcut and forest. *Northwest Science* 61: 199–202.

Deer mice were trapped in two clearcuts and one old-growth forest to determine the effect of glyphosate herbicide on mouse populations. One clearcut was treated with glyphosate herbicide; the other clearcut and the old-growth forest were left untreated. Sites were on northern Vancouver Island, British Columbia. The glyphosate-treated clearcut was dominated by tall blue huckleberry, salmonberry, and fireweed. The untreated clearcut was dominated by tall blue huckleberry, red elderberry, and fireweed. The old-growth stand was dominated by Pacific silver fir and western hemlock. Mouse catch per unit of effort was significantly higher in the old-growth forest than in either clearcut, with catch levels lowest in the glyphosate treatment. Sex ratios, age structure, body length, and body mass of deer mice did not differ significantly among the three sites. Because deer mice in both clearcuts had similar numbers of placental scars and foeti, the authors suggest that the glyphosate treatment did not affect reproductive rates. Glyphosate did reduce deer mice populations in the treated clearcut, perhaps because of changes in vegetation that lowered the quality of food and cover for small mammals.

225. Rochelle, JA, LA Lehmann, and J Wisniewski, eds. 1999. *Forest Fragmentation: Wildlife and Management Implications.* Brill, Boston, MA.

This book summarizes the findings of a scientific conference that synthesized current knowledge about fragmentation in managed forests in the Pacific Northwest. Chapters include an overview of fragmentation issues, discussions of the influence of fragmentation on wildlife populations and productivity and ecological processes, and conclusions about the relationships between land use practices and forest fragmentation. One chapter is annotated in citation 169.

226. Rosenberg, DK, and RG Anthony. 1992. Characteristics of northern flying squirrel populations in young second- and old-growth forests in western Oregon. *Canadian Journal of Zoology* 70(1): 161–166.

Northern flying squirrel populations were compared in second- and old-growth Douglas-fir forests in the Oregon Cascade Range. Second-growth forests were 30–60 years old, and old-growth forests were more than 400 years. Average squirrel density and body mass were similar in the two forest age classes. Second-growth stands had a higher proportion of female squirrels than old-growth stands did. Densities were not correlated with measured habitat characteristics. The authors conclude that northern flying squirrels may be habitat generalists rather than old-growth associates.

227. Rosenberg, DK, and RG Anthony. 1993. Differences in Townsend's chipmunk populations between second- and old-growth forests in western Oregon. *Journal of Wildlife Management* 57(2): 365–373.

The authors studied population differences between Townsend's chipmunks in second-growth and old-growth

Douglas-fir forests in the west central Oregon Cascades. The five second-growth (30–60 years old) and five old-growth stands (>400 years) were dominated by Douglas-fir and western hemlock; second-growth stands regenerated after clearcut harvesting. Estimated chipmunk densities were almost twice as high in the old-growth stands as in the second-growth stands, but body mass was similar in the two stand types. Mean maximum distance traveled by recaptured animals was greater in second growth than in old growth. The authors conclude that old-growth stands provide better habitat for Townsend's chipmunks than young second-growth stands do.

228. Rosenberg, DK, KA Swindle, and RG Anthony. 1994. Habitat associations of California red-backed voles in young and old-growth forests in western Oregon. *Northwest Science* 68(4): 266–272.

Western red-backed vole abundance was compared in young managed stands (30–60 years old) and unmanaged old-growth Douglas-fir stands (>400 years old) in the central Oregon Cascade Range. Four of the five young stands were planted after clearcutting and broadcast burning; the fifth stand regenerated after fire. Significantly more red-backed voles were caught in the old-growth than in the young stands. The authors suggest that managing young stands for deep organic soil, residual large trees and snags, and coarse woody debris may increase suitability for western red-backed voles.

229. Rosenberg, KV, and MG Raphael. 1986. Effects of forest fragmentation on vertebrates in Douglas-fir forests, pp. 263–272 in *Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates,* J Verner, ML Morrison, and CJ Ralph, eds. University of Wisconsin Press, Madison.

Forest inventory results were used for determining possible effects of forest fragmentation on terrestrial vertebrates in northern California. Study areas were National Forest lands dominated by Douglas-fir with varying amounts of tanoak, Pacific madrone, and canyon live oak. All forests surveyed were bordered by recent clearcuts that formed abrupt, high-contrast edges. Bird and amphibian species richness increased in the more fragmented stands and in plots with more edge. Relatively few species responded negatively to forest fragmentation, but species most sensitive to fragmentation were the fisher, gray fox, spotted owl, pileated woodpecker, ringtail, flying squirrel, sharp-shinned hawk, blue grouse, and Pacific giant salamander. Because the occurrence of widespread fragmentation is fairly recent in Douglas-fir forests, the authors were unable to make any definitive conclusions about species tolerances.

230. Ruggiero, LF, KB Aubry, SW Buskirk, LJ Lyon, and WJ Zielinski. 1994. *The Scientific Basis for Conserving Forest Carnivores: American Marten, Fisher, Lynx, and Wolverine in the Western United States*. General Technical Report RM-254, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 184 pp.

This is a comprehensive review of literature on the American marten, fisher, lynx, and wolverine in the western U.S. Information covers current status of populations (size, distribution, range), habitat use and preferences, life histories, home ranges, feeding habits, and responses to human disturbance, forest fragmentation, and timber harvesting. The authors also discuss conservation, management, and information/research needs.

231. Runciman, JB, and TP Sullivan. 1996. Influence of alternative conifer release treatments on habitat structure and small mammal populations in south central British Columbia. *Canadian Journal of Forest Research* 26(11): 2023–2034.

This study tested the hypothesis that conifer release treatments would simplify habitat structure and reduce small mammal populations. Plantations released were in the interior of British Columbia and dominated by lodgepole pine. Release treatments were either manual cutting or glyphosate herbicide applied to cut stumps. Released stands were compared with control stands. Total volumes of herbs, shrubs, conifers, and woody debris were not affected by either release treatment. Hardwood tree volume was reduced the first year after treatment but returned to pre-treatment levels on manually released sites 2 years after treatment. Neither release treatment appeared to affect population sizes of deer mice, yellow-pine chipmunks, southern red-backed voles, or long-tailed voles. Meadow vole response was variable. Sex ratios, mean body weights, reproduction rates, recruitment, and survival of deer mice were similar in all treatments. Release treatments did not appear to negatively impact small mammal populations for the first 2 post-treatment years.

232. Sakai, HF, and BR Noon. 1993. Dusky-footed woodrat abundances in different-aged forests in northwestern California. *Journal of Wildlife Management* 57(2): 373–382.

Dusky-footed woodrat abundance was determined in stands of different ages in Douglas-fir/tanoak forests in northwestern California. Six stands of five different seral stages were chosen. Seral stages were 1) seedling/shrub; 2) sapling/brushy poletimber with Douglas-fir 12.1–27 cm diameter at breast height (DBH), 15–40 years old; (3) small sawtimber with Douglas-fir 27.1–53.0 cm DBH, 41–80 years; 4) large sawtimber with Douglas-fir 53.1–90.0 cm DBH, 80–180 years; and 5) old-growth with Douglas-fir >90.1 cm DBH, >180 years. The highest densities of woodrats were found in the sapling/brushy poletimber stands (>80 animals/ha), followed by the seedling/shrub areas and old-growth stands (each <1 animal/ha). No woodrats were found in the small sawtimber stands, and they were rarely found in the large sawtimber. The authors suggest that where dusky-footed woodrats are a main prey species for old-growth species such as the northern spotted owl, younger successional stage stands near old-growth forests may be sources of woodrats.

233. Salo, EO, and TW Cundy, eds. 1987. *Streamside Management: Forestry and Fishery Interactions.* Contribution no. 57, Institute of Forest Resources, College of Forest Resources, University of Washington, Seattle.

This is the proceedings from the Streamside Management: Forestry and Fishery Interactions symposium held in 1986. Symposium speakers presented relatively in-depth information on salmonid fish populations, stream habitat, natural processes, and forest management and its potential impacts on salmonids. Some of these chapters are annotated in citations 12, 46, 82, 108, and 122.

234. Scott, VE, GL Crouch, and JA Whelan. 1982. *Responses of Birds and Small Mammals to Clearcutting in a Subalpine Forest in Central Colorado*. Research Note RM-422, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 6 pp.

Bird and small mammal responses to 3-acre patch clearcuts were studied in the Rocky Mountains of central Colorado. Subalpine old-growth forests consisting of Engelmann spruce, subalpine fir, and lodgepole pine were patch clearcut in 1977 to enhance water flow in the watershed. The cut areas were compared with adjacent uncut forest. Ground vegetation cover, forage production, and herbivore activity (by elk, mule deer, snowshoe hares) were monitored in cut and uncut forest blocks. Birds and small mammals were sampled from 1976 to 1977 before logging began and from 1978 to 1979 after it ended. Bird species composition and population densities did not differ between cut and uncut areas before or after logging, although mountain chickadees and ruby-crowned kinglets decreased on the cut areas. Small mammal captures increased on both cut and uncut areas after logging, and numbers were similar between areas. The southern red-backed vole was the most abundant species caught, accounting for much of the increase; abundances were similar in both areas. The least chipmunk was more abundant on cut than uncut areas. The authors conclude that the small patch clearcuts had little short-term effect on bird and small mammal populations.

235. Scott, VE, and GJ Gottfried. 1983. *Bird Response to Timber Harvest in a Mixed Conifer Forest in Arizona*. Research Paper RM-245, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 8 pp.

Bird density and species diversity were studied after harvesting in an Arizona mixed conifer forest. The stands were of uneven-aged mixed conifers including Douglas-fir, Engelmann spruce, ponderosa pine, white fir, and other species. Stands were harvested as either group selections or patch clearcuts. Harvested stands were compared with an unharvested control. The authors detected minor changes in bird populations after harvesting. Bird numbers decreased slightly, but the number of species increased. New species after harvest were the house wren, American robin, and pine siskin; only the ruby-crowned kinglet decreased significantly. The authors conclude that harvesting in this area should not adversely affect bird density or diversity if less than 30%–40% of the total stand basal area is removed.

236. Scrivener, JC, and BC Anderson. 1984. Logging impacts and some mechanisms that determine the size of spring and summer populations of coho salmon fry (*Oncorhynchus kisutch*) in Carnation Creek, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences* 41(7): 1097–1105.

This study compared patterns of emergence, seaward movement, in-stream distributions, densities, and growth of coho salmon fry before, during, and after logging. The study was conducted on Carnation Creek in coastal British Columbia. The watershed was dominated by western hemlock and western redcedar. Treatments included 1) intensive treatment (logged 1976–1977), with trees clearcut down to the stream bank and felled and yarded across the channel; 2) careful treatment (logged 1978–1979), with trees clearcut down to the stream bank, but with other vegetation left, no damage to the bank, and few trees felled or yarded across the channel; and 3) leave strip treatment (logged in three openings 1975–1976, 1978–1979, 1980–1981), with the surrounding stand clearcut, but a variable width buffer left along the channel. Coho were sampled from 1970 through 1982.

After streamside logging, coho fry emerged up to 6 weeks earlier and moved seaward more quickly than before logging began. These changes were attributed to higher winter water temperatures and to emergence during a period of more frequent freshets. In sections affected by intense streamside logging, fine logging debris left in streams led to higher densities of fry the summers following logging. Major autumn freshets removed the debris and altered channel morphology 2 years after logging, resulting in decreased fry densities that were lower than pre-logging densities. Fry tended to grow faster in streams with streamside logging. The authors attribute the increase in size to the longer growing season afforded by the fry's earlier emergence.

