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Managing for Wildlife Habitat in Westside Production Forests

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and Gretchen E. Nicholas,
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ABSTRACT

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On October 18, 2006, a workshop was held in Vancouver, WA, with the title "Managing for wildlife habitat in Westside production forests." The purpose of the workshop was to provide prescriptions and guidelines for people who manage Westside forests (those west of the Cascade Mountains' crest) primarily for wood production, but because of mandate or personal preference, want to integrate wildlife values. The audience included over 150 professionals from forest industry, consulting firms, and public and tribal forest and wildlife management agencies. This proceedings includes ten papers based on oral presentations at the workshop plus a synthesis paper summarizing workshop themes, discussions, and related information. Topics include a history of wildlife management research in the Pacific Northwest, elements of habitat and how to manage for them, the challenges of appropriately implementing ecosystem management, and economic implications to private forestland owners.

KEYWORDS: Wildlife habitat, old-forest structure, thinning, coarse woody debris, wildlife trees, management regimes, economic analysis.

ACKNOWLEDGMENTS

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KEYNOTE PRESENTATIONS

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CHANGING PERCEPTIONS OF THE ROLE OF MANAGED FORESTS AS WILDLIFE HABITAT IN THE PACIFIC NORTHWEST

Keith B. Aubry[1]

ABSTRACT

Forest management objectives and the perceived role of managed forests as wildlife habitat in the Pacific Northwest changed in many significant ways during the 20th century. Before 1900, wildlife was generally considered something to be exploited or exterminated, not managed or protected. This perspective began to change in the early 1900s when Theodore Roosevelt promoted the doctrine of "conservation through wise use," and Aldo Leopold established the science and practice of wildlife management with the publication of his seminal textbook, *Game Management*. However, the most revolutionary changes in public and professional perceptions regarding forest management for wildlife objectives occurred in the latter part of the 20th century. Many of these changes began during the 1970s, after the environmental movement of the 1960s resulted in the enactment of federal legislation designed to minimize environmental degradation, perpetuate biological diversity, and protect endangered species. In this paper, I argue that changing perceptions about the role of managed forests as wildlife habitat were associated primarily with the following four key conceptual turning points that were strongly influenced by these legislative mandates and the ground-breaking research and landmark publications of various scientists and resource professionals in this region: (1) for which species should forests be managed? (2) at what spatial or ecological scales should forests be managed? (3) which riparian zones should be managed? (4) can old-growth attributes be created in managed forests?

KEYWORDS: Forest management, landscape, old growth, riparian, wildlife.

INTRODUCTION

Coniferous forests play an important role in the economic health, social values, and biodiversity of the Pacific Northwest. Environmental conditions in this region create extensive forests with very large trees and unusually diverse wildlife communities that include many rare and endemic species. Although the states of Washington and Oregon contain only 4.6% of the land and 6.8% of the conifer forests in the U.S., they contain 25.7% of the softwood timber volume, 37% of the bird species, and 42% of the mammal species (Bunnell and Kremsater 1990). During the late 1980s and early 1990s, conflicts among environmental groups, the timber industry, and federal land management agencies over the population status and habitat requirements of the northern spotted owl (*Strix occidentalis caurina*) and the fate of old-growth forests on federal lands in the Pacific Northwest resulted in profound changes in forest management objectives and the perceived role of managed forests as wildlife habitat (Thomas et al. 1991, FEMAT 1993, Tuchmann et al. 1996). However, the evolution of both public and professional perceptions regarding wildlife in managed forests that accompanied and sometimes directed those changes had its roots in the first decade of the 20th century and continues today. My objective in this paper is to describe that evolution and demonstrate that it was associated with a series of key conceptual turning points that were often initiated or strongly influenced by the ground-breaking research and landmark publications of various scientists and resource professionals in this region.

Wildlife Management Before 1900

Public perceptions and values associated with wildlife changed dramatically in the United States during the 20th century. Before 1900, wildlife was considered by most people as something to be exploited or exterminated, not managed or protected. Additionally, at that time, the concept of

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“wildlife” was much narrower in scope than it is today, and was limited primarily to the relatively large game birds and mammals that provided food and sport; birds that provided feathers for the millenary trade; furbearers that provided pelts for coats, hats, and other fashion accessories; and large predators that needed to be controlled or exterminated to protect people, livestock, and game. At that time, hunting regulations were designed primarily to divide up a dwindling natural resource among the citizenry for as long as possible (Leopold 1933).

Providing the general public with access to game was a uniquely American concept that differed fundamentally from the European tradition of restricting the hunting of game to landowners and other aristocrats. One of the reasons that wildlife management and protection took several centuries to become established in the United States was the common perception that the consumption of wildlife resources was an inalienable right of every citizen. Before the enactment of federal laws during the 20th century to protect wildlife, increased law enforcement of “game hogs” and the prohibition of “market hunting” for food and feathers were considered the best ways to maintain game populations and provide hunting opportunities to everyone. Despite such protective measures, wildlife populations continued to decrease and some species, including the bison (*Bos bison*), sea otter (*Enhydra lutris*), ivory-billed woodpecker (*Campephilus principalis*), Carolina parakeet (*Conuropsis carolinensis*), Eskimo curlew (*Numenius boralis*), and passenger pigeon (*Ectopistes migratorius*) were extirpated in the contiguous U.S. during the first half of the 20th century (Matthiessen 1959). The bison and the passenger pigeon, each of which occurred in astounding abundance historically, were only the most dramatic examples of the catastrophic effects that unrestrained exploitation could have on wildlife populations.

Theodore Roosevelt - “Conservation through Wise Use”

The conceptual foundation for the science and practice of wildlife management in America was laid by President Theodore Roosevelt (fig. 1) in the first decade of the 20th century (Leopold 1933). Roosevelt promoted the doctrine of “conservation through wise use,” which asserted that wildlife, forests, ranges, and waterpower were renewable natural resources that could last forever if they were harvested scientifically, and not faster than they could replenish themselves. This concept influenced the subsequent history of wildlife management in America in three important ways: (1) it recognized human use of all natural resources as an integrated whole; (2) it established the conservation of natural resources as a public responsibility, and private ownership of resources as a public trust; and

Figure 1—Theodore Roosevelt.

(3) it promoted science as the primary tool for meeting that responsibility. In 1909, Roosevelt argued that the best and most democratic approach to game protection would be through a system of public preserves with protected breeding grounds, and laws established to define the conditions under which the public could enjoy the privilege of hunting (Leopold 1933). Roosevelt’s philosophy and activism for wildlife permanently changed American attitudes toward game and other wildlife, and created a new kind of naturalist who believed that the conquest of nature by human activities carried with it a moral responsibility to preserve and protect threatened species.

Aldo Leopold - Managing Forests for Wildlife

The scientific discipline known today as “wildlife management”, “wildlife biology”, or similar derivations, was established almost single-handedly by Aldo Leopold (fig. 2) in 1933 with the publication of his seminal textbook entitled *Game Management* (Leopold 1933). Prior to the publication of this book, the management of wildlife primarily involved hunting restrictions, predator control, wildlife refuges, and game farming. Leopold was convinced that the best way to protect and perpetuate game was to manage habitat conditions (especially forests) in ways that would produce sustainable populations for hunting. The expansion of this discipline to include non-consumptive uses and other species of wildlife, including non-game birds and mammals, amphibians, and reptiles would come later. Leopold’s ideas were strongly influenced

Figure 2—Aldo Leopold.

by his formal training in forestry; he viewed game populations much the same way that foresters viewed trees or farmers viewed crops; game was just a secondary crop that foresters or farmers could produce by modifying their methods of cultivating the primary crop (Leopold 1931). He recognized that "the hope of the future lies not in curbing the influence of human occupancy—it is already too late for that—but in creating a better understanding of the extent of that influence and a new ethic for its governance" (Leopold 1933:21).

Leopold (1933) believed that with scientific guidance, land managers could increase game by manipulating the composition and interspersion of habitat types on the land. Moreover, in his view, foresters played a unique and critically important role in the science and practice of game management (Leopold 1930, 1931). He argued that (1) other than trees, game is the only land crop that is best produced by use of natural species in a natural environment by low-cost, low-yield techniques; (2) both timber and game yields were based on skill in guiding natural processes in relatively small ways; (3) unlike zoologists, who still relied largely on descriptive science, foresters had always used quantitative methods that could be applied directly to game management; and (4) forestry produces salable crops needed by game, and game could furnish additional revenue needed for forestry (Leopold 1930).

Leopold also played an instrumental role in the founding of The Wildlife Society and the establishment of the *Journal of Wildlife Management*. He viewed game management as a specialized branch of applied ecology, not as a sub-discipline of mammalogy or ornithology. At the annual meeting of the Society of American Foresters in 1930, Leopold advocated for the creation of a technical journal modeled after the *Journal of Forestry* in which game management professionals could disseminate new scientific knowledge and share experiences (Leopold 1931). In 1936, a small group of biologists, including Leopold, formed themselves into a temporary organization called the Society of Wildlife Specialists. The following year, that group became The Wildlife Society and published the first issue of the *Journal of Wildlife Management*. Thus, by the late 1930s, many natural resource professionals possessed a conservation ethic and recognized the importance of public and private forests for perpetuating game species in America. In addition, scientifically based tools for increasing game populations by manipulating habitat conditions were being developed and disseminated. However, both public and professional perceptions of the role of managed forests as wildlife habitat would change dramatically in many unforeseen ways during the latter part of the 20th century.

KEY CONCEPTUAL TURNING POINTS

For Which Species Should Forests be Managed?

The inaugural issue of the *Journal of Wildlife Management* explicitly stated that wildlife management is not restricted to game management; rather, it embraces the practical ecology of all vertebrates and their plant and animal associates (Bennitt et al. 1937). However, such a comprehensive approach to wildlife management remained a lofty ideal for most wildlife professionals until the 1970s. The inclusion of species other than game birds and mammals in forest wildlife management began with the addition of economically important, esthetically pleasing, or threatened birds and mammals from the 1940s through the 1960s; all terrestrial vertebrates, including amphibians and reptiles, in the 1970s and 1980s; and finally, to all components of biodiversity, including ecological functions, in the 1990s and 2000s.

The initial broadening of wildlife management beyond game birds and mammals is exemplified by the scope of Ira Gabrielson's (1959) textbook entitled *Wildlife Conservation*. Gabrielson was one of the leading wildlife conservationists of his time; he wrote the first monograph on the birds of Oregon (Gabrielson and Jewett 1940), was the first Director of the U.S. Fish and Wildlife Service, and later served as President of the Wildlife Management Institute. Although the primary emphasis of his textbook was on game and other economically important birds and mammals, he also included chapters on migratory birds, non-game birds and mammals, and rare and vanishing species. However, small mammals are given only one page of text; and amphibians, reptiles, and invertebrates are not even mentioned. The chapter on relations between forestry and wildlife is focused on game animals, sport fish, and furbearers; consideration of other species is limited to brief discussions of injurious rodents and seed-eating birds, and potentially beneficial insectivorous birds. Although Gabrielson had spent many years observing and studying the birds and mammals of Oregon, he believed that old-growth forests of the Pacific Northwest were biologically depauperate (Gabrielson 1959:63-64); consequently, he viewed clearcutting as generally beneficial to wildlife because it opened the canopy and returned densely forested areas to the early seral stages in which most forest game birds and mammals thrived. He did not consider the potential detrimental effects of clearcutting or other forest practices on non-game wildlife or the complex ecological relations of late-successional forests.

The inclusion of all vertebrates in the discipline of wildlife management began in the 1970s, driven primarily by the enactment of three federal laws from 1970 to 1976 that mandated the maintenance of biological diversity in public forests, and changed the science and practice of forest wildlife management in the Pacific Northwest in many significant ways. The National Environmental Policy Act of 1970 (NEPA) required all federal agencies to prepare an Environmental Impact Statement (EIS) for public review that evaluated the environmental consequences of proposed development projects or programs, and included plans for mitigating adverse environmental effects. The Endangered Species Act of 1973 (ESA) required all federal agencies to protect habitat critical to the survival and recovery of any vertebrate, invertebrate, or plant species listed by the U.S. Fish and Wildlife Service as threatened or endangered. The National Forest Management Act of 1976 (NFMA) required the Forest Service to maintain viable populations of all existing native and desirable non-native vertebrate species on National Forest lands, to protect the resources and habitats upon which vertebrate populations and endangered species depend, and to preserve and enhance biological diversity in each management area so that it is equal to that of a natural, unmanaged forest (Stockwell 1990).

The legal mandates and changes in public attitudes and values that were put in place or set in motion by the enactment of these laws are what Jack Ward Thomas was referring to in 1979 when he stated, "Until just a few years ago, forest managers were not especially concerned with wildlife. The law did not require it. The public did not demand it. Politics did not compel it." That statement

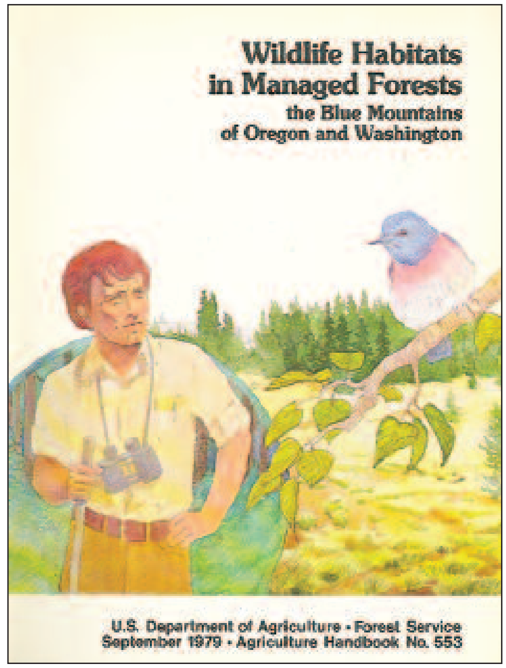

Figure 3—Cover of the book, *Wildlife Habitats in Managed Forests: the Blue Mountains of Oregon and Washington* (Thomas 1979).

appears in the preface of a book that pioneered a revolutionary new approach to forest management for wildlife objectives entitled *Wildlife Habitats in Managed Forests: the Blue Mountains of Oregon and Washington* (fig. 3). Thomas recognized that these new federal laws created daunting new responsibilities to manage public and private forests for wildlife, and that resource managers would need new tools to meet those responsibilities. He also understood that they would be required to make important and far-reaching management decisions regardless of the amount of information that was available.

Although most foresters and wildlife biologists understood that good timber management did not necessarily equal good wildlife management, Thomas (1979) believed that the effectiveness of forest management for wildlife could be greatly enhanced if relevant scientific knowledge and expert opinion (in the absence of that knowledge) were organized in a way that made sense both biologically and silviculturally. Thus, Thomas organized the "Blue Mountains" book according to habitat types or individual structures that were relevant to forest managers (e.g., riparian zones, edges, snags, downed wood, etc.), rather than by wildlife taxa, and explicitly considered silvicultural options and impacts on wood production. Most importantly, he and his colleagues devised a "matrix" approach to presenting

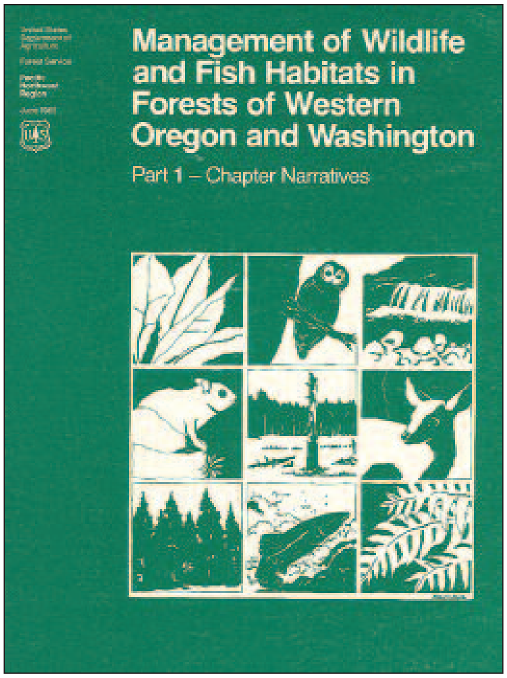

Figure 4—Cover of the book, *Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington* (Brown 1985).

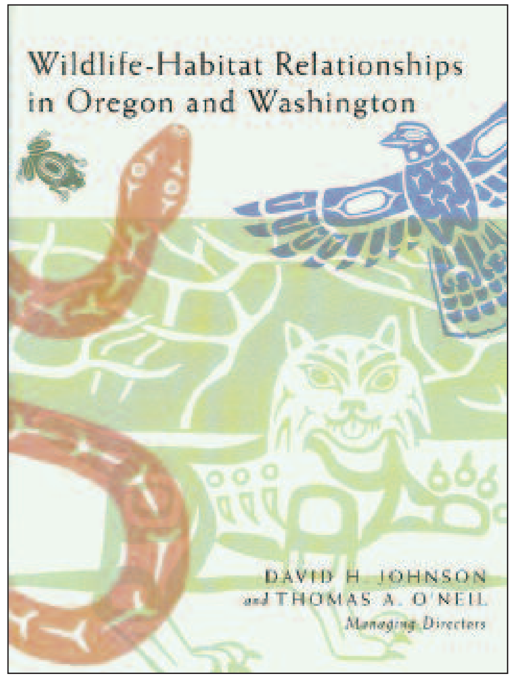

Figure 5—Cover of the book, *Wildlife-Habitat Relationships in Oregon and Washington* (Johnson and O'Neill 2001).

information on wildlife-habitat relationships enabling managers to quickly and easily apply the best information available to predict the potential effects of different forest management activities on a comprehensive array of wildlife species, including reptiles and amphibians. Recognizing the value and utility of this approach, Brown (1985) and his colleagues produced a similar guide for wildlife management in coastal forests of the Pacific Northwest entitled *Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington* (fig. 4). Because of the importance of fish resources and estuarine habitats in coastal forests, Brown's book also included a narrative chapter on salmonids, and habitat-relationship matrices for all freshwater fish and selected species of marine fish and estuarine invertebrates. Although the information presented in both books was focused primarily on vertebrates, these important and influential works ushered in a more holistic approach to forest wildlife management in the Pacific Northwest that eventually included consideration of all aspects of forest biodiversity.

Recently, the matrix approach for assessing the potential effects of forest management activities on wildlife was carried to its logical conclusion, both geographically and ecologically, with the publication of *Wildlife-Habitat Relationships in Oregon and Washington* (fig. 5) by Johnson and O'Neill (2001) and their colleagues. This monumental work covers all major terrestrial, freshwater, and marine habitats in Oregon and Washington, and includes an explicit consideration of salmon-wildlife relationships, and guidelines for identifying and prioritizing areas and habitats for the conservation of biodiversity. Another important improvement over the previous books was the compilation of habitat-relationships matrices on an interactive CD-ROM. However, the publication's most unique and innovative contribution to the wildlife-habitat relationships literature is the consideration of "key ecological functions" in a narrative chapter (Marcot and Vander Heyden 2001) and in the matrices, based on the groundbreaking work of Bruce Marcot and his colleagues. With this new tool, users could not only evaluate how wildlife species would be affected by various management activities, they could also evaluate how those activities may influence important ecological processes. Thus, although the field of wildlife management was established in 1933 with the very narrow objective of providing sustainable populations of game birds and mammals for sport hunting, by the end of the 20th century it had evolved into the science and practice of managing forests to provide habitat for all components of biodiversity (e.g., Bunnell and Johnson 1998; fig. 6) and to protect their ecological integrity.

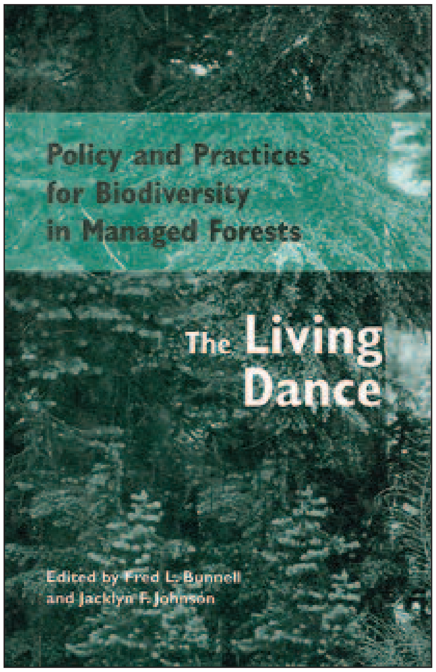

Figure 6—Cover of the book, *Policy and Practices for Biodiversity in Managed Forests: The Living Dance* (Bunnell and Johnson 1998).

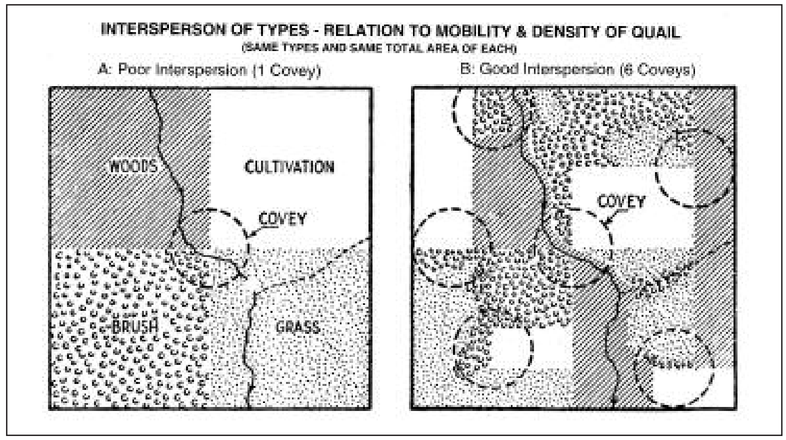

Figure 7—Illustration showing how different interspersions of the same total area of habitat types used by quail results in different levels of abundance (reproduced from Leopold 1933).

At What Spatial or Ecological Scales Should Forests be Managed?

The scale at which forest management for wildlife objectives is applied also changed substantially during the last decades of the 20th century. It began with a considera-tion of wildlife-habitat relationships at the scale of forest stands or other relatively small and homogeneous habitat patches, then broadened to include potential influences occurring at the landscape scale, and eventually culminated in forest management planning in the context of entire ecosystems. Leopold (1933) argued that the most important determinants of game abundance were the composition and interspersion of habitat types required by each game species (fig. 7). Although his recognition of the importance of habitat heterogeneity reflects some of the rudimentary aspects of landscape ecology, he did not consider potential ecological or environmental influences occurring beyond the home-range boundaries of individual game animals.

The first explicit consideration of potential landscape-scale influences on wildlife populations in managed forests of the Pacific Northwest came in 1984 with the publication of *The Fragmented Forest* by Larry Harris (fig. 8). In this landmark book, Harris (1984) proposed applying the concepts of island biogeography (MacArthur and Wilson 1967) to the management of forest landscapes, using forests of the western Cascade Range in Oregon to evaluate the potential effects of habitat fragmentation on wildlife. With the help and support of Robert Ethington, Director of the Pacific Northwest Research Station, and Dave Luman and Bill Neitro of the Bureau of Land Management, Harris was granted leave from the University of Florida and temporarily relocated to western Oregon to develop his ideas and tap into the collective knowledge and experiences of local forest ecologists, wildlife biologists, and resource managers.

Harris was one of the first ecologists to consider the potential effects of habitat isolation on wildlife populations in forested landscapes that contain relatively small, residual old-growth forest "islands" surrounded by a "sea" of younger, managed forests. Harris' ideas and his proposals for mitigating detrimental landscape-scale influences on sensitive wildlife species in managed forests were both important and influential. The seminal textbook, *Landscape Ecology*, by Richard Forman and Michael Godron (1986) was published 2 years after Harris' book and the journal, *Landscape Ecology*, was inaugurated 3 years later in 1987. It is noteworthy that the first article in the first issue of the journal was "Creating landscape patterns by forest cutting: ecological consequences and principles" by Jerry Franklin and Richard Forman (1987).

By the early 1990s, many natural resource professionals in the Pacific Northwest understood that management directed only at the stand scale was comparable to looking at only one small part of a painting or photograph. Both researchers and managers were becoming increasingly aware that important ecological processes operated at multiple spatial and temporal scales, and that the ecological integrity of managed landscapes could be improved by

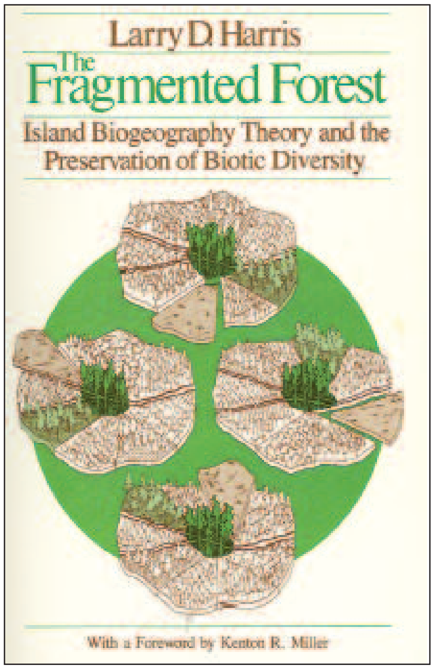

Figure 8—Cover of the book, *The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity* (Harris 1984).

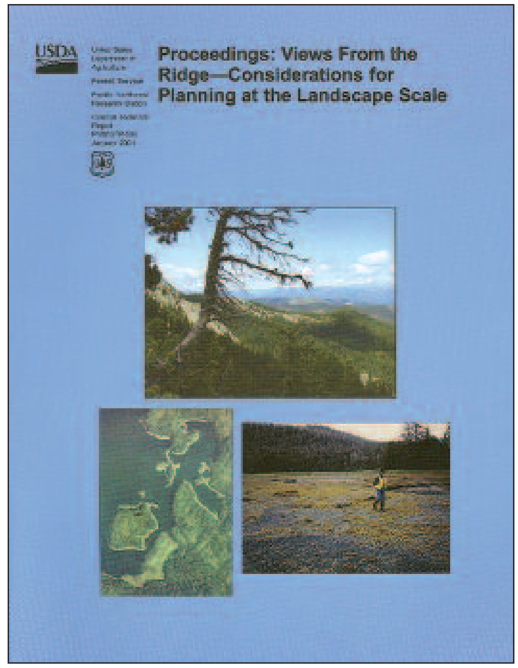

Figure 9—Cover of the book, *Views from the Ridge—Considerations for Planning at the Landscape Scale* (Gucinski et al. 2004).

modifying current forest management strategies based on understandings gained from studying ecological processes at larger spatial scales. Consequently, forest and wildlife scientists began to address research questions at the landscape scale, and ecologists, forest managers, economists, and social scientists began to consider how best to integrate the concepts of landscape ecology into the science and art of forest management. Many of the insights and findings from research conducted in the Pacific Northwest were summarized in the proceedings of a symposium convened in 1999 to discuss landscape-scale management planning entitled *Views from the Ridge—Considerations for Planning at the Landscape Scale* (Gucinski et al. 2004; fig. 9).

However, applying the concepts of landscape ecology to forest management is extremely challenging. The development of new knowledge about landscape-scale influences on forest stands involves quantitative analyses of complex interactions occurring among various attributes of forest composition, structure, and function (Dale and Noon 2004). Conducting research at large spatial scales is further constrained by the difficulty (or, some would argue, the impossibility) of replicating experimental treatments at landscape scales. Moreover, several studies have suggested that landscape-scale influences on many species of wildlife (especially those with small spatial requirements) appear to be relatively weak and difficult to detect (Lehmkuhl et al. 1991, McGarigal and McComb 1995). For these reasons, I suspect we may never be able to predict landscape-scale influences on wildlife populations to the extent that we understand how to manage individual forest stands or structures to benefit wildlife. Nevertheless, consideration of the potential ecological and environmental effects that occur at multiple spatial scales, including landscapes, is now an integral part of forest management planning in the Pacific Northwest.

Once scientists and managers began considering ecological processes operating at spatial scales beyond that of individual forest structures and stands, it was not long before their frame of reference expanded to include entire ecosystems; i.e., to evolve into the conceptual framework of "ecosystem management." Franklin (1997:21) described the development of this new management strategy as a "paradigm shift of massive proportions." He defined ecosystem management as a paradigm for managing land that involves a holistic view of both natural and human resources, and has sustainability as its central premise. Thus, forest managers are now being asked to seek a sustainable

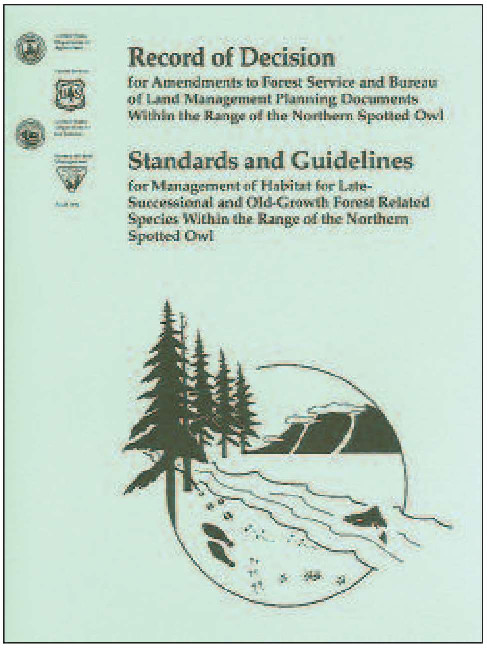

Figure 10—Cover of the Northwest Forest Plan (USDA and USDI 1994).

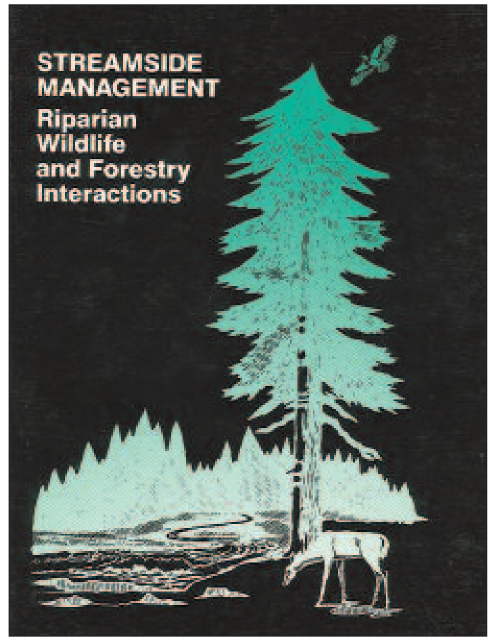

Figure 11—Cover of the book, *Streamside Management: Riparian Wildlife and Forestry Interactions* (Raedeke 1988).

balance between the long-term integrity of entire ecosystems and a broad array of other management objectives and societal values. The Northwest Forest Plan (USDA and USDI 1994; fig. 10), which is a comprehensive, long-term strategy for managing all federal lands occupied by the northern spotted owl in Washington and Oregon, still represents one of the best examples of ecosystem management in practice.

Which Riparian Zones Should be Managed?

Timber volumes in riparian areas can be substantial in coastal forests of the Pacific Northwest; Anderson (1985) estimated that a 100-m swath along streams occurring in the Siskiyou National Forest of Oregon contained 2 million board ft of harvestable timber. Thus, it is not surprising that prior to the 1970s, riparian areas in the Pacific Northwest were typically clearcut and roaded, particularly along non-fish-bearing streams (Anderson 1985). Because riparian areas represent key components of forested ecosystems for wildlife in the Pacific Northwest (Thomas et al. 1979, Oakley et al. 1985), concerns about the ecological impacts of such practices led to increased protection of riparian zones in both private and public forests during the 1970s and 1980s. For example, the National Forest Management Act of 1976 required that special management consideration be given within a minimum of 100 ft (30.5 m) on each side of perennial streams (Kauffman 1988). The First North American Riparian Symposium was held in 1985 (Johnson et al. 1985), and in 1987, a symposium was convened at the University of Washington that focused exclusively on riparian wildlife and forestry interactions in the Pacific Northwest. Its purpose was to present the current state of scientific knowledge about riparian areas and their use by wildlife, riparian management policies and practices on both public and private timber lands, and the social and economic impacts of riparian management. The proceedings of this symposium were published as a book entitled *Streamside Management: Riparian Wildlife and Forestry Interactions* (Raedeke 1988; fig. 11).

Both Thomas' (1979) and Brown's (1985) wildlife-habitat books included narrative chapters on riparian zones that discussed their special importance for wildlife in the Pacific Northwest (Thomas et al. 1979, Oakley et al. 1985). However, the delineation of riparian zones in coniferous forests and associated management guidelines were limited primarily to those occurring along lakes, ponds, rivers, and perennial streams that supported distinctive riparian vegetation (i.e., sedges, rushes, shrubs, and deciduous trees). Because both perennial and intermittent headwater creeks, seeps, and small forested wetlands are often contained within upland coniferous forests, and typically lack riparian vegetation (especially in mesic Westside forests), they had generally not been considered part of the riparian zone (fig. 12).