237. Scrivener, JC, and MJ Brownlee. 1989. Effects of forest harvesting on spawning gravel and incubation survival of chum (*Oncorhynchus keta*) and coho salmon (*O. kisutch*) in Carnation Creek, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences* 46(4): 681–696.

Spawning gravel in Carnation Creek (coastal British Columbia) was sampled from 1973 through 1986 to assess the effects of clearcut logging on spawning gravel composition, intragravel dissolved oxygen, and permeability, as well as the effects of these features on incubation survival of chum and coho salmon. Treatments included 1) intensive treatment (logged 1976–1977), with trees clearcut down to the stream bank and felled and yarded across the channel; 2) careful treatment (logged 1978–1979), with trees clearcut down to the stream bank, but with other vegetation left, no damage to the bank, and few trees felled or yarded across the channel; and 3) leave strip treatment (logged in three openings 1975–1976, 1978–1979, 1980–1981), with the surrounding stand clearcut, but a variable width buffer left along the channel.

After logging, fine materials (pea gravel and sand) increased in the stream bed, with more fine material present in the bottom layer of the streambed substrate; the frequency and magnitude of changes in composition were greater in the top layer. Changes in stream bed fine materials depended on the timing and type of streamside harvest and the timing of large freshets. Suspended sediment did not increase after either road construction or logging. Incubation survival to emergence and average size of fry decreased after logging for both chum and coho salmon.

238. Scrivner, JH, and HD Smith. 1984. Relative abundance of small mammals in four successional stages of spruce–fir forest in Idaho. *Northwest Science* 58(3): 171–176.

Small mammals were trapped in forest stands at four successional stages on the Clearwater National Forest in Idaho. Stands represented stages from clearcut to climax forest and were dominated by grand fir. Two areas were selected for the study; each had one stand in each age class (1–10, 11–39, 40–79, and >80 years old). Deer mice, red-tailed chipmunks, Pacific jumping mice, and southern red-backed voles were live-trapped during two consecutive summers. Deer mice increased with successional stand age; significantly more deer mice were caught in the late-successional stands (>80 years) than in the early-successional stands (1–10 years old). Red-tailed chipmunk abundance varied, but chipmunks were more common in mid-successional stands (11–39 and 40–79 years) than in early- and late-successional stands. Pacific jumping mice were significantly more common in willow–alder (*Salix–Alnus*) thickets within mid-successional stands than elsewhere. Southern red-backed voles were significantly more abundant in the oldest stands than in the youngest stands.

239. Sears, HS, and WR Meehan. 1971. Short-term effects of 2,4-D on aquatic organisms in the Nakwasina River watershed, southeastern Alaska. *Pesticide Monitoring Journal* 5(2): 213–217.

The object of this study was to determine possible lethal effects of 2,4-D herbicide on aquatic organisms. A 400-acre clearcut area in southeastern Alaska was aerially sprayed with 2,4-D to control red alder and shrubs competing with Sitka spruce and western hemlock regeneration. Salmonids in the affected streams included resident Dolly Varden, two age classes of juvenile coho salmon, pink salmon fry, and chum salmon fry. Sample fish were caught and placed in holding traps in the streams. Some fish and invertebrate mortality did occur, but none of the immediate mortality of salmonids or aquatic invertebrates was attributable to the spray. Water and fish tissue samples had 2,4-D concentrations well below the level considered lethal to aquatic organisms. The authors considered the results inconclusive because of the lack of pre-treatment data on test organisms; they point out that test fish may not have had adequate time to recover from handling and being placed in traps, which may have led to the death of some fish.

240. Shephard, JF. 1994. *Initial Response of Small Mammals to New Forestry and Overstory Removal Timber Harvests*. MS thesis, University of Montana, Missoula.

Immediate responses by small mammals to timber harvesting in Montana's mixed conifer forests (dominated by Douglas-fir) were studied by the author. Small mammals were trapped for a very short period during the summers before and after harvesting. Three harvesting treatments were used: 1) unharvested control; 2) overstory removal; and 3) a modified overstory removal the author calls the "new forestry" treatment. In the overstory removal treatment, 250–500 trees/ha were harvested based on species and diameter size. The "new forestry" treatment was similar except that 13–25 dominant trees/ha were retained, plus all snags and hardwoods. Small mammal abundance showed no significant treatment differences during the year after harvest. Trends suggest that red-tailed chipmunks decreased after harvest and yellow-pine chipmunks and southern red-backed voles increased. There was no apparent change in meadow vole abundance after harvest.

241. Sheridan, WL, and WJ McNeil. 1968. Some effects of logging on two salmon streams in Alaska. *Journal of Forestry* 66(2): 128–133.

Spawning bed sedimentation and changes in pink salmon densities were studied in relation to clearcut logging in southeastern Alaska. Over the course of the 7-year study period, the watersheds surrounding two streams were logged in various amounts. After logging, there was a temporary increase in fine particles in spawning beds. Pink salmon densities (both spawning adults and fry) increased over the study period; the authors speculate that the increase was primarily due to changes in commercial fishing regulations that outlawed the use of salmon traps in 1959.

242. Simons, LH. 1985. Small mammal community structure in old growth and logged riparian habitat, pp. 505–506 in *Riparian Ecosystems and Their Management: Reconciling Conflicting Uses—First North American Riparian Conference,* April 16–18, 1985. General Technical Report RM-120, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 523 pp.

Small mammal communities were compared in riparian areas surrounded by old-growth conifers and riparian areas that had been clearcut. Study sites were in northern California and dominated by Douglas-fir, white fir, sugar pine, and incense-cedar. Red-backed voles were found only in old-growth riparian areas. Species that were similar in both old-growth and clearcut riparian areas were the deer mouse, western jumping mouse, Pacific marsh shrew, Trowbridge's shrew, long-tailed vole, and yellow-pine chipmunk.

243. Skovlin, JM, LD Bryant, and PJ Edgerton. 1989. *Timber Harvest Affects Elk Distribution in the Blue Mountains of Oregon*. Research Paper PNW-RP-415, USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 10 pp.

The responses of elk to different methods of harvesting mature grand fir/Engelmann spruce forests were studied in the Blue Mountains of Oregon. Harvesting treatments included small-patch clearcut, large-block clearcut, partial cut, and uncut control. Timber harvesting increased the abundance and variety of forage, particularly on the clearcuts. Uncut areas appeared to provide habitat for resting and concealment around the harvested units. Elk use generally increased during the 5 years after harvest. By the fifth year, however, use had dropped to pre-harvest levels. Small-patch clearcuts led to more elk use than partial cut treatments did.

244. Smithey, DA, MJ Wisdom, and WW Hines. 1985. Roosevelt elk and black-tailed deer response to habitat changes related to old-growth forest conversion in southwestern Oregon, pp. 41–45 in *Proceeding of the 1984 Western States and Provinces Elk Workshop*, April 17–19, 1984, RW Nelson, ed. Wildlife Branch, Alberta Fish and Wildlife Division, Edmonton.

Roosevelt elk and black-tailed deer populations were monitored in several Oregon Coast Range drainages to study the effects of converting old-growth forests to younger seral stages. Drainages were dominated by Douglas-fir and western hemlock and were heavily roaded. In each drainage, elk densities decreased as the proportion of old-growth forest decreased. The authors suggest that elk carrying capacity is directly associated with the amount of old-growth habitat available. Deer densities were not correlated with old growth or with any seral stage past the age of 12 years. Deer densities increased as the proportion of clearcuts (0–12 years old) increased.

245. Snyder, GG, HF Haupt, and GH Belt, Jr. 1975. *Clearcutting and Burning Slash Alter Quality of Stream Water in Northern Idaho*. Research Paper INT-168, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 34 pp.

Changes in stream water quality were monitored after three conifer stands in northern Idaho were clearcut and burned. Stands were composed primarily of >100-year-old Douglas-fir and western white pine. No buffers were left along the streams in the clearcuts. Water was sampled above, within, and below the clearcut for a year following burning; stream reaches above and below clearcuts were in uncut forests. After clearcutting and burning, samples taken within the clearcuts showed significant increases in pH, electrical conductivity, turbidity, suspended solids, bicarbonate, sulfate, potassium, calcium, and magnesium. Samples taken below the clearcut had slightly higher levels of electrical conductivity, bicarbonate, sulfate, calcium, and magnesium than samples from above the clearcuts.

246. Sullivan, DS, and TP Sullivan. 1982. Effects of logging practices and Douglas-fir, *Pseudotsuga menziesii*, seeding on shrew, *Sorex* spp., populations in coastal coniferous forest in British Columbia. *Canadian Field-Naturalist* 96(4): 455–461.

Shrew populations on burned and unburned clearcuts in British Columbia were compared with those in uncut forests. The study was conducted in 45- to 49-year-old forests dominated by western hemlock and western redcedar. Treatments included a clearcut with slash burn, a clearcut with no slash burn, and an uncut control. Species trapped included masked, dusky, and vagrant shrews. Shrew densities were lowest in the burned clearcut and highest in the uncut forest. Densities in the burned clearcut were lowest the year after burning; during the second year they increased to levels similar to those on the unburned clearcut. The response of shrews to direct seeding of Douglas-fir was studied on a smaller area, and seeding did not appear to affect shrew density.

247. Sullivan, TP. 1979. Demography of populations of deer mice in coastal forest and clear-cut (logged) habitats. *Canadian Journal of Zoology* 57: 1636–1648.

This study tested the premise that clearcuts support higher populations of deer mice than forests do. The study area was in British Columbia and included two clearcuts with sparse ground cover and one forested stand (43–45 years old) dominated by western redcedar and western hemlock. The average density of deer mice was slightly higher on clearcuts than in the forested stand. The density of deer mice declined each winter on the clearcuts to levels similar to that in the forested stand. The authors conclude that the clearcuts may be acting as dispersal or behavioral sinks.

248. Sullivan, TP. 1980. Comparative demography of *Peromyscus maniculatus* and *Microtus oregoni* populations after logging and burning of coastal forest habitats. *Canadian Journal of Zoology* 58: 2252–2259.

Deer mouse and creeping vole population demographics were compared in burned and unburned clearcuts in the western hemlock region of British Columbia. One burned clearcut (logged 1973, burned 1974) and two unburned clearcuts (logged 1973 and 1976) were sampled in 1978. Little variation in the proportion of breeding animals of either species was found among the three areas. Male deer mice survived better on the burned than unburned sites, but there was no apparent difference in survival of female deer mice or of male or female creeping voles. Population demographics for deer mice and creeping voles were similar on burned and unburned clearcuts 4–5 years after logging.

249. Sullivan, TP. 1990. Demographic responses of small mammal populations to a herbicide application in coastal coniferous forest: Population density and resiliency. *Canadian Journal of Zoology* 68(5): 874–883.

Changes in small mammal population demographics in response to herbicide-induced habitat changes were studied in two 7-year-old Douglas-fir plantations in British Columbia. One plantation was treated with glyphosate herbicide to release the conifers, and the other was left untreated. Two and four years after spraying, deer mouse, creeping vole, and shrew (*Sorex* spp.) abundances were similar on the two plantations. Townsend's chipmunk numbers temporarily decreased 2 years after spraying and increased by the fourth year. The proportion of breeding animals and length of life of deer mice and shrews were similar on the two plantations. The author concludes that these species should be able to persist in coastal Douglas-fir stands that are released with glyphosate herbicide.

250. Sullivan, TP. 1990. Influence of forest herbicide on deer mouse and Oregon vole population dynamics. *Journal of Wildlife Management* 54(4): 566–576.

This 5-year study examined the effects on small mammal populations after glyphosate herbicide was used for site preparation. Two western hemlock/western redcedar stands in British Columbia were clearcut and planted to Douglas-fir; one site was burned prior to planting and the second site was sprayed with glyphosate. Small mammals were live trapped before and after burning or herbicide treatment. Deer mouse recruitment decreased during the first year after spraying but increased in subsequent years to levels similar to those on the burned site. Creeping vole recruitment and survival were similar on burned and sprayed areas. Body mass and growth rates of both species were similar regardless of site treatment. Sullivan concludes that the glyphosate treatment had little or no direct effects on the development of the young and probably did not have adverse effects on the population demographics of either species.

251. Sullivan, TP. 1994. Influence of herbicide-induced habitat alteration on vegetation and snowshoe hare populations in sub-boreal spruce forest. *Journal of Applied Ecology* 31: 717–730.

The responses of snowshoe hare populations to herbicide-induced habitat changes were studied in the sub-boreal spruce zone of British Columbia. A white spruce x Engelmann spruce hybrid plantation was released with glyphosate herbicide and compared with an untreated control stand. After herbicide application, herb biomass and cover decreased but recovered in 2–3 years. Shrub and tree biomass and cover were not affected. Habitat changes caused by glyphosate treatment did not affect snowshoe hare abundance.

252. Sullivan, TP. 1996. Influence of forest herbicide on snowshoe hare population dynamics: Reproduction, growth, and survival. *Canadian Journal of Forest Research* 26: 112–119.

The effects of glyphosate herbicide release of conifers on the population dynamics of snowshoe hares were studied in two areas in central British Columbia. Caine Creek was dominated by hybrid Engelmann x white spruce and consisted of two control areas (untreated) and one treated area; Chief Lake was dominated by white spruce and included one control and one treated area. During the 3 years after spraying at Caine Creek, the proportion of adult hares in breeding condition and the number of successful pregnancies showed no consistent differences between control and treated populations. Recruitment of hares was generally similar except that more juvenile females entered the control than the treatment population. At Chief Lake, total recruitment was higher in the treatment population than in the control population for the 2-year period following spraying. Sullivan suggests that the similarity in mean body mass and growth rates of juvenile hares indicates that the herbicide treatment had little effect on juvenile development, and that treatment did not affect snowshoe hare population demographics.

253. Sullivan, TP, and JO Boateng. 1996. Comparison of small-mammal community responses to broadcast burning and herbicide application in cutover forest habitats. *Canadian Journal of Forest Research* 26(3): 462–473.

Site preparation practices for regenerating clearcuts were compared and possible effects on small mammal populations were assessed in coastal and interior British Columbia forests. Coastal sites were in the coastal western hemlock zone, with interior sites in the sub-boreal spruce and Engelmann spruce/subalpine fir zones. Sites were broadcast burned, sprayed with glyphosate herbicide, or left untreated. Deer mice showed a short-term decline after treatment on the coastal sites but not on the interior sites. Townsend's and yellow-pine chipmunks did not appear to be affected by treatment at either site. The authors conclude that neither burning nor herbicide treatment affected overall species diversity of small mammals. Small mammal species abundance was affected, however, and the effects of burning appeared to be more extreme than those of herbicide treatment.

254. Sullivan, TP, W Klenner, and PK Diggle. 1996. Response of red squirrels and feeding damage to variable stand density in young lodgepole pine forest. *Ecological Applications* 6(4): 1124–1134.

The responses of red squirrel populations to thinning lodgepole pine were examined in British Columbia. Three different biogeoclimatic zones were examined (interior Douglas-fir, montane spruce, and sub-boreal spruce). Young lodgepole pine stands were thinned to low density (500 stems/ha), medium density (1000 stems/ha), high density (2000 stems/ha), or left unthinned. The young stands were compared with an unmanaged old-growth pine stand. Red squirrels were captured, tagged, and released during 3 consecutive years. Numbers of red squirrels were higher in the medium- and high-density stands than in the low-density stands. Squirrel populations in the unthinned and old-growth stands were similar to or smaller than those in thinned stands. There were no consistent differences among the different stands in proportion of squirrels breeding, recruitment, mean survival over summer and winter, or mean body mass. More trees were damaged by squirrels in the high-density stands than in the low- or medium-density stands. Feeding damage in unthinned and old-growth stands was not assessed.

255. Sullivan, TP, and RA Moses. 1986. Demographic and feeding responses of a snowshoe hare population to habitat alteration. *Journal of Applied Ecology* 23: 53–63.

Snowshoe hare population demographics and feeding responses to site preparation were studied in British Columbia's interior forests. The study looked at replanting a 4-year-old white spruce plantation that had experienced high seedling mortality due to hare damage. The study area was scarified in rows by bulldozer. Scarified strips alternated with narrower, unscarified rows of standing vegetation and windrowed brush and slash. A mixture of white spruce and Douglas-fir was planted in the scarified plot and an adjacent unscarified plot. The hare population in the scarified plot decreased sharply over the winter, while recruitment continued in the unscarified plot; both recruitment and adult survival were highest in the unscarified plot. Tree seedling mortality was high on both the scarified (80%) and the unscarified plots (95%).

256. Sullivan, TP, and RA Moses. 1986. Red squirrel populations in natural and managed stands of lodgepole pine. *Journal of Wildlife Management* 50(4): 595–601.

The authors studied the responses of red squirrel populations to thinning lodgepole pine stands, along with squirrel-caused feeding damage to pines, in interior British Columbia forests. Twenty-year-old lodgepole pine stands were thinned and compared with unthinned stands of the same age and a 110-year-old mature stand. Squirrel populations were less dense in thinned stands than in the unthinned and mature stands, which had similar densities. Although thinning reduced squirrel densities, the authors did not find a consistent reduction in feeding damage. They suggest that increasing the size of thinned areas to more than 100 ha may help reduce damage.

257. Sullivan, TP, C Nowotny, RA Lautenschlager, and RG Wagner. 1998. Silvicultural use of herbicide in sub-boreal spruce forest: Implications for small mammal population dynamics. *Journal of Wildlife Management* 62(4): 1196–1206.

This study tested the hypothesis that herbicides used to control competing vegetation in young conifer stands would reduce small mammal populations in a sub-boreal spruce forest. Sites were located in the interior of British Columbia and had been clearcut and planted either with interior hybrid spruce (Engelmann x white) or with a mixture of hybrid spruce, Douglas-fir, and/or lodgepole pine 2–3 years prior to glyphosate herbicide treatment. Treated sites were compared with similar untreated control sites. During the 5 years after spraying, more southern red-backed voles and shrews (*Sorex* spp.) were found on the untreated than treated sites. Abundances of meadow voles and deer mice were similar on both types of sites, and long- and short-tailed weasels were commonly caught after both treatments. The authors conclude that the magnitudes of demographic changes in red-backed vole and deer mouse populations after spraying were well within the mean natural fluctuation levels for demographic variables. They note that when vegetation is temporarily reduced by herbicide treatment, some small mammal populations may be temporarily affected until food and cover become reestablished, a pattern that seemed evident for red-backed voles and shrews in this study. The authors recommend that in northern coniferous forests dominated by early-successional vegetation, herbicide treatments should be staggered in time and space to allow recovery of vegetation (2–3 years) and small mammal species.

258. Sullivan, TP, and JA Rochelle. 1992. Forest fertilization and wildlife, pp. 194–199 in *Forest Fertilization: Sustaining and Improving Nutrition and Growth of Western Forests*, HN Chappell, GF Weetman, and RE Miller, eds. Contribution no. 72, Institute of Forest Resources, University of Washington, Seattle.

This is a review of direct and indirect effects of urea fertilization of forests on wildlife in North America (including the Pacific Northwest) and Europe. Studies on operational urea applications have shown minimal hazards to wildlife species. Animal damage may actually increase after fertilization if forests are already susceptible to such damage. Since fertilization can increase the quantity and quality of forage as well as increasing the rate of vegetation succession, the authors recommend that the impacts of stand fertilization on wildlife should be viewed from a large-scale perspective.

259. Sullivan, TP, and DS Sullivan. 1981. Responses of a deer mouse population to a forest herbicide application: Reproduction, growth, and survival. *Canadian Journal of Zoology* 59(6): 1148–1154.

The responses of deer mouse populations to herbicide used to release a 20-year-old Douglas-fir plantation were studied in British Columbia. One stand was treated with glyphosate herbicide; it was compared with an untreated stand. At 1 year after application, the herbicide treatment had apparently led to no negative effects on reproduction, growth, or survival of deer mice.

260. Sullivan, TP, and DS Sullivan. 1982. Responses of small-mammal populations to a forest herbicide application in a 20-year-old conifer plantation. *Journal of Applied Ecology* 19: 95–106.

The authors examined the responses of small mammal populations to habitat changes resulting from herbicides used to release young conifer stands in a 20-year-old British Columbia Douglas-fir plantation. Glyphosate was applied to the plantation to control competing vegetation. Small mammals were trapped the year before and the year after spraying, and populations were compared with those in a younger untreated plantation. Glyphosate application did not appear to negatively affect the overall distribution and abundance of small mammals 1 year after treatment.

261. Sullivan, TP, and DS Sullivan. 1988. Influence of stand thinning on snowshoe hare population dynamics and feeding damage in lodgepole pine forest. *Journal of Applied Ecology* 25: 791–805.

The impact of thinning lodgepole pine stands on snowshoe hare populations was studied in British Columbia. The authors trapped snowshoe hares in one thinned and one unthinned stand; they also assessed feeding damage to pine trees caused by hares. During the first winter after thinning, snowshoe hare density and recruitment increased in the thinned stand but declined thereafter as the habitat became less attractive to them. Fallen branches from the thinning operation were used as food. Two years after thinning, more hares were trapped in the unthinned stand than in the thinned stand. Thinning had no apparent effect on hare reproduction or survival, but mean body weight decreased. Because of the availability of fallen branches, hares apparently did not damage the pine trees during the first year after thinning.

262. Sullivan, TP, DS Sullivan, RA Lautenschlager, and RG Wagner. 1997. Long-term influence of glyphosate herbicide on demography and diversity of small mammal communities in coastal coniferous forest. *Northwest Science* 71(1): 6–17.

This study examined the long-term effects on small mammal populations of using glyphosate herbicide to release young Douglas-fir stands in British Columbia. Treated and untreated stands were examined in young forests of two ages; small mammals were sampled 9 years after herbicide was applied to a 7-year-old stand and 11 years after it was applied to a 20-year-old stand. Because the two sites were of different ages, they were not directly compared. At the 9-year-post-treatment site (the younger one), deer mouse densities were lower and creeping vole densities higher on the sprayed than on the unsprayed stand. At the 11-year-post-treatment site (older), deer mouse densities were similar after both treatments, but creeping vole densities were higher on the sprayed than on the unsprayed stand. The average density of shrew (*Sorex* spp.) populations did not differ between the treatments at either site. Small mammal species richness and diversity changed little during the decade after spraying. The authors conclude that glyphosate did not adversely affect reproduction, survival, or growth of deer mice or creeping voles a decade after application. They also suggest that the post-harvest successional development of the stands may have had a stronger effect on small mammal populations than herbicide treatments had.

263. Sullivan, TP, RG Wagner, DG Pitt, RA Lautenschlager, and DG Chen. 1998. Changes in diversity of plant and small mammal communities after herbicide application in sub-boreal spruce forest. *Canadian Journal of Forest Research* 28: 168–177.