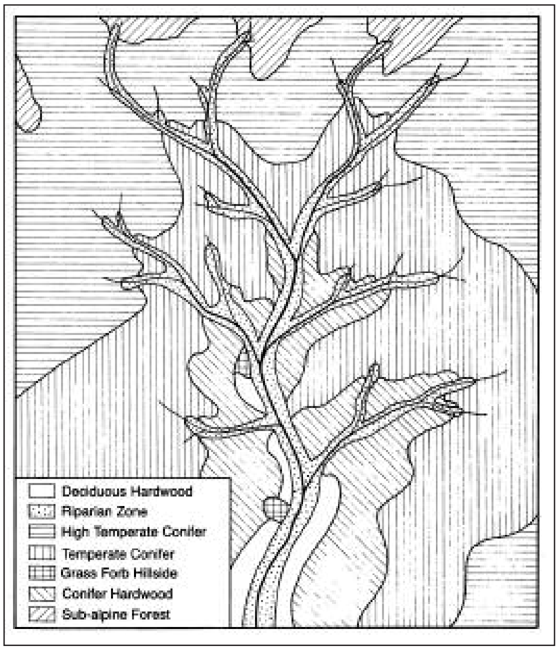

Figure 12—Depiction of the riparian zone in forested habitats; note that headwater creeks extend outside the riparian zone into forested habitats (reproduced from Oakley et al. 1985).

Figure 13—Cover of the Forest Ecosystem Management Assessment Team (FEMAT) report (FEMAT 1993).

In the late 1980s and early 1990s, the potential importance of a much broader array of riparian habitats for wildlife began to be recognized. Corn and Bury's (1989) ground-breaking study on the effects of timber harvesting on headwater habitats and stream amphibians in western Oregon demonstrated the need to consider the entire complement of riparian areas in forest management planning, including very small headwater streams and seeps. This comprehensive view of riparian influences in coniferous forests was integrated into forest management in the Pacific Northwest with the publication of *Forest Ecosystem Management: An Ecological, Economic, and Social Assessment*, commonly referred to as the "FEMAT Report" (FEMAT 1993; fig. 13). The FEMAT team, led by Jack Ward Thomas and Martin Raphael, evaluated the potential effects of various ecosystem management alternatives on both terrestrial and aquatic ecosystems within the range of the northern spotted owl. For the first time, aquatic ecosystems were given equal consideration as terrestrial ecosystems in forest management planning. In addition, FEMAT (1993) expanded the taxonomic scope of management considerations for riparian zone habitats to include mollusks, mosses, lichens, and vascular plants. This extremely important and influential assessment established an effective process for ecosystem management planning that provided the empirical basis for standards and guidelines in aquatic ecosystems in the Northwest Forest Plan (USDA and USDI 1994), and substantially changed the management of riparian habitats in this region.

Can Old-Growth Attributes be Created in Managed Forests?

Perceptions about the ecological importance of old-growth coniferous forests in the Pacific Northwest changed dramatically in the 1980s. Gabrielson's (1959) view of the value of old-growth forests for wildlife habitat and biological diversity provides a stunning example of the misconceptions some biologists had about the ecological importance of old-growth forests. He stated, "In remaining virgin stands of spruce, fir, and redwood in the Pacific Northwest ...one may travel for miles without seeing any wildlife except a few specialized birds and mammals... Biologists have long recognized that an unbroken stand of mature forest is much nearer a biological desert than are the sandy wastes of popular imagination." (Gabrielson 1959:63-64). Such perspectives ended in 1981 with the publication of seminal research that Jerry Franklin and his colleagues conducted in the central Cascade Range of Oregon entitled *Ecological Characteristics of Old-Growth Douglas-fir Forests* (Franklin et al. 1981; fig. 14). This slim volume had a significant effect on the perceptions of both biologists and managers about the unique characteristics and ecological importance of old-growth forests. These researchers

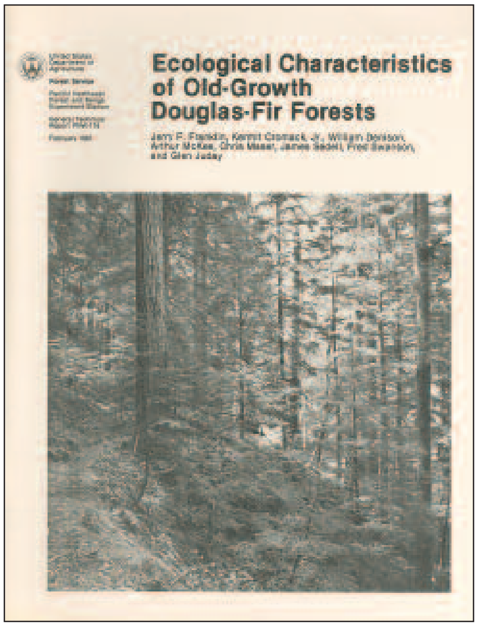

Figure 14—Cover of the book, *Ecological Characteristics of Old-Growth Douglas-fir Forests* (Franklin et al. 1981).

documented many important differences in species composition, ecological functions, and structural attributes of old-growth forests compared to both managed and unmanaged (naturally regenerated) younger forests, based on empirical evidence obtained in the field. They also speculated that some old-growth characteristics could be created or maintained in managed forests by promoting the development of four key structural components: large live trees, large snags, large logs on the ground, and large logs in streams (Franklin et al. 1981).

Their assessments of the importance of old-growth Douglas-fir (*Pseudotsuga menziesii*) forests as wildlife habitat were largely inferential in nature, however. Eric Forsman's pioneering research on the habitat relations of the northern spotted owl in Oregon (Forsman et al. 1984) had not yet been published, and the battle among environmental groups, the timber industry, and public land managers over the fate of spotted owls and old-growth forests that would engulf the Pacific Northwest during the 1980s (Ervin 1989, Thomas et al. 1990) had not yet begun. Biologists still did not know if old-growth Douglas-fir forests provided significantly different habitat for wildlife than other stages of forest development, nor how many wildlife or plant species might depend upon or find optimal habitat in such forests. In 1982, in response to growing concerns about the management of old-growth Douglas-fir forests and to meet legal mandates of NFMA and related regulations, the Forest Service chartered the Old-Growth Forest Wildlife Habitat Research and Development Program under the leadership of Leonard Ruggiero and Andrew Carey. The objectives of this program were to (1) define old-growth Douglas-fir forests for management purposes, (2) identify wildlife species that are closely associated with old-growth forests, and (3) determine the biological requirements and ecological relationships of closely associated species (Ruggiero 1991). To address the second objective, a large group of forest and wildlife ecologists implemented a rigorously designed field study to characterize the wildlife and plant communities occurring in young (35-79 years), mature (80-195 years), and old-growth (>200 years) age-classes of unmanaged, naturally regenerated, closed-canopy Douglas-fir forests in Washington, Oregon, and northern California (Ruggiero et al. 1991a).

The results of this unique and extremely ambitious program of research were presented at a major symposium held in 1989 in Portland, Oregon that was attended by almost 900 people, including reporters from several national news and scientific organizations. Two years later, the final study results were published in the book *Wildlife and Vegetation of Unmanaged Douglas-fir Forests* (Ruggiero et al. 1991a; fig. 15). The Pacific Northwest Research Station described this landmark book as one of the most important publications it has produced during the last 75 years (Duncan and Miner 2000). One of the key findings of these studies was that relatively few plants or vertebrates were significantly more abundant, or occurred exclusively, in old-growth forests (Ruggiero et al. 1991b). Although some old-growth characteristics, including the development of massive tree crowns and buffered canopy microclimates, were generally found only in old growth, other characteristics such as gaps, deeply shaded and cool understories, and accumulations of woody debris on the forest floor were also found to some degree in young and mature unmanaged forests (Spies and Franklin 1991). Similarities in the wildlife communities occurring in naturally regenerated young, mature, and old-growth forests were attributed to the spatial and structural heterogeneity that is characteristic of forests with complex disturbance histories, and to the structural components (primarily large live trees, snags, and logs) that had survived stand-replacing fires and were "carried over" into the young, regenerating stand (Ruggiero et al. 1991b).

By the late 1980s, there were growing concerns among many forest ecologists in the Pacific Northwest that forest lands would be partitioned into two categories: (1) forests that are managed primarily for timber production, and (2) late-successional preserves that are protected from timber harvesting (Franklin 1989, Thomas et al. 1990). Given that

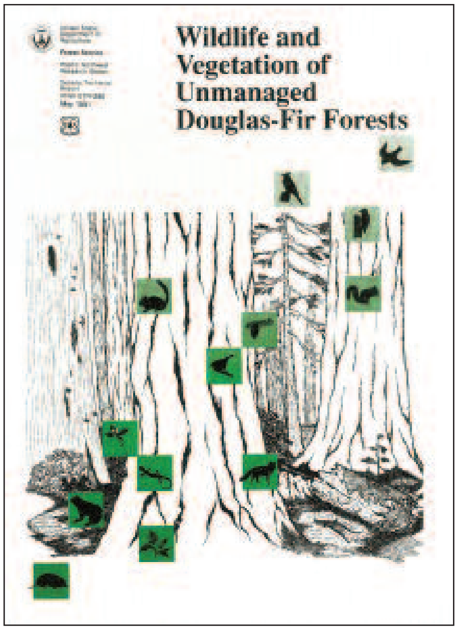

Figure 15—Cover of the book, *Wildlife and Vegetation of Unmanaged Douglas-fir Forests* (Ruggiero et al. 1991a).

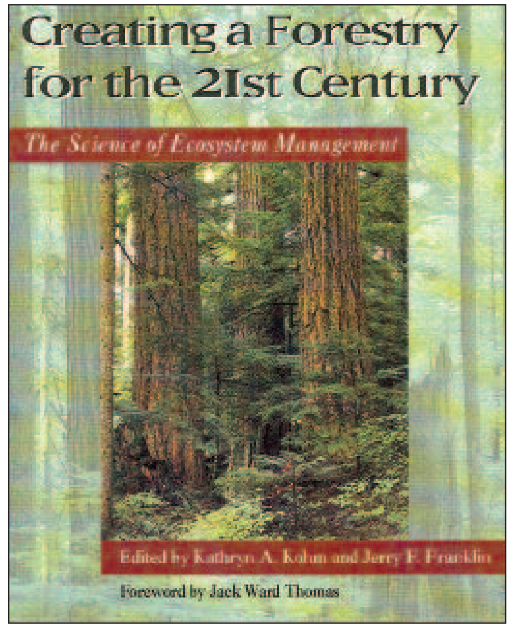

Figure 16—Cover of the book, *Creating a Forestry for the 21st Century: The Science of Ecosystem Management* (Kohm and Franklin 1997).

most of the old-growth forests in this region had already been harvested (Marcot et al. 1991), such an approach would have resulted in the allocation of a large percentage of forest lands into the first category, which many believed would have a detrimental effect on regional biodiversity. These concerns, combined with insights gained from the research findings of the "Old-Growth Program" and other ecological studies, led Jerry Franklin to suggest another alternative that he called "New Forestry" (Franklin 1989). He envisioned this new approach as a "kinder and gentler forestry that better accommodates ecological values, while allowing for the extraction of commodities"; i.e., the development of creative silvicultural approaches that focus on the perpetuation of diverse forest ecosystems, not simply on regenerating and growing trees. Important aspects of this new silviculture included retaining structural legacies during timber harvesting and designing timber sales to minimize forest fragmentation. However, Franklin's objective was not simply to propose a new set of management prescriptions; rather, it was to stimulate current and future generations of silviculturists and ecologists to begin thinking about how to manage forests and forest landscapes in ways that would maintain resilient, diverse, and sustainable forest ecosystems (Franklin 1989).

Many of these alternative silvicultural approaches were incorporated into the standards and guidelines for harvest units in the Northwest Forest Plan (USDA and USDI 1994), including leaving or creating coarse woody debris on the ground; retaining dispersed and aggregated trees with an emphasis on the largest, oldest live, decadent, or leaning trees and hard snags occurring in the unit; and establishing riparian reserves along all riparian zones, including intermittent streams and small wetlands. Innovative planting and thinning prescriptions have also been proposed as a means of improving habitat conditions for wildlife in managed forests by creating or accelerating the development of late-successional characteristics. For example, Carey and Curtis (1996) proposed a "biodiversity pathway" for forest management that included planting of Douglas-fir at wide spacing to provide for natural or artificial regeneration of other coniferous and deciduous tree species, extended rotations ($\geq$80-130 yr) to enhance biodiversity and increase wildlife habitat quality at the landscape scale, and three different kinds of thinnings: (1) a pre-commercial thinning to delay canopy closure and increase diversity of understory and overstory vegetation, (2) a heavy, variable-density commercial thinning to maintain tree growth and promote understory development, and (3) subsequent variable-density thinnings to add coarse woody debris to the ecosystem. Kohm and Franklin (1997) brought together these and many other alternative approaches to managing forests for ecosystem sustainability in the book, *Creating a Forestry for the 21st Century: The Science of Ecosystem Management* (fig. 16). This important and wide-ranging book presented the current state of knowledge about the implementation of variable-retention harvest systems, silvicultural practices for shaping stand development to achieve multiple objectives, the role of extended rotations, implications for forest genetics, and the ecological roles of phytophagous insects, plant pathogens, and mycorrhizal fungi in managed forests.

CONCLUSIONS

Changes in the perceived role of managed forests as wildlife habitat took place throughout most of the 20th century. However, the evolution of those perceptions started slowly and changed in incremental and relatively insignificant ways until the environmental movement of the 1960s resulted in federal legislation that permanently changed the way forests are managed in the Pacific Northwest. Initially, huntable wildlife was a useful secondary crop from plantation forestry; by the 1980s and 1990s, timber production had become one of many competing objectives of forest management that included maintaining or creating habitat for a broad array of vertebrate and invertebrate wildlife. Forest stands that are managed for wildlife objectives are now being designed to include diverse conifer, hardwood, and shrub species; a broad array of structural and ecological elements characteristic of old-growth forests; vertical and horizontal heterogeneity; gaps and patches of intact forest; and ameliorated microclimates, among others. Forest management planning at the landscape scale now includes consideration of stand composition, size, shape, context, and connectivity, as well as the integrity of all riparian zones occurring in the watershed. Lastly, management consideration is increasingly being focused on the maintenance of biodiversity, ecosystem complexity, and ecological functions. I suspect that the kinds of revolutionary changes in perceptions and management objectives I've described here will diminish in the coming years; in many ways, our course has been set. Future challenges will probably have less to do with determining what the objectives of forest management should be than with determining how best to address ecosystem management objectives in effective and sustainable ways.

ACKNOWLEDGMENTS

I thank the organizers of the *Managing for Wildlife Habitat in Westside Production Forests* workshop for inviting me to prepare this paper. Tim Harrington, Gretchen Nicholas, Richard Miller, and Cathy Raley provided helpful comments on previous drafts of this manuscript. Much of the history and information presented here reflects in various ways my personal experiences working with forest wildlife of the Pacific Northwest during the last 25 years. Acccordingly, I have undoubtedly failed to include all of the people and publications that made important contributions to the perceptual evolution I've described here. To anyone who may feel slighted, please accept my apologies and be assured that any such omission was unintentional.

LITERATURE CITED

Anderson, M.T. 1985. Riparian management of coastal Pacific ecosystems. In: Johnson, R.R.; Ziebell, C.D.; Patton, D.R.; Ffolliott, P.F.; Hamre, R.H., tech. coords. Riparian ecosystems and their management: reconciling conflicting uses. Proceedings of the First North American Riparian Conference. Gen. Tech. Rep. RM-120. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 364-369.

Bennitt, R.; Dixon, J.S.; Cahalane, V.H.; Chase, W.W.; McAtee, W.L. 1937. Statement of policy. Journal of Wildlife Management. 1: 1-2.

Brown, E.R., tech. ed. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1—Chapter narratives, 332 p. Part 2—Appendices, 302 p. Publ. R6-F&WL-192-1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Bunnell, F.L.; Johnson, J.F., eds. 1998. Policy and practices for biodiversity in managed forests: the living dance. Vancouver, BC: UBC Press. 162 p.

Bunnell, F.L.; Kremsater, L.L. 1990. Sustaining wildlife in managed forests. Northwest Environmental Journal. 6: 243-269.

Carey, A.B.; Curtis, R.O. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. Wildlife Society Bulletin. 24: 610-620.

Corn, P.S.; Bury, R.B. 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. Forest Ecology and Management. 29: 39-57.

Dale, V.H.; Noon, B.R. 2004. What is a landscape and how is it studied? In: Gucinski, H.; Miner, C.; Bittner, B., eds. Proceedings: views from the ridge—considerations for planning at the landscape scale. Gen. Tech. Rep. PNW-GTR-596. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 11-14.

Duncan, S.; Miner, C. 2000. Closer to the truth: 75 years of discovery in forest and range research. Misc. Pub. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 76 p.

Ervin, K. 1989. Fragile majesty: the battle for North America's last great forest. Seattle, WA: The Mountaineers. 272 p.

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [et al.]. [Irregular pagination].

Forman, R.T.T.; Godron, M. 1986. Landscape ecology. New York: John Wiley and Sons. 619 p.

Forsman, E.D.; Meslow, E.C.; Wight, H.M. 1984. Distribution and biology of the spotted owl in Oregon. Wildlife Monographs. 87: 1-64.

Franklin, J.F. 1989. Toward a new forestry. American Forests. November/December: 37-44.

Franklin, J.F. 1997. Ecosystem management: an overview. In: Boyce, M.S.; Haney, A., eds. Ecosystem management: applications for sustainable forest and wildlife resources. New Haven, CT: Yale University Press: 21-53.

Franklin, J.F.; Cromack, K., Jr.; Denison, W.; McKee, A.; Maser, C.; Sedell, J.; Swanson, F.; Juday, G. 1981. Ecological characteristics of old-growth Douglas-fir forests. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 48 p.

Franklin, J.F.; Forman, R.T.T. 1987. Creating landscape patterns by forest cutting: ecological consequences and principles. Landscape Ecology. 1: 5-18.

Gabrielson, I.N. 1959. Wildlife conservation. New York: The Macmillan Co. 244 p.

Gabrielson, I.N.; Jewett, S.G. 1940. Birds of Oregon. Corvallis, OR: Oregon State College. 650 p.

Gucinski, H.; Miner, C.; Bittner, B. 2004. Proceedings: views from the ridge—considerations for planning at the landscape scale. Gen. Tech. Rep. PNW-GTR-596. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 133 p.

Harris, L.D. 1984. The fragmented forest. Chicago, IL: University of Chicago Press. 211 p.

Johnson, D.H.; O'Neill, T.A., manag. directors. 2001. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press. 736 p.

Johnson, R.R.; Ziebell, C.D.; Patton, D.R.; Ffolliott, P.F.; Hamre, R.H., tech. coords. 1985. Riparian ecosystems and their management: reconciling conflicting uses. Proceedings of the First North American Riparian Conference. Gen. Tech. Rep. RM-120. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 523 p.

Kauffman, J.B. 1988. The status of riparian habitats in Pacific Northwest forests. In: Raedeke, K.J., ed. Streamside management: riparian wildlife and forestry interactions. Contribution No. 59. Seattle, WA: University of Washington, Institute of Forest Resources: 45-55.

Kohm, K.A.; Franklin, J.F., eds. 1997. Creating a forestry for the 21st century: the science of ecosystem management. Washington, DC: Island Press. 475 p.

Lehmkuhl, J.F.; Ruggiero, L.F.; Hall, P.A. 1991. Landscape-scale patterns of forest fragmentation and wildlife richness and abundance in the southern Washington Cascade Range. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 425-442.

Leopold, A. 1930. Environmental controls for game through modified silviculture. Journal of Forestry. 28: 321-326.

Leopold, A. 1931. The forester's role in game management. Journal of Forestry. 29: 25-31.

Leopold, A. 1933. Game management. New York: Charles Scribner's Sons. 481 p.

Matthiesen, P. 1959. Wildlife in America. New York: Viking Press. 304 p.

MacArthur, R.H.; Wilson, E.O. 1967. The theory of island biogeography. Princeton, NJ: Princeton University Press. 203 p.

Marcot, B.G.; Holthausen, R.S.; Teply, J.; Carrier, W.D. 1991. Old-growth inventories: status, definitions, and visions for the future. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 47-60.

Marcot, B.G.; Vander Heyden, M. 2001. Key ecological functions of wildlife species. In: Johnson, D.H.; O'Neill, T.A., manag. directors. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press: 168-183.

McGarigal, K.; McComb, W.C. 1995. Relationship between landscape structure and breeding birds in the Oregon Coast Range. Ecological Monographs. 65: 235-260.

Oakley, A.L.; Collins, J.A.; Everson, L.B.; Heller, D.A.; Howerton, J.C.; Vincent, R.E. 1985. Riparian zones and freshwater wetlands. In: Brown, E.R., tech. ed. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1—Chapter narratives, 332 p. Part 2—Appendices, 302 p. Publ. R6-F&WL-192-1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region: 57-80.

Raedeke, K.J., ed. 1988. Streamside management: riparian wildlife and forestry interactions. Contribution No. 59. Seattle, WA: University of Washington, Institute of Forest Resources. 277 p.

Ruggiero, L.F. 1991. Wildlife habitat relationships in unmanaged Douglas-fir forests: a program of research. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 5-7.

Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. 1991a. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 533 p.

Ruggiero, L.F.; Jones, L.L.C.; Aubry, K.B. 1991b. Plant and animal habitat associations in Douglas-fir forests of the Pacific Northwest: an overview. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 447-462.

Spies, T.A.; Franklin, J.F. 1991. The structure of natural young, mature, and old-growth Douglas-fir forests in Oregon and Washington. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 91-109.

Stockwell, S.S. 1990. U.S. national policies related to maintaining biological diversity in forests. In: Hunter, M.L., Jr. Wildlife, forests, and forestry: principles of managing forests for biodiversity. Englewood Cliffs, NJ: Prentice Hall: 291-295.

Thomas, J.W., tech. ed. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Washington, DC: U.S. Department of Agriculture, Forest Service. 512 p.

Thomas, J.W.; Forsman, E.D.; Lint, J.B.; Meslow, E.C.; Noon, B.R.; Verner, J. 1990. A conservation strategy for the northern spotted owl: a report of the Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl. Portland, OR: U.S. Department of Agriculture, Forest Service and U.S. Department of Interior, Bureau of Land Management, Fish and Wildlife Service, and National Park Service. 427 p.

Thomas, J.W.; Maser, C.; Rodiek, J.E. 1979. Riparian zones. In: Thomas, J.W., tech. ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Washington, DC: U.S. Department of Agriculture, Forest Service: 40-47.

Tuchmann, E.T.; Connaughton, K.P.; Freedman, L.E.; Moriwaki, C.B. 1996. The Northwest Forest Plan: a report to the President and Congress. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 253 p.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. [Place of publication unknown]. 74 p. [plus attachment A: standards and guidelines].

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FOREST ECOSYSTEM MANAGEMENT: MIRACLE OR MIRAGE?

J.P. (Hamish) Kimmins[1]

ABSTRACT

Forestry is, first and foremost, about people. We are faced with a three to four billion increase in the human population within this century, and steps should be taken to ensure that the multiple resource values and environmental services provided by existing forests are sustained and, wherever possible, depleted forests renewed. Forestry must balance the diverse short-term needs and desires of today's human population, the anticipated needs of future generations, and the maintenance of long-term forest ecosystem conditions, functions and organisms. The most effective way to satisfy these obligations may be to use the paradigm of ecosystem management (EM) as the template for forestry. Ecosystem management requires long-term tenure and the management of all desired values and services under an integrated management plan that spans at least one full rotation (multiple rotations for short rotation timber crops) and has inputs from multiple stakeholders. The management plan should cover a defined forest area sufficiently large to permit the management of key ecological processes. All marketable values should be managed under a single plan to facilitate value tradeoff analysis, and targets for the management of non-marketable values should be an integral part of the plan rather than merely a constraint on the profits from a single marketable value such as timber, as is often the case. These ideas are not new, but have proven to be difficult to implement. Fundamental to achieving EM is appropriate tenure systems of adequate duration and area, the involvement of multiple stakeholders in setting management objectives, active management and marketing of multiple values at the landscape scale, and the explicit definition of a "desired forest future." The tenure system should permit the management of the entire forest landscape ecosystem as a single endeavor, with economic rewards to the managing agency, consortium or collective for all marketable values, while targets are set for the maintenance, at the landscape scale, of non-marketable values. Equally fundamental is the need to understand and respect the ecology of the resources and other values that are to be sustained, including the critical role of ecosystem disturbance in sustainability.

One of several major impediments to implementation of EM has been the lack of, or failure to use, ecosystem management scenario and value tradeoff analysis tools. Multi-value, ecosystem-level decision support systems are required to evaluate the most effective stand and landscape management strategies to achieve a desired forest future. Such tools should incorporate both the ecosystem processes responsible for biophysical sustainability, and the social values that relate to social and economic sustainability. In the absence of these and other prerequisites for successful EM, this logical endpoint in the evolution of forestry may remain an "ecotopian" ideal rather than a practical reality: a mirage rather than a miracle. While the evolution from administrative forestry to ecosystem-based forestry constitutes major progress, it is not enough and we should continue to press to make EM a reality.

KEYWORDS: Ecosystem management, pre-requisites for ecosystem management, ecosystem-level decision support tools, visualization, ecological rotations, ecological "theatre."

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INTRODUCTION

The good news is that human population growth is slowing. The bad news is that the world's forests will have to service the needs and desires of another three to four billion people by the end of this century (Lutz et al. 2001). The current population of about 6.7 billion is posing unpre- cedented pressure on the world's forests, especially in developing countries at tropical and subtropical latitudes. A plethora of new paradigms have been suggested as a template for managing the world's forests in the face of this human pressure. These include ecosystem management (EM), adaptive management (AM), zonation, emulation of natural forest disturbance (ENFD) and natural/historical range of variation (NRV/HRV), concepts that are not mutually exclusive and will often be employed in combination (Kimmins 2004a).

In this paper I review my interpretation of forest EM and what I perceive to be some of the major impediments to achieving it. I then discuss the planning and communication tools needed for the design and assessment of EM that will be necessary for public acceptance of this forest management paradigm. The paper closes with an assessment of the likelihood that EM will come to dominate forestry.

FOREST ECOSYSTEM MANAGEMENT: BUZZWORD OR MEANINGFUL CONCEPT?

Forestry is constantly facing new social pressures, ideas, buzzwords and paradigms. Politically correct and trendy assertions are constantly being made about forestry and how it should change. These are often made by well-intentioned but frequently incompletely informed public pressure groups. Foresters, forest companies and government forest-related agencies have often responded to these social pressures in an equally uninformed manner. There is an urgent need for clearer definitions of suggested new paradigms, including EM, and for the ability to forecast their social and environmental consequences over both short and long time scales and small and large spatial scales before they are implemented. Only when we are equipped with these forecasts can we have some confidence that the suggested new approaches to forest management will indeed honor intergenerational equity issues, and not just indulge short term desires and preferences.

Forestry is the art (skill), practice, science and business of managing forest stands and forested landscapes to sustain the balance of values and environmental services that are ecologically possible and desired by society. There are two corollaries of this definition. 1) Forestry should change when society changes the desired balance of values if existing polices and practices are not appropriate for the new balance. 2) Suggested changes should be resisted if these are inconsistent with the ecology and sociology of the desired new set of values. As society comes to an understanding of the integrated and dynamic, ever changing character of forest ecosystems, it is increasingly demanding "ecosystem management" as a replacement for traditional timber or other single value management. It is the responsibility of the forestry profession to make this transition once it is clear what is meant by EM, but only after an assessment that the management practices envisaged by some particular definition of EM will respect the ecology of the forests and values in question. The vision of EM must have a high probability of satisfying the needs of both local people and society in general, both now and in the future; it must also recognize that desired values at different time and space scales can sometimes be in conflict. Once these issues have been assessed and a strategy to address them devised, foresters will face the difficult challenge of persuading the public to accept what needs to be done to achieve EM.

The term ecosystem management has seen increasing usage over the past two decades. Vogt et al. (1997) present a history of development of ecosystem ideas in forestry, largely in North America, including the development of the use of the term EM. Background on the development of the EM concept can be found in Agee and Johnson (1988), Gordon (1993), Grumbine (1994), Christensen et al. (1996), Boyce and Haney (1997), Kohm and Franklin (1997), Schlaepfer (1997), Vogt et al (1997), D'Eon et al (2000), Kimmins (2004b) and Perera et al (2004). Much of the discussion of EM has focused on biophysical aspects (e.g. Lindenmayer and Franklin et al. 2002, Burton 2005), but the social aspects must also be given adequate (= equal, once the biophysical possibilities have been established) consideration (Slocombe 1993). This is essential since forestry is about people – their needs, desires and values. Focus on any one subset of EM will cause this desirable management paradigm to fail.

From the outset, EM has been poorly defined, ambiguous and subject to diverse interpretations. The recent origins of the term lie in the evolution of new paradigms and nomenclature in forestry that occurred in the Pacific Northwestern U.S. in the 1980s. These developed in response to concerns about wilderness, antipathy towards clearcutting and the harvesting of old growth forests, and the issue of the northern spotted owl. The central question was whether it was better to have relatively few but large reserves of old forest within a matrix of young, even-age forests managed by conventional silviculture, or to maintain elements of old forest scattered throughout the younger forest landscape in the new form of silviculture envisaged by “New Forestry.” This term aroused considerable opposition, largely based on a lack of comprehension of the objectives of this new approach (Kimmins 1997a) and because it was ubiquitously and prescriptively applied, so it was replaced by “Forest Ecosystem Management,” a term that could be more understandable and acceptable to the critics of forestry and the public at large. The most recent evolution of concepts associated with the EM approach to forest stand management is associated with variable retention silviculture and structure management silviculture that includes variable density thinning (Carey and Johnson 1995; Carey and Curtis 1996; Franklin et al. 1997, 2002; Mitchell and Beese 2002; Lindenmayer and Franklin et al. 2002).

There are many different interpretations of EM. The one presented here is somewhat broader than that envisaged by some, perhaps because it is inclusive of much of the diversity of interpretations of EM. Understanding EM must start, with an understanding of forest ecosystems.

What is a Forest Ecosystem?

Forest ecosystems are areas of the landscape that are dominated by trees and consist of biologically integrated communities of plants, animals and microbes, together with the local soils (substrates) and atmospheres (climates) with which they interact. Forests are much more than the present population or community of trees. Forests that have been recently killed or altered by fire, insects, disease, wind or logging are still forests because of the biological and physical legacies from the previous forest – legacies of forest soil, organic matter, microbes, minor vegetation and animals. Under a regime of sustainable forest management, many or most of these legacies persist during the period between forest disturbance and the redevelopment of tree cover. As long as the processes of ecosystem development are active within the historic range of variation, the temporary structural change in the ecosystem is not synonymous with ecosystem destruction or damage as is often asserted.

Forest ecosystems are both a stand-level and a landscape phenomenon, the latter being a mosaic of stands that vary in age, species composition, structure, function and time since disturbance. Forest landscapes generally include areas such as lakes, rivers, rock outcrops, and shrub, herb and other non-treed communities. However, the character of these non-forest inclusions is strongly influenced by their location in the forested landscape. Periodic disturbance is a key attribute of most forest ecosystems, and maintenance of their historical character and values will generally require maintenance of historical disturbance regimes, or the ecological effects thereof (Attiwill 1994, Perera et al. 2004).

Because a forest ecosystem is an integrated biophysical system, a forest is as much a set of ecosystem processes as a set of forest ecosystem components. Short term changes in the structure of the forest do not constitute loss of the forest as long as the processes of the forest ecosystem remain in operation at acceptable levels.

What is Forest Ecosystem Management?

Management is the act of controlling, directing, administering or regulating an object or system. Forest management is the management of forests to achieve a set of management objectives. Forest ecosystem management (EM) approaches forest conservation, utilization, administration and regulation on the basis that the forest is a highly-integrated, complex, generally resilient, multi-value biophysical system that has thresholds of tolerance for disturbance (either too much or too little) beyond which its resilience and certain values and environmental services are changed. Ecosystem management is the management of forest ecosystem processes and disturbance regimes to sustain the desired values and ecosystem services from a shifting mosaic of different ecosystem conditions across the landscape, and a non-declining pattern of change over time in the values and services provided by each stand in that landscape. It is also the management of the human use of, and interactions with, the forest because humans are part of forest ecosystems.

Based on these definitions, it is clear that forest ecosystem management is far more than a politically correct buzzword, although it has frequently been used as such. However, if we are to be successful in implementing it as the biophysical template for sustainable, multi-value forestry, we must understand the impediments to, and necessary conditions for, its successful application. Successful application of the EM concept as the basis for forestry involves much more than the simple acceptance that EM is a nice idea.

ELEMENTS OF FOREST ECOSYSTEM MANAGEMENT

There are many suggested lists of the basic attributes of EM. According to Christensen et al. (1996) it includes the following elements:

- Sustainability—EM does not focus primarily on "deliverables" but rather regards intergenerational sustainability as a precondition.
- Goals—EM establishes measurable goals that specify future processes and outcomes necessary for sustainability.
- Sound ecological models and understanding—EM relies on a scientific approach to understanding at all levels of ecological organization (note the need for all three components of science – knowing (experience, inductive), understanding (experimental, deductive) and predicting (synthesis, projection Kimmins et al. 2005).
- Complexity and connectedness—EM recognizes that biological diversity provides the genetic resources necessary to adapt to long-term change, and structural complexity may strengthen ecosystems against disturbance.
- The dynamic character of ecosystems—Recognizing that change and evolution are components of ecosystem sustainability, EM avoids attempts to "freeze" ecosystems in a particular state or configuration.
- Context and scale—Ecosystem processes operate over a wide range of spatial and temporal scales, and their behavior at any given location is greatly affected by surrounding systems. Thus, there is no single appropriate scale or timeframe for EM.
- Humans as ecosystem components—EM values the active role of humans in achieving sustainable management goals.
- Adaptability and accountability—EM acknowledges that current knowledge and paradigms of ecosystem function are provisional, incomplete, and subject to change. Management approaches must be viewed as hypotheses to be tested by research and monitoring programs.

There are also several different lists of the key themes in ecosystem management. The following is a distillation of those lists (Kimmins 2004a):

- Establish a clear set of management goals (objectives – a desired forest future) that respect the ecological tolerances and resilience of the ecosystems, species, and values of interest.
- Manage forests as ecosystems, crossing levels of biological organization and integration.
- Define management areas ecologically, and vary the practices of management to respect the ecological and biological diversity therein.
- Assign the management of forest ecosystems at both the stand and landscape scales, over a defined forest area and for ecologically appropriate time scales, to a single agency or organization under a single plan that has the mandate to manage for a sustained balance of values across the landscape and the temporal variation in these values in any one stand. Management under a single integrated plan greatly increases the probability that value tradeoffs will be managed successfully.
- Maintain ecosystem function, seral sequences, and species composition within historical ranges of variation (emulation of natural forest disturbance –ENFD) or a socially acceptable yet ecologically sustainable subset thereof.
- Manage adaptively, constantly learning and changing practices as indicated by monitored outcomes, and using ecologically-based forecasting tools to support management planning where experience does not yet provide the needed guidance over ecologically and management-relevant temporal and spatial scales.
- Risk spreading – avoid applying the same practices everywhere.

It should be clear from these two lists that the task of defining EM is not a simple one. Ecosystem management is more of a management philosophy than a specific management method, and the application of EM will vary considerably from one type of forest to another, and according to the needs of people and other organisms, which also vary in time and from place to place.

ECOSYSTEM MANAGEMENT IS MORE THAN ECOSYSTEM-BASED MANAGEMENT

The terms ecosystem management (EM) and ecosystem-based management (EBM) are often used interchangeably. I believe that they are different.

EBM is the management of individual resources and values based on respect for their ecology and the ecological role they play in the forest ecosystem. However, it is not implicit in EBM that all forest resources and values will be managed in an integrated, coordinated manner under a single forest ecosystem management plan. EBM therefore provides less assurance than does EM that the key ecosystem processes that play out over long periods of time and over large areas will be managed in a way that sustains the desired balance and diversity of values and ecosystem conditions. It is my opinion that there is less chance that EBM will satisfy the attributes and themes of EM listed above than EM implemented under an appropriate ecosystem management plan.

SOME PREREQUISITES FOR FOREST ECOSYSTEM MANAGEMENT

The following is a list of the many conditions that must be met before EM can become an effective paradigm for forestry.

Appropriate Tenure Systems

Forests can only be managed as ecosystems if all values are managed under a single, integrated, multi-value and ecologically-based plan implemented by a single agency/organization/collective over time scales that are consistent with the ecosystem processes responsible for resilience and sustainability. The tenure and plan should also cover an area large enough to encompass the key ecosystem processes. The objectives of the plan must be established by a multi-stakeholder process that respects the ecology of the local and regional ecosystems and desired values therefrom.

Most forests are managed today for a single value or limited value set, with other values being a constraint on efforts to optimize the target value(s). Most forest companies are licensed to manage only timber values for profit. While there are often regulations to achieve non-timber objectives and there may be a requirement for passive management of non-timber resources (e.g. maintain wildlife habitat), there is rarely explicit financial or other incentives to encourage achievement of these non-timber goals. They are simply a constraint on the main management objective.

This is not EM. Even if the regulations concerning timber and non-timber management are related to our understanding of the ecology of these values (ecologically-based or even ecosystem-based management), only if the entire forest ecosystem is managed by a single entity under a single plan can we legitimately refer to EM. This plan must cover an area sufficiently large to incorporate the key ecosystem processes responsible for the renewal of desired values. It must recognize the vital role of ecosystem disturbance and be able to ensure appropriate disturbance regimes, or emulate the effects thereof (Attiwill 1994; Kimmins 1996a, b, 2004; Perera et al. 2004). It must be based on scenario analyses that permit evaluation of trade-offs between different values both in time and space. For a more in-depth discussion of ecosystem management tenures see Kimmins (2006).

Establishment of Overall Long-Term Objectives

There must be an explicit definition of a “desired forest future.” This must replace a simple statement of objectives with respect to individual values. A static, snapshot view of these values must be replaced by a dynamic assessment. What is the desired pattern of change over time in the characteristics of individual stands and the overall landscape? How will the availability and location of different values vary over time? Only when the management plan has a statement of the full range of values and conditions that are to be available at various times and locations in the future can there be a plan as to how to achieve this. Short-term values are important, but these must be balanced against the achievement of long-term goals.

Adequate Inventory

An ecosystem management plan must be based on an inventory of ecological, biological and social characteristics. There must be ecological site classification - the zonation of the forest landscape being managed into reasonably homogeneous climatic zones, topographies and soil types (different “ecological stages” to use the metaphor of “ecological theatre” (Kimmins 2004)) that define the biological potential of the land (fig. 1). There must be an inventory of the different biotic communities (the “ecological plays” and “ecological actors” in figure 1) – different forest types, ages, conditions and values – associated with this ecological diversity. And there must be an inventory of the variety of social values being managed, their spatial distribution across the landscape and how they change as a shifting mosaic over time.

Acceptance of the Dynamic Nature of Ecosystems

A key prerequisite for ecosystem management is acceptance of the dynamic nature of forest ecosystems, and the role of ecosystem disturbance in the long-term main-tenance of desired values. Disturbance may lead to short-term reductions in some values, but may be required to sustain the same values over the long-term. Where such disturbance is necessary for desired future levels of measures of biodiversity, beauty, productivity, employment and other values, there must be an acceptance of short-term change. The forest is not some ancient cathedral. It is not an art gallery of unchanging images. It is a dynamic, changing ecological system, the integrity of which requires change at some level, spatial scale and frequency.

Sustainability of forest ecosystems is not related to lack of change. At the stand level it is non-declining patterns of change over time, either within the natural (or historical) range of ecosystem variation or within a socially acceptable subset thereof. At the landscape scale, it is a shifting mosaic of changing stand level conditions, the overall character of the mosaic remaining reasonably constant over time.

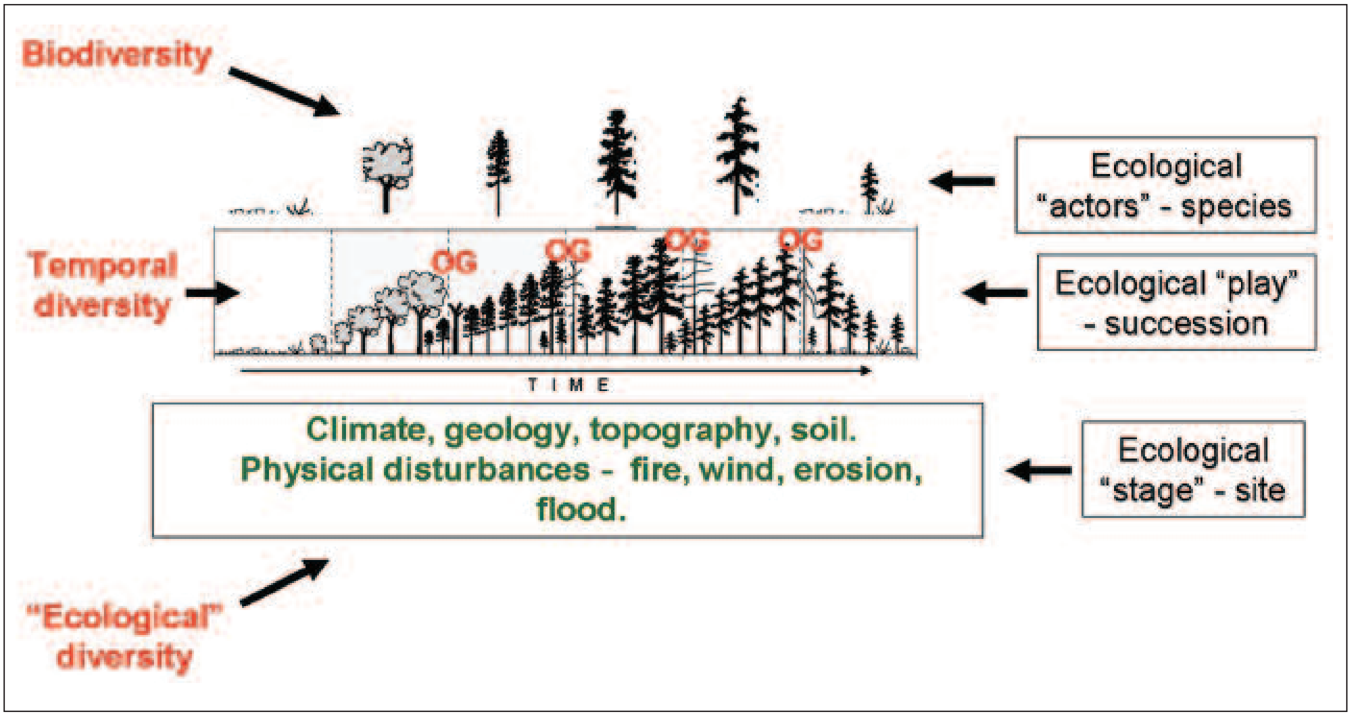

Figure 1—Diagrammatic representation of the concept of "ecological theater." Only one or a few plant species ("actors") are shown for each "act" (seral stage and its biotic community) of the ecological "play" (the successional sequence of communities/seral stages), whereas in reality there will be many species ("actors") "on stage" in each "act". This diagram implies that the "script" or "storyline" for the "ecological play" is constant and will be repeated exactly following ecosystem disturbance. In reality, it can vary according to different types, severities, spatial scales and timing of disturbances, differences in ecosystem character and condition, and the resultant variation in the processes of ecosystem development. "Biodiversity" refers to the diversity of genes, species and biotic communities. The physical diversity of the landscape and physical disturbances constitute "ecological diversity." This is the environmental framework within which biodiversity develops; it is not in itself biodiversity, contrary to the many definitions that claim that it is. Temporal diversity is the change in biotic and local physical conditions over time. Note that "old growth" – a phase of stand dynamics – develops at the end of each "act" (seral stage) of the "ecological play" (after Kimmins 2005).

Communication of this dynamic nature of sustainability requires ecologically-based planning tools linked to visualization and other output systems.

Founding the Management of Forest Ecosystems on the Concept of "Ecological Rotations"

Because of the vital ecological role of ecosystem disturbance, and because forest management involves management of "natural" and human-caused disturbance, sustainable EM should be founded on the concept of "ecological rotations" (Kimmins 1974).

An ecological rotation is that combination of severity, scale, pattern and frequency of ecosystem disturbance and ecosystem resilience (speed of return to predisturbance condition, or to some desired new condition) that results in non-declining patterns of stand level change, and a shifting landscape mosaic of acceptably constant overall character (fig. 2).

The ecological rotation concept provides foresters with choices. If rotations are to be short for economic or other reasons and this creates a greater-than-historical frequency of disturbance, this may need to be matched by a lower-than-historical severity and scale of disturbance, depending on the natural disturbance regime to which the ecosystem in question is adapted. Similarly, where a higher-than-historical severity of disturbance is required for ecological or social reasons, the frequency of disturbance should be reduced (longer rotations). Alternatively, management interventions can be made to increase the resilience of the ecosystem (e.g. planting, competition control, fertilization) so that more frequent and/or more severe disturbance remains sustainable.

Different values have different ecological rotations, which suggests that variable retention silviculture (different elements within the ecosystem are managed on different ecological rotations) should be a major component of ecological rotation-based forestry.

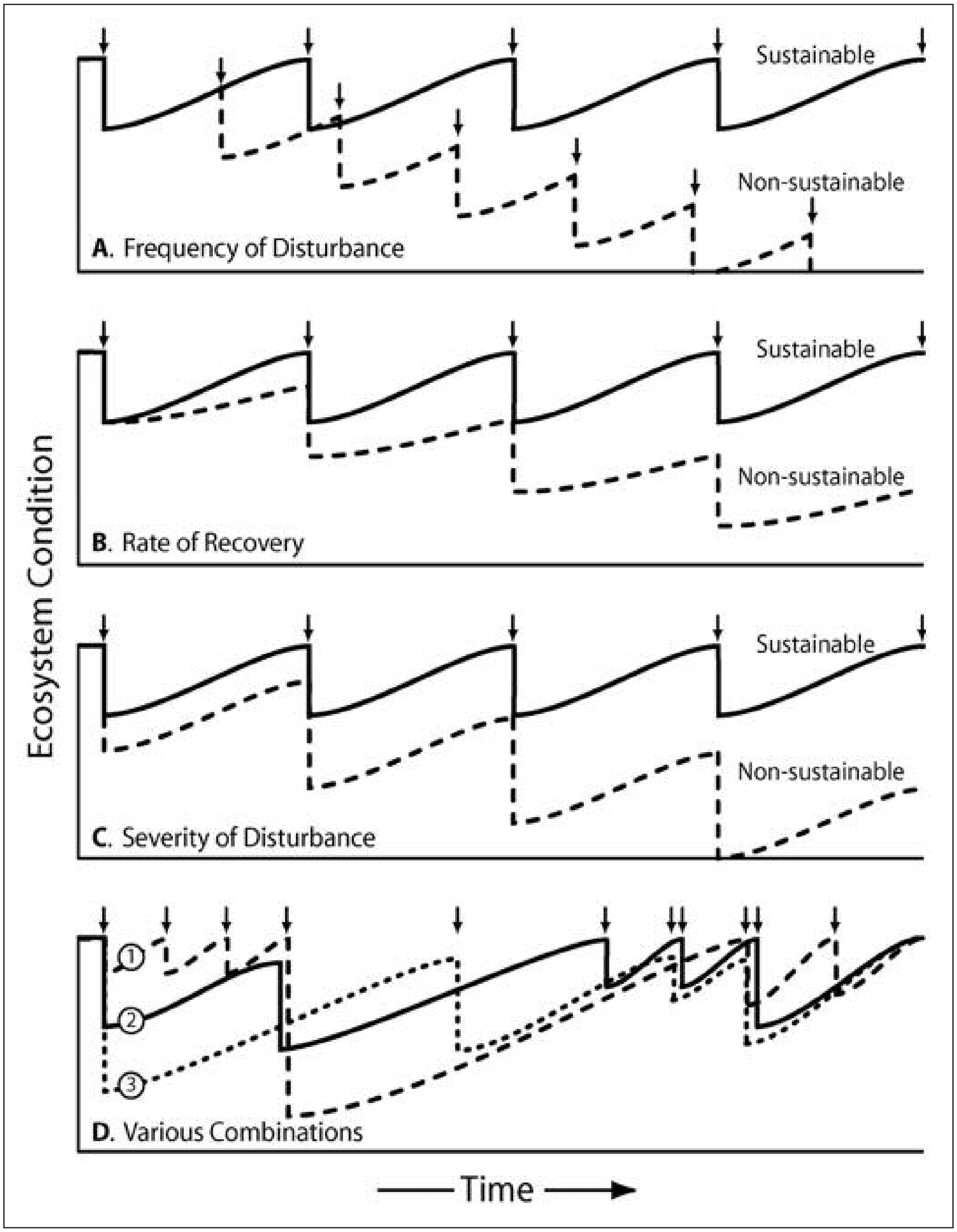

Figure 2—Concept of ecological rotations. Post-disturbance restoration of ecosystem conditions and values depends on severity and frequency of disturbance and rate of ecosystem recovery. Non-sustainability can result from a frequency that is too high for a particular severity and recovery rate (A); a rate of recovery that is too slow for a particular frequency and severity of disturbance (B); and a severity of disturbance that is too great for a particular frequency and rate of recovery (C). A, B and C depict a sustained repetition of the levels of the three variables – something that is generally unlikely to occur. D shows a more realistic scenario in which the severity and frequency of disturbance will vary over time. It shows that a wide range of disturbance severity and frequency can be sustainable if the other of these two variables is changed appropriately. Management alteration of the rate of ecosystem recovery adds a third dimension of complexity and choice.

Selection of that balance of frequency, severity, scale and management of resilience that meets the objectives of EM most effectively is a challenging task. It calls for ecologically based planning tools – ecosystem management models – capable of dealing with ecosystem processes, multiple values, the spatial and temporal scales involved, and the interactive effects of severity, scale, frequency of disturbance and ecosystem resilience. Conventional tree population models that have provided the basis for decision-support tools in timber-focused forestry in the past are simply inadequate for this task.

The ecological aspects of disturbance are explored in detail in Kimmins (2004b) and Perera et al. (2004).

Economic Sustainability

Unless forestry is economically viable it may revert to exploitation, which is not forestry. Forest ecosystem management is based on the concept that humans are part of and dependent on forest ecosystems, and therefore in self interest, if for no other reason, we should manage them sustainably. The management tasks required to do this are expensive. Exploitation is cheaper in the short-term. To prevent forest ecosystem management from becoming exploitation under the guise of managing ecosystems, the endeavor must be economically viable. Where the economics of forestry is marginal, over-cutting may occur. By marketing non-timber as well as timber products – a major feature of EM – forestry that is uneconomic based on timber alone may become economic. Where the economics of stand thinning prevents this silvicultural practice, sustainable harvesting and marketing of understory plants for floriculture may render thinning economic where there is an adjacent market for such products and for those ecosystems that support sustainable communities of floriculture species. This would probably only work if a single agency were able to market and collect revenues from a variety of forest products – timber and non-timber – and marketable services. Thinning reduces the accumulation of dead trees in the ecosystem by reducing inter-tree competition and related mortality, which will reduce those values that are dependent on dead wood. EM requires that the implications of different silvicultural scenarios be assessed both economically and for non-timber values.

Planning and Communication Tools

The establishment of EM objectives involves recognition of the biological possibilities and limitations in the area being managed. It requires the ability to forecast the biological, environmental and social consequences of different strategies to achieve the desired forest future. Establishment of ecologically and socially achievable objec-tives and evaluation of the most acceptable way of satisfying these requires planning tools that have capabilities far in excess of those traditionally used in forestry. It also requires an improved capability to communicate the output of such tools to the public.

Traditional planning tools have generally been limited to stand-level growth and yield models, and landscape/forest estate timber supply models driven by these stand models. Multi-value, estate management models have been developed, but are generally based on simple assumptions and models that do not address the fundamental ecosystem processes responsible for sustainability. Because of the importance of involving multiple stakeholders in the development of management plans, planning tools should have outputs that facilitate understanding by non-technical people of the choices available and the accompanying value tradeoffs. The analytical output (graphs, tables, maps) that foresters deal with are poor communication tools for many in the general public. To complement this quantitative, analytical output, planning tools should be linked to visualization systems: scientifically-based (representing key ecosystem processes) simulated images of the future states of stands, landscapes and their values integrated into movies that span the time and space dimensions of the issues in question (Sheppard and Harshaw 2000, Kimmins 1999, 2000).

All the new paradigms for forestry listed earlier require the use of such planning and communication tools, not just EM.

ECOSYSTEM MANAGEMENT MODELS AS COMMUNICATION AND PLANNING DECISION SUPPORT SYSTEMS

Setting objectives, assessing tradeoffs between values, balancing the needs of the present generation against the legacies we want to pass to future generations, and communicating choices, risks, uncertainties and possible outcomes to the public requires the use of a new generation of decision support tools. Traditional planning tools will continue to be essential. These range from forest site classifications, to GIS systems, to timber supply analysis tools. However, the increasing complexity of forestry and the imperative to manage forest ecosystems rather than populations of trees or individual games species require decision support tools that can address this complexity. This can be provided by forest ecosystem management models (Messier et al. 2003). These should be linked to user-friendly interfaces and visualization systems (Sheppard and Harshaw 2000) to facilitate their use by the non-technical public.

Forest decision support tools fall into three major categories: experience-based, empirical (historical bioassay (HB) models; e.g. growth and yield models); knowledge-based (process simulation (PS) models); and hybrid simulation (HS) models that combine both experience and knowledge in hybrid historical bioassay-process simulation systems (Kimmins 1990). The emerging consensus is that HB models will always be useful in forestry for short term, tactical, individual value decisions; that PS models are needed especially in research and to assist in understanding ecosystems (Korzukhin et al 1996; Johnsen et al. 2001) but that they are often too complex to use in forest management (Mohren et al. 1994); and that a hybrid of the two – HS models – will be the way of the future (Zeide 2003, Landsberg 2003).

There is growing acceptance of the need for forestry models to address the complexity of forest ecosystems and their management. This reflects the adage: a problem is an issue that does not get solved; an issue that gets solved quickly is not a problem; problem issues often persist because they are complex and people offer only simple solutions. This trend also honors the full intent of the principle of parsimony – Occam's Razor – that theories, explanations and models should be as simple as possible, but as complex as necessary. As Einstein noted, make everything as simple as possible, but not simpler.

Messier et al. (2003) review a variety of stand and landscape models for use in sustainable forest management planning, and the literature and the internet are rich in information about the rapidly expanding choice of models as research, decision support and communication tools in forestry. I mention here a selection of the models I am most familiar with as an example of the type of EM model that I believe is needed now, and will be needed increasingly in the future.

Twenty-nine years of development of forest ecosystem management models by the Forest Ecosystem Management Simulation Group at University of British Columbia's Department of Forest Sciences has produced a range of hybrid simulation ecosystem management decision support tools. The computer model, FORECAST (FORest and Environmental Change ASsessmenT), is a non-spatial, multi-value, stand-level, ecosystem management simulator that represents key ecosystem components and processes and can simulate all major stand management activities (Kimmins et al. 1999; Seely et al. 1999, 2002). The FORECAST model has been used to replace traditional tree growth and yield models in timber supply models such as ATLAS (Forest Planning Studio), converting it to a landscape ecosystem management model. The FORECAST model is also used to simulate the stands in a small-to-medium-scale watershed landscape model, Possible Forest Futures (PFF), which is designed as a multi-value, scenario analysis and value trade-off tool for education, extension and public participation processes, as well as forest management gaming. A spatially-explicit, individual-tree, complex stand model, FORCEE, is under development based on FORECAST, which is also being used in LLEMS (Local Landscape Ecosystem Management Simulator), an adaptation of PFF for the design and assessment of complex cutblocks of up to 2,000 ha. The LLEMS model is intended for the evaluation of alternative variable retention harvesting and structure management silviculture – ecosystem management - designs. All these tools have user-friendly interfaces so that, once calibrated, they are accessible to relatively non-technical users, and they are linked to visualization output tools including the preparation of movies of possible futures for multiple values under different management scenarios. They provide a basis for comparing visual assessments with evaluations of ecosystem responses (Kimmins 1999, 2000a), the degree to which different management paradigms and methods respect nature (Kimmins 2000b), and how we can evolve forestry to deal with the case of "future shock" that it is currently undergoing (Kimmins 2002).

Visualization tools always pose the distinct risk of being merely "pretty pictures" ("Potemkin Villages"; Sheppard and Harshaw 2000; Sheppard 2001), of over-impressing the viewer by technical elegance, and of failing to convey the great uncertainty and risks inherent in predicting the future. Nevertheless, the reality is that the public are generally better able to understand and evaluate forestry through pictorial than through tabular, graphical and 2-dimensional map representations. The key is to ensure that the scientific basis for the images being presented is also communicated in as understandable a format as possible in order to establish a level of confidence in the images. Users of visualization tools should also ensure that the message is never given that there is only one possible future. The visualizations should incorporate representations of natural and human-caused risks and uncertainties, and clearly communicate that there are many different possible forest futures – there is a variety of "ecological plays" that are possible on a particular "ecological stage."

An important question with respect to forestry models is: can they be used by foresters in developing countries, or are they tools restricted to foresters in wealthy, developed countries? While it is true that there are knowledge and technology barriers that limit the use of such tools in many parts of the world at present, computers are rapidly becoming omnipresent wherever there is electricity. Computer models can harness knowledge and experience from developed countries at any latitude, and make them available as heuristic, educational and extension tools to countries that presently lack the wherewithal to locally calibrate and use such tools. Local traditional knowledge can also act as an "expert system" by which to undertake initial calibration. It may be some years or decades before foresters in less developed countries gain the local information needed to make them accurate tools for local prediction, but the day when this will be possible is approaching, and it is time to start to customize this type of tool for this future use. Several forest ecosystem models already exist for tropical forests, and there are many for temperate forests. Their development should be continued in anticipation of the day that foresters in developing tropical and temperate countries are ready for them. Equipping these models for agroforestry assessment as well as forest management applications is also important

CONCLUSIONS

The prime directive in forestry is to change as the balance of desired forest values and environmental services changes, but an equally important responsibility is to resist change that is inconsistent with the ecology and the sociology of the desired new balance of values. To respond in a responsible and ethical manner to the challenges posed by the addition of three to four billion to the global human population, foresters must stop managing forests for timber, or for wildlife, or for water, or for any other single value individually. They should be managed as ecosystems for multiple values. This does not imply that all forests are managed for all values all the time. Wilderness, ecological, genetic and potable water production reserves and recreational areas will be part of the mosaic of different land management designations within a forest landscape, but the whole should be managed as a landscape ecosystem. Park and others reserve boundaries do not stop fires, insects, diseases or timber/wildlife poaching. Forestry that fails to address the human needs of local people, or to respect the processes of local and landscape ecosystems, is unlikely to be sustained or sustainable. Only when the forest is managed as a system with people and their multiple values respected and incorporated into management will we reduce conflict in forestry and balance the multiple and competing demands of today's generation against our desire to leave a suitable legacy for the future.

Forestry is primarily about people, not ecology, biodiversity, timber or any other single value. The fact that ecology is now the essential biophysical foundation for forestry, and that wildlife, water and biodiversity have become as important in forestry as timber, is because people have recognized their value and have insisted that they become an objective of management. If foresters are to obtain the social license to manage the world's forests, they should strive to implement ecosystem management, with humans as part of the ecosystems. Many changes are required to achieve success in this vital endeavor. One of them is the synthesis of ecological knowledge, both "traditional" and that derived from "western science," into ecosystem management scenario analysis and visualization tools.

A final and critically important element of implementing EM is public trust. This is perhaps the greatest challenge to foresters, but it will not be gained over the long run by acquiescence to "flavor-of-the-month" beliefs and unfounded assertions about forest ecosystems. Stewardship and forest ethics ultimately must be based on an integration of experience (including "traditional knowledge"), human values and science-based understanding of forest ecosystems.

Forestry has always been changing, and will continue to do so. This is implicit in the "prime directive" identified in the definition of our profession. The evolution will hopefully take us to ecosystem management, and not "leave us at the station" of ecosystem-based management, useful though this is. At the present time the impediments to the widespread application of EM render this an ideal to aim for rather than a fully operational system of management. Overcoming these impediments involves recognizing them and taking energetic steps to overcome them. Space limitations prevent further exploration of these ideas here, but the reader might seek the paper on EM tenure reform noted above (Kimmins 2006).

LITERATURE CITED

Agee, J.; Johnson, D., eds. 1988. Ecosystem management for parks and wilderness. Seattle, WA: University of Washington Press. 237 p.

Attiwill, P.M. 1994. The disturbance of forest ecosystems: the ecological basis for conservation management. Forest Ecology and Management. 63: 247-300.

Boyce, M.S.; Haney, A. 1997. Ecosystem management. applications for sustainable forest and wildlife resources. New Haven, CT: Yale University Press. 361 p.

Burton, P.J. 2005. Ecosystem management and conservation biology. In: Watts, S.B.; Tolland, L. Forestry Handbook for British Columbia. 5th ed. Vancouver, BC: Faculty of Forestry, University of British Columbia: 308-322.

Carey, A. B.; Curtis, R.O. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. Wildlife Society Bulletin. 24: 610-620.

Carey, A.B.; Johnson, M.L. 1995. Small mammals in managed, naturally young, and old-growth forests. Ecological Applications. 5: 336-352.

Christensen, N.L.; Bartuska, A.M.; Brown, J.H.; Carpenter, S.D.; Antonio, C.; Francis, R.; Franklin, J.F.; MacMahon, J.A.; Noss, R.F.; Parsons, D.J.; Peterson, C.H.; Turner, M.G.; Woodmansee, R.G. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. Ecological Applications. 6(3): 665–691.

D'Eon, R.G.; Johnson, J.; Ferguson, E.A., eds. 2000. Ecosystem management of forested landscapes: directions and implementation. Vancouver, BC: University of British Columbia Press. 432 p.

Franklin, J.F. 1997. Ecosystem management: an overview. In: Boyce, M.S.; Haney, A., eds. Ecosystem management: applications for sustainable forest and wildlife resources. New Haven, CT: Yale University Press: 21-53.

Franklin, J.F.; Berg, D.R.; Thornberg, D.A.; Tappeiner, J.C. 1997. Alternative silviculture approaches to timber harvesting: variable retention harvesting systems. In: Kohm, K.A.; Franklin, J.F., eds. Creating a forestry for the 21st century: the science of ecosystem management. Washington, DC: Island Press: 11-139.

Franklin, J.F.; Spies, T.A.; Van Pelt, R.; Carey, A.B.; Thornburgh, D.A.; Berge, D.R.; Lindenmayerf, D.B.; Harmon, M.E.; Keeton, W.S.; Shaw, D.C.; Biblea, K.; Chen, J. 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. Forest Ecology and Management. 155: 399-423.

Gordon, J.C. 1993. Ecosystem management: an idiosyncratic overview. In, Aplet, G.H.; Johnson, N.; Olson, J.T.; Sample, V.A., eds. Defining sustainable forestry. Covelco, CA: Island Press: 240-244.

Grumbine, R.E. 1994. What is ecosystem management? Conservation Biology. 8: 27-38.

Johnsen, K.; Samuelson, L.; Teskey, R.; McNulty, S.; Fox, T. 2001. Process models as tools in forest research and management. Forest Science. 47(1): 2-8.

Kimmins, J.P. 1974. Sustained yield, timber mining, and the concept of ecological rotation: a British Columbian view. Forestry Chronicle. 50: 27-31.

Kimmins, J.P. 1990. Modeling the sustainability of forest production and yield for a changing and uncertain future. Forestry Chronicle. 66: 271-280.

Kimmins, J.P. 1996a. Importance of soil and role of ecosystem disturbance for sustained productivity of cool temperate and boreal forests. Soil Science Society of America Journal. 60: 1643-1654.

Kimmins, J.P. 1996b. The health and integrity of forest ecosystems: are they threatened by forestry? Ecosystem Health. 2: 5-18.

Kimmins, J.P. 1997a. Biodiversity and its relationship to ecosystem health and integrity. Forestry Chronicle. 73: 229-232.

Kimmins, H. 1997b. Balancing act: environmental issues in forestry. 2nd ed. Vancouver, BC: University of British Columbia Press**.**

Kimmins, J.P. 1999. Biodiversity, beauty and the beast – are beautiful forests sustainable, are sustainable forests beautiful, and is "small" always ecologically desirable? Forestry Chronicle. 75: 955-960.

Kimmins, J.P. 2000a. Visible and non-visible indicators of forest sustainability: beauty, beholders and belief systems. In: Sheppard, S.R.J.; Harshaw, H.W., eds. Forests and landscapes: linking ecology, sustainability and aesthetics. United Kingdom: CABI Publishing: 43-56.