This study tested the hypothesis that glyphosate herbicide used to control competing vegetation in young conifer stands would reduce the diversity of plant and small mammal species in a sub-boreal spruce forest. Sites were located in the interior of British Columbia and had been clearcut; 2–3 years prior to spraying, sites were planted either with interior hybrid spruce (Engelmann x white) or with a mixture of hybrid spruce, Douglas-fir, and/or lodgepole pine. Treated and similar untreated sites were compared. Herbicide treatment reduced shrub cover volume index; shrub species richness was reduced in the first year and remained low over the 5-year study period, but shrub diversity indices did not vary after treatment. Herbaceous plant crown volume was initially reduced after herbicide treatment but quickly recovered. Neither herbaceous plant species diversity nor small mammal community diversity was affected by herbicide treatment. The diversity of plant and small mammal communities seemed to be maintained after herbicide treatment; the authors conclude that treating sites may not lower overall forest diversity. Conifer release treatments may contribute diversity to stand structures and wildlife habitat if correctly designed and implemented.

264. Szaro, RC, and RP Balda. 1979. *Effects of Harvesting Ponderosa Pine on Nongame Bird Populations*. Research Paper RM-212, USDA Forest Service, Rocky Mountain Forest and Range Experimental Station, Fort Collins, CO. 7 pp.

Bird populations were examined after stands in northern Arizona ponderosa pine forests were uncut, clearcut, heavily thinned, cut in irregular strip shelterwood, or single-tree harvested. Study plots were dominated by ponderosa pine and included varying amounts of gambel oak and alligator juniper. Plots were treated 0–8 years before bird populations were surveyed. Harvesting did not significantly affect bird species diversity or species richness except in the clearcut area. Bird populations were larger in the single-tree harvested and shelterwood plots than in the uncut forests, but smaller on the thinned and clearcut plots. Forest openings created by harvesting favored open-habitat species such as the rock wren, American robin, western wood-pewee, and yellow-rumped warbler. Species requiring closed forest habitat—including the western flycatcher, red-faced warbler, black-headed grosbeak, and pygmy nuthatch—had smaller populations on treated plots than on the control.

265. Thedinga, JF, ML Murphy, J Heifetz, KV Koski, and SW Johnson. 1989. Effects of logging on size and age composition of juvenile coho salmon (*Oncorhynchus kisutch*) and density of presmolts in southeast Alaska streams. *Canadian Journal of Fisheries and Aquatic Sciences* 46(8): 1381–1391.

The authors examined the short-term effects of clearcut logging with and without buffer strips on juvenile coho salmon in 18 southeastern Alaskan streams. Stream reaches were in undisturbed old-growth Sitka spruce/western hemlock forest, in clearcut areas with logging down to at least one bank, or in clearcut areas with buffer strips along both banks. Fish and habitat were surveyed 1–12 years after the logging. There were more coho salmon fry in both buffered and unbuffered clearcut reaches than in old-growth reaches. Fry numbers in all reach types decreased by an average of 20% from summer to winter. Fry length and condition factor were greater in both kinds of clearcut reaches than under old growth, but parr size did not differ among reach types. A higher percentage of large fry remained in buffered reaches than in non-buffered clearcut or old-growth reaches, which means that buffered reaches had the most fry that were potentially large enough to become smolts the next spring (presmolts). The authors speculate that fry were larger in buffered and non-buffered clearcut reaches because of the earlier fry emergence resulting from the increase in water temperature associated with clearcutting.

266. Thomas, DW. 1988. The distribution of bats in different ages of Douglas-fir forests. *Journal of Wildlife Management* 52(4): 619–626.

Bat activity was monitored in Douglas-fir/western hemlock forests of different ages in the Oregon Coast Range and the Washington Cascades. The forests were unmanaged and were categorized by age as old growth (>200 years), mature (100–165 years), and young (<75 years). Bat species present were the big brown bat, California myotis, fringed myotis, hoary bat, little brown myotis, long-eared myotis, long-legged myotis, Keen's myotis, silver-haired bat, Townsend's big-eared bat, western small-footed myotis, and Yuma myotis. In both regions, bats were 3–10 times as abundant in old-growth forests, as in younger forests. Feeding activity was low in all forests, but within each study area, it was higher over streams or ponds. Activity levels suggest that that old-growth stands were used primarily for roosting and rearing young rather than for feeding. Based on this study and others, Thomas concludes that reductions in available old-growth forests from logging may have a more severe impact on breeding bat populations in the Coast Range than in the Cascades.

267. Thompson, ID, and AS Harestad. 1994. Effects of logging on American martens, and models for habitat management, pp. 355–367 in *Martens, Sables, and Fishers: Biology and Conservation*, SW Buskirk, AS Harestad, MG Raphael, and RA Powell, eds. Comstock, Ithaca, NY.

The authors review the short- and long-term effects of clearcut logging old-growth forests on American martens and explain that martens prefer old-growth stands to earlier successional stages. They then present a management model for American martens within managed young-growth forests, concluding that marten populations cannot be maintained in young stands without available old-growth forests nearby.

268. Thompson, FR, III, JR Probst, and MG Raphael. 1993. Silvicultural options for neotropical migratory birds, pp. 353–362 in *Status and Management of Neotropical Migratory Birds*, September 21–25, 1992, DM Finch and PW Stangel, eds. General Technical Report RM-229, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 422 pp.

This paper reviews the potential effects on neotropical migratory birds of various silvicultural systems and other factors that may affect forest bird populations. The authors discuss uneven- and even-aged silvicultural practices such as shelterwood and seed tree cuts, single tree and group selections, and clearcuts, as well as discussing regeneration practices and rotation length. They recommend that management schemes include 1) establishing a regional management context, 2) determining desired landscape composition and structure, 3) establishing management unit goals, and 4) developing stand/habitat level management prescriptions.

269. Thompson, FR, III, JR Probst, and MG Raphael. 1995. Impacts of silviculture: Overview and management recommendations, pp. 201–219 in *Ecology and Management of Neotropical Migratory Birds*, TE Martin and DM Finch, eds. Oxford University Press, New York, NY.

The authors review information on forest management factors that can affect neotropical migratory bird populations at the local, landscape, and regional levels. They briefly discuss and define relevant silvicultural practices and their possible impacts on neotropical migratory birds. They also discuss such management activities as even-aged systems (clearcuts, seed tree harvests), uneven-aged systems (group and single tree selection), thinning, rotation length, species conversion, and road-building. The authors recommend that multi-scale management goals should include 1) establishing a regional management context, 2) determining desired landscape composition and structure, 3) establishing management unit goals, and 4) developing stand/habitat level management prescriptions.

270. Tobalske, BW, RC Shearer, and RL Hutto. 1991. *Bird Populations in Logged and Unlogged Western Larch/Douglas-fir Forest in Northwestern Montana*. Research Paper INT-442, USDA Forest Service, Intermountain Research Station, Ogden, UT. 12 pp.

Population responses of 10 bird species to timber harvesting in Montana were studied by the authors. Stands of old-growth western larch and Douglas-fir were originally cut in the 1940s, with seed trees left. In 1988–1989, the seed trees were removed by either clearcutting or partial cutting; slash was piled and burned. Harvested stands were compared with unharvested seed tree stands and contiguous old-growth forests. Tree swallows, dark-eyed juncos, and pine siskins were more abundant in logged areas than in uncut stands, but golden-crowned kinglets, Swainson's thrushes, varied thrushes, and Townsend's warblers were less abundant in these areas. Ruby-crowned kinglets and fox sparrows were more abundant in partial-cut or unharvested seed tree stands than in clearcuts and old-growth forest. Chipping sparrows were more common in logged and surrounding unlogged stands than in old-growth forest.

271. Tripp, DB, and VA Poulin. 1992. *The Effects of Logging and Mass Wasting on Juvenile Salmonid Populations in Streams on the Queen Charlotte Islands*. Land Management Report 80, Research Branch, B.C. Ministry of Forests, Victoria, B.C. 38 pp.

This study assessed the effects of mass wasting—the fall or slide of a hillslope that results in the movement of soil, organic debris, and rock—on the growth, abundance, and overwinter survival of juvenile salmonids on the Queen Charlotte Islands, British Columbia. The authors also examined the effects of logging on salmonid populations in order to separate the effects of clearcutting from those associated with mass wasting. Salmonids sampled were coho salmon, steelhead trout, and Dolly Varden. The study included stream reaches in undisturbed old-growth forests (unlogged), in logged forests that were not directly affected by mass wasting (logged), and in logged forests directly affected by mass wasting. Logged reaches had less undercut bank cover than unlogged reaches but did not differ greatly for any other habitat variable measured. Mass wasted reaches had even less undercut bank cover, less large woody debris, fewer pools and glides, and more riffles, shallower summer pools, and less overwinter cover than the other reaches had. Logged reaches had higher coho fry densities than the other stream types. Fish in the mass wasted reaches had faster growth rates, but juvenile overwinter survival was low. The authors conclude that the impact of mass wasting on juvenile fish (coho in particular) may jeopardize the existence of self-sustaining populations in directly affected stream reaches.

272. Tschaplinski, PJ, and GF Hartman. 1983. Winter distribution of juvenile coho salmon (*Oncorhynchus kisutch*) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. *Canadian Journal of Fisheries and Aquatic Sciences* 40(4): 452–461.

The objective of this study was to describe the numbers and distributions of juvenile coho salmon overwintering in different sections of Carnation Creek (coastal British Columbia) in relation to the distribution of freshets and different logging practices. Forests dominated by western hemlock and western redcedar adjacent to streams were clearcut except for a riparian buffer strip or clearcut to the bank with no buffer strip. No trees were felled into or yarded across the two buffered stream sections. One of the three unbuffered sections had trees felled into and yarded across it, but the other two did not. Coho juvenile numbers were determined in autumn and winter before and after logging.

The largest reduction in coho juveniles occurred with the onset of the first seasonal freshets in autumn. Stream sections containing winter habitat in the form of deep pools, log jams, and undercut banks with tree roots and debris lost fewer fish during freshets and maintained higher numbers of coho than sections lacking these features. Up to 48% of the coho population remained in sections that had adequate habitat available; such habitat was typical of sections where trees remained along the bank after logging (buffered streams). Almost no coho remained in two of the three unbuffered clearcut reaches, where unstable banks collapsed during winter freshets. The third clearcut reach had a stable log debris mass located in a deep pool that provided shelter for overwintering fish. Fish emigrating from the main channel to low-velocity tributaries and valley sloughs had high apparent survival rates, and logging did not appear to reduce their numbers. The authors recommend that access to these tributaries and sloughs should be maintained during and after logging operations by preventing the build-up of sediment and debris.

273. Van Dyke, FG, RH Brocke, HG Shaw, BB Ackerman, TP Hemker, and FG Lindzey. 1986. Reactions of mountain lions to logging and human activity. *Journal of Wildlife Management* 50(1): 95–102.

The reactions of mountain lions (cougars) to logging and other human disturbances were studied in northern Arizona and southern Utah. Few details are given on the study areas except that they varied from subalpine grassland and subalpine conifer forests to mid-elevation conifer forests, great basin conifer forests, and desert scrubland. Logging systems were not specified. Radiotracking of individuals indicated that resident lions rarely visited areas that had been logged within the past 6 years. Most of the mountain lions that did visit recently logged areas were dispersing juveniles, and few took up residency in these areas. Established residents and young mountain lions selected residence areas that had low road densities, no recent logging activity, and few or no human homes. Logging appears to have a strong negative impact on mountain lions, and the authors suggest that in order to minimize these impacts, logged areas should be proportionately smaller than a mountain lion's home range, and uncut forest should be left adjacent to logged areas.

274. Van Horne, B. 1983. Density as a misleading indicator of habitat quality. *Journal of Wildlife Management* 47(4): 893–901.