Kimmins, J.P. 2000b. Respect for nature: an essential foundation for sustainable forest management. In: D'Eon, R.G.; Johnson, J.; Ferguson, E.A., eds. Ecosystem management of forested landscapes: directions and implementation. Vancouver, BC: University of British Columbia Press: 3–24.

Kimmins, J.P. 2002. Future shock in forestry: where have we come from; where are we going; is there a right way to manage forests? Lessons from Thoreau, Leopold, Toffler, Botkin and nature. Forestry Chronicle. 78: 263-271.

Kimmins, J.P. 2004a. Ecosystem management and landscape ecology: the ultimate focus in forest ecology. In: Kimmins, J.P. Forest ecology: a foundation for sustainable forest management and environmental ethics in forestry. 3rd ed. Upper Saddle River, NJ: Prentice Hall. 611 p.

Kimmins, J.P. 2004b. Emulation of natural forest disturbance. What does this mean? In: Perera, A.H.; Buse, L.J.; Weber, M., eds. Emulating natural forest landscape disturbances: concepts and applications. New York: Columbia University Press: 8-28.

Kimmins, J.P. 2005. The ecological stage, the ecological play, and the ecological actors in forest ecosystems. In: Watts S.B.; Tolland., L., eds. Forestry handbook for British Columbia. Vancouver, British Columbia: Faculty of Forestry, University of British Columbia: 433-471.

Kimmins, J.P. 2006. Ecosystem management tenures - institutional arrangements to promote stewardship and sustainability. In: British Columbia Forum on Forest Economics and Policy, Creating new opportunities: forest tenure and land management in British Columbia (www.bc-forum.org, accessed January 10, 2007).

Kimmins, J.P.; Mailly, D.; Seely, B. 1999. Modelling forest ecosystem net primary production: the hybrid simulation approach used in FORECAST. Ecological Model. 122: 195-224.

Kimmins, J. P.; Welham, C.; Seely, B.; Meitner, M.; Rempel, R.; Sullivan, T. 2005. Science in forestry: why does it sometimes disappoint or even fail us? Forestry Chronicle. 81: 723-734.

Kohm, K.A.; Franklin, J.F., eds. 1997. Creating a forestry for the 21st century: the science of ecosystem management. Washington, DC: Island Press. 475 p.

Korzukhin, M.D.; Ter-Mikaelian, M.T.; Wagner, R.G. 1996. Process versus empirical models: which approach for forest ecosystem management? Canadian Journal of Forest Research. 26: 879-887.

Landsberg, J. 2003. Modelling forest ecosystems: state of the art, challenges, and future directions. Canadian Journal of Forest Research. 33: 385-397.

Lindenmayer, D.B.; Franklin, J.F. 2002. Conserving biodiversity: a comprehensive multi-scaled approach. Washington, DC: Island Press. 351 p.

Lutz, W.; Sanderson, W.; Scherbov, S. 2001. The end of world population growth. Nature. 412: 543-543.

Messier, C.; Fortin, M.J.; Schmiegelow, F.; Doyon, F.; Cumming, S.G.; Kimmins, J.P.; Seely, B.; Welham, C.; Nelson, J. 2003. Modeling tools to assess the sustainability of forest management scenarios. In: Burton, P.J.; Messier, C.; Smith, D.W.; Adamowicz, W.L., eds. Towards sustainable management of the boreal forest. Ottawa, Ontario: National Research Council Canada Research Press: 531-580. Chap. 14.

Mitchell, S.J.; Beese, W.J. 2002. The retention system: reconciling variable retention with the principles of silvicultural systems. Forestry Chronicle. 78: 397-403.

Mohren, G.M.L.; Burkhart, H.E.; Jansen, J.J., 1994. Contrasts between biologically-based process models and management-oriented growth and yield models. Forest Ecology and Management. 69: 1-5.

Perera, A.H.; Buse, L.J.; Weber, M., eds. 2004. Emulating natural forest landscape disturbances: concepts and applications. New York: Columbia University Press. 315 p.

Schlaepfer, R. 1997. Ecosystem-based management of natural resources: a step towards sustainable development. IUFRO Occasional Paper No. 6. Wein, Austria: International Union of Forestry Research Organizations. 36 p.

Seely, B.; Kimmins, J.P.; Welham, C.; Scoullar, K.A. 1999. Defining stand-level sustainability, exploring stand-level stewardship. Journal of Forestry. 97: 4-10.

Seely, B.; Welham, C.; Kimmins, J.P. 2002. Carbon sequestration in a boreal forest ecosystem: results from the ecosystem simulation model, FORECAST. Forest Ecology and Management. 169: 123-135.

Sheppard, S.R.J. 2001. Guidance for crystal ball gazers: developing a code of ethics for landscape visualization. Landscape Urban Planning. 54:183-199.

Sheppard, S.R.J.; Harshaw, H.W., eds. 2000. Forests and landscapes: linking ecology, sustainability and aesthetics. United Kingdom: CABI Publishing. 294 p.

Slocombe, D. S. 1993. Implementing ecosystem-based management. BioScience. 43: 612-622.

Vogt, K.A.; Gordon, J.C.; Wargo, J.P. [et al.]. 1997. Ecosystems: balancing science with management. New York: Springer-Verlag. 470 p.

Zeide, B. 2003. The U-approach to forest modeling. Canadian Journal of Forest Research. 33: 480-489.

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SILVICULTURAL APPLICATIONS

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KEY ELEMENTS OF STAND STRUCTURE FOR WILDLIFE IN PRODUCTION FORESTS WEST OF THE CASCADE MOUNTAINS

Joan C. Hagar[1]

ABSTRACT

Silvicultural practices have an important influence on wildlife habitat by manipulating stand structure. Forests managed for timber production tend to have simplified structure compared to natural forests due to the emphasis on mid-seral stage conifers. Large diameter trees, snags, and logs, and floristic diversity are necessary to maintain habitat for forest wildlife, yet typically are underrepresented in intensively managed forests. Trees that develop complex structure over time offer an array of unique niches that contribute to wildlife diversity at the stand scale, and legacy trees provide refugia and dispersal habitat for species associated with older forests. Snags and down wood are critical habitat elements used by more than 150 species of wildlife in Northwest conifer forests. Current guidelines for augmenting volumes of woody debris in managed forests may be inadequate to maintain populations of all associated species in intensively managed forests. Floristic diversity, in particular the presence of shrubs and hardwood trees, provides important food and cover resources for a surprising number of species in coniferous forests. Allowing greater development of non-coniferous vegetation in managed forests would make a significant contribution to the maintenance of wildlife diversity. Production forests can enhance wildlife habitat throughout all phases of stand management by incorporating the key elements of stand structure discussed in this paper.

KEYWORDS: Coarse wood, floristic diversity, stand structure, wildlife habitat.

INTRODUCTION

Silvicultural treatments can significantly influence abundance and distribution of wildlife through manipulation of vegetation at the stand level (McComb 2001). Manipulations to stand structure and composition are likely to directly affect wildlife species whose home ranges are smaller than or equal to a typical unit managed as a stand, and thus have the potential to influence wildlife community composition. Structural diversity is a key characteristic of stands, representing resources available for wildlife (Hunter 1990). The number of species that find suitable habitat in a stand increases with increasing structural diversity for two reasons. First, each species relies on a diversity of resources to meet its needs; i.e., most species use different resources for cover than for foraging. Therefore, the combination of resources for foraging and cover is necessary to provide suitable habitat for individual species. Second, each species has unique habitat requirements, so a diversity of resources is necessary to support a diversity of species. Structurally complex stands support an array of niches that can be exploited by a diversity of species.

Structural diversity is missing from many forests that emphasize timber production because an emphasis on conifers in mid-seral stages typically leads to homogeneous, simplified stand structure (Hansen et al. 1991). Key structural features for wildlife that are missing or are relatively underrepresented in production forests include large trees, snags and logs, and a diversity of tree and shrub species (Carey and Johnson 1995, Bunnell et al. 1999). Forest regeneration systems that remove all components of the previous stand have substantially reduced the number of trees, snags, and logs that represent the upper range of diameter distributions characteristic of natural forests. A focus on early establishment of conifers on forestlands managed for timber production also has truncated the diverse, shrub-dominated stage of forest succession. Rapid

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establishment of conifers following clear-cutting, involving vegetation management and narrow spacing of conifer seedlings to reduce competition from other species (Walstad and Kuch 1987), has produced young, closed-canopy second-growth forests across thousands of hectares in the Pacific Northwest. This stand condition is productive from a timber management perspective, but the homogeneous structure supports low diversity of wildlife (Hayes et al. 1997).

Although many wildlife species often are associated with particular seral stages of conifer forests (Bruce et al. 1985), most species are actually more responsive to the availability of structural features that tend to be correlated with stand age in managed forests than to stand age per se (Bunnell et al. 1997). For example, species that reach their highest abundance in old-growth Douglas-fir (*Pseudotsuga menziesii*), such as the spotted owl (*Strix occidentalis*) and many species of cavity-nesting birds, also occur in younger natural forests that support the necessary habitat elements, large trees and snags (Carey et al. 1991, Huff and Raley 1991, Lundquist and Mariani 1991). Similarly, many wildlife species that are commonly associated with early seral habitat can occur with great regularity and in abundance throughout all stages of forest development when suitable understory cover is present. In a chronosequence of unmanaged forest stands throughout Oregon and Washington, understory characteristics had low discriminatory power among age classes (Spies and Franklin 1991), and most vertebrate wildlife species associated with understory vegetation did not differ in abundance among forest age classes (Ruggiero et al. 1991). This suggests that the maintenance of key structural features throughout forest development could help maintain habitat for a diversity of native wildlife, even in intensively managed forests. The goal of this paper is to describe the importance of large trees, snags, and logs, and floristic diversity in supporting key wildlife species, and to review management options for retaining these features in forests managed for timber production.

KEY STRUCTURAL FEATURES

Large Trees

As trees age and increase in size, they develop increasingly complex structural characteristics that provide a diversity of niches for wildlife. Habitat attributes such as large limbs, decay and disease infestation sites, and complex bark structure are positively associated with tree size (Bull et al. 1997). Large-diameter limbs provide resting and nesting platforms for many species of arboreal mammals and birds, including marbled murrelets, *Brachyramphus marmoratus* (Hamer and Nelson 1995). Thick horizontal branches also support abundant growth of epiphytes, which in turn provide nesting material, forage, and a source of arthropod prey for insectivores (Pettersson et al. 1995). Lichens that grow close to the ground on large limbs of open-grown trees, or on limbs fallen from higher in the canopy provide important forage for herbivores such as deer (*Odocoileus* spp.) and elk, *Cervus canadensis* (Richardson and Young 1977, Maser et al. 1984). Abundance of epiphytic lichens is positively associated with branch size and age because large branches offer more growing substrate and because lichen colonization and growth is a relatively slow process (Esseen et al. 1996). Large branches, deformities, witches' brooms, and other structural irregularities of older trees provide nesting and resting cover for species such as northern flying squirrel, *Glaucomys sabrinus* (Maser et al. 1984, Carey 1995), fisher *Martes pennanti* (USFWS 2004), northern spotted owl (Forsman 2003), and northern goshawk, *Accipiter gentilis* (Marshall 2003).

Older live trees are more likely than young trees to develop forms of decay that can function like snags (Bunnell et al. 2002), such as hollows, natural cavities, peeling bark, and dead tops or branches. Hollows and large cavities formed by heartwood fungi in live trees provide critical roosting habitat for bats (Ormsbee and McComb 1998), roosting and nesting sites for Vaux's swifts, (*Chaetura vauxi*; Bull and Collins 1993), night roosts for pileated woodpeckers (*Dryocopus pileatus*; Bull et al. 1992), and den sites for black bears (*Ursus americanus*; Bull et al. 2000). Large diameter (> 50 cm) also is a critical feature of trees, snags, and logs with hollows used as den sites by marten, *Martes americana* and fisher (Raphael and Jones 1997, USFWS 2004). Natural cavities formed when limbs break off from the bole, or when branches break off from large limbs, are used for nesting and roosting by secondary cavity nesters that are unable to excavate their own cavities, such as nuthatches (*Sitta* spp.) and chickadees (*Poecile* spp.).

Changes in bark characteristics as trees grow and age further increase the complexity of habitat and resources offered by mature trees. Chickadees, nuthatches, brown creeper (*Certhia Americana*), and woodpeckers all glean spiders, grubs, and other arthropods from crevices in bark on the boles and branches of trees. The deeper the crevices, the more invertebrate prey they are likely to contain (Mariani and Manuwal 1990). This may explain why older conifers with deeply fissured bark are preferred foraging habitat for species such as the brown creeper (Weikel and Hayes 1999). Bark pulling away from bole provides nest sites for brown creepers and Pacific-slope flycatchers, *Empidonax difficilis* (Canterbury 2003, Weikel 2003) and roosting sites for bats (Barclay et al. 1988).

Large trees that survive stand-replacing disturbances can provide critical habitat for species associated with older forests, allowing persistence or facilitating dispersal following disturbance events. These legacy trees function as refugia for small organisms with limited dispersal ability, such as amphibians, arthropods (Wessell 2005), and lichens (Neitlich and McCune 1997). The protection of gaps, "wolf trees", and remnant old-growth trees has been recommended as a strategy for maintaining diversity and distribution of epiphytic macrolichens (Nietlich and McCune 1997), many species of which are important forage for wildlife, including deer and elk, in Northwest conifer forests. Retained trees also facilitate dispersal through otherwise unsuitable habitat for some forest-associated species. For example, relatively even dispersal of large trees in harvested areas can facilitate movement of forest interior species such as the brown creeper (Rosenberg and Raphael 1986, Brand and George 2001).

The time required for trees to develop structural characteristics used by many wildlife species associated with older forests is considerably longer than the typical rotation age for production forests. In addition, different conditions than are commonly found in production forests may enhance some habitat features. Stand density influences tree architecture because open-grown trees develop deeper crowns and larger limbs (Tappeiner et al. 2002). The development of limbs large enough to provide nesting platforms and substrate for epiphytes requires that trees grow in the open for many decades. Growth rates of trees in contemporary old-growth stands were comparable to plantations with densities of 40-50 trees per acre (Tappeiner et al. 1997), suggesting that abundant growing space may be needed for trees to develop the specific characteristics attributed to old-growth trees, such as large diameter branches and deep crowns. Furthermore, the greater taper that develops in the boles of trees grown at wide spacing increases stability and longevity of the habitat provided. Stems > 63 cm may remain standing for 250 years even after they become snags (Mellen and Ager 2002).

Options for recruiting and maintaining some trees with complex architecture include green tree retention at harvest, the management of some stand components on longer rotations than those used for timber production, and density management of young stands. Density management to achieve wide spacing is recommended where the goal is to hasten development of large trees, but is not likely to meet the goals of most production forests. Instead, managers of production forests who want to maintain key habitat components can designate individual trees within stands for the development of complex architecture associated with big trees. These wildlife trees should be established in gaps or on stand edges to provide the space needed to develop the desired structure and to protect them from management operations.

Retaining large live trees also may be an efficient means of recruiting dead wood habitat because 1) live trees with partial decay could be considered along with snags towards meeting dead wood management goals (Rose et al. 2001) and 2) large trees are the source of recruitment for future large snags and logs. Because of the longevity of large diameter trees and the negative relationship between snag diameter and fall rate, the contribution of a large live tree to meeting snag retention requirements is likely to last for multiple rotations.

Dead Wood

Wildlife in Pacific Northwest forests have evolved with disturbances that create large amounts of dead wood, so it is not surprising that many species are closely associated with standing (snags) or down dead wood. Although numbers of species that use snags and down wood to meet requirements for food and cover vary by forest type, approximately one-quarter to one-third of forest-dwelling vertebrates are strongly associated with dead wood (Bunnell et al. 1999, Hayes and Hagar 2002). In Oregon and Washington, more than 150 species of wildlife are reported to use dead wood in forests (O'Neil et al. 2001), highlighting the importance of this critical resource. In general, down wood provides cover for breeding and dispersal for amphibians, reptiles, and ground-dwelling mammals, while snags or dying trees provide nesting, roosting, and denning habitat for birds, bats, and small mammals. Thirty-four sensitive and special status species are associated with dead wood (table 1). These are key species for management consideration because their small or declining populations are often related to loss of suitable dead wood habitat (Marshall et al. 1996).

Woodpeckers, as primary excavators, also are key species for consideration in dead wood management because they perform keystone functions in forest ecosystems by creating cavities for secondary cavity-nesters (Martin and Eadie 1999) and facilitating the colonization and dispersal of decay agents (Farris et al. 2004). A diverse guild of secondary cavity-users (including swallows, bluebirds, several species of ducks and owls, ash-throated flycatcher (*Myiarchus cinerascens*), flying squirrel, bats, and many other species) is unable to excavate dead wood, and therefore relies on cavities created by woodpeckers for nesting sites. Suitable nest cavities are essential for reproduction, and their availability limits population size. If populations

Table 1—Special status species associated with coarse woody debris habitats in Oregon and Washington forests

Common name	Scientific name	OR status[a]	WA status[b]
Cope's giant salamander	*Dicamptodon copei*	S-U	none
Larch Mountain salamander	*Plethodon larselli*	FCo, S-V	FCo, SS
Del Norte salamander	*Plethodon elongatus*	S-V	none
Siskiyou Mountains salamander	*Plethodon stormi*	S-V	none
clouded salamander	*Aneides ferreus*	S-U	none
black salamander	*Aneides flavipunctatus*	S-P	none
Oregon slender salamander	*Batrachoseps wrighti*	S-U	none
California slender salamander	*Batrachoseps attenuatus*	S-P	none
sharptail snake	*Contia tenuis*	S-V	SC
harlequin duck	*Histrionicus histrionicus*	S-U	none
bufflehead	*Bucephala bucephala*	S-U	none
Barrow's goldeneye	*Bucephala islandica*	S-U	none
flammulated owl	*Otus flammeolus*	S-crit	SC
northern pygmy-owl	*Glaucidium gnoma*	S-crit	none
northern spotted owl	*Strix occidentalis*	FT, ST	FT, SE
great gray Owl	*Strix nebulosa*	S-V	none
Vaux's swift	*Chaetura vauxi*	none	SC
Williamson's sapsucker	*Sphyrapicus thyroideus*	S-U	none
Lewis' woodpecker	*Melanerpes lewis*	S-crit	SC
white-headed woodpecker	*Picoides albolarvatus*	S-crit	SC
three-toed woodpecker	*Picoides tridactylus*	S-crit	none
black-backed woodpecker	*Picoides arcticus*	S-crit	SC
pileated woodpecker	*Dryocopus pileatus*	S-V	SC
purple martin	*Progne subis*	S-crit	SC
pygmy nuthatch	*Sitta pygmaea*	S-crit	none
western bluebird	*Sialia mexicana*	S-V	none
ringtail	*Bassariscus astutus*	S-U	none
western gray squirrel	*Sciurus griseus*	FCo, S	FCo, ST
American marten	*Martes americana*	S-V	none
fisher	*Martes pennanti pacifica*	S-crit	SE
lynx	*Lynx canadensis*	FT	FT, ST
long-eared myotis	*Myotis evotis*	FCo, S-U	FCo, SM
fringed Myotis	*Myotis thysanodes*	S-V	SM
Townsend's big-eared bat	*Plecotus townsendii*	FCo, S-crit	FCo, SC
Pac. western big-eared bat	*P. townsendii townsendii*	FCo	Fco, SC
Keen's myotis	*Myotis keenii*	S	SC
silver-haired bat	*Lasionycteris noctivagans*	S-U	none
long-legged myotis	*Myotis volans*	S-U	SM
Yuma myotis	*Myotis yumanensis*	FCo, S	FCo, none
white-footed vole	*Phenacomys albipes*	S-U	none

[a] FCo: Federal Species of Concern; FT: Federal Threatened; S-CR = Sensitive: Critical; S-U = undetermined status; S-V = Sensitive: Vulnerable; S-P = Sensitive: peripheral or naturally rare; ST = state threatened; None: No listing status (Oregon Department of Fish and Wildlife 2006).

[b] FCo: Federal Species of Concern; FT: Federal Threatened; SE: State Endangered; ST: State Threatened; SC: State Candidate; SS: State Sensitive; SM: State Monitor; None: No listing status (Washington Department of Fish and Wildlife 2005).

of primary excavators decrease as a result of nest-site limitations, populations of secondary cavity-nesters also can be expected to decrease. Past management strategies have focused only on providing nesting habitat for woodpeckers (Neitro et al. 1985), but foraging habitat also is critical for sustaining populations, and many species have different requirements for fulfilling each function. For example, several cavity-nesting species spend considerable time foraging on live trees, as well as on logs and snags (Weikel and Hayes 1999). Species specific information on nesting, foraging, and roosting habitat for woodpeckers in various forest types of Oregon and Washington can be found in the DecAID advisory system discussed below (Mellen et al. 2006; available at http://wwwnotes.fs. fed.us:81/pnw/DecAID/DecAID.nsf).

The size and decay stage of dead wood are two easily identifiable characteristics that influence habitat suitability for individual wildlife species. A large body of literature indicates that habitat value increases with dead wood diameter. Average diameter of snags used by all wildlife species for nesting or denning in western Oregon and Washington exceeds 50 cm (Mellen et al. 2006). The minimum size of nest trees is determined by the space needed to accommodate an adult inhabitant plus young. When snags of the preferred size are unavailable, smaller snags may be used for nesting, but this is likely to result in lower reproductive capacity because fewer eggs and young can be accommodated. Typically, snags selected as nest and roost sites exceed the minimum size for physical space requirements because cavities with thicker walls are more secure from predators, external climate, and probability of stem breakage at the cavity site (O'Connor 1978). In addition, patterns of decay may drive a selection for larger snags as nest sites (Bunnell et al. 1999). Snags preferred by cavity excavators have decaying heartwood and intact sapwood. Because the time required for heart rot to develop in conifers such as Douglas-fir is relatively long, trees are large by the time they acquire pockets of decay suitable for cavity excavation (Cline 1977). Snag diameter appears to be a more important factor in nest-site selection than snag height, although few species select snags < 5 m in height for nesting (Schreiber and deCalesta 1992.)

Large-diameter logs also offer habitat to more species than small-diameter logs. The overhang of a log above the ground increases with diameter, providing important protective cover for small mammals. Small mammals such as chipmunks (*Tamias townsendii*) select logs that have larger average diameters than randomly available wood to use as travel paths (Waldien et al. 2006). Den sites for large animals (e.g., black bear) are limited to logs of sufficient size (i.e., > 80 cm). In addition, large logs that retain moisture serve as refugia for amphibians during periods of drought (Bartels et al. 1985). Clearly, with regard to dead wood size, bigger is better because there is no upper limit on the size of dead wood used by wildlife, but small snags and logs are of limited value as habitat. Furthermore, large pieces of dead wood, whether standing or down, take longer to decay than small pieces, and consequently persist as habitat for longer periods of time.

Snags and logs decay over time as the result of weathering and the activity of decomposing agents, such as fungi and insects. As dead wood changes structurally with decay, the associated wildlife species also change. Decay stage of snags influences the ability of cavity-using species to excavate nest sites. Strong excavators such as red-breasted sapsuckers tend to use hard snags, whereas weak excavators, such as chickadees and nuthatches, often modify cavities in soft, well-decayed snags (Lundquist and Mariani 1991). Decay stage of logs also influences function as habitat. Hard logs are more likely to have overhanging cover along their sides than soft logs, and can offer den sites if they have hollow interiors. As decay progresses, logs become more suitable cover for amphibians, and colonization by fungi and arthropods increases the abundance of food resources for many wildlife species. Some species use different stages of decay for different purposes. For example, hairy woodpeckers (*Picoides villosus*) typically nest in snags of intermediate decay (Church 1997), but forage extensively on large-diameter snags in advanced decay stages (Weikel and Hayes 1999). A diversity of decay stages of snags and logs is necessary to provide all the habitat functions of dead wood.

In general, managed forests have a low abundance of decaying wood relative to natural forests, and the management of woody debris is a major issue in Pacific Northwest forests (Rose et al. 2001). Past practices have drastically reduced the quality and quantity of dead wood habitat in production forests. Intensive management reduces recruitment of dead wood through density management, directly reduces availability of dead wood habitat through snag removal for safety and salvage, and severely limits the upper size ranges of woody debris as a result of short rotations. Compared to levels in unmanaged old-growth, two rotations of intensive management have been estimated to reduce the abundance of dead wood by 90 percent (Rose et al. 2001). As a result, the large wood that is critical to maintaining wildlife populations is becoming increasingly scarce where legacy structures have not been carried forward from rotation harvests. The time it takes to produce trees of adequate size to support nesting habitat for several species of primary excavators is equivalent to two to three rotation lengths (Bunnell et al. 1999). If managing habitat for these key species is a goal, managers could consider retaining trees at harvest for recruitment of future large snags.

Recently revealed information about the functions of decaying wood as wildlife habitat suggests that current guidelines for augmenting volumes of woody debris in managed forests may be insufficient to maintain populations of all species associated with dead wood (Rose et al. 2001, Wilhere 2003). For example, the Oregon Forest Practices Act Standards for "Wildlife Trees" call for the retention of five snags or green trees per hectare with a minimum diameter of 27.5 cm on state lands. However, five snags per hectare represents only the lowest end of the natural range of snag densities, and is well below the densities associated with use by cavity-nesting wildlife (at least 10 snags that are at least 25 cm dbh per hectare; Hayes and Hagar 2002, Mellen et al. 2006). Furthermore, the average diameter of snags used by cavity-using species, > 56 cm (Mellen et al. 2006), is twice the minimum set by the Oregon Forest Practices Act Standards.

A management strategy for maintaining populations of species associated with dead wood should ensure spatial and temporal continuity of habitat (Hayes and Hagar 2002). First, existing snags and logs should be maintained during timber harvest whenever possible. In particular, maintaining large snags likely to endure for long periods might be a less costly and more effective means of providing habitat than recruiting smaller snags every rotation. Secondly, future recruitment of dead wood needs to be planned. A long-term view is necessary because the lag effect of management on the amounts and types of dead wood may not appear for 100-200 years, when the last of large legacy dead wood from previous old-growth is gone. Trees with defects and of low economic value make good candidates for retention to become future snags. For safety concerns and operational considerations, retained trees can be clumped in patches (Kellogg et al. 2002). The few data that are available to address the effects of spatial distribution of snags (clumped vs. dispersed) on their use by wild-life suggest that some species (e.g., woodpeckers) may select snags in patches (Bunnell et al. 1999, Saab and Dudley 1998), but the effect of snag distribution is not understood for most species. Finally, augmenting dead wood resources may sometimes be necessary. Creating snags and cavities and supplementing with nest boxes are techniques that have been used. However, these approaches typically require an intensive investment of time and money, and have not always been successful in providing habitat (Bunnell et al. 1999).

Mellen et al. (2006) developed an advisory tool, DecAID, to help managers evaluate effects of forest conditions and existing or proposed management activities on organisms that use snags and down wood. The DecAID database, compiled from a thorough review of the empirical literature on wildlife-dead wood relationships, summarizes habitat associations of wildlife in terms of dead wood diameter and abundance. Managers can use this information to evaluate the risks and tradeoffs between timber production and wildlife habitat involved at various levels of dead wood retention. Either the species that would be provided for by retaining various densities and diameters of coarse woody debris, or the levels of dead wood needed to provide habitat for species of interest can be determined. This fine-filter approach to dead wood management is complemented by a coarse-filter component of the tool: information on naturally occurring levels of dead wood is available for guiding decisions about amounts and distribution of dead wood at landscape scale. Another tool available to managers is the Coarse Wood Dynamics model (Mellen and Ager 2002). Coarse Wood Dynamics model can be used to project the recruitment, fall rate, and decay rate of snags and down wood to predict future amounts of dead wood habitat and guide decisions about green tree retention and creation of snags and down wood.

Floristic Diversity

Although it may seem paradoxical, many wildlife species that occur in Pacific Northwest conifer forests rely on non-coniferous vegetation within these forests to meet at least some of their life requirements. Hagar (submitted[2]) lists more than 75 forest-dwelling terrestrial vertebrate species for which an association with non-coniferous vegetation has been documented. Understory shrubs and herbs provide hiding cover for small mammals and nesting cover for many shrub- and ground-nesting bird species. Understory vegetation also provides a diversity of food resources in the form of flowers, seeds, fruits, foliage and invertebrates. Several species of forest-associated hummingbirds rely on nectar from flowering plants such as currant (*Ribes* spp.), salmonberry (*Rubus spectabilis*), and Pacific madrone (*Arbutus menziesii*) (Patterson 2003, Patterson

[2] Hagar, J.C. [No date]. Wildlife species associated with non-coniferous vegetation in Pacific Northwest conifer forests: A review. Manuscript submitted. Forest Ecology and Management. On file with: USGS Forest & Rangeland Ecosystem Science Center, 777 NW 9th St, Suite 400, Corvallis, OR 97330.

and Scheuering 2003). The fruit of shrubs such as salal (*Gaultheria shallon*), salmonberry, huckleberry (*Vaccinium* spp.), and Oregon-grape (*Mahonia* spp.) provide critical energy resources for migration and winter survival for many species of birds (e.g., American robin, (*Turdus migratorius*), cedar waxwing, (*Bombycilla cedrorum*), Swainson's (*Catharus ustulatus*) and varied thrushes (*Ixoreus naevius*)) (Parrish 1997) and small mammals (e.g., chipmunks, squirrels, mice, voles) (Maser et al. 1984). Hardwood trees also support different food and cover resources than conifers as a consequence of differences in phenology, reproductive strategies, leaf palatability, branch structure, and decay processes (Bunnell et al. 1999, Hayes and Hagar 2002). In particular, deciduous trees and shrubs support a diverse assemblage of herbivorous insects such as caterpillars (*Lepidoptera*) (Hammond and Miller 1998), an important prey for many insectivores, especially neotropical migrant birds. This may explain a consistent pattern of positive correlations between abundance and diversity of birds and abundance and distribution of hardwoods in conifer-dominated landscapes (Morrison and Meslow 1983, Carey et al. 1991, Gilbert and Allwine 1991, Huff and Raley 1991). Several bird species depend on the presence of a deciduous component in coniferous forests of the Pacific Northwest. For example, warbling vireos (*Vireo gilvus*) are neotropical migrants that rely on caterpillars from deciduous trees, particularly red alder (*Alnus rubra*) (Gardali and Ballard 2000); MacGillivray's Warbler (*Oporornis tolmiei*) and Wilson's Warbler (*Wilsonia pusilla*), both neotropical migrant species that consume caterpillars, rarely occur in Oregon Coast Range Douglas-fir stands unless cover of deciduous shrubs is greater than 35 percent (Hagar 2004).

Hardwood trees also make important contributions to cavity and snag resources in conifer forests. Pacific madrone (Raphael 1987), big-leaf maple (*Acer macrophyllum*), and Oregon white oak (*Quercus garryana*) (Gumtow-Farrior 1991) tend to form natural cavities in live trees, providing a higher density of nesting and roosting opportunities for secondary cavity-using species than live conifers. In several conifer forest types of the Pacific Northwest, a large proportion of cavity-nesting birds and bat species select hardwoods as nesting and roosting sites (Bunnell et al. 1999). Hardwoods may be preferred by many species because wood properties and decay patterns often result in softened heartwood that is easily excavated, while the sapwood remains unaffected by decay (Harestad and Keisker 1989). In contrast, sapwood of Douglas-fir snags often decays by the time heartwood is sufficiently softened for cavity excavation (Cline et al. 1980). Because of these differences, hardwoods can provide suitable cavity sites at relatively smaller diameters than conifers (Bunnell et al. 1999).

Traditionally, non-coniferous vegetation, particularly woody shrubs and hardwoods, has not been favored in management practices aimed at timber production. Early and sustained conifer dominance in production forests, by means of vegetation management and planting high densities of tree seedlings at stand initiation, shortens the period of herb and shrub dominance following harvest, and reduces the abundance and distribution of understory vegetation and hardwoods in managed forests (Hansen et al. 1991). As a result of management practices that remove competing vegetation to enhance growth of crop trees, shrub and hardwood tree cover in the Oregon Coast Range has declined over the past five decades (Kennedy and Spies 2004). Wildlife species that depend on the resources provided by shrubs and hardwoods are unlikely to persist in forests where these vegetation components are scarce.

Ideally, management of forests to provide habitat for species associated with non-coniferous vegetation would begin early in stand development. Controlling density at an early age, before canopy closure, can help to maintain diverse stand structure throughout the life of a stand, and can preserve future management options (Tappeiner et al. 2002). Although shrubs may dominate early stages of natural succession, it is unlikely that clear-cutting a forest stand can be used to immediately create quality habitat for shrub-associated species. The age of shrubs is an important factor in the habitat offered. Older shrubs have more foliage (i.e., provide more cover) and support more epiphytes (Rosso 2000). Furthermore, maximum flower and fruit production by many shrub species occurs only after a certain stage of maturity is attained (Harrington et al. 2002; Kerns et al. 2004).