This paper discusses the assumption in wildlife management that a positive correlation exists between the abundance of a species and habitat quality. The author discusses the background and weaknesses of the assumption, citing examples from literature in which the assumption is likely to be valid or invalid. Van Horne suggests that habitat quality should be defined in terms of the survival and production characteristics of a species, as well as its density. He also points out that habitat quality is rarely measured during the winter months, a period that may be crucial for species in northern areas; identification of habitat quality based only on summer-time densities can be misleading.

275. Vega, RMS. 1993. *Bird Communities in Managed Conifer Stands in the Oregon Cascades: Habitat Associations and Nest Predation*. MS thesis, Oregon State University, Corvallis.

Birds were surveyed in managed Douglas-fir stands to determine community structure and habitat associations in the Oregon Coast Range. Stands included clearcuts (4–7 years since harvest), clearcuts with green tree retention (2–3 years since harvest), and unharvested mature stands (90–160 years old). Predation on artificial nests in each habitat was also examined. Species diversity was greater in mature stands than in either clearcut type, but total bird abundance and species richness did not vary among stand types. Community competition varied among stand types and appeared to be related to vegetation structure and composition. Green tree retention appeared to provide habitat for species associated with early- and late-seral habitats. Ground nest predation was highest in clearcuts, while shrub nest predation was highest in retention stands, suggesting that snags and retained trees may serve as perches allowing predators to locate nests.

276. Vesely, DG. 1997. *Terrestrial Amphibian Abundance and Species Richness in Headwater Riparian Buffer Strips, Oregon Coast Range*. MS thesis, Oregon State University, Corvallis.

This study examined the differences between amphibian populations in unmanaged forests, clearcuts, and riparian buffer strips in the Oregon Coast Range. Sites were dominated by Douglas-fir, western hemlock, western redcedar, and red alder. Unmanaged stands were more than 100 years old, and clearcuts were less than 5 years old; riparian buffer strips were classified as narrow (0–20 m wide), intermediate (21–40 m), and wide (>40 m). The abundances of ensatinas, western redback salamanders, Dunn's salamanders, and torrent salamanders (*Rhyacotriton* spp.) were greater in unmanaged forests and buffer strips than in clearcuts. Species richness increased as buffer strip width increased, but fewer species were found in even the widest buffer strips than in unmanaged forest. Vesely did not find strong associations between amphibian species abundance or richness and the habitat variables measured in the study.

277. Von Treba, C, DP Lavender, and TP Sullivan. 1998. Relations of small mammal populations to even-aged shelterwood systems in sub-boreal spruce forest. *Journal of Wildlife Management* 62(2): 630–642.

The possible effects of shelterwood systems on small mammals were studied in Douglas-fir plantations in the interior of British Columbia. The authors also evaluated seed production, predation, and germination. Shelterwood stands had 30% and 50% basal area removed and were compared with uncut stands. Levels of abundance and recruitment of red-backed voles were higher in shelterwood stands than uncut stands. Deer mouse abundances were similar in the different stand types. Survival of the two species did not vary with stand treatment. Seed predation fluctuated with seasonal changes in small mammal populations (less predation in spring and more in fall) but not with the amount of seed crop available. Small mammals did not appear to affect tree regeneration success (as measured by seed survival and establishment) under the shelterwood system.

278. Wallmo, OC, and JW Schoen. 1980. Response of deer to secondary forest succession in southeast Alaska. *Forest Science* 26(3): 448–462.

This study assessed the way Sitka black-tailed deer use two kinds of forest stands in southeast Alaska. Twenty silviculturally “overmature” uneven-aged, old-growth western hemlock/Sitka spruce forest stands were examined; they had healthy dominant trees at least 300 years old with evidence of old tree mortality spread over long periods of time. Even-aged second-growth stands were 0–147 years old, with two stands originating after fires in 1830 and 1892 and the remaining 18 stands originating after clearcut logging. Most old-growth stands had scattered clumps of small suppressed hemlock trees 50–100 years old. Deer used the old-growth stands more heavily than adjacent or nearby even-aged second-growth stands, regardless of age. Old-growth forests had a more diverse and abundant understory than second-growth forests of 30–147 years. The authors conclude that these younger coniferous forests with even-aged management will generally have a significantly smaller deer carrying capacity than old-growth forests have.

279. Walters, BB. 1991. Small mammals in a subalpine old-growth forest and clearcuts. *Northwest Science* 65(1): 27–31.

Small mammal populations were compared in a subalpine old-growth forest, a burned clearcut, and an unburned clearcut in British Columbia. The sites were dominated by Pacific silver fir, western hemlock, and mountain hemlock. The old-growth forest was >1200 years old. Clearcuts were logged (and one was burned shortly afterward) 16–17 years prior to sampling. Deer mice and yellow-pine chipmunks were more abundant on the clearcuts than in the old-growth forest. Masked shrew abundances were similar in all three areas. Southern red-backed vole abundance was higher in the old-growth forest and the unburned clearcut than on the burned clearcut. Based on results published on low-elevation studies, Walters concludes that the general effects of clearcutting on small mammal populations in subalpine conifer forests are similar to those at low elevations.

280. Ward, AL. 1976. Elk behavior in relation to timber harvest operations and traffic on the Medicine Bow Range in south-central Wyoming, pp. 32–43 in *Proceedings of the Elk, Logging, Roads Symposium,* December 16–17, 1975. Forest, Wildlife, and Range Experiment Station, University of Idaho, Moscow.

Elk activity was monitored in relation to timber harvest activities and road use in the Medicine Bow Mountain Range in Wyoming. High-elevation subalpine spruce–fir forests and middle-elevation lodgepole pine forests were examined in the study. Clearcutting occurred in both forest types followed by slash cleanup (piling and burning or roller-chopping). Elk stayed at least 800 m away from the harvest activities. At this distance and beyond, their behavior did not appear to be affected by the harvesting. Elk usually returned to the area within 3 weeks after harvesting activities had ended; they tended to be more averse to timber harvest activities than to logging road traffic (including recreational traffic), which did not appear to affect activity more than 400 m from the road. However, Ward recommends that buffers at least 100 m wide be left around new roads to prevent disturbance to elk.

281. Waters, JR, and CJ Zabel. 1995. Northern flying squirrel densities in fir forests of northeastern California. *Journal of Wildlife Management* 59(4): 858–866.

Northern flying squirrel densities were compared in unharvested old-growth forest, shelterwood, and fire-regenerated young stands in the northern California Cascade Range. Stands were dominated by white and red fir. Old-growth and shelterwood stands were >200 years old, and young stands were 75–95 years. Shelterwood stands were logged followed by site preparation 5 years before flying squirrels were trapped. Flying squirrel densities were higher in old-growth and young stands than in shelterwood stands. Similarly, sporocarps of hypogeous fungi (a common food source for flying squirrels) were found most frequently in old-growth and young stands and least frequently in shelterwood stands. Frequency of sporocarps was positively correlated with squirrel density. The authors conclude that heavy logging followed by site preparation in the shelterwood stands negatively affected flying squirrel populations.

282. Weikel, JM. 1997. *Habitat Use by Cavity-Nesting Birds in Young Thinned and Unthinned Douglas-fir Forests of Western Oregon*. MS thesis, Oregon State University, Corvallis.

Young Douglas-fir stands (30–45 years old) in the northern Oregon Coast Range were thinned to determine the effects of thinning intensity on cavity-nesting birds. Stands of even-aged Douglas-fir that had regenerated after catastrophic fires were unthinned, moderately thinned (to a relative density of 35), or heavily thinned (relative density 20). Birds were surveyed 1 year before thinning and for 2 years after thinning. Chestnut-backed chickadee abundances were similar before and after thinning and did not differ with thinning intensity. Red-breasted nuthatch abundances varied between years but not between treatments. Hairy woodpecker abundance increased in thinned stands after thinning, but there was no difference between the moderately and heavily thinned stands. The abundance of brown creepers did not appear to be affected by moderate thinning, but it was negatively affected by heavy thinning.

283. Welsh, HH, Jr., and AJ Lind. 1996. Habitat correlates of the southern torrent salamander, *Rhyacotriton variegatus* (Caudata: Rhyacotritonidae), in northwestern California. *Journal of Herpetology* 30(3): 385–398.

The authors examined southern torrent salamander habitat associations and relationships to forest succession in the Coast and Cascade Ranges in northern California. Forests were mixed conifer–hardwood dominated by Douglas-fir and coast redwood. Stands were categorized as clearcut (0–30 years), young (31–99 years), mature (100–200 years), or old growth (>200 years). Southern torrent salamanders occurred within a narrow range of physical and microclimatic conditions most often present in late seral forests. They were associated with headwater to low-order streams with loose, coarse substrates and clear cold water in humid forests with large conifers, abundant moss, and >80% canopy cover. Direct impacts of logging on the salamander are not fully known, but the authors suggest that the effects may be more pronounced in interior areas that lack the ameliorating effects of the coastal maritime climate.

284. West, SD, RG Ford, and JC Zasada. 1980. *Population Response of the Northern Red-backed Vole* (Clethrionomys rutilus) *to Differentially-Cut White Spruce Forest*. Research Note PNW-362, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 15 pp.

The responses of northern red-backed vole populations to timber harvesting in Alaska were studied in 160-year-old white spruce forests. Stands were clearcut, shelterwood cut, or left uncut. During the summer after logging, red-backed vole densities were lowest in the clearcut and similar in the shelterwood and uncut stands. Population demographics such as age and sex composition, reproduction, and subadult survival were similar in the three treatments.

285. Wetmore, SP, RA Keller, and GEJ Smith. 1985. Effects of logging on bird populations in British Columbia as determined by a modified point-count method. *Canadian Field-Naturalist* 99(2): 224–233.

Bird populations in two southern British Columbia forest types were surveyed to determine their responses to clearcutting of mature forests. One forest was dominated by mountain hemlock, western hemlock, and Pacific silver fir, with forested steep valleys, clearcut mid-elevation stands, and uncut high-elevation stands. The second forest was dominated by Engelmann spruce, lodgepole pine, and subalpine fir on rolling terrain; it was clearcut in a patchwork of polygons with interconnected unlogged stands. In the first forest, the uncut hemlock forests upslope of the clearcuts supported bird communities similar to those in forests that were continuous from valley floor to near-alpine elevations. In the second forest, bird communities in forests interspersed with clearcuts were similar to those in continuous spruce forests. The authors conclude that although mature forest bird communities are altered on clearcuts, the surrounding residual mature forests still maintain community densities similar to those before harvest.

286. Whitaker, JO, Jr., SP Cross, JM Skovlin, and C Maser. 1983. Food habits of the spotted frog (*Rana pretiosa*) from managed sites in Grant County, Oregon. *Northwest Science* 57(2): 147–154.

Spotted frogs were captured in ponds on four sites in the Oregon Blue Mountains in order to determine their food habits in relation to land management. Two pond sites were surrounded by meadows grazed by cattle, one pond was surrounded by mixed-conifer forest (species not specified) that had been thinned and under-seeded with grass, and one was surrounded by mixed-conifer forest with no active timber harvesting but with grazing by cattle. The frogs from the four sites ate a variety of foods, the majority being insect material; diets varied by site. The authors suggest that land management practices may have caused changes in the abundance or composition of local insect populations. They acknowledge, however, that lack of replications and incomplete knowledge of insect habitat requirements prevented them from determining whether differences were related to natural habitat variations or to land management activities.

287. Wilson, TM, and AB Carey. 1996. Observations of weasels in second-growth Douglas-fir forests in the Puget Trough, Washington. *Northwestern Naturalist* 77: 35–39.