Commercial thinning is a forest management tool that has the potential to significantly increase habitat availability for shrub-associated wildlife in second-growth conifer stands (Hayes et al. 1997, Haveri and Carey 2000, Hagar et al. 2004). By reducing canopy cover and increasing light availability to the understory, thinning can promote the development of forest floor vegetation (Tappeiner et al. 1991, Bailey et al. 1998, Thomas et al. 1999). Cover and productivity of fruit- and seed-bearing understory plants are influenced by characteristics of forest overstory structure (O'Dea et al. 1995, Klinka et al. 1996, Huffman and Tappeiner 1997), and may respond positively to thinning (Minore 1984, Kerns et al. 2003). Increased availability of mast from understory vegetation in thinned stands may explain the positive response to thinning of several bird species that include fruit in their diet (e.g., Swainson's thrush, Townsend's solitaire (*Myadestes townsendi*), western tanagers (*Piranga ludoviciana*), and spotted towhees

(*Pipilo maculates*)) (Muir et al. 2002, Hayes et al. 2003, Hagar et al. 2004). Variable density thinning can be used to further enhance habitat by increasing spatial heterogeneity over that typical of stands with evenly spaced trees (Carey et al. 1999, Carey 2003). Biologically meaningful criteria, rather than spacing, may be used for selecting leave trees. For example, selecting leave trees based on tree characteristics such as presence of cavities or large limbs can provide habitat for species associated with complex tree architecture, as discussed above.

Although single, large deciduous trees or small patches of deciduous vegetation (e.g., 15-20 square meters) (Morrison 1982) can provide important habitat if they are not too isolated, a few hardwoods suppressed in the understory are not likely to provide sufficient forage or cover for most species. Identifying sites where growth of shrubs and hardwoods minimizes impacts on timber production may be the most reasonable approach for maintaining associated species in intensively managed forests. Seeps, wet depressions, small wetlands, and riparian areas may be unproductive for or protected from timber production, but support deciduous trees and shrubs such as big-leaf maple, red alder, elderberry (*Sambucus* spp.), and salmonberry. In addition, road edges, logging landings, and root rot pockets provide opportunities for the development of patches of deciduous growth, particularly red alder. Forest gaps established to foster the development of large trees with complex structure (previous section) also are excellent places to allow growth of shrubs and hardwoods. In fact, goals for providing habitat associated with large trees, snags, and floristic diversity could be met simultaneously in intentionally managed gaps.

CONCLUSIONS

Large trees, large dead wood, and a diversity of vegetation provide critical food and cover resources, collectively accounting for at least some of the habitat requirements of most forest wildlife species. Forest stands in which these elements are present are therefore expected to support a richer wildlife community than stands representing a single size class of a single tree species. Furthermore, maintaining some large trees, large dead wood, and floristic diversity would likely benefit much more than vertebrate wildlife. Fungi, lichens, mosses, terrestrial and aquatic invertebrates, and the ecological processes in which these organisms function also are affected by forest management that influences these elements (Bunnell et al. 1999). Diversity is important for maintaining forest function over the long-term (Hooper et al. 2005).

Production forests can enhance wildlife habitat by incorporating key elements of structure throughout all phases of stand management. Managers are already familiar with the silvicultural tools and techniques necessary to foster structural diversity, such as density management and selective harvesting. Modifications to the conventional application of these tools will provide opportunities for increasing wildlife diversity in production forests. However, a major challenge will be to decide on the amounts and distributions of large wood and non-coniferous habitat elements within stands managed for timber production. Such decisions will primarily be driven by the goals of each landowner, and an evaluation of the trade-offs between the ecological benefits and economic costs of investments in wildlife habitat. Managers of production forests are keenly aware of the costs of dedicating space to non-commercial resources, but many also recognize the benefits of sustaining biodiversity, even though they are not easily translated into economic metrics and are not always obvious in the short term. Monitoring is likely to be invaluable for providing information with which to evaluate trade-offs and demonstrate the effectiveness of alternative management strategies. Given the implicit goal of production forests to be managed primarily for timber, they will likely represent the low end of the range of tree and snag retention and floristic diversity. Therefore, from a research standpoint, production forests can serve as a valuable point of reference against which to assess the response of wildlife to a full range of retention represented at the landscape scale.

LITERATURE CITED

Bailey, J.D.; Mayrsohn, C.; Doescher,P.S.; St. Pierre, E.; Tappeiner, J.C. 1998. Understory vegetation in old and young Douglas-fir forests of western Oregon. Forest Ecology and Management. 112: 289-302.

Barclay, R.M.R.; Faure, P.A.; Farr, D.R. 1988. Roosting behavior and roost selection by migrating silverhaired bats (*Lasionycteris noctivagans*). Journal of Mammalogy. 69: 821-825.

Bartels, R.; Dell, J.D.; Knight, R.L.; Schaefer, G. 1985. Dead and down woody material. In: Brown, E.R., ed. Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1 – Chapter narratives. Publ. No. R6-F&WL-192-1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest Range and Experiment Station: 171-186.

Brand, L.A.; George, T.L. 2001. Response of passerine birds to forest edge in coast redwood forest fragments. The Auk. 118: 678-686.

Bruce, C.; McMillan, A.; Edwards, D.; Owens, T.; Mellen, K.; Sturgis, H. 1985. Wildlife relationships to plant communities and stand conditions. In: Brown, E.R., editor. Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1 – Chapter narratives. Publ. No. R6-F&WL-192-1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Portland, OR: Pacific Northwest Forest Range and Experiment Station: 33-55.

Bull, E.L., Holthausen, R.S.; Henjum, M.G. 1992. Roost trees used by pileated woodpeckers in northeastern Oregon. Journal of Wildlife Management. 56: 786-793.

Bull, E.L.; Collins, C.T. 1993. Vaux's swift (*Chaetura vauxi*). In: Poole, A.; Gill, F., eds. The birds of North America. No. 77. Washington, DC: The Academy of Natural Sciences.

Bull, E.L.; Parks, C.G.; Torgerson, T.R. 1997. Trees and logs important to wildlife in the Interior Columbia River Basin. Gen. Tech. Rep. PNW-GTR-391. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Bull, E.L.; Akenson, J.J.; Henjum, M.G. 2000. Characteristics of black bear dens in trees and logs in northeastern Oregon. Northwestern Naturalist. 81: 148-153.

Bunnell, F.L.; Kremsater., L.L.; Wells, R.W. 1997. Likely consequences of forest management on terrestrial, forest-dwelling vertebrates in Oregon. Portland, OR: Oregon Forest Resources Institute. 130 p.

Bunnell, F.L.; Kremsater, L.L.; Wind, E. 1999. Managing to sustain vertebrate richness in forests of the Pacific Northwest: relationships within stands. Environmental Reviews. 7: 97-146.

Bunnell, F.L.; Houde, I.; Johnston, B.; Wind, E. 2002. How dead trees sustain live organisms in western forests. In: Laudenslayer Jr., W.F.; Shea, P.J.; Valentine, B.; Weatherspoon, C.P.; Lisle, T.E., eds. Proceedings of the symposium on the ecology and management of dead wood in western forests. Gen. Tech. Rep. PSW-GTR-181. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 291-318.

Canterbury, G.E. 2003. Pacific-slope flycatcher. In: Marshall, D.B.; Hunter, M.G.; Contreras, A.L., eds. Birds of Oregon: A general reference. Corvallis, OR: Oregon State University Press: 386-388.

Carey, A.B. 1995. Sciurids in Pacific Northwest managed and old-growth forests. Ecological Applications. 5: 648-661.

Carey, A.B. 2003. Biocomplexity and restoration of biodiversity in temperate coniferous forest: inducing spatial heterogeneity with variable-density thinning. Forestry. 76: 127-136.

Carey, A.B.; Hardt, M.M.; Horton, S.P.; Biswell, B.L. 1991. Spring bird communities in the Oregon Coast Range. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region: 123-142.

Carey, A.B.; Johnson, M.L. 1995. Small mammals in managed, naturally young, and old-growth forests. Ecological Applications. 5: 336-352.

Carey, A.B.; Thysell, D.R., and Brodie, A.W. 1999. The forest ecosystem study: background, rationale, implementation, baseline conditions, and silvicultural assessment. Gen. Tech. Rep. PNW-GTR-457. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 129 p.

Church, T.A. 1997. Habitat associations of cavity nesters at multiple scales in managed forests of the southern Oregon Cascades. MS thesis. Corvallis, OR: Oregon State University.

Cline, S.P. 1977. The characteristics and dynamics of snags in Douglas-fir forests of the Oregon Coast Range. Ph.D. dissertation. Corvallis, OR: Oregon State University.

Cline, S.P.; Berg, A.B.; Wight, H.M. 1980. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. Journal of Wildlife Management. 44: 773-786.

Esseen, P.A.; Renhorn, K.E.; Pettersson, R.B. 1996. Epiphytic lichen biomass in managed and old-growth boreal forests: effect of branch quality. Ecological Applications. 6: 228-238.

Farris, K.L.; Huss, M.J.; Zack, S. 2004. The role of foraging woodpeckers in the decomposition of ponderosa pine snags. Condor. 106: 50-59.

Forsman, E.D. 2003. Spotted owl. In: Marshall, D.B.; Hunter, M.G.; Contreras, A.L., eds., Birds of Oregon: A general reference. Corvallis, OR: Oregon State University Press: 319-320.

Gardali, T.; Ballard, G. 2000. Warbling Vireo (*Vireo gilvus*). In: Poole, A.; Stettenheim, P.; Gill, F., eds. The Birds of North America, No. 551. Philadelphia: Washington, DC: The Academy of Natural Sciences; The American Ornithologists' Union.

Gilbert, F.F.; Allwine, R. 1991. Spring bird communities in the Oregon Cascade Range. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 145-158.

Gumtow-Farrior, D.L. 1991. Cavity resources in Oregon white oak and Douglas-fir stands of western Oregon. Corvallis, OR: Oregon State University. 89 p. M.S. thesis.

Hagar, J.C. 2004. Functional relationships among songbirds, arthropods, and understory vegetation in Douglas-fir forests, western Oregon. Corvallis, OR: Oregon State University. Ph.D. dissertation.

Hagar, J.C.; Howlin S.; Ganio, L.M. 2004. Short-term response of songbirds to experimental thinning of young Douglas-fir forests in the Oregon Cascades. Forest Ecology and Management. 199: 333-347.

Hamer, T.E.; Nelson, S.K. 1995. Characteristics of marbled murrelet nest trees and nesting stands. In: Ralph, C.J.; Hunt, G.L.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 69-82.

Hammond, P.C., Miller, J.C. 1998. Comparison of the biodiversity of lepidoptera within three forested ecosystems. Annals of the Entomological Society of America. 91: 323-328.

Hansen, A.J.; Spies, T.A.; Swanson, F.J.; Ohmann, J.L. 1991. Conserving biodiversity in managed forests. BioScience. 41: 382-391.

Harestad, A.S.; Keisker, D.G. 1989. Nest tree use by primary cavity-nesting birds in south central British Columbia. Canadian Journal of Zoology. 67: 1067-1073.

Harrington, C.A.; Buermeyer, K.R.; Brodie, L.C.; Wender, B.W. 2002. Factors influencing growth and flowering of understory plants in conifer stands in western Washington. In: Johnson, A.C.; Haynes, R.W.; Monserud, R.A., eds. Congruent management of multiple resources: proceedings from the Wood Compatibility Initiative workshop. Gen. Tech. Rep. PNW-GTR-563. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 159-168.

Haveri, B.A.; Carey, A.B. 2000. Forest management strategy, spatial heterogeneity, and winter birds in Washington. Wildlife Society Bulletin. 28: 643-652.

Hayes, J.P.; Chan, S.S.; Emmingham, W.H.; Tappeiner, J.C.; Kellogg, L.D.; Bailey, J.D. 1997. Wildlife response to thinning young forests in the Pacific Northwest. Journal of Forestry. 95: 28-33.

Hayes, J.P.; Hagar, J.C. 2002. Ecology and management of wildlife and their habitats in the Oregon Coast Range. In: Hobbs, S.D.; Hayes, J.P.; Johnson, R.L.; Reeves, G.H.; Spies, T.A.; Tappeiner, J.C. II; Wells, G.E., eds. Forest and stream management in the Oregon Coast Range. Corvallis, OR: Oregon State University Press: 99-134.

Hayes, J.P.; Weikel, J.M.; Huso, M. 2003. Effects of commercial thinning on breeding birds in the northern Coast Range of Oregon. Ecological Applications. 13: 1222-1232.

Hooper, D.U.; Chapin, F.S.; Ewel, J.J.; Hector, A.; Inchausti, P.; Lavorel, S.; Lawton, J.H.; Lodge, D.M.; Loreau, M.; Naeem, S.; Schmid, B.; Setala, H.; Symstad, A.J.; Vandermeer, J.; Wardle, D.A. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs. 75: 3-35.

Huff, M.H.; Raley, C.M. 1991. Regional patterns of diurnal breeding bird communities in Oregon and Washington. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 177-205.

Huffman, D.W.; Tappeiner, J.C., II. 1997. Clonal expansion and seedling recruitment of Oregon-grape (*Berberis nervosa*) in Douglas-fir (*Pseudotsuga menziesii*) forests: comparisons with salal (*Gaultheria shallon*). Canadian Journal of Forest Research. 27: 1788-1793.

Hunter, M.L. 1990. Wildlife, forests, and forestry: principles of managing forests for biological diversity. Englewood Cliffs, NJ: Prentice-Hall. 370 p.

Kellogg, L.D.; Milota, G.V.; Stringham, B. 2002. Timber harvesting to enhance multiple resources. In: Hobbs, S.D.; Hayes, J.P.; Johnson, R.L.; Reeves, G.H.; Spies, T.A.; Tappeiner, J.C., II; Wells, G.E., eds. Forest and stream management in the Oregon Coast Range. Corvallis, OR: Oregon State University Press: 135-171.

Kennedy, R.S.H.; Spies, T.A. 2004. Forest cover changes in the Oregon Coast Range from 1939 to 1993. Forest Ecology and Management. 200: 129-147.

Kerns, B.K.; Pilz, D.; Ballard, H.; Alexander, S.J. 2003. Managing for understory forest resources. In: Johnson, A.C.; Haynes, R.W.; Monserud, R.A., eds. Compatible forest management: case studies from Alaska and the Pacific Northwest. The Netherlands: Kluwer Academic Publishers: 337-381.

Kerns, B.K.; Alexander, S.J.; Bailey, J.D. 2004. Huckleberry abundance, stand conditions, and use in western Oregon: evaluating the role of forest management. Economic Botany. 58: 668-678.

Klinka, K.; Chen, H.Y.H.; Wang, Q.; de Montigny, L. 1996. Forest canopies and their influence on understory vegetation in early seral stands on West Vancouver Island. Northwest Science. 70: 193-200.

Lundquist, R.W.; Mariani, J.M. 1991. Nesting habitat and abundance of snag-dependent birds in the southern Washington Cascade Range. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 221-240.

Maser, C.; Mate, B.R.; Franklin, J.F.; Dyrness, C.T. 1984. Natural history of Oregon coast mammals. Special Publication. Eugene, OR: Museum of Natural History, University of Oregon. 496 p.

Mariani, J.M.; Manuwal, D.A. 1990. Factors influencing brown creeper (*Certhia americana*) abundance patterns in the southern Washington Cascade range. Studies in Avian Biology. 13: 53-57.

Marshall, D.B. 2003. Northern goshawk. In: Marshall, D.B.; Hunter, M.G.; Contreras, A.L., eds. Birds of Oregon: a general reference. Corvallis, OR: Oregon State University Press: 151-153.

Marshall, D.B.; Chilcote, M.; Weeks, H. 1996. Species at risk: sensitive, threatened, and endangered vertebrates of Oregon. Portland, OR: Oregon Department of Fish and Wildlife.

Martin, K.; Eadie, J.M. 1999. Nest webs: a community-wide approach to the management and conservation of cavity-nesting forest birds. Forest Ecology and Management. 115: 243-257.

McComb, W.C. 2001. Management of within-stand forest habitats. In: Johnson, D.H.; O'Neil, T.A., man. dirs. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press: 140-153

Mellen, T.K.; Ager, A.A. 2002. Coarse wood dynamics model for the western Cascades. In: Laudenslayer, W.F., Jr.; Shea, P.J.; Valentine, B.; Weatherspoon, C.P.; Lisle, T.E., eds. Proceedings of the symposium on the ecology and management of dead wood in western forests. Gen. Tech. Rep. PSW-GTR-181. Vallejo, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 503-516.

Mellen, K.; Marcot, B.G; Ohmann, J.L.; Waddell, K; Livingston, S.A.; Willhite, E.A.; Hostetler, B.B.; Ogden, C.; Dreisbach, T. 2006. DecAID, the decayed wood advisor for managing snags, partially dead trees, and down wood for biodiversity in forests of Washington and Oregon. Version 2.0. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, U.S. Department of Interior, Fish and Wildlife Service. Available at: http://wwwnotes.fs.fed.us:81/pnw/DecAID/DecAID.nsf [Access date unknown].

Minore, D. 1984. *Vaccinium membranaceum* berry production seven years after treatment to reduce overstory tree canopies. Northwest Science. 58: 208-212.

Morrison, M.L. 1982. Response of avian communities to herbicide-induced vegetation changes, western Oregon. Corvallis, OR: Oregon State University. Ph.D. dissertation. 77 p.

Morrison, M.L.; Meslow, E.C. 1983. Bird community structure on early-growth clearcuts in western Oregon. American Midland Naturalist. 110: 129-137.

Muir, P.S.; Mattingly, R.L.; Tappeiner, J.C., II; Bailey, J.D.; Elliot, W.E.; Hagar, J.C.; Miller, J.C.; Peterson, E.B.; Starkey, E.E. 2002. Managing for biodiversity in young Douglas-fir forests of western Oregon. U.S. Geological Survey - Biological Resources Division, Biological Science Report: USGS/BRD/BSR-2002-0006. 76 p.

Neitlich, P.N.; McCune, B. 1997. Hotspots of epiphytic lichen diversity in two young managed forests. Conservation Biology. 11: 172-182.

Neitro, W.A.; Binkley, V.W.; Cline, S.P.; Mannan, R.W.; Marcot, B.G.; Taylor, D.; Wagner, F.F. 1985. Snags. In: Brown, E.R., ed. Management of wildlife and fish habitats in forests of western Oregon and Washington. 1: Chapter narratives. Publ. No. R6-F&WL-192. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest Range and Experiment Station: 129-169.

O'Connor, R.J. 1978. Nest-box insulation and the timing of laying in the Wytham Woods population of great tits *Parus major*. Ibis. 120: 534–537.

O'Dea, M.E.; Zasada, J.C.; Tappeiner, J.C., II. 1995. Vine maple clone growth and reproduction in managed and unmanaged coastal Oregon Douglas-fir forests. Ecological Applications. 5: 63–73.

O'Neil, T.A.; Johnson, D.H.; Barrett, C.; Trevithick, M.; Bettinger, K.A.; Kiilsgaard, C.; Vander Heyden, M.; Greda, E.L.; Stinson, D.; Marcot, B.G.; Doran, P.J.; Tank, S.; Wunder, L. 2001. Matrixes for wildlife-habitat relationship in Oregon and Washington. In: Johnson, D.H.; O'Neil, T.A., Manag. dirs. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press.

Oregon Department of Fish and Wildlife. 2006. Wildlife diversity program: sensitive species list. Salem, OR: Available at http://www.dfw.state.or.us/wildlife/diversity/index.asp.

Ormsbee, P.C.; McComb, W.C. 1998. Selection of day roosts by female long-legged myotis in the central Oregon Coast Range. Journal of Wildlife Management. 62: 596-603.

Parrish, J.D. 1997. Patterns of frugivory and energetic condition in nearctic landbirds during autumn migration. Condor. 99: 681-697.

Patterson, M. 2003. Rufous hummingbird. In: Marshall, D.B.; Hunter, M.G. Contreras, A.L., eds. Birds of Oregon: a general reference. Corvallis, OR: Oregon State University Press: 346-348.

Patterson M.; Scheuering, R.W. 2003. Allen's hummingbird. In: Marshall, D.B., Hunter, M.G., Contreras, A.L., Editors, Birds of Oregon: A general reference. Corvallis, OR: Oregon State University Press: 348-349.

Pettersson, R.B.; Ball, J.P.; Renhorn, K.-E.; Esseen, P.A.; Sjoberg, K. 1995. Invertebrate communities in boreal forest canopies as influenced by forestry and lichens with implications for passerine birds. Biological Conservation. 74: 57-63.

Raphael, M.G. 1987. Use of Pacific-madrone by cavity-nesting birds. In: Plumb, T.R., tech. coord. Symposium on multiple-use management of California's hardwood resources: Gen. Tech. Rep. PSW-100. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 198-201.

Raphael, M.G.; Jones, L.L.C. 1997. Characteristics of resting and denning sites of American martens in central Oregon and western Washington. In: Proulx, G.; Bryant, H.N.; Woodward, P.M., eds. Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton: 146-165.

Richardson, D.H.S.; Young, C.M. 1977. Lichens and vertebrates. In: Seaward, M.R.D., ed. Lichen ecology. London, England: Academic Press: 121-144.

Rose, C.L.; Marcot, B.G.; Mellen, T.K.; Ohmann, J.L.; Wadell, K.L.; Lindley, D.L.; Schreiber, B. 2001. Decaying wood in Pacific Northwest forests: concepts and tools for habitat management. In: Johnson, D.H.; O'Neil, T.A., manag. dirs. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press: 580-623.

Rosenberg, K.V.; Raphael, M.G. 1986. Effects of forest fragmentation on vertebrates in Douglas-fir forests. In: Verner, J.; Morrison, M.L.; Ralph, C.J., eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Madison, WI: University of Wisconsin Press: 263-272.

Rosso, A.L. 2000. Shrub epiphyte communities in relation to stand management in forests of western Oregon. Corvallis, OR: Oregon State University. 125 p. Ph.D. dissertation.

Ruggiero, L.F.; Jones, L.L.C.; Aubry, K.B. 1991. Plant and animal habitat associations in Douglas-fir forests of the Pacific Northwest: an overview. In: Ruggiero, L.F.; Aubry, K.A.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 447-462.

Saab, V.A.; Dudley, J.D. 1998. Response of cavity-nesting birds to stand-replacement fire and salvage in ponderosa pine/Douglas-fir forests of southwestern Idaho. Res. pap. RMRS-RP-11. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Schreiber, B.; deCalesta, D.S. 1992. The relationship between cavity-nesting birds and snags on clearcuts in western Oregon. Forest Ecology and Management. 50: 299-316.

Spies, T.A.; Franklin, J.F. 1991. The structure of natural young, mature, and old-growth Douglas-fir forests in Oregon and Washington. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 91-110.

Tappeiner, J.C. II; Zasada, J.C.; Ryan, P.; Newton, M. 1991. Salmonberry clonal and population structure: the basis for persistent cover. Ecology. 72: 609-618.

Tappeiner, J.C., Huffman, D.; Marshall, D.; Spies, T.A. 1997. Density, ages, and growth rates in old-growth and young-growth forests in coastal Oregon. Canadian Journal of Forest Research. 27: 638-648.

Tappeiner J.C., II; Emmingham, W.H.; Hibbs, D.E. 2002. Silviculture of Oregon Coast Range forests. In: Hobbs, S.D.; Hayes, J.P.; Johnson, R.L.; Reeves, G.H.; Spies, T.A.; Tappeiner J.C., II; Wells, G.E., eds. Forest and stream management in the Oregon Coast Range. Corvallis, OR: Oregon State University Press: 172-190.

Thomas, S.C.; Halpern, C.B.; Falk, D.A.; Liguori, D.A.; Austin, K.A. 1999. Plant diversity in managed forests: understory responses to thinning and fertilization. Ecological Applications. 9: 864-879.

U.S. Fish and Wildlife Service (USFWS). 2004. 12-month finding for a petition to list the west coast distinct population segment of the fisher (*Martes pennanti*); proposed rule. Federal Register. 69(68): 18769-18792.

Waldien, D.L.; Hayes, J.P.; Huso, M.P. 2006. Use of downed wood by Townsend's chipmunks (*Tamias townsendii*) in western Oregon. Journal of Mammalogy. 87: 454-460.

Walstad, J.D.; Kuch, P.J. 1987. Forest vegetation management for conifer production. New York, NY: John Wiley and Sons. 523 p.

Washington Department of Fish and Wildlife. 2005. Species of concern lists. Available at http://wdfw.wa.gov/wlm/diversty/soc/concern.htm.

Weikel, J.M. 2003. Brown creeper. In: Marshall, D.B.; Hunter, M.G.; Contreras, A.L., eds. Birds of Oregon: a general reference. Corvallis, OR: Oregon State University Press: 453-456.

Weikel, J.M.; Hayes, J.P. 1999. The foraging ecology of cavity-nesting birds in young forests of the northern Coast Range of Oregon. Condor. 101: 58-66.

Wilhere, G. F. 2003. Simulations of snag dynamics in an industrial Douglas-fir forest. Forest Ecology and Management. 174: 521-539.

Wessell, S.J. 2005. Low-mobility species assemblages in managed forests of western Oregon: biodiversity in leave islands, thinned and unthinned forests. Corvallis, OR: Oregon State University. 156 p. M.S. thesis.

SILVICULTURAL GUIDELINES FOR CREATING AND MANAGING WILDLIFE HABITAT IN WESTSIDE PRODUCTION FORESTS

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ABSTRACT

Conventional silvicultural treatments (planting, competition control, and thinning) are being considered as techniques for creating and managing wildlife habitat in Westside production forests of the Pacific Northwest. These methods can be used to diversify forest structure (i.e., species, size, age, and spatial arrangement of trees and other vegetation) and facilitate development of old-forest characteristics. Pre-treatment planning is essential for identifying management intensities appropriate for a given area, retaining existing structural elements, or providing conditions for development of new structural elements. Hardwoods and shrubs from the pre-harvest stand can be managed for habitat within a new conifer plantation if they are given sufficient growing space. Conifer seedlings can be established successfully under low overstory densities, but their growth can be strongly reduced by competition from overstory trees and understory vegetation. Combining thinning and moderate soil disturbance during harvest will create favorable conditions for germination, sprouting, and rhizome expansion of understory species. Thinning will result in a heterogeneous forest structure if it is applied with uneven spacing and retains minor species, standing dead trees, and pockets of tree regeneration. Site-specific characteristics, such as root-rot pockets, soil and topographic variability, and potential for wind damage, should be considered when designing a thinning treatment. The inherent productivity of a forest site will determine the rate at which a diverse stand structure will develop; however, some characteristics of old forests (large cavities in snags, high abundance of coarse woody debris, and nesting platforms on large limbs) will take decades to develop.

INTRODUCTION

Silviculture (from the Latin, *silva cultura*, or forest culture) has been defined as the theory and practice of controlling forest establishment, composition, structure, and growth (Smith et al. 1997). It encompasses systems for regenerating forests as well as specific treatments for tending them. Much of the forest land west of the Cascade Mountain crest (i.e., the Westside) is dominated by relatively young (< 100 years old), naturally-regenerated or planted stands of coast Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*). For most of the 20th century, traditional silvicultural practices in this region were focused primarily on managing forests for wood products. Today's broader view of silviculture for Westside production forests includes managing portions or entire stands for wildlife habitat and other ecological services.

Wildlife habitat has been defined as "the sum total of the environmental factors – food, cover, and water – that a given species of animal needs to survive and reproduce" (Trefethen 1964). Specific forest stand features that can be managed to improve wildlife habitat include density and height of overstory conifers and mid-story hardwoods, cover and height of shrubs, abundance of standing and down woody debris (Hagar et al. 1996), and diversity and abundance of herbaceous species (Hanley et al. 2006, Deal et al. 2004). In this paper we discuss some of the theory behind treatments used to create and sustain habitat and provide general guidelines for their application in Westside production forests. Topics include how to design new stands following timber harvest, how to establish new trees and shrubs in existing stands, and how to thin existing stands to create old-forest structure.

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DESIGNING NEW STANDS

Pre-harvest planning is essential to creating the desired structure of a new forest stand because opportunities for retention or creation of specific habitat features often exist prior to or immediately after harvest including:

- forage (mast, browse, or grazing) species
- nest sites
- snags (standing dead trees) and green trees
- shrub cover
- down wood

For example, selected conifers, hardwoods, or shrubs can be protected during logging and retained into the next stand, providing habitat that otherwise would have taken decades to develop as seedlings or sprouts. Reasons for protecting such vegetation include their ability to provide nesting sites, forage, and cover during the period of establishing a new stand of conifers. Table 1 provides examples of native woody plants that provide important habitat values to Westside wildlife. Wender et al. (2004) found that plant size and age and overstory density were the primary determinants of flowering and fruiting for nine Westside shrub species. This indicates that the largest and oldest individual plants and those growing under low overstory densities have the greatest potential for providing forage for wildlife.

To focus regeneration treatments appropriately, areas within the future stand can be designated for wood production only, a combination of wood production and wildlife habitat, and habitat only. In this way, treatments such as competing vegetation control and fertilization would be applied to the areas where they most effectively encourage wood production. Some herbicide treatments used in site preparation and competition release (e.g., imazapyr and hexazinone) have been shown to improve wildlife habitat in the Southern U.S. by favoring blackberry (*Rubus* spp.), huckleberry (*Vaccinium* spp.), and legume species, and by reducing vegetation height and promoting sprouting and succulent growth of woody species (Miller and Miller 2004). Mechanical crushing or cutting treatments also can be used to reduce height and stimulate succulent growth of browse species. Piles of woody debris typically left after timber harvest can be retained to provide cover in selected areas within the stand. However, rodent and rabbit populations are likely to increase in and around these debris accumulations; therefore, such habitat should be reserved for areas not designated primarily for wood production because of potential animal damage to conifer seedlings.

Snags provide critical habitat for many species of birds and small mammals. The Washington State Department of Natural Resources (2006) provides the following guidelines for creating snags from living trees, especially those with broken tops or large branches:

- For safety, locate snags away from trails, roads, buildings, and other structures. Guidelines for selecting reserve trees and snags should be consulted prior to timber harvest (e.g., Washington State Department of Labor and Industries 2006).
- Conifer snags last longer than hardwood snags; selected trees should have a stem diameter of at least 14 in to provide nest sites and for increased longevity.
- Trees should be topped or girdled at or above the first whorl of branches, at least 14 ft above ground and, ideally, much higher. Smaller trees or stumps at least 3 ft tall may be useful for some cavity nesters.
- Following are desirable features of snags:
    - A jagged top decays faster, making it more useable for some wildlife species.
    - Artificial cavities (at least 6 in deep and 4 in high) in newly-created snags also accelerate decay.
    - Large branches (2 ft long or more) provide foraging habitat.
    - Roosting slits (angled upward at least 8 in deep and 2 in wide) are used by bats and some birds.

If new seedlings or sprouts of hardwoods and shrubs are to be grown to maturity within a conifer plantation, an unplanted buffer area (two or more planting rows wide) should be provided around them to ensure adequate growing space for their survival. Conifer seedlings designated for wood production should not be planted in the buffer area or otherwise they may succumb to mortality from overtopping (fig. 1).

ESTABLISHING UNDERSTORY CONIFERS

Conifer stands in Westside production forests often have a relatively dense, single-layered canopy structure. Such structures can be diversified by creating or accelerating development of additional canopy layers either by promoting existing understory trees or by planting tree seedlings. Using existing understory trees is easier and cheaper than planting seedlings, but planting may be necessary if establishing selected species is the goal.