Weasels in second-growth Douglas-fir forests in southwestern Washington were incidentally caught in a study of small mammals. Two second-growth forests were studied—an intensively managed 65-year-old forest that had been thinned twice over the previous 20 years, and a 56-year-old unthinned forest. In each forest, eight stands were delineated for study; half were thinned in 1993. Small mammals were trapped during summer months from 1992 through 1994. Thirty short-tailed weasels were caught; most (23) were caught in thinned stands where the understory was dense but large woody debris was sparse. The remaining seven were caught in unthinned forests. Fifteen long-tailed weasels were caught; 14 were trapped in unthinned stands, which had little understory development but high levels of coarse woody debris; only one was trapped in a thinned stand. The authors conclude that stand management history may influence abundance and diversity of weasels.

288. Wilzbach, MA, and KW Cummins. 1986. Influence of habitat manipulations on interactions between cutthroat trout and invertebrate drift. *Ecology* 67(4): 889–911.

This study examined the effects of streamside logging and prey availability on the prey capture efficiency and growth of resident cutthroat trout in an Oregon Cascade Range stream. The authors also looked at the impact of trout predation on the composition of invertebrate drift (invertebrates moving in the water column). The upper section of the study area had been logged 7 years prior to the study, and the lower section was an unlogged old-growth conifer forest (450+ years old). Trout were temporarily confined during the study by placing barriers around experimental pools in each stream section. Researchers controlled trout densities by removing all trout and then replacing exact numbers. The short-term relative growth of trout was higher in the logged section than in the unlogged section. Differences in growth rates were attributed to invertebrate drift density and to trout foraging efficiencies related to overhead shade and substrate crevices. A logarithmic relationship was found between trout foraging efficiency and surface light of pools; foraging efficiency decreased with overhead shading.

289. Witmer, GW, and DS deCalesta. 1983. Habitat use by female Roosevelt elk in the Oregon Coast Range. *Journal of Wildlife Management* 47(4): 933–939.

Female Roosevelt elk were radio-tracked to determine habitat use in an Oregon Coast Range basin with various managed and unmanaged stands. The basin consisted of recent clearcuts, brushy older clearcuts, sapling/poletimber stands, mixed stands, hardwood stands, and old growth. Habitat component characteristics were recorded for random coordinates for each area. The authors used mean characteristic values as expected values to determine whether elk were using habitat components preferentially; they used statistical analysis to compare actual and expected elk use by season and time of day. Elk preferred the old-growth forests and hardwood stands. Mixed forests and second-growth sapling/poletimber stands were used less than expected, although sapling/poletimber use increased during elk hunting season, when the dense stands appeared to provide better cover for hiding. Brushy clearcuts were used more often than recent clearcuts and more often for foraging than other stands. Old-growth stands were used more often for mid-day bedding down than other stands were.

290. Witmer, GW, and DS deCalesta. 1985. Effect of forest roads on habitat use by Roosevelt elk. *Northwest Science* 59(2): 122–125.

Six cow elk were monitored by radio tracking for 1 year in a central Oregon Coast Range basin dominated by 190-year-old stands of mixed conifers interspersed with 0- to 3-year-old clearcuts, regenerating conifer stands, and hardwood stands. The basin was divided into north and south bands for the study. Paved roads, dirt roads, and gravel-surfaced spur roads were present throughout the study area. Spur roads pervaded the area. Traffic was not monitored, but heavy log and rock trucks used the roads on weekdays, with recreational traffic on weekends. All roads were open to traffic except the southern area spur roads, which were closed during elk hunting season. Frequency distributions of the distance of elk from roads (observed values) were compared with expected frequency distributions derived from 200 randomly located points in each band. Elk were found at half the expected frequency within a 500-m-wide band surrounding paved roads. Significantly fewer elk than expected were found within the narrow 125-m band around spur roads open to vehicular traffic, but there were no differences near closed spur roads, indicating that vehicular traffic on forest roads alters the distribution of elk habitat use. The authors suggest that the impact of traffic may be mitigated by road closure, particularly during rut and calving season.

291. Wolff, JO, and JC Zasada. 1975. *Red Squirrel Response to Clearcut and Shelterwood Systems in Interior Alaska*. Research Note PNW-255, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 7 pp.

The responses of red squirrel populations to clearcutting and shelterwood cuts were studied in Alaskan stands dominated by 125-year-old white spruce. Squirrel middens were counted and mapped as an indicator of animal density before timber harvesting and 2 years after harvesting. In all units, the total number of middens decreased after harvest; territories in clearcuts were abandoned. In the shelterwoods, squirrel densities decreased and home range size appeared to increase. Population densities in uncut

buffers around the harvest units also decreased, but densities in adjacent uncut stands remained stable.

292. Young, KA, SG Hinch, and TG Northcote. 1999. Status of resident coastal cutthroat trout and their habitat twenty-five years after riparian logging. *North American Journal of Fisheries Management* 19: 901–911.

Resident cutthroat trout populations were studied in two sections of a headwater stream subjected to two types of streamside logging. One section (section A) was clearcut to the stream bank with all existing wood and logging debris left in the channel and on the adjacent hill slopes. The second section (B) was also clearcut to the stream bank, but all logging residue and existing instream wood was removed from the channel and the adjacent slopes. Harvested sections were compared with an undisturbed upstream section. Harvesting occurred in 1973, and hill slopes were burned in 1974. Trout populations were surveyed after logging from 1973 to 1976 and again in 1983 and 1997. Waterfalls restricted anadromous fish from reaching any of the sections.

In section A, summer maximum stream temperatures reached 30ºC immediately after logging but had moderated by 1975 and were similar to those in the undisturbed section by 1983; percentage of pool area increased with time after logging. Trout density was low after logging but returned to levels similar to those in the undisturbed section by 1983, and it was double the density found in the undisturbed section by 1997. In section B, water temperature, instream habitat (pool percentage and large woody debris (LWD)), and trout density levels were similar to those in the undisturbed section in all sampling years. The authors suggest that the recent increase in fish density in section A may have been related to instream habitat enhancement projects and riparian thinnings conducted in 1985. They conclude that LWD left in and over small streams after riparian logging may help protect resident trout populations.

293. Zarnowitz, JE, and DA Manuwal. 1985. The effects of forest management on cavity-nesting birds in Northwestern Washington. *Journal of Wildlife Management* 49(1): 255–263.

Cavity nesting bird population characteristics and nest-site preferences were studied in four successional stages of Douglas-fir/western hemlock forests in the Olympic Mountains of Washington. Stands were chosen on the basis of successional stage and relative snag density (high or low). The four stand types were 1) 1- to 15-year-old clearcuts, 2) 25- to 50-year-old second-growth forest, 3) 60- to 120-year-old second-growth forest, and 4) >200-year-old old-growth forest. The species richness, density, and diversity of cavity-nesting birds increased with increasing snag density. The number of active cavity nests was five times as high on high-density snag plots as on low-density snag plots. Snags appeared to be a limiting factor for breeding cavity-nesting bird populations. The authors suggest that snags in various stages of decay be left in all stand types. Snags should be of different tree species, and most should be more than 50 cm diameter.

294. Zinkl, JG, PD Mack, and ME Mount. 1984. Brain cholinesterase activity and brain and liver residues in wild birds of a forest sprayed with acephate. *Environmental Toxicology and Chemistry* 3(1): 79–88.

Possible levels of bird exposure to the insecticide acephate were determined in a northern Arizona ponderosa pine forest after the insecticide was used to control an outbreak of Pandora moths. Birds were collected by shooting, and tissue was examined to assess inhibition of brain cholinesterase and presence of residues in brain and liver tissues. Inhibition of cholinesterase was not detected on the day of application, but it was present by the next day. The greatest amount of inhibition was found in bird species with the smallest territories (yellow-rumped warbler, Grace's warbler, pygmy nuthatch, and dark-eyed junco). Residues of acephate and methamidophos in brain and liver tissues were highest on the day of spraying and dropped to undetectable levels in 14 days. Brain cholinesterase inhibition appeared to be a better indicator of exposure than tissue residue analysis. The authors conclude that birds may suffer sub-lethal effects that have not yet been

identified, but death is unlikely at the insecticide application rate used in this study.

295. Zinkl, JG, RB Roberts, CJ Henny, and DJ Lenhart. 1980. Inhibition of brain cholinesterase activity in forest birds and squirrels exposed to aerially applied acephate. *Bulletin of Environmental Contamination and Toxicology* 24: 676–683.

Forests in Idaho were sprayed with acephate (an organophosphorus insecticide) to control western spruce budworm (*Choristoneura occidentalis*). Birds and squirrels were collected 3 and 6 hours after spraying and again after 1, 3, 6, 25, and 26 days to determine brain cholinesterase (ChE) activity levels and residue concentrations. On the day of spraying, 50% of birds sampled had depressed ChE activities. After 1 day, 67% were depressed; after 6 days, 67% were depressed; and after 25–26 days, 16% were depressed. Brain ChE activity was inhibited in Columbian ground squirrels on post-spray days 3, 6, and 25–26 and in red squirrels on days 1, 3, and 6. Residue analysis for acephate and methanidorphos was conducted on brain tissues of western tanagers, dark-eyed juncos, and Swainson's thrushes. The only birds with detectable residues were 2 of 21 western tanagers. The authors suggest that if the birds in the study were continuously exposed through feed and perhaps via air through the skin, they may have been in a life-threatening situation, even though no mortality was recorded in the field.

296. Zwickel, FC, and JF Bendell. 1985. Blue grouse—Effects on, and influences of, a changing forest. *Forestry Chronicle* 61(2): 185–188.

The authors summarize 30 years of blue grouse observation and monitoring in managed forests on Vancouver Island, British Columbia. Blue grouse quickly colonized low-elevation clearcuts, but population densities were variable and unpredictable. As clearcuts develop into young, open stands, grouse populations may decline because of nonreplacement of adults that have died. Breeding adults did not appear to inhabit managed forests until the canopy cover reached 75% and the understory became well developed and diversified.