Planted seedlings of most Westside conifer species will survive under a wide range of overstory densities, although their growth will be slowed greatly relative to full sunlight conditions. Douglas-fir is relatively intolerant of shade, and

Table 1—Common woody plants native to Westside forests of the Pacific Northwest that provide habitat values for wildlife (USDA Natural Resources Conservation Service 2006)

Common name	Scientific name	Habitat values
bigleaf maple	*Acer macrophyllum* Pursh	browse, cover
bitter cherry	*Prunus emarginata* (Dougl. ex Hook.) D. Dietr.	mast, browse
black hawthorn	*Crataegus douglasii* Lindl.	mast, browse
California black oak	*Quercus kelloggii* Newberry	mast, browse
California hazelnut	*Corylus cornuta* Marh. var. *californica* (A. DC.) Sharp	mast, cover
cascara	*Rhamnus purshiana* DC.	browse, cover
ceanothus	*Ceanothus* spp.	browse, cover
cottonwood	*Populus* spp.	browse
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco	browse, cover
elderberry	*Sambucus* spp.	mast, browse, cover
huckleberry	*Vaccinium* spp.	mast, browse, cover
Oregon ash	*Fraxinus latifolia* Benth.	browse
Oregon white oak	*Quercus garryana* Dougl.	mast, browse
Pacific madrone	*Arbutus menziesii* Pursh	mast
red alder	*Alnus rubra* Bong.	browse
western redcedar	*Thuja plicata* Donn ex D. Don	browse
red-osier dogwood	*Cornus sericea* L.	mast, browse, cover
salal	*Gaultheria shallon* Pursh	mast, browse, cover
salmonberry	*Rubus spectabilis* Pursh	mast, browse, cover
Saskatoon serviceberry	*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roemer	mast, browse, cover
tanoak	*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.	mast, cover
trailing blackberry	*Rubus ursinus* Cham. & Schlecht.	mast, browse
western mountain ash	*Sorbus sitchensis* M. Roemer	mast
willow	*Salix* spp.	browse, cover
woods rose	*Rosa woodsii* Lindl.	browse
vine maple	*Acer circinatum* Pursh.	mast, browse, cover

Figure 1—A 7-year-old sprout clump of bigleaf maple (right) that has competed with and killed all of the slower growing Douglas-fir seedlings under its canopy. *Photo by Robert G. Wagner*

therefore reasonable rates of seedling growth require much lower overstory densities than required by seedlings of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) or western redcedar (*Thuja plicata* Donn ex D. Don). Douglas-fir seedlings need greater than 20 percent of full sunlight to survive, at least 40 percent for continued morphological development (Mailly and Kimmins 1997), and full sunlight for maximum growth rates (Drever and Lertzman 2001). Western redcedar seedlings require only 10 percent of full sunlight to survive (Wang et al. 1994), and their maximum growth rates can occur at only 30 percent of full sunlight (Drever and Lertzman 2001).

If the goal is to manage understory conifers so they provide a second story for habitat and ultimately become mature crop trees, a relatively low overstory density is recommended. Assuming a relative density of 65 for a fully-stocked stand of Douglas-fir (Curtis 1982), overstory densities of 40 percent of full stocking (thinned stands) reduced fifth-year stem volume of Douglas-fir, western hemlock, and western redcedar seedlings by 87, 85, and 76 percent, respectively, relative to seedlings growing in clearcuts (fig. 2a) (Harrington 2006). Overstory densities of 16 percent of full stocking (shelterwoods) reduced stem volume of Douglas-fir and western hemlock by 46 and 30 percent relative to seedlings growing in clearcuts, respectively; however, redcedar attained its maximum stem volume in shelterwoods. Brandeis et al. (2001) observed similar reductions in growth of under-planted seedlings of western hemlock, western redcedar, and grand fir (Abies grandis (Dougl. ex D. Don) Lindl.) with increasing overstory density. Overall, these results suggest that overstory densities should not exceed 20 percent of full stocking if reasonable rates of development are expected for conifer seedlings.

If conifer seedlings are to be planted near overstory trees, it may be necessary to locate them so that overstory trees: (1) do not compete excessively with them, and (2) can be har-vested without severely damaging them. Overstory trees are effective competitors for soil water and nitrogen, and even low overstory densities can strongly reduce availabi-lity of these resources (Prescott 1997, Harrington 2006). Overstory density can be managed via either one intensive removal (i.e., leaving < 10 percent of full stocking) or several removals (i.e., each leaving 20 percent of full stocking) to maintain the vigor of understory conifers over time.

A dense cover of shrub and herbaceous vegetation will provide further competition for conifer seedlings in what is already a highly-competitive understory environment. In such conditions, it may be necessary to reduce height and cover of competing vegetation to provide adequate availability of light and soil water to support seedling development. Some of the reduction in understory competition can be accomplished during logging; however, in other cases manual cutting (to reduce vegetation height) or herbicide application (to reduce vegetation cover) will be needed to create viable planting spots and to ensure that the seedlings will survive and grow at reasonable rates. Regardless of overstory density, controlling competing vegetation around individual seedlings doubled the fifth-year stem volume of Douglas-fir and redcedar, while it tripled the volume of western hemlock (fig. 2b) (Harrington 2006). Brandeis et al. (2001) observed similar increases in growth of under-planted seedlings of western hemlock and grand fir following control of competing vegetation. Salal is especially competitive with western hemlock (Mallik and Prescott 2001, Harrington 2006) probably because the fine roots of both species are concentrated in the upper forest floor (Bennett et al. 2002).

In mesic environments near the Pacific Coast or at moderate elevations, reductions in overstory density can stimulate development of excess accumulations of conifer regeneration, especially western hemlock (Deal and Farr 1994). Although desirable at lower densities, these seedlings can form a dense canopy layer that prevents or suppresses development of other understory species important to wildlife. Drastic reduction in density of hemlock regeneration may be necessary to maintain a diverse community of herbaceous species and promote germination of shrubs. Such density reductions can be accomplished via moderate soil disturbance during timber harvest or a subsequent pre-commercial thinning.

Animal damage, particularly browsing on Douglas-fir and western redcedar by black-tailed deer (*Odocoileus hemionus columbianus* Richardson) and Roosevelt elk (*Cervus canadensis roosevelti* Merriam) (Brandeis et al. 2002), can further delay conifer seedling development. Frequency of seedlings browsed can increase as redcedar becomes increasingly visible either from reductions in density of overstory trees or understory vegetation (Harrington 2006). Deer browse on western hemlock is rare; however, seedlings of most Westside conifers are susceptible to antler scraping by deer and elk. Gaps in understory vegetation created by mountain beaver (*Aplodontia rufa pacifica* Merriam) will contribute to the structural diversity of new conifer stands.

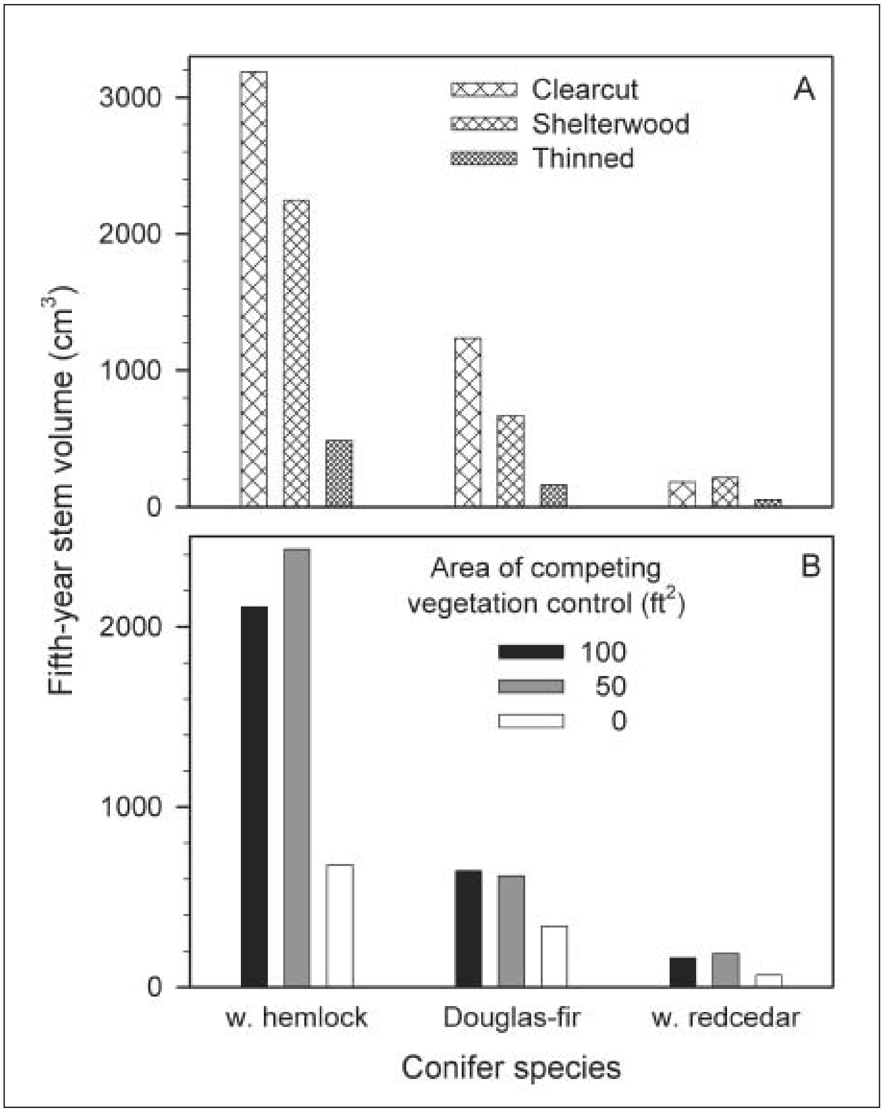

Figure 2—Stem volume of western hemlock, Douglas-fir, and western redcedar seedlings five years after planting in clearcuts, shelterwoods, or thinned stands with 100, 50, or 0 ft^2 areas of competing vegetation control around each seedling (Harrington 2006). Average responses to overstory density and competing vegetation control are shown in (a) and (b), respectively.

PROMOTING UNDERSTORY VEGETATION

During the past decade, experiments and surveys were initiated to quantify the effects of thinning on forest structure (Hayes et al. 1997, Bailey and Tappeiner 1998). By increasing availability of light in the understory, and perhaps also belowground resources, thinning facilitates increases in seed production and vegetative growth of existing understory vegetation. Species can expand their site occupancy through spread of rhizomes (e.g., salal, trailing blackberry, and salmonberry) or layering (rooting) of prostrate stems (e.g., vine maple).

When thinning is combined with a moderate intensity of soil disturbance, such as from skidding of logs during timber harvest, it creates germination substrates that facilitate seedling regeneration of woody and herbaceous species. Increases in seedling germination and survival of both shade-tolerant species (e.g., salal, vine maple, huckleberry, tanoak, and bigleaf maple) and shade-intolerant species (e.g., red alder, salmonberry, and Pacific madrone) have been observed after thinning Douglas-fir stands (Haeussler et al. 1995, Huffman et al. 1994, Huffman and Tappeiner 1997, Tappeiner et al. 1986, Tappeiner and Zasada 1993). However, development of shrub cover and wildlife forage occurs much more rapidly from sprouts, and thus, this method of regeneration is likely to be preferred over that of seedlings.

Thinning intensity and pattern will influence the spatial distribution of woody debris and soil disturbance. For example, in the Demonstration of Ecosystem Management Options (DEMO) study, depth and cover of debris were greater at the highest thinning intensity and in aggregated versus dispersed retentions of overstory trees (Halpern and McKenzie 2001). Reduced abundances of late-seral herbaceous species observed soon after harvest probably were associated with the patterns of debris accumulation and soil disturbance that resulted from thinning (Aubry et al. 2004).

USING THINNING TO CREATE OLD-FOREST STRUCTURE

General Principles

The high productivity of many Westside forests enables managers to grow structural characteristics of old forests (e.g., large trees, standing and down woody debris, a multi-layered and spatially heterogeneous canopy, and a high diversity of plant species) in a much shorter time interval than occurs through typical patterns of forest succession. Prescriptions for managing young stands to achieve old-forest characteristics generally call for thinning of overstory trees because most young stands were planted at high densities to grow high yields of wood. In conventional thinning, the smaller trees are removed (thinning from below) at a relatively uniform spacing to enable the largest, most vigorous trees to close the stand canopy and continue their rapid growth. Thinning for old-forest characteristics will likely remove large and small trees in an irregular pattern to promote not only the growth of large trees, but also a diverse tree, or shrub understory. There has been relatively little long-term experience in thinning to achieve old-forest characteristics; however, following are some principles from research and observation that should apply:

- Maintain large trees from the previous stand. These trees are apt to have large limbs, cavities, and rough bark that are important habitat for wildlife. In addition they may be a source of propagules for lichens, mosses, and mycorrhizae to enable regeneration of these species in the new stand.

- Protect minor species. Certain tree species may occur infrequently, such as western redcedar, western hemlock, yew (*Taxus brevifolia* Nutt.), Sitka spruce (*Picea sitchensis* (Bong.) Carr.), and Engelmann spruce (*Picea engelmannii* Parry ex Engelm.). Retaining these trees could provide a seed source that enables the species to increase their numbers on the site and contribute to species diversity and stand heterogeneity.

- Create seedbeds for establishment of understory plants. Some disturbance to the forest floor (e.g., skidding of logs during harvest) can provide a seed bed to aid establishment of understory woody and herbaceous plants.

- Control understory competition when it becomes excessive. A dense understory of shrubs like salal, vine maple, salmonberry, huckleberry, or blackberry, or hardwoods like bigleaf maple, Pacific madrone, or tanoak can interfere with seedling establishment of conifers and other species. In these cases it might be necessary to control shrub and hardwood density and plant conifer seedlings to establish a multi-storied stand.

- Manage some trees or parts of stands at low density. Large old-growth trees generally grew quite rapidly when they were young, and their diameters at 200 to > 300 years were correlated with their size and growth rates when they were 50 years old (Tappeiner et al. 1997, Poage and Tappeiner 2002). This research suggests that some trees should be grown at low density when they are young and the tree density around them kept low for several decades. This can be accomplished by thinning around selected large trees – those that have the most rapid growth – in order to provide space, maintain large crowns and continue rapid diameter growth.

- Use thinning to favor patches of regeneration. Thinning can be concentrated around patches of advanced tree regeneration to facilitate development of multi-storied stands.

- Allocate some trees for production of woody debris. In stands where there are few large snags or logs on the forest floor, it may be necessary to grow large trees to kill for snags or logs or to ensure there are enough large trees to make snags and logs from natural agents (wind, insects and root pathogens) and to maintain a large tree component in the overstory. Risk of an outbreak of Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) from such treatments should be

Figure 3—A dense 23-year-old Douglas-fir plantation that has encroached upon and suppressed a slower growing multi-stemmed tree of bigleaf maple. *Photo by Timothy B. Harrington*

minimal (Ross et al. 2006). For specific guidelines on managing stands to produce appropriate abundances and sizes of woody debris, consult the DecAID Wood Advisor (Mellen et al. 2003).

- Relatively dense overstories favor some herbaceous species. Maintaining dense patches of overstory trees or excessive conifer regeneration may retard establishment of a dense cover of shrubs and provide sites for late-seral herbaceous plants (Lindh 2005).

- Old trees will respond positively to thinning. Age or size of conifer trees is not an obstacle to thinning or use of prescribed fire. Very large (> 40 in diameter), old (> 200 years) trees can respond positively to thinning (Latham and Tappeiner 2002).

- Create space for development of hardwoods. Height growth of conifers at ages of 50 years or more is usually greater than that of hardwoods. As hardwoods become overtopped and encroached upon by neighboring conifers, their crowns will decline in size and vigor (fig. 3). Therefore, reducing density of conifer trees around hardwoods will enable hardwoods to maintain vigorous, full crowns that can produce mast for wildlife, provide cavities for nesting, and support bryophyte and lichen populations. A heavy thinning around 0.25- to 0.6-acre patches of hardwoods will ensure they remain a viable part of a vigorous conifer stand.

When used according to these principles, thinning specifications will be spatially variable throughout a stand. For example minor species, opportunities to release seedlings and saplings, and trees remaining from the previous stand, may occur sporadically. Similarly large, rapidly growing trees usually do not occur in a regular pattern due to differences in stand density and site productivity. If the focus is on the objectives stated above, then parts of the stand might not be thinned or would only be lightly thinned. Given this variability, flexibility in prescription writing and application is advised, since it is unlikely that all objectives will be accomplished on each acre. For example if the goal is to grow 30 large trees per acre, the range in per-acre density might be > 40 trees in some areas and < 10 trees in other areas with an average of 30 trees over an area of five to ten acres. Variable density thinning, a recent approach for conserving biodiversity while encouraging development of old-forest structure in young, fully-stocked stands of Douglas-fir, creates gaps and retains uncut areas within a stand matrix that is thinned in a conventional manner (Carey and Curtis 1996, Harrington et al. 2005).

Forest- or site-specific information may be needed upon which to base treatments to accelerate development of old-forest structure. Most of this information can be collected at the local forest type, or plant association level and it includes:

- Sizes, densities, and species composition of large overstory trees and second-story trees needed to produce multi-storied stands.
- The stand density or gap size needed to grow understory trees.
- Sizes and densities of snags and logs on the forest floor. This should help determine numbers of trees to leave after thinning.
- The effects of snow, wind, insects, and pathogens on tree mortality and the associated production of snags, logs on the forest floor, and cavities for nesting.

Site productivity and potential for tree growth vary considerably throughout the Westside; therefore age alone is not a good descriptor of a stand. On low productivity sites, stands can take over 100 years to reach the same stage of development that they could reach in 50 years on productive sites.

There are site-specific variables that affect stand development. Root diseases that kill overstory trees are widespread in Westside forests; however, their effects on stand development vary substantially within and among stands, killing Douglas-fir and favoring species like western hemlock, western redcedar, and vine maple in some stands. Swiss needle cast, a foliage disease caused by the fungus, *Phaeocryptopus gaeumannii*, is currently epidemic in parts of northwestern Oregon, and appears to be nearly eliminating Douglas-fir from some stands and converting them to western hemlock and western redcedar. This disease clearly has a major impact on stand development and the potential for infected stands to achieve old-forest characteristics. The effects of pathogens, insects, and wind can be beneficial especially in older stands as they make snags, logs on the forest floor, and nesting cavities. However, their potential effects need to be considered in young stands, because they can have major impacts on stand development.

Past management has varied across the region, affecting the potential for development of old-forest characteristics. Some stands have been planted at low densities or thinned at early ages, and therefore, have the potential for rapid development of large trees and establishment of an understory. However, tree growth rates are slow in stands that have grown at high density for several decades and there may be little understory present. Also trees in high density stands will require more time to respond to thinning than trees in less dense stands, and they may be susceptible to damage by wind, snow, and ice until their stem diameters increase relative to height. Older stands (> 30 years) that have been thinned often have a conifer understory established that can be released by subsequent thinnings to produce multi-storied stands. Species composition can be affected during reforestation, competition control, and early thinning. For example, stands reforested with mixed species will develop differently than those that have had most hardwoods and shrubs removed to reduce competition with conifers.

Tree and Stand Responses to Thinning

Thinning affects both the growth of individual trees and development of the stand. Thinning reduces the leaf area of the canopy, thereby increasing light and often availability of soil water and nutrients. Reduced competition for these resources increases the growth of overstory trees and the abundance of understory plants. Site resources become available to fewer trees and shrubs enabling them to increase their growth rates.

A major response of trees to thinning is the maintenance or increase in crown size. Increased light or space among trees enables the lower branches on the crown to remain alive and not be shaded out by adjacent trees. Thus, tree crowns expand in width as branches grow longer and thicker. Tree crown length increases as low branches remain alive and height growth continues. Crown expansion also occurs via epicormic branching (i.e., sprouting of new branches below the crown as the tree stem is exposed to increased light from removal of neighboring trees). Epicormic branching is common in Douglas-fir and often forms fan-like branches that are important roosting structures for birds and arboreal rodents.

Growth in the stem and branches of trees is accelerated by thinning because foliage density or leaf area within the crown increases and crown length is maintained or increased. This increase in leaf area enables trees to increase their photosynthesis; consequently, they have the resources to increase stem and branch diameter or volume. As crown length increases, stem diameter growth is maintained or increased on the lower part of the stem. Thus, the tree's stem becomes more tapered and consequently more resistant to windthrow or stem breakage.

An increase in diameter may occur within three to five years after thinning depending upon stand density and tree growth before thinning. If trees are growing slowly an obvious increase in ring width may occur. If trees are growing vigorously, thinning may maintain their rate of growth but there will be no obvious increase. Repeated measurements of stem diameter or increment coring will be needed to evaluate stem growth responses to thinning. Short-term effects of thinning on crown size and density are more difficult to measure or observe. With variable density thinning, growth will be greater for trees near gaps or along skid trails than for those in uncut areas (Harrington et al. 2005).

Important Caveats to Consider

Planning a program of young stand management is an important part of the development of old-forest characteristics. Currently a very small percentage of the young stands are being thinned. It appears that many stands will reach maturity and final harvest without being thinned. Forest managers may choose the option of either: (a) treating very few stands with thorough, one-time treatments and severe reduction in density, or (b) conducting a light thinning in many stands to begin the process of old-forest development and develop options for future treatments. For example the initial treatment might enable the establishment of trees in the understory and begin the development of large trees. A second thinning would release the understory trees and provide for the continued growth of large trees. A caution in thinning approach (a) (above) might be that a single heavy thinning could establish a dense shrub (or conifer) understory, making it difficult for a diverse understory to develop. Thinning around bigleaf maple, Pacific madrone, or California black oak may be needed to maintain or develop them for habitat. As conifers overtop them, hardwoods lose their ability to produce mast and large limbs and eventually may die from competitive effects of shade (fig. 3).

It is important to realize that it takes time to develop old-forest attributes. Probably, the most obvious effects of thinning are an increase in understory density and the establishment and growth of seedlings in the understory. The early increase in understory abundance can be important to wildlife species. A diverse shrub understory supports insect populations that are prey for a variety of birds. Increased mast production can benefit birds and small mammals. Browse for ungulates may also be an important early result. However, some attributes of old forests, such as large cavities, nesting platforms on large limbs, or a high abundance of coarse woody debris, will take decades to develop.

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LITERATURE CITED

Aubry, K.B.; Halpern, C.B.; Maguire, D.A. 2004. Ecological effects of variable-retention harvests in the northwestern United States: the DEMO study. In: Szaro, R.C., Peterson, C.E.; von Gadow, K.; Kräuchi, N., eds. Creating a legacy for sustainable science-based forest management: lessons learned from field experiments. Forest Snow and Landscape Research. 78: 119-137.

Bailey, J.D.; Tappeiner, J.C. 1998. Effects of thinning on structural development in 40- to 100- year-old Douglas-fir stands in western Oregon. Forest Ecology and Management. 108: 99-113.

Bennett, J.N.; Andrew, B.; Prescott, C.E. 2002. Vertical fine root distributions of western redcedar, western hemlock, and salal in old-growth cedar-hemlock forests on northern Vancouver Island. Canadian Journal of Forest Research. 32: 1208-1216.

Brandeis, T.J.; Newton, M.; Cole, E.C. 2001. Underplanted conifer seedling survival and growth in thinned Douglas-fir stands. Canadian Journal of Forest Research. 31: 302-312.

Brandeis, T.J.; Newton, M.; Cole, E.C. 2002. Biotic injuries on conifer seedlings planted in forest understory environments. New Forests. 24: 1-14.

Carey, A.B.; Curtis, R.O. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. Wildlife Society Bulletin. 24: 610-620.

Curtis, R.O. 1982. A simple index of stand density for Douglas-fir. Forest Science. 28: 92-94.

Deal, R.L.; Farr, W.A. 1994. Composition and development of conifer regeneration in thinned and unthinned stands of western hemlock and Sitka spruce in southeast Alaska. Canadian Journal of Forest Research. 24: 976-984.

Deal, R.L.; Hennon, P.E.; Orlikowska, E.H.; D'Amore, D.V. 2004. Stand dynamics of mixed red alder-conifer forests of southeast Alaska. Canadian Journal of Forest Research. 34: 969-980.

Drever, C.R.; Lertzman, K.P. 2001. Light-growth responses of coastal Douglas-fir and western redcedar saplings under different regimes of soil moisture and nutrients. Canadian Journal of Forest Research. 31: 2124-2133.

Haeussler, S.; Tappeiner, J.C.; Greber, B. 1995. Germination and first-year survival of red alder seedlings in the central Oregon Coast Range. Canadian Journal of Forest Research. 25: 1487-1491.

Hagar, J.C.; McComb, W.C.; Emmingham, W.H. 1996. Bird communities in commercially thinned and unthinned Douglas-fir stands of western Oregon. Wildlife Society Bulletin. 24: 353-366.

Halpern, C.B.; McKenzie, D. 2001. Disturbance and post-harvest ground conditions in a structural retention experiment. Forest Ecology and Management. 154: 215-225.

Hanley, T.A.; Deal, R.L.; Orlikowska, E.W. 2006. Relations between red alder (*Alnus rubra* Bong.) and understory vegetation in a gradient of mixed hardwood-conifer, young-growth forest. Canadian Journal of Forest Research. 36: 738-748.

Harrington, C.A.; Roberts, S.D.; Brodie, L.C. 2005. Tree and understory responses to variable-density thinning in western Washington. In: Balancing ecosystem values: innovative experiments for sustainable forests. Peterson, C.E. and Maguire, D.A., eds. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 97-106.

Harrington, T.B. 2006. Five-year growth responses of Douglas-fir, western hemlock, and western redcedar seedlings to manipulated levels of overstory and understory competition. Canadian Journal of Forest Research. 36: 2439-2453.

Hayes, J.P.; Chan, S.S.; Emmingham, W.H.; Tappeiner, J.C.; Kellogg, L.D.; Bailey, J.D. 1997. Wildlife response to thinning young forests in the Pacific Northwest. Journal of Forestry. 95: 28-33.

Huffman, D.W.; Tappeiner, J.C.; Zasada, J.C. 1994. Regeneration of salal in the central Coast Range forests of Oregon. Canadian Journal of Botany. 72: 39-51.

Huffman, D.W.; Tappeiner, J.C. 1997. Clonal expansion and seedling recruitment of Oregon-grape (*Berberis nervosa*) in Douglas-fir (*Pseudotsuga menziesii*) forests: comparison with salal (*Gaultheria shallon*). Canadian Journal of Forest Research. 27: 1788-1793.

Latham, P.; Tappeiner, J.C. 2002. Response of old-growth conifers to reduction in stand density in western Oregon forests. Tree Physiology. 22: 137-146.

Lindh, B. 2005. Effects of conifer basal area on understory herb presence, abundance, and flowering in a second-growth Douglas-fir forest. Canadian Journal of Forest Research. 35: 938-948.

Mailly, D.; Kimmins, J.P. 1997. Growth of *Pseudotsuga menziesii* and *Tsuga heterophylla* seedlings along a light gradient: resource allocation and morphological acclimation. Canadian Journal of Botany. 75: 1424-1435.

Mallik, A.U.; Prescott, C.E. 2001. Growth inhibitory effects of salal on western hemlock and western red cedar. Agronomy Journal. 93: 85-92.

Mellen, K.; Marcot, B.G.; Ohmann, J.L.; Waddell, K.L.; Livingston, S.A.; Willhite, E.A.; Hostetler, B.B.; Ogden, C.; Dreisbach, T. 2003. DecAID, the Decayed Wood Advisor for managing snags, partially dead trees, and down wood for biodiversity in forests of Washington and Oregon. Version 2.0. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station and Pacific Northwest Region; Portland, OR; U.S. Department of the Interior, Fish and Wildlife Service. http://wwwnotes.fs.fed.us:81/pnw/DecAID/DecAID.nsf (Accessed 3 October 2006).

Miller, K.V.; Miller, J.H. 2004. Forestry herbicide influences on biodiversity and wildlife habitat in southern forests. Wildlife Society Bulletin. 32(4): 1049-1060.

Poage, N.J.; Tappeiner, J.C. 2002. Long-term patterns of diameter and basal area growth of old-growth Douglas-fir trees in western Oregon. Canadian Journal of Forest Research. 32: 1232-1243.

Prescott, C.E. 1997. Effects of clearcutting and alternative silvicultural systems on rates of decomposition and nitrogen mineralization in a coastal montane coniferous forest. Forest Ecology and Management. 95: 253-260.

Ross, D.W.; Hostetler, B.B.; Johansen, J. 2006. Douglas-fir beetle response to artificial creation of down wood in the Oregon Coast Range. Western Journal of Applied Forestry. 21: 117-122.

Smith, D.M.; Larson, B.C.; Kelty, M.J.; Ashton, P.M.S. 1997. The practice of silviculture: applied forest ecology. 9th ed. New York: John Wiley and Sons. 537 p.

Tappeiner, J.C.; McDonald, P.M.; Hughes, T.F. 1986. Survival of tanoak and Pacific madrone seedlings in forests of southwestern Oregon. New Forests. 1: 43-55.

Tappeiner, J.C.; Zasada, J.C. 1993. Establishment of salmonberry, salal, vine maple and bigleaf maple seedlings. Canadian Journal of Forest Research. 23: 1175-1780.

Tappeiner, J.C.; Huffman, D.; Marshall, D.; Spies, T.A.; Bailey, J.D. 1997. Density, ages, and growth rates in old-growth and young-growth forests in coastal Oregon. Canadian Journal of Forest Research. 27: 638-648.

Trefethen, J.B. 1964. Wildlife management and conservation. Boston, MA: D.C. Heath and Co. 120 p.

USDA Natural Resouces Conservation Service. 2006. PLANTS database. http://plants.usda.gov (Accessed 16 October 2006).

Wang, G.G.; Qian, H.; Klinka, K. 1994. Growth of *Thuja plicata* seedlings along a light gradient. Canadian Journal of Forest Research. 72: 1749-1757.

Washington State Department of Labor and Industries. 2006. Guidelines for selecting reserve trees. http://www.lni.wa.gov/ipub/417-092-000.pdf (Accessed 3 October 2006).

Washington State Department of Natural Resources. 2006. Tips for creating snags. http://www.dnr.wa.gov/htdocs/rp/stewardship/bfs/WESTERN/tipsforcreatingsnags.html (Accessed 3 October 2006).

Wender, B.W.; Harrington, C.A.; Tappeiner, J.C. 2004. Flower and fruit production of understory shrubs in western Washington and Oregon. Northwest Science. 78: 124-140.

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WILDLIFE HABITAT MANAGEMENT PRACTICES ON PRIVATE NON-INDUSTRIAL FORESTLANDS

Jim Bottorff[1]

ABSTRACT

Non-industrial private forestlands (NIPF), also known as family-owned forests or family forests, represent one of the bigger challenges facing forestland managers (including timber harvesters, foresters, and forest wildlife biologists) in Washington State and probably beyond. Those practicing traditional forestry (timber harvest based revenue production) may be particularly challenged, and professionally rewarded, when working with NIPF landowners due to the combination of diverse past site management and highly variable landowner objectives. Many of these objectives may or may not be related to forest management and income production (Gootee 2004). One of the biggest impediments to effective wildlife habitat management is getting the practicing forestland managers to understand the objectives and recognize opportunities to protect, enhance, and create wildlife habitat. There may be a professional/personal conflict with accepting and implementing landowner wildlife objectives as co-equal with timber management and especially as a primary objective. Perkey (1989) stated it succinctly: "those of us involved with management of the private non-industrial forest must learn to use our silvicultural knowledge effectively to accomplish non-silvicultural landowner objectives, including wildlife habitat management." These challenges are continuing to be met through the Forest Stewardship Program (FSP) now within the Small Forest Landowner Office (SFLO) of the Washington State Department of Natural Resources (DNR). The wildlife goal of the FSP has been to implement practices that protect, enhance, and even create wildlife habitat in conjunction with standard timber management activities and done in such a way that is cost effective for the landowner and easily learned by the on-site forest worker. Most of the techniques are based on well-documented long-term observations and emerging science. For effective development and implementation of wildlife habitat practices it is essential to understand the background and motivation of these forestland owners and the relationship of these forested parcels within the forested landscape.

KEYWORDS: Non-industrial private forestlands, habitat management practices, wildlife trees, coarse woody debris.

CHARACTERISTICS OF FAMILY FOREST OWNERS

Family forest owners come from very diverse backgrounds and levels of experience but usually unrelated to forestry. They have very wide ranges of management objectives and reasons for acquiring and/or retaining ownership of forestland. Creighton et al. (2002) reported a wide range of characteristics. Fourteen percent owned less than 10 acres while 23 percent owned more than 100 acres. The median ownership from their surveys was just less than 40 acres. Only one-half the owners lived on their land and for those that did not, about one-half lived more than 50 miles distance. The NIPF owner tends to be well educated: three percent have not completed high school; whereas, well over one-half have at least some college education including 17 percent that have attended graduate schools. They also tend to be older than the general populace: over one-half are older than 55 and seven percent are under 40 years of age. It should be noted that this advancing age scenario directly influences wildlife habitat practices they are interested in and willing to implement. Although a whole host of long-range practices that will enhance numerous generations of

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wildlife are available, the visible benefits are too far into the future to warrant much landowner interest.

Their reasons for owning forestland are probably the most revealing characteristic that creates challenges for forestland managers. When given choices to rate as important reasons for land ownership over 80 percent cited providing wildlife habitat. Just less than one-half listed income from timber harvest as very to somewhat important.

CHARACTERISTICS, LOCATION, AND SIGNIFICANCE OF NIPF

About 59 percent of forestland in the United States is family-owned (Johnson 1997) while family forests comprise about 19 percent (about 2.6 million acres) of the total forestland in Washington State (USDA 2000). Due to Endangered Species Act issues and public expectations; timber harvest on public lands has declined significantly. Private lands have taken up the slack with family-owned forests (with only 19 percent of the ownership) accounting for almost 30 percent of the harvest by volume (WDNR 1999).

Family forests are often located in the more fertile lowlands with high site potential and productivity. These lands are also subject to increasing development pressures (Johnson 1997). Almost 90 percent of NIPF land in Washington is located below 3,000 feet elevation and almost one-half is below 1,500 feet elevation (WDNR 2002).

WILDLIFE HABITAT PRACTICES

Ideally, management practices should be applied to intact ecosystems or at least to identifiable landscapes to benefit the greatest number of species over time (Urban et al. 1987). Because of the ownership characteristics, family-owned forests must be managed as ‘patches’ of forested wildlife habitat within and not across the landscape. Therefore, management practices must fit into individual stand management considerations, and as stated above, they must be cost-effective and easily applied. The Forest Stewardship Program has also strived to recommend those practices that will benefit the greatest number of species within the listed constraints. The most common practices then are as follows.

Snags and Wildlife Trees

These include both snags (dead trees) and wildlife trees (those with substantial defect such as broken tops, multiple tops, dying tops, stem damage and decay, numerous large dead branches, or other forms of obvious vigor decline). This is one of the most, if not the most important habitat feature in managed forests in terms of the number of species it serves (Neitro et al. 1985). Existing Forest Practice Act requirements are insufficient in capturing the amount of this structural component for all but an absolute minimum number of dependent species and then it is dependent on assuring that the appropriate size, type, and distribution is achieved. (Zarnowitz and Manuwal 1985). Several methods are available to protect, enhance, or even create this habitat type as a component of food, shelter, and cover for almost 100 species of snag-dependent wildlife. These include:

- identification of suitable snags and wildlife trees for retention in every stand age to be managed,
- enhancement and creation of snags of various heights and diameters,
- high-stumping (stumps at least 3 ft in height),
- appropriate numbers and distribution of snags and wildlife trees.

Coarse Woody Debris

Like snags, coarse woody debris is essential to a broad array of wildlife species and is a regulated resource as well. It is an easy and effective resource to manage if the needs of dependent wildlife species are considered. Coarse woody debris can be created and/or retained in stands of all size and age classes. Management of this resource includes:

- identification and distribution of suitable pieces for retention,
- creation and distribution of suitable pieces of coarse woody debris.

Understory Vegetation

This vegetation supplies food, shelter, and cover for about 100 species of wildlife including all game species. This vegetative component includes not only the herbaceous layer but deciduous shrubs and trees. Those that produce hard or soft mast (nuts and certain fruits) are of particular concern due to the large number of wildlife species (including nectaring species) that depend on this relatively small number of tree and shrub species for their well-being. These practices include:

- identification and retention of mast-producing trees and shrubs,
- planting appropriate trees and shrubs,
- thinning overstory trees to assure suitable space and sunlight is available for these species.

Forage Seeding

Several wildlife forage seed mixes are available that can readily be applied to disturbed areas such as skid roads, logging roads, landings, slash burn sites, or other disturbed sites. Appropriately applied in the spring and/or fall, these mixes often result in increased wildlife forage for birds and mammals, nest site availability, reduced erosion, and reduced invasion and establishment of non-native invasive weed species on those sites.

Variable Density Thinning

There are many different approaches to adding both vertical and horizontal diversity within even-aged stands with variable density thinning, a very workable system when thinning (both precommercial and commercial) stands. This involves creating openings in closed canopy stands that are at least one site-standard tree height in diameter and leaving clumps of the same general size that are lightly thinned or unthinned to accommodate those species needing hiding, nesting, or escape cover in closed canopy stands. Residual trees can be left in openings if the canopy closure is less than 40 percent after thinning. Shrubs may be retained in openings or planted along with a forage seed mix to accommodate understory and shrub-dependent wildlife. Snags of all heights including high stumps may be created or retained in these openings. Hazard trees may be centered in unthinned or lightly thinned patches so safety is not compromised while retaining wildlife structure. In even-aged stands, these variations to the standard prescribed thinning regime should total at least one-fourth of the stand. Stands proposed for a variable thinning regime should be evaluated on the basis of surrounding stand structure and stand size.

Hydrological Restoration

Very well-developed and stringent legal requirements are in place for identified riparian zones and forested wetlands. However, opportunity exists to protect very important aquatic and adjacent terrestrial habitats through seep and spring development, identification and protection of headwall environments, and alternate plans developed through the SFLO of the DNR. Most of the techniques have been developed to protect aquatic species with an emphasis on salmonids. However wildlife habitat, for both terrestrial and aquatic species, can be created by restoring or creating small spring and seep pools where they have been disturbed from previous forest activities.

Other techniques are available that are wildlife-species and site specific and are tailored for those individual situations and landowners desiring to create special habitats. These may include watering devices, tree inoculation to produce habitat for cavity-nesting species in live trees, nest boxes and platforms, and special plantings, among other activities.

TECHNICAL/FINANCIAL ASSISTANCE

Several sources of technical or financial assistance are available through the DNR and other agencies. These include:

Forest Stewardship Program (FSP) - contact at: www.forest_stewardship@wadnr.gov , (360) 902-1706, or a regional Stewardship Forester. FSP includes technical assistance in general forest management, wildlife, forest health, fire hazard reduction, forest stewardship management plans, and educational programs including Coached Stewardship Planning classes in conjunction with WSU Extension Forestry. The FSP also oversees cost-share practices for the above areas through the Forestland Enhancement Program.

Small Forestland Owners Office (SFLO) - contact at: www.dnr.wa.gov/sflo, (360) 902-1391 or regional SFLO foresters. SFLO programs include technical assistance for Forests and Fish issues. Cost-share programs include Forestry Riparian Easement Program, Riparian Open-Space, and the Family Forest Fish Passage Program.

The Natural Resources Conservation Service of the U.S. Department of Agriculture administers cost-share programs that may benefit small forestland owners. These include: Environmental Quality Incentives Program, Wildlife Habitat Incentives Program, and the Conservation Reserve Enhancement Program.

The Washington Department of Fish and Wildlife administers the Landowner Incentives Program for specific wildlife species or habitats.

The U.S. Fish and Wildlife Service of the Department of Interior also administers several cost-share programs for selected species or geographic areas that may be of benefit to some forestland owners.

SUMMARY

Family forests are different in distribution, size, and content from managed public and industrial forests. Furthermore, family forest owners often have very different objectives and concerns for their forests when compared to those managed primarily for timber resources. Protecting or enhancing wildlife habitat is often a primary objective for these NIPF lands. Many techniques are available that protect, enhance, and even create several important habitat features that accommodate the majority of wildlife resources found in these smaller privately owned low-elevation stands. These techniques can be implemented in the course of standard forest management activities including pre-commercial and commercial thinning and final overstory removal in Westside forests. The challenge to foresters is to not only include these techniques in their standard silvicultural prescriptions but consider an ecosystem approach in the future. While landowners are constrained to applying these wildlife habitat management techniques to their land, the majority not only recognize the value of landscape and ecosystem management, but also are highly interested in joining with other family-owned forest owners in applying ecosystem management principles (Creighton et al. 2005).

LITERATURE CITED

Baumgartner, D.L.; Creighton, J.H.; Blatner, K.A. 2003. Use and effectiveness of Washington State's extension Forest Stewardship Program. Small-scale Forest Economics, Management and Policy. 2(1): 1-13.

Creighton, J.H.; Baumgartner, D.M.; Blatner, K.A. 2002. Ecosystem management and non-industrial private forest landowners in Washington State, USA. Small-scale Forest Economics, Management and Policy. 1(1): 55-69.

Creighton, J.H. 2005. Personal communication. Department of Natural Resource Sciences. Pullman, WA: Washington State University.

Gootee, R.J. 2004. Family forests: challenges of investment and stewardship. In: Baumgartner, D.M.; ed. Proceedings of human dimensions of family, farm, and community forestry international symposium. Pullman, WA: Washington State University: 13-16.

Johnson, A. 1997. The importance and differences in non-industrial forest landowners. Western Forester. 42(7): 1-4.

Mannan, R.; Meslow, E.C.; Wight, H. 1984. Use of snags by birds in Douglas-fir forests, western Oregon. Journal of Wildlife Management. 44: 787-797.

Neitro, W.; Mannan, R.; Taylor, D. [et al.]. 1985. Snags. In: Brown. E., tech. ed. Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1, Chapter narratives. R6-F&WL-192-1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region: 129-169.

Perkey, A. 1989. Assessing wildlife habitat management objectives on the private non-industrial forest. National Woodlands. January-February 1989: 6-8.

U.S. Department of Agriculture [USDA]. 2000. Summary Report: 1997 National Resources Inventory (revised December 2000). Natural Resources Conservation Service, Washington, DC, and Statistical Laboratory, Iowa State University, Ames, Iowa. 89 p. http://www.nrcs.usda.gov/TECHNICAL/NRI/1997/summary_report/. (Date accessed unknown).

Urban, D.; O'Neil, R.; Shugart, H., Jr. 1987. Landscape ecology—a hierarchical perspective can help scientists understand spatial patterns. Bioscience. 37: 119-127.

Washington State Department of Natural Resources [WDNR]. 1999. Forest statistics. Olympia, WA: Forest Stewardship Program.

Washington State Department of Natural Resources [WDNR]. 2002. Forest statistics, Small Forest Landowners Office. 1 p.

Zarnowitz, J.E.; Manuwal, D.A. 1985. The effects of forest management on cavity nesting birds in northwestern Washington. Journal of Wildlife Management. 49(1): 255-263.

ECONOMIC CONSIDERATIONS

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COMBINING MANAGEMENT GOALS OF WILDLIFE HABITAT CONSERVATION AND REVENUE ON WASHINGTON STATE TRUSTS

Angus Brodie[1], Michael Bowering[2], Weikko Jaross[3], Don Reimer[4], and Bryan Lu[5]

ABSTRACT

In 1997, the Washington State Department of Natural Resources (WDNR) adopted a multiple species Habitat Conservation Plan (HCP) with the United States Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration – Fisheries (NOAA Fisheries) for 1.6 million acres of State Trust forestland. Between 2001 and 2004, WDNR analyzed a number of management alternatives in western Washington. A fundamental management challenge of the HCP is the integration of wildlife habitat enhancement and revenue generation. This paper describes the forest modeling and silvicultural analysis, conducted as part of the sustainable harvest calculation, with a focus on management strategies to create high quality nesting habitat for the northern spotted owl in accordance with the goals of the HCP. Results are reported for both stand- and landscape-level analysis in terms of selected environmental and economic performance metrics. Discussion on the application and implementation of these regimes at the tactical and operational levels are included.

KEYWORDS: Silviculture, Douglas-fir, western hemlock, northern spotted owl habitat, forest management.

INTRODUCTION

People in Oregon and Washington are interested in conserving wildlife (Carey, 2003), biodiversity and local economies, while obtaining other useful services from the forests. Forestry professionals are struggling to keep up with changing societal demands (Kimmins 2002). A major challenge for forest managers in recent decades has been habitat conservation for threatened and endangered species. One of the more visible species of concern has been the northern spotted owl (*Strix occidentalis caurina*). The northern spotted owl rests on top of a complex food web in natural old forest habitats in western Oregon and Washington (Carey 2003). Because of its position in the food web, the northern spotted owl represents a keystone complex, and serves as a focal point for understanding the ecological processes and structural functionality of older large diameter conifer forests. Ecological processes in the forest are a product of dynamic forest development through time (Franklin et al. 2002). It is through investigation of forest development that management approaches will be found to improve habitats for the owls and other species associated with old forests.

In 1997, the Washington State Department of Natural Resources (WDNR) adopted a multiple species Habitat Conservation Plan (HCP) with the United States Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration– Fisheries (NOAA Fisheries) for 1.6 million acres of State Trust forestland. While the HCP was developed to provide habitat conservation for multiple wildlife species, one of the main species of concern was the northern spotted owl. The stated conservation objective for the northern spotted owl "… is to provide

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habitat that makes a significant contribution to demographic support, maintenance of species distribution, and facilitation of dispersal" (WDNR 1997).

Development of a managed forest is determined by the objectives of the landowner and achieved through the practice of silviculture. Nyland (1996) defines silviculture as "…the theory and practice of controlling the establishment, composition, character and growth of forest stands to satisfy specific objectives." Research projects have been implemented in recent years to investigate alternative silvicultural approaches designed to integrate achievement of habitat enhancement with revenue generation in Pacific Northwest forests (Curtis et al. 2004, Peterson and Maguire 2005). Computer-generated stand- and landscape-level simulations provide an additional method by which to examine alternative management approaches (McCarter 2001). In this paper, we present WDNR simulation and analysis of stand- and landscape level silvicultural regimes for the management of wildlife habitat and revenue on State Trusts forestlands in western Washington.

The purpose of our analysis was to examine management alternatives identifying economically effective regimes that could create forest structures suitable for northern spotted owl nesting habitat. We chose two performance criteria to test the performance of potential regimes. For economic comparisons, a net present value (NPV) was calculated based upon simulated management costs and revenues. For habitat comparisons, the time to reach the desired future condition (as defined by nesting habitat forest structure attributes) was estimated from treatment and growth projections.

METHODS

Habitat Threshold Targets

Unlike traditional commercial thinning regimes that focus on creating forest stands to maximize timber values (i.e. harvest revenue, clear wood, recovery of mortality, increased growth rates), our regime analysis focused primarily on creating forest structures to satisfy the Habitat Conservation Plan habitat definition. The design of our silviculture regimes incorporated biodiversity pathway concepts adopted from Carey et al. (1996), Lippke et al. (1996) and Bare et al. (1997). In particular, we examined the influence of initial stand density, pre-commercial thinning and commercial thinning treatments on habitat development during the first 100 years after forest establishment. Treatment regimes were designed to produce stand attributes associated with high quality owl habitat as identified by the WDNR HCP (WDNR 1997). The high quality owl habitat threshold targets are presented in table 1.

Problems in the definition and measurement of canopy closure or canopy cover (Jennings et al. 1999) convinced us that attempts to use canopy parameters for assessing habitat thresholds were unworkable. We therefore did not address this criterion in our tests. Canopy closure plays an important role in the life history requirements of the northern spotted owl, providing cover from predators and thermal regulation (Hanson et al. 1993). Instead, we assumed the combination of overstory trees of the required diameters and the development of understory shrubs and trees occurring 30 to 40 years after thinning would adequately fulfill the life history requirements of the spotted owl and its associated prey.

The HCP requires a relatively high proportion of large snags relative to what occurs in the modeling output of a younger managed stand, therefore we assumed that if snags are absent within the stand, they will need to be created from live trees. This notion of snag recruitment was discussed in Carey et al. (1996), and the cost for creating these snags was deemed negligible (Lippke et al. 1996). To achieve the required proportion of live and dead trees per acre and maintain sufficient recruitment for large down woody debris, we identified a minimum residual stand density for the final thinning to be 45 trees per acre. Retention of at least 45 trees per acre provided a margin of 14 trees of the requisite diameters with which to recruit additional potential snags and down woody debris as a result post-harvest.

Operational Considerations

Dense stands with small live crowns may be exposed to abiotic loss (i.e. snowpress, breakage, windthrow) after thinning if the height/diameter ratio is greater than 100 (Daniel et al. 1979). Although this varies somewhat among species, if the live crown ratios of thinned stands are small, it is likely that trees will show little growth response. To minimize the effects of these factors, two additional decision rules were incorporated into the analysis:

1) The height/diameter ratios of the residual stand must be less than 100.
2) The live crown ratio must be greater than 45 percent.

In addition, a minimum thinning harvest of 8,000 board foot per acre was used as a test to rank the feasibility of the regimes. This thinning harvest level represents the average thinning sale yield from WDNR over the last 5 years (2000-2005).

Table 1—Threshold target conditions used for ranking the treatment combinations (regimes)

Criteria	Description	Modeled and used to screen regimes
Biological high quality nesting owl habitat description[a]	At least 31 trees per acre greater than or equal to 21 inches dbh, with at least 15 trees per acre greater than or equal to 31 inches dbh	X
	At least 12 snags per acre larger than 21 inches dbh	X
	Minimum 70 percent canopy closure	
	Minimum 5 percent ground cover of LWD.	X[b]
Operational	The height/diameter ratios of the residual stand must be less than 100	X
	The live crown ratio must be greater than 45 percent.	X
	Minimum thinning harvest of at least 8,000 board feet per acre	X
Economic	The earliest time at which they will meet the forest structural targets	X
	The maximum NPV returns to the department at the time of the final commercial thinning	X

[a] WDNR (1997). Final Habitat Conservation Plan, Washington State Department of Natural Resources, Olympia, Washington.
[b] This was indirectly modeled. An assumption was made that required the retention of more live trees per acre at the final commercial thinning treatment to supply logs for down woody debris

Treatment combinations producing stands that failed to meet the HCP stand attribute requirements, with the exception of canopy closure; resulted in a residual stand having a height/diameter ratio greater than 100 or a live crown ratio less than 45 percent; or had a thinning harvest less than 8,000 board feet per acre at some point in the yield projection were rejected from further analysis.

Financial data

Our investigation was to identify management regimes that could reach the target conditions in an economically efficient manner therefore, all treatment combinations were modeled using a set of treatment costs, planting scenarios, merchantability limits and interest rate assumptions as shown in table 2. Log prices were developed from 2002-03 data with consultation from WDNR marketing staff (Bowering and Reimer 2003).

Silvicultural regime analysis was conducted using D.R. Systems' proprietary silvicultural analysis model, SILVIRR. The model, SILVIRR, uses the Stand Projection System (SPS version 4.1H, as supplied by Mason Bruce and Girard) to project stand attributes. The model, SPS, is a growth and yield model that simulates the development of individual trees and reports by diameter class. While other growth and yield models were considered for this analysis, we chose SPS because it was integrated with the forest estate or harvest scheduling model that WDNR used to model the sustainable forest management recommendations for the Board of Natural Resources in 2004 (WDNR 2004).

The analysis conducted on representative single species Douglas-fir (*Pseudotsuga menzieii*) and western hemlock (*Tsuga heterophylla*) stands, across five site classes. The species-specific site index values presented in table 3 were species converted by SPS to an equivalent Douglas-fir site index. SPS uses a ratio of 0.9 times the Douglas-fir site index for western hemlock to produce the Douglas-fir equivalent. The height growth is, however, based upon the appropriate height growth curves (King 1966, Wiley 1978). Due to the number of treatment combinations, only the representative site indices presented in table 1 were analyzed.

Regimes

A series of regimes were developed to meet the threshold target conditions of high quality nesting habitat. Regimes were designed to incorporate a spectrum of initial planting densities, pre-commercial (PCT) treatments, fertilization following the PCT age (for Douglas-fir stands only), and a series of commercial thinning combinations using single, double or triple entries prior to the final harvest. For the single, double and triple pass treatments, a range of treatment timing intervals and treatment intensities were tested.

All regimes were assumed to be planted with 2 year-old seedlings and were modeled to reflect a range of initial planting densities between 200-700 trees per acre in intervals of 50. Where the regime included a PCT treatment, the earliest PCT age was selected to minimize damage to the residual stand due to an excessive height/diameter ratio. Earliest PCT age selected was between 7 and 22 years after establishment; dependent upon species and site quality. Where a PCT treatment was simulated, stand densities were reduced to 300 trees per acre (12-by-12 ft spacing). This is consistent with PCT density targets discussed in Carey et al. (1996) and (Lippke et al. 1996). For stand conditions

Table 2—Assumptions about treatment costs, interest rates, stand establishment and merchantability limits used for modeling the management regimes

Management Regime Characteristic	Assumption
Treatment Cost	
Regeneration Harvest Treatment Cost	$180/MBF
CT Treatment Cost	$280/MBF
Selection Cut Treatment Cost	$280/MBF
Regeneration Cost	$0.5/seedling
Brushing Cost	$160/ac
Pre Commercial Thin Cost	$160/ac
Interest Rates	
Wood Appreciation Rate	0.3%
Inflation Rate	2%
Discount Rate	7.5%
Stand Establishment	
Regeneration Method	Planted (100%)
Regeneration Delay	2 yrs
Seedling Stock Type	1+1
Merchantability	
Minimum Top DIB as % DBH	15%
Stump Height	1.2 feet
Minimum DBH	6 inches
Minimum Top DIB	4 inches
Nominal Log Length	32.5 feet
Minimum Log Length	12.5 feet
Average Defect	2%
Pre Commercial Thin d/D ratio	1.0
Commercial Thin d/D ratio	0.9
Fertilization	
Application Rate (DF species only)	200 lbs N/ac
Cost	$90

Table 3—Site index classes and the representative site index for each species

Site Class	Douglas-fir Site Index	Western hemlock Site Index
Site I	143	159
Site II	127	141
Site III	109	121
Site IV	89	99
Site V	68	77

with an initial planting density of 300 trees per acre or less, no PCT was simulated. We also simulated a fertilizer treatment for the Douglas-fir stands. The fertilizer treatment was applied 1 year after the PCT treatment or at an equivalent age for low initial density stands.

Thinning Treatment Combinations

A set of thinning treatment combinations were designed to explore alternative approaches to accelerating achievement of forest structure threshold targets. The thinning treatments varied with the frequency of entries, the time

Table 4—Matrix of treatment components for the treatment scenarios

		Thinning treatment entries					
	Pre-commerical	Single entry		Two entries		Three entries	
Planting densities	thinning and fertilization	Age	Residual trees per acre	Age	Residual trees per acre	Age	Residual trees per acre
				First entry		First entry	
200	Douglas-fir	30	45	30	75	30	150
250	No PCT	35	55	35	100	35	175
300	PCT to 300TPA	40	65	40	125	40	
350	PCT to 300TPA						
	Fertilization	45			150		
400		50			175		
450	Western hemlock	55					
500	No PCT	60					
				Second entry		Second entry	
550	PCT to 300TPA			50	45	50	75
600				60	55	60	100
650				70		125	
700							
750							
						Third entry	
						70	45
						80	55

[a] All regimes were assumed planted with 1/1 stock
[b] PCT treatments were not applied to stands below 300 tpa at the time of the PCT treatment
[c] Fertilization of 200 lbs of N per acre, at a cost of $90/acre

that a stand might be entered, and the amount of residual trees that would be left after the thinning (table 4). The combinations of multiple planting densities, PCT, fertilization, and commercial thinning options, applied across the five site classes, resulted in 45,900 regimes for Douglas-fir stands and 30,600 regimes for western hemlock (table 5). The total number of regimes simulated in SILVIRR was 76,500.

All stands were simulated for 150 years of age. Net Present Value (NPV) was evaluated at the final commercial thinning, not at regeneration harvest.

Post Simulation Analysis

A compilation algorithm was developed to select suitable treatment combinations that met the set of biological, operational and economic threshold targets (table 2). Treatment combinations for Douglas-fir and western hemlock by site class were initially screened using the following priorities: 1) the residual stand meets the stand structural objectives for high quality nesting habitat at some point in the 150 year projection; 2) the residual stand and thinning treatment met the operational tests. Once the screening was complete, the regimes were ranked according to the two evaluation criteria: maximum Net Present Value (NPV) and the least time to reach the desired future habitat condition.

Once the regime screening was complete, silvicultural considerations, such as thinning timing, intensity and residual target densities of the highest ranking treatment scenarios were used as input variables for a landscape simulation model that was developed for the analysis of alternatives for sustainable forest management of State Trust lands in western Washington (WDNR 2004). Forest stands were assigned regimes in the landscape simulator based on the land classification and existing stand conditions. Regimes that create forest structures suitable as high quality nesting habitat for northern spotted owls were labeled "biodiversity pathways" after Carey et al. (1996). Both short and long-

Table 5—Number of regimes for each species and site class

Treatment combinations	Douglas-fir	Western hemlock	Total
No PCT + Single Pass CT	252	252	504
No PCT + Double Pass CT	1,080	1,080	2,160
No PCT + Triple Pass CT	1,728	1,728	3,456
PCT + Single Pass CT	252	252	504
PCT + Double Pass CT	1,080	1,080	2,160
PCT + Triple Pass CT	1,728	1,728	3,456
PCT + Fertilization + Single Pass CT	252	—	252
PCT + Fertilization + Double Pass CT	1,080	—	1,080
PCT + Fertilization + Triple Pass CT	1,728	—	1,728
Total Combinations by Site Class	9,180	6,120	15,300
Total Run Combinations for all Five Site Classes:	45,900	30,600	76,500

Table 6—Number of the regimes that passed, conditionally passed and failed to meet HCP high quality habitat stands during the 150 year projection

	Douglas-fir	Western hemlock	Total
Pass	10,448	9,703	20,151
Conditional pass	1,825	2,318	4,143
Fail	30,333	16,559	46,892
Total	42,606	28,580	71,186

rotation biodiversity pathways were developed for areas of these State forest lands; identified as important for northern spotted owl conservation, riparian habitat enhancement, protection of unstable slopes, or maintenance of forested visual areas.

We developed two additional rules to allocate the short- and long-rotation biodiversity pathways to current stands in the landscape simulator. The first rule was that biodiversity regimes were only applied to conifer dominated stands. The second rule was designed to minimize the risks of stand failure (wind-throw) due to heavy thinning (Somerville 1980, Wilson and Oliver 2000, Cameron 2002). Long-rotation biodiversity pathway regimes were assigned only to stands with an inventory basal area per acre less than the projected average yield curve for their forest type and site class. Short rotation biodiversity pathway regimes were assigned to stands with inventory basal areas per acre greater than the estimated basal areas per acre from the projected average yield curve for their forest type and site class.

RESULTS

A total of 24,294 regimes produced high quality nesting habitat for owls (table 6). The conditionally passed label indicated that a stand had met all the criteria with the exception of meeting the 31-inch diameter-at-breast-height (DBH) limit for the 15 largest trees per acre. The HCP indicates that if this required number of large trees per acre is not present then the next largest should be maintained to provide a total of 31 trees per acre larger than 21 inches DBH (WDNR 1997).

The regimes that ranked highest in terms of maximum NPV are presented in table 7. On medium to high sites (site class III and higher), the highest ranking regimes had moderate levels of initial stocking (planting densities of between 300 and 650 trees per acre), did not receive PCT (except on DF site class III) and incorporated two commercial thinnings. The first commercial thinning occurred between 30 and 40 years of age with a residual density of 125 and 175 trees per acre. The second thinning occurred 10 to 20 years later depending on the site with a residual density of 45 trees per acre. The NPV at this last commercial thinning was $257 per acre (site class III western

Table 7—Regimes that provided the highest NPV at the final commercial thinning

Species	Site class	Regime description	Initial stock-ing	First thin-ning	Re-sidual stock-ing	Second thin-ning	Re-sidual stock-ing	NPV at final thin-ning	Forest structure status	Attainment of forest structure
			(tpa)	(yrs)	(tpa)	(yrs)	(tpa)	($/ac)		(yrs)
DF	I	Two thinnings	500	30	174	50	45	1,424	Pass	90
DF	I	Fertilization and two thinnings	300	35	149	50	45	1,202	Pass	80
DF	II	Two thinnings	600	30	149	50	45	975	Pass	100
DF	II	Fertilization and two thinnings	300	35	149	50	45	944	Pass	90
WH	I	Two thinnings	550	40	124	50	45	837	Pass	100
WH	II	Two thinnings	500	40	174	50	45	540	Pass	110
DF	III	Two thinnings	650	40	124	50	45	460	Pass	150
DF	III	Fertilization and two thinnings	300	40	99	60	45	351	Pass	120
WH	III	Two thinnings	350	40	174	50	45	257	Pass	120
DF	IV	Fertilization and one thinning	300	40	44			96	Pass	150
DF	V	One thinning	250	55	44			3	Condition	150
WH	IV	One thinning	200	55	44			(2)	Pass	150
DF	V	Fertilization and one thinning	300	50	44			(4)	Condition	150
WH	V	One thinning	200	60	44			(56)	Condition	140
DF	IV	PCT and one thinning	600	45	44			(125)	Pass	150

hemlock) and $1,423 per acre (site class I Douglas-fir). Stands on medium sites achieved the desired structural condition between stand age 90 and 150 years. Dependent upon site, fertilization of the stand could reduce the stand age at which the structural condition was attained by 10 to 30 years (table 7).

Ranking the regimes provided results in terms of which regime performed the best under economic and time criteria. To illustrate the amount and the source of the variation produced by the regime analysis, we chose to examine in-depth the economic performance of regimes for one species and site class: Douglas-fir site class III.

Figure 1 illustrates the variation in NPV and the stand age when habitat criteria are attained for Douglas-fir site class III regimes. The results indicate that a higher NPV at the final commercial thinning results in a delay in the attainment of habitat. Regimes with the highest NPV attained habitat at a stand age of 140 years. The regimes that return the highest NPV at 140 years tend to be regimes with only thinning treatments in them rather than regimes with thinning and a combination of PCT and fertilization (fig. 2). The influence of initial stocking on NPV for thinning only regimes that attained habitat at 140 years is presented in figure 3. The results illustrate a trend: moderate (400-599 trees per acre) to high (600-750 trees per acre) densities with multiple thinning entries result in the highest NPV.

On lower sites (site class IV and poorer), the silvicultural regimes were characterized by lower initial stocking (except site class IV Douglas-fir) with planting densities of 200-300 trees per acre, no pre-commercial thinning and only one thinning entry at between 40 and 55 years of age designed to leave a residual density of 45 trees per acre. The NPV at last commercial thinning ranged from $-125 (site class V Douglas-fir) to $98 per acre (site class V Douglas-fir with fertilization). Fertilization on very poor sites (site class V) improved the economic performance of the NPV from a negative value to above zero. Stands on lower sites took between 140 and 150 years to reach the desired structural condition and fertilization did not appear to speed the development of the stand.

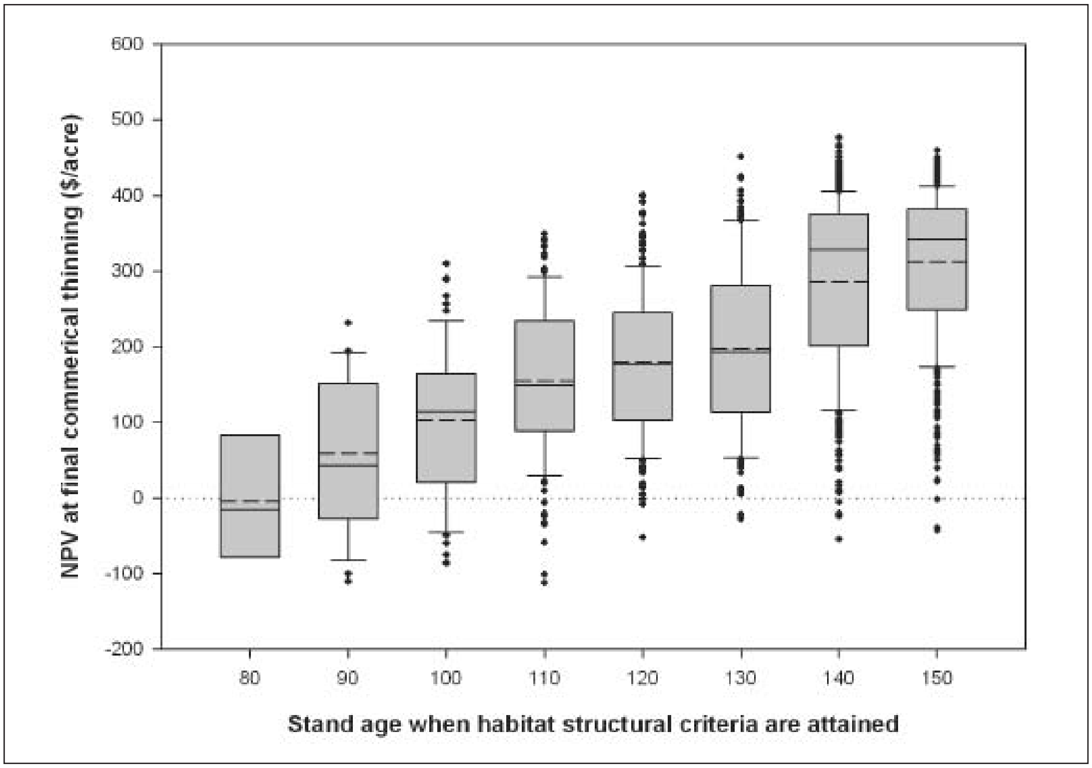

Figure 1—Douglas-fir site class III all regimes (mean (dashed line) median, 10^{th}, 25^{th}, 75^{th}, and 90^{th} percentile)

The most successful strategy found to maximize NPV while accelerating development of the target forest structural conditions employed a moderate first commercial thinning at age 30 to 40 years of age (~ 150 trees per acre, Curtis' relative density (RD) target of 35-45) followed by a second thinning 10 to 20 years later to a residual stand density target of RD 20-25 and approximately 45-50 trees per acre.