Appendix A

List of Species Mentioned in Annotations

Trees

Lodgepole pine	*Pinus contorta*
Ponderosa pine	*Pinus ponderosa*
Southwestern white pine	*Pinus strobiformis*
Sugar pine	*Pinus lambertiana*
Western white pine	*Pinus monticola*
Western larch	*Larix occidentalis*
Blue spruce	*Picea pungens*
Engelmann spruce	*Picea engelmannii*
Sitka spruce	*Picea sitchensis*
White spruce	*Picea glauca*
Douglas-fir	*Pseudotsuga menziesii*
Mountain hemlock	*Tsuga mertensiana*
Western hemlock	*Tsuga heterophylla*
Grand fir	*Abies grandis*
Noble fir	*Abies procera*
Pacific silver fir	*Abies amabilis*
Subalpine fir	*Abies lasiocarpa*
White fir	*Abies concolor*
Coast redwood	*Sequoia sempervirens*
Western redcedar	*Thuja plicata*
Incense-cedar	*Calocedrus decurrens*
Alaska-cedar	*Chamaecyparis nootkatensis*
Alligator juniper	*Juniperus deppeana*
Quaking aspen	*Populus tremuloides*
Red alder	*Alnus rubra*
Tanoak	*Lithocarpus densiflorus*
California black oak	*Quercus kelloggii*
Gambel oak	*Quercus gambelii*
Canyon live oak	*Quercus chrysolepis*
Bigleaf maple	*Acer macrophyllum*
Pacific madrone	*Arbutus menziesii*

Shrubs and herbs

Western serviceberry	*Amelanchier alnifolia*
Ocean spray	*Holodiscus discolor*
Salmonberry	*Rubus spectabilis*
Thimbleberry	*Rubus parviflorus*
Trailing blackberry	*Rubus ursinus*
Vine maple	*Acer circinatum*
Redstem ceanothus	*Ceanothus sanguineus*
Snowbrush	*Ceanothus velutinus*
Salal	*Gaultheria shallon*
Tall blue huckleberry	*Vaccinium ovalifolium*
Red elderberry	*Sambucus racemosa*
Fireweed	*Epilobium angustifolium*

Fishes

Longnose dace	*Rhinichthys cataractae*
Speckled dace	*Rhinichthys osculus*
Dolly Varden	*Salvelinus malma*
Cutthroat trout	*Oncorhynchus clarki*
Steelhead / Rainbow trout	*Oncorhynchus mykiss*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Pink salmon	*Oncorhynchus gorbuscha*
Shorthead sculpin	*Cottus confuses*
Reticulate sculpin	*Cottus perplexus*

Amphibians

Northwestern salamander	*Ambystoma gracile*
Pacific giant salamander	*Dicamptodon tenebrosus*
Southern torrent salamander	*Rhyacotriton variegatus*
Olympic salamander	*Rhyacotriton olympicus*
Clouded salamander	*Aneides ferreus*
Black salamander	*Aneides flavipunctatus*
California slender salamander	*Batrachoseps attenuatus*
Ensatina	*Ensatina eschscholtzii*
Dunn's salamander	*Plethodon dunni*
Del Norte salamander	*Plethodon elongatus*
Western redback salamander	*Plethodon vehiculum*
Roughskin newt	*Taricha granulosa*
Western toad	*Bufo boreas*

Pacific treefrog	*Hyla regilla*
Tailed frog	*Ascaphus truei*
Red-legged frog	*Rana aurora*
Spotted frog	*Rana pretiosa*

Reptiles

Northern alligator lizard	*Elgaria coerulea*
Southern alligator lizard	*Elgaria multicarinata*
Sagebrush lizard	*Sceloporus graciosus*
Western fence lizard	*Sceloporus occidentalis*
Western skink	*Eumeces skiltonianus*

Breeding birds

Sharp-shinned hawk	*Accipiter striatus*
Cooper's hawk	*Accipiter cooperii*
Northern goshawk	*Accipiter gentilis*
Red-tailed hawk	*Buteo jamaicensis*
American kestrel	*Falco sparverius*
Blue grouse	*Dendragapus obscurus*
Mountain quail	*Oreortyx pictus*
Marbled murrelet	*Brachyramphus marmoratus*
Band-tailed pigeon	*Columba fasciata*
Mourning dove	*Zenaida macroura*
Flammulated owl	*Otus flammeolus*
Great horned owl	*Bubo virginianus*
Northern spotted owl	*Strix occidentalis*
Great gray owl	*Strix nebulosa*
Long-eared owl	*Asio otus*
Boreal owl	*Aegolius funereus*
Vaux's swift	*Chaetura vauxi*
Calliope hummingbird	*Stellula calliope*
Rufous hummingbird	*Selasphorus rufus*
Red-breasted sapsucker	*Sphyrapicus ruber*
Yellow-bellied sapsucker	*Sphyrapicus nuchalis*
Hairy woodpecker	*Picoides villosus*
Black-backed woodpecker	*Picoides arcticus*
Northern flicker	*Colaptes auratus*
Pileated woodpecker	*Dryocopus pileatus*
Olive-sided flycatcher	*Contopus borealis*
Western wood-pewee	*Contopus sordidulus*
Willow flycatcher	*Empidonax traillii*
Hammond's flycatcher	*Empidonax hammondii*
Dusky flycatcher	*Empidonax oberholseri*
Pacific-slope flycatcher	*Empidonax difficilis*
Tree swallow	*Tachycineta bicolor*
Violet-green swallow	*Tachycineta thalassina*
Gray jay	*Perisoreus canadensis*
Steller's jay	*Cyanocitta stelleri*
American crow	*Corvus brachyrhynchos*
Common raven	*Corvus corax*
Mountain chickadee	*Parus gambeli*
Chestnut-backed chickadee	*Parus rufescens*
Bushtit	*Psaltriparus minimus*
Red-breasted nuthatch	*Sitta canadensis*
White-breasted nuthatch	*Sitta carolinensis*
Pygmy nuthatch	*Sitta pygmaea*
Brown creeper	*Certhia americana*
House wren	*Troglodytes aedon*
Winter wren	*Troglodytes troglodytes*
Golden-crowned kinglet	*Regulus satrapa*
Ruby-crowned kinglet	*Regulus calendula*
Western bluebird	*Sialia mexicana*
Townsend's solitaire	*Myadestes townsendi*
Swainson's thrush	*Catharus ustulatus*
Hermit thrush	*Catharus guttatus*
American robin	*Turdus migratorius*
Varied thrush	*Ixoreus naevius*
Cassin's vireo	*Vireo cassinii*
Hutton's vireo	*Vireo huttoni*
Warbling vireo	*Vireo gilvus*
Solitary vireo	*Vireo solitarius*
Orange-crowned warbler	*Vermivora celata*
Nashville warbler	*Vermivora ruficapilla*
Yellow-rumped warbler	*Dendroica coronata*
Black-throated gray warbler	*Dendroica nigrescens*
Townsend's warbler	*Dendroica townsendi*
Hermit warbler	*Dendroica occidentalis*
Grace's warbler	*Dendroica graciae*
MacGillivray's warbler	*Oporornis tolmiei*
Wilson's warbler	*Wilsonia pusilla*
Red-faced warbler	*Cardellina rubrifrons*
Western tanager	*Piranga ludoviciana*
Black-headed grosbeak	*Pheucticus melanocephalus*

Spotted towhee	*Pipilo maculatus*
Rufous-sided towhee	*Pipilo erythrophthalmus*
Chipping sparrow	*Spizella passerina*
Fox sparrow	*Passerella iliaca*
White-crowned sparrow	*Zonotrichia leucophrys*
Song sparrow	*Melospiza melodia*
Dark-eyed junco	*Junco hyemalis*
Brown-headed cowbird	*Molothrus ater*
Purple finch	*Carpodacus purpureus*
Cassin's finch	*Carpodacus cassinii*
Red crossbill	*Loxia curvirostra*
Pine siskin	*Carduelis pinus*
American goldfinch	*Carduelis tristis*
Evening grosbeak	*Coccothraustes vespertinus*

MAMMALS

Vagrant shrew	*Sorex vagrans*
Montane shrew	*Sorex monticolus*
Pacific shrew	*Sorex pacificus*
Pacific marsh shrew	*Sorex palustris*
Water shrew	*Sorex bendirii*
Trowbridge's shrew	*Sorex trowbridgii*
Masked shrew	*Sorex cinereus*
Dusky shrew	*Sorex obscurus*
Shrew-mole	*Neurotrichus gibbsii*
Western small-footed myotis	*Myotis ciliolabrum*
California myotis	*Myotis californicus*
Little brown myotis	*Myotis lucifugus*
Long-eared myotis	*Myotis evotis*
Keen's myotis	*Myotis keenii*
Fringed myotis	*Myotis thysanodes*
Long-legged myotis	*Myotis volans*
Yuma myotis	*Myotis yumanensis*
Silver-haired bat	*Lasionycteris noctivagans*
Big brown bat	*Eptesicus fuscus*
Townsend's big-eared bat	*Corynorhinus townsendii*
Pallid bat	*Antrozous pallidus*
Hoary bat	*Lasiurus cinereus*
Snowshoe hare	*Lepus americanus*
Mountain beaver	*Aplodontia rufa*
Least chipmunk	*Tamias rufa*
Red-tailed chipmunk	*Tamias ruficaudus*
Yellow-pine chipmunk	*Tamias amoenus*
Townsend's chipmunk	*Tamias townsendii*
Allen's chipmunk	*Tamias senex*
Columbian ground squirrel	*Spermophilus columbianus*
Western gray squirrel	*Sciurus griseus*
Red squirrel	*Tamiasciurus hudsonicus*
Douglas' squirrel	*Tamiasciurus douglasii*
Northern flying squirrel	*Glaucomys sabrinus*
Deer mouse	*Peromyscus maniculatus*
Piñon mouse	*Peromyscus truei*
Brush mouse	*Peromyscus boylii*
Forest field mouse	*Peromyscus oreas*
Dusky-footed woodrat	*Neotoma fuscipes*
Southern red-backed vole	*Clethrionomys gapperi*
Western red-backed vole	*Clethrionomys californicus*
Northern red-backed vole	*Clethrionomys rutilus*
White-footed vole	*Phenacomys albipes*
Red tree vole	*Phenacomys longicaudus*
Townsend's vole	*Microtus townsendii*
Long-tailed vole	*Microtus longicaudus*
Creeping vole	*Microtus oregoni*
Meadow vole	*Microtus pennsylvanicus*
Pacific jumping mouse	*Zapus trinotatus*
Western jumping mouse	*Zapus princeps*
Coyote	*Canis latrans*
Common gray fox	*Urocyon cinereoargenteus*
Black bear	*Ursus americanus*
Grizzly bear	*Ursus horribilis*
Ringtail	*Bassariscus astutus*
American marten	*Martes americana*
Fisher	*Martes pennanti*
Ermine (short-tailed weasel)	*Mustela erminea*
Long-tailed weasel	*Mustela frenata*
Wolverine	*Gulo gulo*
Western spotted skunk	*Spilogale gracilis*
Mountain lion (cougar)	*Felis concolor*
Lynx	*Lynx canadensis*
Elk	*Cervus elaphus*
Black-tailed deer	*Odocoileus hemionus columbianus*
Mule deer	*Odocoileus hemionus hemionus*
White-tailed deer	*Odocoileus virginianus*

Appendix B

Glossary of Terms Used in Annotations

Aggradation: Raising of the stream channel bed elevation due to sediment deposition.

Alevin: The developmental life stage of young salmon and trout that is between the egg and fry stage. The alevin has not absorbed its yolk sac and has not emerged from the spawning gravel.

Allochthonous organic matter: Derived from outside a system, such as the leaves of terrestrial plants that fall into a stream.

Aufwuchs: Complex assemblages of plants and animals living on the surface of a submerged mineral or organic substrate.

Autochthonous organic matter: Derived from within a system, such as organic matter in a stream resulting from photosynthesis by aquatic plants.

Benthic organisms/Benthos: Organisms, both plant and animal, that live on or in the bottom of a stream, lake, or ocean.

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

Broadcast burn: A prescribed fire allowed to burn over a designated area within well-defined boundaries, often used to reduce logging slash as part of site preparation or to control understory vegetation. Also called controlled burn.

Clearcut: An even-aged method of harvest in which all or most trees in a stand are removed in a single entry for the development of a new age class; also called regeneration cut.

Clearcut with reserves: A clearcutting method in which varying numbers of reserve live trees are left standing to attain management goals other than regeneration, such as providing wildlife habitat.

Density: The number of individuals per unit area.

Diameter-limit cut: The removal of all merchantable trees above or below a specified diameter.

Even-aged management: Methods that regenerate and maintain a stand with a single age class; includes clearcutting, seed tree cuts, and shelterwood cuts.

Fidelity coefficients: Fidelity coefficients range from -1.0, meaning no association between an animal's annual home ranges (i.e., no home-range fidelity) to 1.0, reflecting complete home-range fidelity.

Freshet: A rapid temporary increase in streamflow due to heavy rains or snowmelt.

Fry: A developmental stage in young salmon and trout in which the fish has absorbed its yolk sac, has emerged from the spawning gravel, is rearing in the stream, and is between the alevin and parr development stages.

Group selection: An uneven-aged management method in which trees are removed and new age classes are established in small groups.

Hypogeous fungi: Fungi that fruit underground; spores are often disseminated by fungi-consuming animals. Fruiting bodies are often called truffles.

Large woody debris (LWD): Dead woody material lying on the ground or in streams. The type and size of material designated as LWD varies among classification schemes.

Old growth: Late-successional stage of forest development that often has large live trees, multilayered canopy, large snags, and large downed logs. The term "old growth" is often used to describe older forests with little or no human-caused disturbance such as logging.

Overstory removal: The cutting of trees of the upper canopy layer to release trees or other vegetation in an understory.

Parr: The developmental life stage of salmon and trout when the young have developed parr marks (distinctive vertical bars on sides) and are actively feeding in fresh water. The parr stage is between alevin and smolt stages.

Patch cut/Patch clearcut: Clearcutting done in groups or patches. For example, an area may be systematically patch cut over time to allow natural reseeding that would not occur if all the timber were removed in a single harvest.

Periphyton: Algae and associated microorganisms growing attached to any submerged surface.

Poletimber: Trees between the size of saplings and sawtimber; size varies by region.

Pre-smolt: A juvenile salmon or trout that has not yet reached the physiological state known as a smolt.

Redd: Nest made in gravel, consisting of a depression dug by a fish for egg deposition (and then filled) and associated gravel mounds.

Relative density: Forest stocking, expressed as the actual density of trees in a stand relative to the theoretical maximum density possible for trees of that size.

Release operation: A treatment designed to free young trees (either manually or with herbicides) from undesirable, usually overtopping, competing vegetation.

Resident fish: Non-migratory fish that remain in the same stream network their entire lives (e.g., resident cutthroat trout).

Sapling: A tree larger than a seedling but smaller than a pole (see "poletimber"); size varies by region.

Salvage logging: The removal of trees that are dead, dying, or injured (other than through competition) to recover economic value that would otherwise be lost.

Sawtimber: Trees with minimum diameter and length suitable for conversion to lumber and with acceptable stem quality; a tree that has reached merchantability standards.

Second growth: A relatively young forest that has regenerated naturally or artificially after a large-scale disturbance. The term typically refers to a forest that has regenerated after harvest, but it can include forests regenerated after catastrophic events such as wind storms, disease, insect attack, or fire.

Selection cut/Selection harvest: Removal of only a part of a stand for purposes other than regenerating a new age class; also called partial cutting.

Shelterwood: An even-aged management method that harvests most overstory trees, leaving those needed to produce sufficient shade to produce a new age class. After regeneration is established, a removal cut harvests remaining overstory trees to release the regeneration.

Single tree selection: An uneven-aged management method in which individual trees of all size classes are removed fairly uniformly throughout the stand to promote growth of remaining trees and regeneration, also call individual tree selection.

Site preparation: Hand or mechanized manipulation (including burning and chemical applications) of a site designed to enhance the success of tree regeneration.

Smolt: The developmental life stage of salmon and trout between parr and adult, when the juvenile is at least 1 year old and has undergone physiological changes to survive in the marine environment.

Species abundance: The number of organisms in a population, a measure that combines density within inhabited areas and number and size of inhabited areas.

Species composition: The wildlife or plant species on a site or in a successional stage of a plant community.

Species diversity: A measure that incorporates both species richness and species evenness.

Species equitability: A measure of relative species distribution calculated as a diversity index, also called evenness.

Species evenness: The distribution of individuals among the species, also called equitability.

Species frequency: The ratio between the number of sample units that contain a species and the total number of sample units.

Species richness: A measurement or expression of the number of species present in an area.

Thalweg: The line connecting the lowest or deepest points along a streambed.

Thinning: A cultural treatment made to reduce tree stand density, primarily to improve growth, enhance forest health, or harvest trees that would die when the stand becomes dense.

Uneven-aged management: Methods to regenerate and maintain a multi-aged stand structure by removing some trees in all size classes; includes group selection and single tree selection.

Young growth: Relatively young stands that have regenerated after a large-scale disturbance; also called second growth. In recent literature, young growth is sometimes used to distinguish young forests naturally regenerating after an event such as catastrophic fire, windstorm, or insect or disease outbreak from forests regenerating after timber harvest (second growth).

Appendix C

General References

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Appendix D

World Wide Web Links

Literature Databases

Some sites may require individual accounts or site licenses, but many offer free trial use. Other databases and providers are available; consult your resource librarian.

Biblioline (includes Fish & Fisheries Worldwide, Wildlife Worldwide)
http://www.nisc.com/

Cambridge Scientific Abstracts (includes Aquatic Sciences & Fisheries Abstracts)

http://www.csa2.com/

FirstSearch Databases (includes Agricola, Worldcat, Biological & Agricultural Index)

http://firstsearch.oclc.org/

UnCover Reveal Journal Service

http://uncweb.carl.org/

USDA National Agricultural Library (public access to Agricola databases)

http://www.nalusda.gov/

Online Bibliographies

Habitat Use by Snag-Associated Species: A Bibliography for Species Occurring in Oregon and Washington

http://www.cof.orst.edu/cof/pub/home/rc/rc33.htm

International Conference on Wood in World Rivers Searchable Database

http://riverwood.orst.edu/html/intro.html

Effects of Recreation on Rocky Mountain Wildlife: Online Bibliography

http://www.montanatws.org/pages/page4b.html

Bibliography on the Conservation of Biological Diversity: Biological, Ecological, Economic, and Policy Issues

http://www.orst.edu/dept/ag_resrc_econ/biodiv/biblio.html

Endangered Species Bibliography

http://www.calacademy.org/research/library/biodiv/biblio/endanger.htm

Annotated Bibliography: Adaptive Management References

http://www.for.gov.bc.ca/hfp/amhome/annobib/ambib.htm

Wildlife–Roadway Interactions: A Bibliography and Review of Roadway and Wildlife Interactions

http://www.fs.fed.us/pnw/wenlab/research/projects/wildlife

US Government

USDA Forest Service

http://www.fs.fed.us/

USDA Forest Service, Pacific Northwest Research Station

http://www.fs.fed.us/pnw/

USDA Forest Service, Rocky Mountain Research Station

http://www.fs.fed.us/rm/

USDA Forest Service, Pacific Northwest Region

http://www.fs.fed.us/r6/

USDA Forest Service, Rocky Mountain Region

http://www.fs.fed.us/r4/

USDA Forest Service, Intermountain Region

http://www.fs.fed.us/r4/

USDI Fish and Wildlife Service

http://www.fws.gov/

USDI Fish and Wildlife Service, Pacific Region

http://www.r1.fws.gov

USDI Bureau of Land Management

http://www.blm.gov/nhp/

USDI Bureau of Land Management, Oregon and Washington

http://www.or.blm.gov/

USDI Bureau of Land Management, Idaho

http://www.id.blm.gov/

USGS Forest and Rangeland Ecosystem Science Center

http://fresc.fsl.orst.edu/

Cooperative Forest Ecosystem Research Program (CFER)

http://www.fsl.orst.edu/cfer

USDC NOAA National Marine Fisheries

http://www.nmfs.noaa.gov/

US Environmental Protection Agency, Office of Pesticide Programs

http://www.epa.gov/pesticides/

US Government Printing Office
http://www.access.gpo.gov/

US Library of Congress
http://marvel.loc.gov/

Canadian Government

Canadian Forest Service, The Pacific Forestry Centre
http://www.pfc.cfs.nrcan.gc.ca/main/index.html
or **http://www.pfc.forestry.ca**

Natural Resources Canada
http://www.NRCan-RNCan.gc.ca/homepage/index.html
or **http://www.nrcan.gc.ca/**

Ministry of Forests, British Columbia, Research Branch
http://www.for.gov.bc.ca/research/

University Departments and Libraries

Oregon State University, College of Forestry
http://www.cof.orst.edu/

Oregon State University, Department of Fisheries and Wildlife
http://osu.orst.edu/dept/fish_wild/

Oregon State University Library
http://osulibrary.orst.edu/

University of Washington, College of Forest Resources
http://www.cfr.washington.edu/

University of Washington, School of Aquatic and Fishery Sciences
http://www.fish.washington.edu/

University of Washington Library
http://www.lib.washington.edu/

University of Idaho, College of Natural Resources
http://www.uidaho.edu/cnr/

University of Idaho Library
http://www.lib.uidaho.edu/

University of British Columbia, College of Forestry
http://www.forestry.ubc.ca/

University of British Columbia, Department of Zoology
http://www.zoology.ubc.ca/

Cooperative Extension Services

Oregon State University Cooperative Extension Service, Extension Forestry Program
http://www.cof.orst.edu/cof/extended/extserve/

Washington State University Cooperative Extension Service, Natural Resource Sciences
http://ext.nrs.wsu.edu/

University of Idaho Cooperative Extension Service, Extension Forestry
http://www.ets.uidaho.edu/extforest/homepage.htm

State Agencies and Programs

Alaska Department of Fish and Game
http://www.state.ak.us/adfg/adfghome.htm

Alaska Department of Natural Resources, Forestry Division
http://www.dnr.state.ak.us/forestry/index.htm

Oregon Department of Forestry
http://www.odf.state.or.us/

Oregon Department of Fish and Wildlife
http://www.dfw.state.or.us/

Oregon Plan for Salmon and Watersheds
http://www.oregon-plan.org/

Independent Multidisciplinary Science Team, Oregon Plan for Salmon and Watersheds
http://www.fsl.orst.edu/imst/

Idaho Department of Fish and Game
http://www2.state.id.us/fishgame/

Idaho Department of Lands, Forestry Bureaus
http://www2.state.id.us/lands/bureaus.htm

Washington Department of Natural Resources

http://www.wa.gov/dnr/

Washington Department of Fish and Wildlife

http://www.wa.gov/wdfw/

Professional Organizations

Society of American Foresters

http://www.safnet.org/

Oregon Chapter, Society of American Foresters

http://www.forestry.org/

Washington Chapter, Society of American Foresters

http://www.waforestry.org/

The Wildlife Society

http://www.wildlife.org/index.html

The Wildlife Society, Oregon Chapter

http://www.orst.edu/dept/fish_wild/tws/index.htm

American Fisheries Society

http://www.fisheries.org/

American Fisheries Society, Oregon Chapter

http://osu.orst.edu/groups/orafs/

The Native Fish Society

http://www.teleport.com/~salmo/

American Water Resources Association

http://www.awra.org/index.html

Others

Forestry and Wildlife Interactions

http://www.rr.ualberta.ca/wildlife_impacts/log1.htm

Dead Tree Web Site

http://www.for.gov.bc.ca/research/deadwood/

Oregon Forest Resources Institute

http://oregonforests.org/

Northwest Aquatic Information Network

http://www.streamnet.org/

National Council for Air and Stream Improvement, Inc. Forestry Program

http://www.ncasi.org/forestry.stm

Integrated Taxonomic Information Service

http://www.itis.usda.gov/

Appendix E

British to Metric Unit Conversion Factors

1 inch = 2.54 cm

1 foot = 0.3048 m

1 mile = 1.60934 km

1 acre = 0.404686 ha

Basal Area: 1 square foot per acre = 0.229568 square meters per hectare

Celsius = ((F-32)/9)*5

Fahrenheight = ((9*C)/5)+32

Author Index*

* Indexed by citation number

SUBJECT INDEX*

* Indexed by citation number

Please note: Not all of the species listed in the index will be mentioned in the annotations, but they are included in the original cited works

D

E

F

G

H

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M

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V

W

Y

Z

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