The management regimes that ranked highest in accelerating development of the desired structural conditions are presented in table 8. The most successful strategy for attaining the forest structural conditions at the earliest age on site class III for Douglas-fir and western hemlock had a stand establishment density of 350 tree per acre, PCT to 350 trees per acre combined with fertilization and one commercial thinning at age 30. Attainment of the forest structural threshold on site class III stands would occur at a stand age of approximately 80 years. For higher sites, site class I and II, the strategy is similar except that initial stand establishment density levels are lower (200-250 trees per acre), there is no pre-commercial thinning treatment applied and structural targets are reached as soon as 60 years.

Analysis results indicate that two or more commercial thinning treatments may delay the attainment of the forest structural targets by as much as 40-50 years. For example, in site class III lands, desired stand structural conditions are delayed from 80 to 120 years. Two commercial thinning entries on Douglas-fir site class III increase the NPV per acre by $250. This $250 per acre can be considered as the present value of the opportunity cost of faster attainment of desired forest structure.

The forest treatments found to maximize NPV and the treatments producing the earliest attainment of desired structural conditions were input into a landscape model. Two regimes were developed, a long-rotation "biodiversity pathway" and a short-rotation "biodiversity pathway" (WDNR 2004). The long-rotation "biodiversity pathway" favored the silvicultural characteristics of the scenarios that maximized NPV, while the short-rotation "biodiversity pathway" followed more closely the silvicultural approaches of the treatment combinations that accelerated development of desired structural conditions at the earliest age.

In the landscape simulation all stands are assigned to a regime at the beginning of the simulation. Twenty-seven percent of the State Trust forestland in western Washington

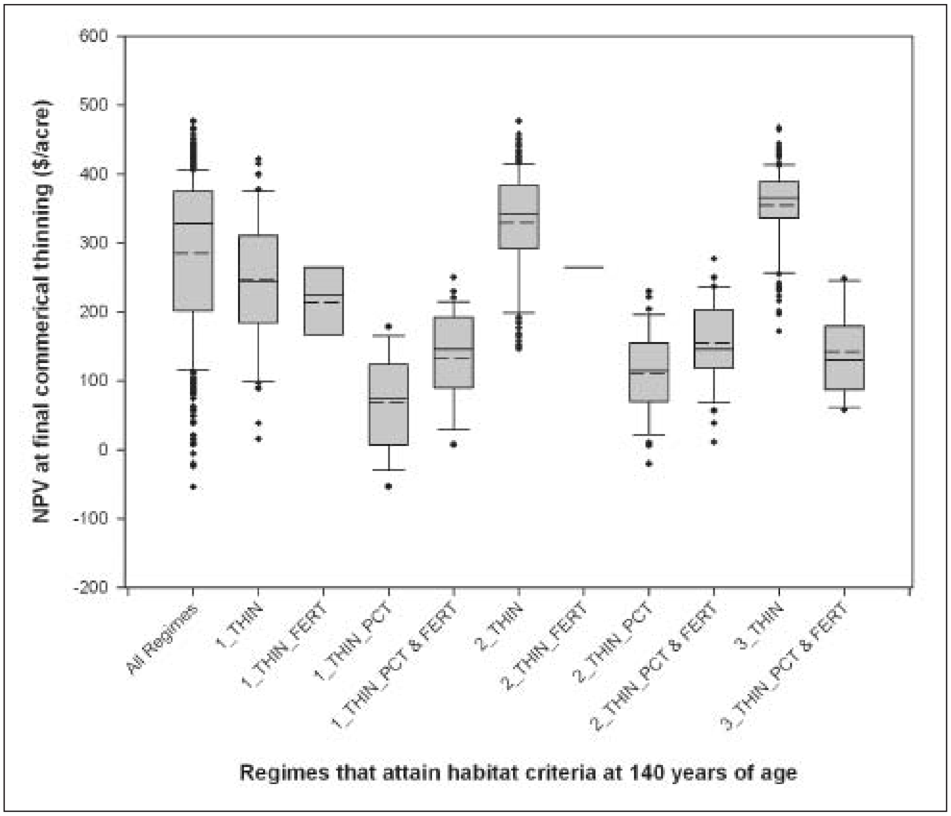

Figure 2—Regimes for Douglas-fir site class III that attained the habitat criteria at 140 years of age (mean (dashed line) median, 10th, 25th, 75th and 90th percentile).

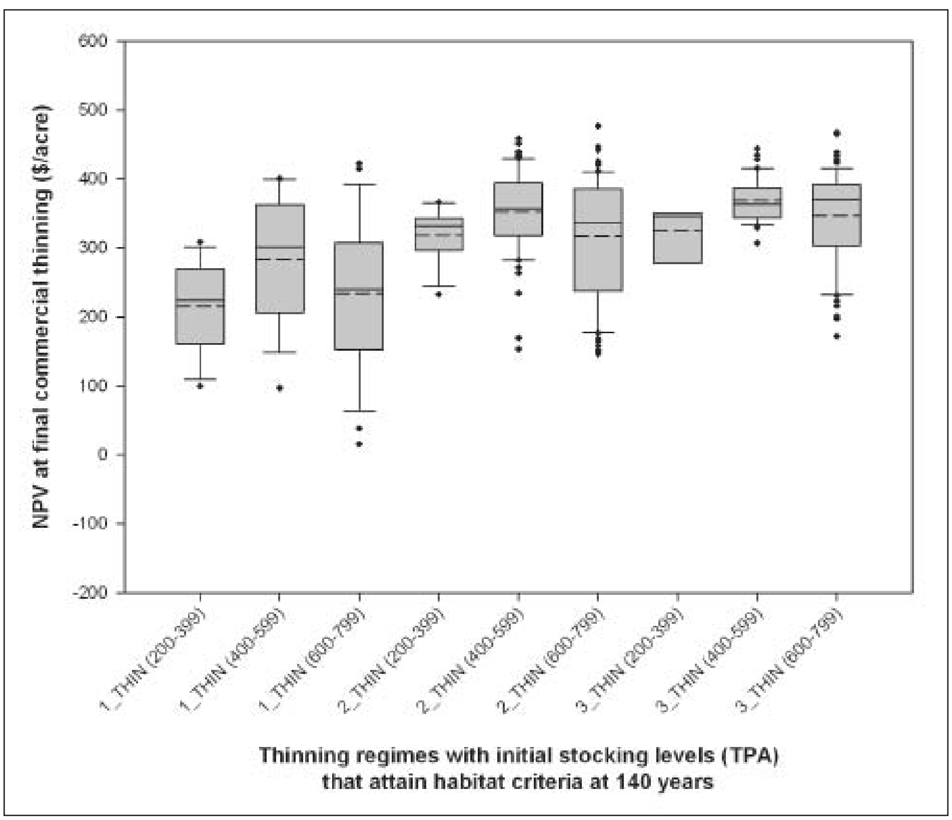

Figure 3—Initial stocking effect on regimes with thinning treatment only (no PCT or fertilization) for Douglas-fir site class III that attained the habitat criteria at 140 years of age (mean (dashed line) median, 10th, 25th, 7th and 90th percentile).

Table 8—Regimes that provided the earliest age of meeting the HCP high quality habitat objectives by species and site class

Species	Site class	Regime description	Initial stock-ing	First thin-ning	Re-sidual stock-ing	Second thin-ning	Re-sidual stock-ing	NPV at final thin-ning	Forest structure status	Attainment of forest structure
			(tpa)	(yrs)	(tpa)	(yrs)	(tpa)	($/ac)		(yrs)
DF[a]	I	Fertilization and one thinning	250	35	44			903	Pass	60
DF	I	One thinning	350	30	44			739	Pass	60
WH[b]	I	One thinning	250	30	44			341	Pass	60
DF	II	One thinning	45	30	44			626	Pass	70
WH	II	One thinning	250	30	44			136	Pass	70
DF	III	Fertilization, PCT[c] and one thinning	350	30	44			102	Pass	80
WH	III	One thinning	250	30	44			-0.4	Pass	80
DF	III	One thinning	350	30	44			194	Pass	90
DF	V	Fertilization, PCT and one thinning	350	55	64			-97	Condition	130
DF	V	One thinning	400	60	64			-112	Condition	130
WH	IV	One thinning	350	35	44			-62	Pass	130
DF	IV	Fertilization and one thinning	250	40	44			66.6	Pass	140
WH	V	One thinning	200	60	44			-56	Condition	140
DF	V	PCT and one thinning	600	45	44			-125	Pass	150

[a] Douglas-fir
[b] Western hemlock
[c] PCT = pre-commercial thinning

was assigned a long-rotation biodiversity pathway regime, and 43 percent was assigned a short-rotation biodiversity pathway regime. The remaining 30 percent of the forest was assigned to regimes that maximized NPV while retaining large, structurally unique trees, snags and down woody debris.

In addition to these regime allocations, the simulation model has stand- and landscape-level rules that represent the WDNR's policy objectives and operational constraints. The modeling rules will modify or prevent some treatments from occurring. For example, WDNR's HCP contains a landscape management strategy to maintain 50 percent of a watershed in a suitable northern spotted owl habitat condition in designated areas. Stands in these watersheds that are selected by the model to contribute to the target must maintain a specific relative density (RD) at all times. A thinning treatment may be available in the simulation run for these stands; however the landscape rule will prevent the thinning action from lowering the relative density below the specified landscape-level rule.

Compared with the performance of a conventional thinning alternative[6] from the 2004 analysis (WDNR 2004), the biodiversity pathways thinning approach resulted in a lower NPV over the 64-year planning horizon. The biodiversity pathway alternative produced an NPV of $3.0 billion while a more conventional thinning approach resulted in an NPV of $3.3 billion. However, the biodiversity pathway alternative produced nearly twice as much "high

[6] In this conventional thinning alternative, commercial thinning treatments are limited to 30-35 percent removal of basal area per acre per entry. This intensity of thinning is representative of commercial thinning practices in the Pacific Northwest (Curtis et al. 1998).

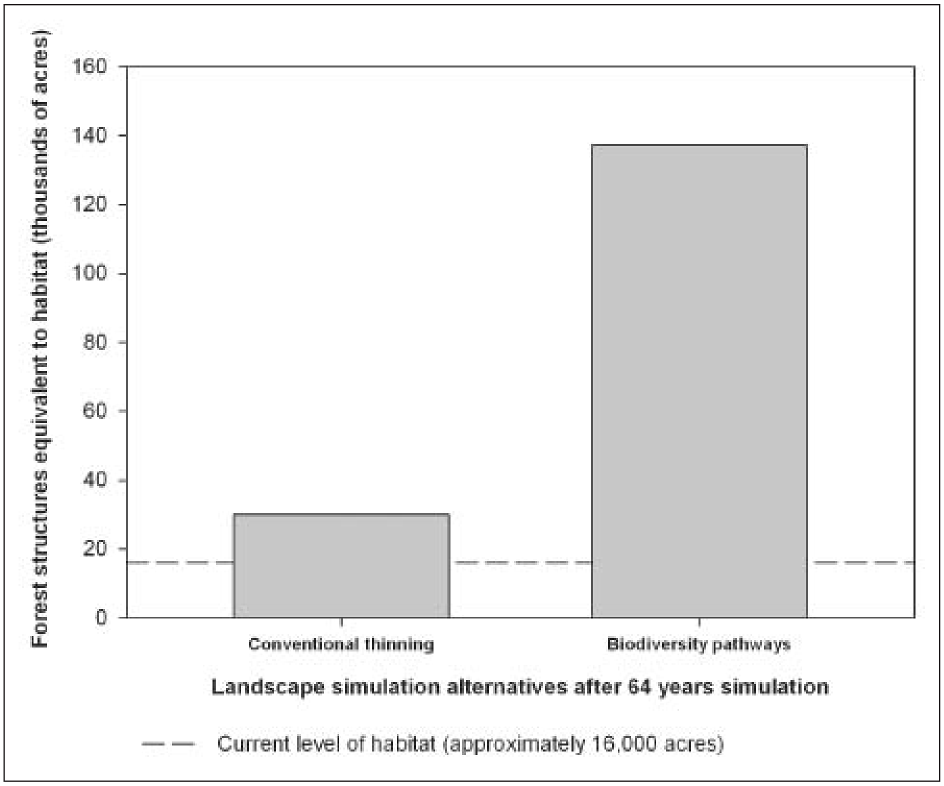

Figure 4—Landscape simulation model outputs comparing alternative silvicultural approaches to developing high quality nesting habitat.

Table 9—Projection of 1.4 million acres of State Trust lands managed by the WDNR for three alternative management scenarios

Alternatives	Forest structures equivalent to high quality nesting habitat in 2064[a]	Net Present Value in 2064
	Acres	$ billions
Convention thinning approach	30,000	$3.3
Biodiversity pathways	137,200	$3.0

[a] Forest stand development stages that are equivalent to high quality nesting habitat are Niche diversification and Full functional stages (WDNR 2004). Current conditions for 2004 are estimated at 16,100 acres.

quality" forest structure (137,000 acres) as compared to the conventional thinning alternative (30,000 acres) (fig. 4, table 9).

DISCUSSION

Managing for wildlife habitat and revenue is an explicit policy objective of WDNR (WDNR 2006). The WDNR adopted a HCP in the mid-nineties (WDNR 1997) and developed landscape level strategies to support northern spotted owl conservation through active habitat management. In 2004, the WDNR presented to the Board of Natural Resources a new plan by which to achieve these objectives and generate revenue.

In developing the new plan, we undertook a silvicultural regime analysis to search for the most economically efficient and effective management approaches to develop forest structural conditions that meet the WDNR HCP high quality spotted owl nesting habitat definition (WDNR 1997).

Results suggest that heavy thinning treatments at an early age combined with an extended rotation, up to 140 years, may be the most effective. Our proposed "biodiversity pathway" regimes represent a departure from more commercial silvicultural practices targeted toward maintaining fully stocked stands, capturing mortality and shortening rotations (Curtis et al. 1998, Hummel 2003).

Our proposed regimes are similar to those developed a decade ago by Lippke et al. (1996) and Bare et al. (1997) for their analysis of biodiversity pathways. Latta and Montgomery (2004) and Andrews et al. (2005) describe developing similar regimes to achieve old forest structural forest conditions in western Oregon. Zobrist and Hinckley (2005) also describe similar silvicultural regimes in their review of management practices to support increased biodiversity in Douglas-fir plantations.

The residual tree densities of our final thinning treatment are low, 45-60 trees per acre. A number of retrospective studies of forest development suggest that existing old-growth stands may have developed at similar low tree densities (Tappeiner et al. 1997, Acker et al. 1998, Poage and Tappeiner 2004). Other studies, such as Winter et al. (2002) and Zenner (2005), have suggested that old-growth forest structures can develop with higher initial densities after extended periods of growth and differentiation. Our simulation results suggest that a low-tree-density development pathway may be viable to use in young plantations and could lead to the development of large overstory diameter trees.

Our analyses concentrated on the development of the overstory trees and lead us to deficiencies in simulating important owl habitat criteria, such as canopy closure. Regeneration of a new cohort post thinning is a typical phenomena in Douglas-fir and western hemlock stands (DeBell et al. 1997, Bailey and Tappeiner 1998). Other studies, such as Andrews et al. (2005), provided an analysis using ORGANON of understory development post thinning. Heavy thinnings implemented in low quality owl habitat (sub-mature and young forest marginal) will lead to a reduction of canopy closure, and therefore, a loss habitat until canopy closure is restored. Being able to demonstrate the recovery of canopy closure is a deficiency in our simulations and requires further study.

The spatial arrangement of the residual trees after the thinning entries should be an important consideration in planning for the growth of the overstory and understory. Unfortunately, spatially explicit modeling of stem distributions is problematic and was not attempted as part of this investigation. Unlike traditional, uniform thinning; the thinning treatments associated with these biodiversity pathway regimes will likely be irregular, with differing densities, unthinned patches, and small openings across the stand (Curtis et al. 1998). Such an approach to thinning treatment has been described as "variable density thinning" (Carey and Curtis 1996, Carey et al. 1999).

The final thinning entry, simulated in this analysis, retained a relatively low average residual tree density of approximately 45 trees per acre. This treatment can be considered as a partial harvest (WDNR 2004) or as a variable retention harvest, similar to those described by Barg and Hanley (2001) and Franklin et al. (1997). Appropriate naming of selected treatments with descriptive silvicultural terms can aid in the communication of management alternatives to foresters, wildlife biologists and other interested parties.

At the stand-level, biodiversity pathway regimes do not produce economic returns equivalent to commercial even-aged silviculture. The management regimes developed in this project with early heavy thinning show, however, that economic benefits can be improved when some merchantable timber is removed early in the rotation. We suggest that it is at the landscape- or forest-level scale that the performance of biodiversity pathways should be compared to more traditional silvicultural approaches. Forest-level objectives for habitat conservation, as mandated by the HCP, preclude maximization of economic return. Under circumstances where integrated environmental and economic forest outcomes are desired, our analysis joins that of Carey and others (1999) suggesting that biodiversity pathways are the most effective means for reaching the combined goals of forest habitats and revenue generation.

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LITERATURE CITED

Acker, S.A.; Sabin, T.E.; Ganio, L.M.; McKee, W.A. 1998. Development of old-growth structure and timber volume growth trends in maturing Douglas-fir stands. Forest Ecology and Management. 104: 265-280.

Andrews, L.S.; Perkins, J.P.; Thrailkill, J.A.; Poage, N.J.; Trappeiner, J.C. 2005. Silvicultural approaches to develop northern spotted owl nesting sites, central coast ranges, Oregon. Western Journal of Applied Forestry. 20: 13-27.

Bailey, J.D.; Tappeiner, J.C. 1998. Effects of thinning on structural development in 40- to 100-year-old Douglas-fir stands in western Oregon. Forest Ecology and Management. 108: 99-113.

Bare, B.B.; Lippke, B.R.; Xu, W.; Oliver, C.D.; Moffett, J.D.; Waggener, T.R. 1997. Demonstration of the Trust impacts from management alternatives to achieve habitat conservation goals on Washington Department of Natural Resources managed lands. Seattle, WA: College of Forest Resources, University of Washington. 58 p.

Barg, A.K.; Hanley, D.P. 2001. Silvicultural alternatives: variable retention harvests in forest ecosystems of western Washington. Cooperative Extension Bulletin EB1899. Seattle, WA: Washington State University. 20 p.

Bowering, M.; Reimer, D.R. 2003. Analysis of biodiversity pathways concepts applicable to the Washington Department of Natural Resources' westside landbase. D.R. Systems Northwest Inc. 902 'A' Street, Suite B Auburn, WA 98002. 241 p.

Cameron, A.D. 2002. Importance of early selective thin ning in the development of long-term stand stability and improved log quality: a review. Forestry. 75: 25-35.

Carey, A.B. 2003. Managing for wildlife: a key component for social acceptance of compatible forest management. In: Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. Compatible Forest Mangement. Dordrecht, The Netherlands: Kluwer Academic Publishers: 401-425.

Carey, A.B.; Curtis, R.O. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. Wildlife Society Bulletin. 24: 610-620.

Carey, A.B.; Elliot, C.; Lippke, B.R.; Sessions, J.; Chambers, C.J.; Oliver, C.D.; Franklin, J.F.; Raphael, M.G. 1996. Washington Forest Landscape Management Project – A pragmatic, ecological approach to small-landscape management. U.S. Department of Aagriculture, Forest Service, Washington State Department of Fish and Wildlife, and Washington State Department of Natural Resources**.** 110 p.

Carey, A.B.; Thysell, D.R.; Brodie, A.W. 1999. The Forest Ecosystem Study: background, rationale, implementation, baseline conditions, and silvicultural assessment. Gen. Tech. Rep. PNW-GTR-457. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 129 p.

Curtis, R.O., DeBell, D.S.; Harrington, C.A.; Lavender, D.P.; St. Clair, J.B.; Tappeiner, J.C.; Walstad, J.D. 1998. Silviculture for multiple objectives in the Douglas-fir region Gen. Tech. Rep. PNW-GTR-435. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 123 p.

Curtis, R.O.; Marshall, D.; DeBell, D.S. 2004. Silvicultural options for young-growth Douglas-fir forests: the Capitol Forest study—establishment and first results. Gen. Tech. Rep. PNW-GTR-598. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 110 p.

Daniel, T.W.; Helms, J.A.; Baker, F.S. 1979. Principles of silviculture. New York: McGraw-Hill Book Company. 500 p.

DeBell, D. S., Curtis, R. O., Harrington, C. A. and Tappeiner, J. C. 1997. Shaping stand development through silvicultural practices. In: Kohm, K.A.; Franklin, J.F., eds. Creating a Forestry for the 21st Century. Washington, DC: Island Press**.** 475 p.

Franklin, J.F.; Spies, T.A.; Van Pelta, R.; Carey, A.B.; Thornburgh, D.A.; Berge, D.R.; Lindenmayerf, D.B.; Harmong, M.E.; Keetona, W.S.; Shawh, D. C.; Biblea, K.; Cheni, J. 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. Forest Ecology and Management. 155: 399-423.

Hanson, E.; Hays, D.; Hicks, L.; Young, L.; Buchanan, J. 1993. Spotted owl habitat in Washington: a report to the Washington Forest Practices Board, Washington State Department of Natural Resources, Spotted Owl Scientific Advisory Group, Forest Practices Board. Olympia, WA. 116 p.

Hummel, S.S. 2003. Managing structural and compositional diversity with silviculture. In: Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. Compatible Forest Management. [Place of publication unknown]: Kluwer Academic Publishers: 85-119.

Jennings, S.B.; Brown, N.D.; Sheil, D. 1999. Assessing forest canopies and understorey illumination: canopy closure, canopy cover and other measures. Forestry. 72: 59-73.

Kimmins, J.P. 2002. Future shock in forestry. Where have we come from; where are we going; is there a right way to manage forests? Lessons from Thoreau, Leopold, Toffler, Botkin and Nature. The Forestry Chronicle. 78: 263-271.

King, **J.E. 1966**. **Site index curves** for Douglas-fir in the pacific Northwest. Weyerhaeuser Forestry Paper 8: Centralia, WA. 49 p.

Latta, G.; Montgomery, C.A. 2004. Minimizing the cost of stand level management for older forest structure in western Oregon. Western Journal of Applied Forestry. 19: 221-231.

Lippke, B.R.; Sessions, J.; Carey, A.B. 1996. Economic analysis of forest landscape management alternatives. CINTRAFOR Spec. Pap. 21. Seattle, WA. College of Forest Resources, University of Washington. 157 p.

McCarter, J.B. 2001. Landscape management system (LMS): background, methods, and computer tools for integrating forest inventory, GIS, growth and yield, visualization and analysis for sustaining multple forest objectives. Seattle, WA: University of Washington. 101 p. Ph.D. dissertation.

Nyland, R.D. 1996. Silviculture concepts and applications. New York: McGraw Hill. 633 p.

Peterson, C. E. and Maguire, D.A., eds. 2005. Balancing ecosystem values: innovative experiments for sustainable forestry: Proceedings of a conference Gen. Tech. Rep. PNW-GTR-635. Portland, OR**:** U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 389 p.

Poage, N.J.; Tappeiner, J.C. 2004. Tree species and size structure of old-growth Douglas-fir forests in central western Oregon, USA. Forest Ecology and Management. 204: 329-343.

Somerville, A. 1980. Wind stability: forest layout and silviculture. New Zealand Journal of Forest Science. 10: 476-501.

Tappeiner, J.C.; Huffman, D.; Marshall, D.; Spies, T.A.; Bailey, J.D. 1997. Density, ages and growth rates in old-growth and young-growth forests in coastal Oregon. Canadian Journal of Forest Research. 27: 638-648.

Washington State Department of Natural Resources [WDNR]. 1997. Final Habitat Conservation Plan. Olympia, WA**:** Washington State Department of Natural Resources 223 p.

Washington State Department of Natural Resources [WDNR]. 2004. Final Environmental Impact State on Alternatives for Sustainable Forest Management of State Trust lands in western Washington and for determining the sustainable harvest level. Olympia, WA: Washington State Department of Natural Resources.

Washington State Department of Natural Resources [WDNR]. 2006. Final environmental impact statement on the policy for sustainable forests. Olympia, WA: Washington State Department of Natural Resources.

Wiley, K.N. 1978. Site index tables for western hemlock in the Pacific Northwest. For. Pap. 17. Centralia, WA: Weyerhaeuser Forest Research Center. 28 p.

Wilson, J. S.; Oliver, C.D. 2000. Stability and density management in Douglas-fir plantations. Canadian Journal of Forest Research. 30: 910-920.

Winter, L.E.; Brubaker, L.B.; Franklin, J.F.; Miller, E.A.; DeWitt, D.Q. 2002. Initiation of an old-growth Douglas-fir stand in the Pacific Northwest: a reconstruction from tree-ring records. Canadian Journal of Forest Research. 32: 1039-1056.

Zenner, E.K. 2005. Development of Tree Size Distributions In Douglas-Fir Forests Under Differing Disturbance Regimes. Ecological Applications. 15: 701-714.

Zobrist, K.W.; Hinckley, T.M. 2005. A literature review of management practices to support increased biodiversity in intensively managed Douglas-fir plantations. Final Technical Report to the National Commission on Science for Sustainable Forestry (NCSSF). Seattle, WA: Rural Technology Initiative, College of Forest Resources, University of Washington.

ISSUES AND ALTERNATIVES ASSOCIATED WITH PRIVATE FOREST WILDLIFE AND RIPARIAN HABITAT MANAGEMENT

Bruce Lippke[1], Kevin W. Zobrist[2], and Kevin Ceder[3]

ABSTRACT

Efforts to provide habitat for species in decline invariably fall back on managing stands to emulate older forest conditions as the forest structure in greatest decline. To more quickly achieve old forest structural conditions that were thought important to the survival of the northern spotted owl (*Strix occidentalis*), biodiversity thinning pathways were designed to reinitiate understory and more complex structures including consideration for retaining downed logs, snags and multiple canopy layers. Stream buffer rules have since evolved to target natural old forest conditions as the desired future condition (DFC) along streams. The economics of no-management and even longer rotations to achieve old forest structures generally falls below acceptable rates of return providing motivation for land conversion. Alternative management approaches that allow thinning treatments and narrow buffers cost landowners much less, reduce the motivation for land-conversions, and have been shown to accelerate development of desired old forest conditions along streams. Thinning in upland stands improves young forest habitat at minimal cost while placing stands on a trajectory that can ultimately produce old forest structure albeit at an unacceptable cost for private owners. Incentives coupled with thinning harvests can be used to offset landowner losses and may help reduce the motivation for land conversion while contributing to achievement of habitat objectives.

KEYWORDS: Riparian buffers, forest regulations, sustainable forestry, biodiversity pathways, old forest habitat, private forests.

INTRODUCTION

Two decades ago, declines in old forest habitats with consequent impacts on certain species such as the northern spotted owl prompted interest in forest management strategies that integrate protection of habitat and other ecological values with acceptable economic returns. In 1993, the Washington Forest Landscape Management Project brought together an interdisciplinary team of scientists to investigate the potential for intentionally managing stands to accelerate development of old forest conditions as a method that might improve wildlife habitat and avoid future endangered species listings (Carey et al. 1996, Carey et al. 1999, Lippke et al. 1996). Old forest habitat has declined as a consequence of commercial management, forest conversions, and disturbance events that result in continued risk of habitat loss and species listings in absence of direct attempts to provide more of these old forest conditions. A range of prescriptive treatments called biodiversity pathways was developed to accelerate old forest functionality while providing economic revenues. The treatments were characterized by repeated thinnings and longer rotations than typical commercial management, with attention to retaining downed logs, snags, and multi-layered canopies. Evaluations of the biodiversity pathways indicate that they could be used to develop late seral characteristics in young, dense, managed stands more rapidly and at less cost than by setting the stands aside as no-harvest reserves, which would require a long time for natural processes to result in the desired structural diversity associated with older forests.

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More recently, in response to declining salmon runs, attention has shifted towards mitigating the environmental impacts associated with commercial forest management adjacent to streams in the Pacific Northwest. Similar to habitat objectives for the protection of upland species, the goal of riparian harvest regulations in Washington and Oregon is to allow the development of riparian forest structure similar to more complex older forests, also referred to as the desired future conditions (DFC). An especially important component of the DFC is the development of large conifers as a source of shade and long-term large woody debris (LWD) recruitment to streams. In the absence of active management it will likely take an undesirably long time for riparian areas in young, dense stands to achieve the DFC (Carey et al. 1999, Chan et al. 2004). This is especially true in Washington, which requires wider buffers with significant portions where no harvesting is allowed.

The riparian harvest regulations in both Oregon and Washington permit landowners to deviate from the regulatory prescription and pursue alternative management plans for stands that are unlikely to achieve DFC without active management. The Washington regulations further suggest that management templates be developed for riparian stands that are overly dense, which are expected to be common situations given historical management practices. Templates would provide specific guidelines to streamline the process for developing and approving alternate plans.

The principle biodiversity pathways that were developed earlier to restore old forest conditions in upland areas provide useful guidance for managing riparian forests for old forest structure as well. This management approach was noted early-on as an alternative to reduce the cost of no-harvest stream buffers in the development of the Washington State Department of Natural Resources (WDNR) Habitat Conservation Plan (Bare et al. 1997), and it has since been evaluated more thoroughly in an examination of sustainable harvest practices on state forests in western Washington (WDNR 2004). In an examination of management alternatives for small private forestlands, Zobrist et al. (2004, 2005) found that landowners, through a series of thinning harvests modeled as biodiversity pathways, could achieve the long-term desired condition of old forest structure in riparian zones while protecting short-term functions and maintaining an acceptable economic return.

A defining characteristic of the biodiversity pathways is that treatments must start early in young, dense stands so that the height-to-diameter ratio for the retained trees is low enough to resist wind-throw, there is enough live crown for a vigorous treatment response, and the maximum structure benefit is achieved over time. Since dense, closed-canopy stands offer the least habitat diversity, early thinnings tend to support understory development with increased habitat at a young age while also putting stands on a trajectory to develop more older forest functionality in the long run. Thus these pathways achieve multiple habitat objectives over time. Concurrently, thinnings provide early revenue opportunities to partially offset the economic costs of longer rotations. This paper will develop the use of these methods for managing riparian and upland forests for better habitat while noting some of the many ecological and economic complexities that need to be understood to promote sustainable forest policies and avoid unintended consequences.

ASSESSING HABITAT QUALITY

A challenge with biodiversity pathways is how to identify the best management alternatives. Since the goal of the treatment path is to develop a desired stand structure, a statistical assessment procedure was developed to determine how well a given pathway produces stand structure similar to that of older forest structures (Gehringer 2006). Treatment alternatives can be simulated to see how long it takes for a stand to develop old forest conditions and how long that the stand retains those conditions. Greater tree height and diameter, and lower stand density provide most of the discriminating characteristics that structurally describe an older forest in the Pacific Northwest.

The assessment procedure, in combination with an economic assessment of treatment alternatives, can provide a coarse filter for identifying the most successful management pathways. Management alternatives that produce old forest structure are likely to be more sustainable if economic returns are sufficient to sustain the land in forestry with a lower risk of conversion to other uses. Supplemental screening of alternatives can also be applied using additional metrics of interest, such as the potential for LWD recruitment to streams. The variability of LWD recruitment potential is so high, even in old forests, that it does not help in the discrimination of old forest conditions. However, alternatives that produce the DFC and also have high LWD recruitment potential are considered more desirable for stream protection on the Westside.

DEVELOPING TEMPLATES

To identify the best treatment alternatives, a range of biodiversity pathways are defined and evaluated for the percent of time they result in statistically similar structure to old forests, provide sustainable economic returns, and provide other specific attributes of interest such as LWD for stream habitat or snags that provide habitat for woodpeckers and other species. Best performing alternatives can be developed as templates, which would provide pre-established management guidelines for an appropriate range of site parameters. Templates would minimize the time and expense for management planning for landowners, providing both the timing information needed for treatments and a robust ecological and economic justification for the management approach. We will present example management alternatives and a corresponding simplified template designed for implementation of the best management alternatives at a reasonable cost.

EXAMPLE RIPARIAN MANAGEMENT TARGETS

To develop a management template for producing old forest conditions in riparian areas, quantitative, objective evaluation criteria are needed. To develop a first order ecological criterion to assess pathways relative to the DFC, a reference dataset was established using subplots from the Pacific Resource Inventory, Monitoring, and Evaluation (PRIME) database, which is part of the USDA Forest Service's Forest Inventory and Analysis (FIA) program. To select conditions representative of the DFC (mature, unmanaged, riparian stands), subplots were selected that were at least 80 years old, were within 215 ft of a stream and did not have a history of management.

The structural attributes of this reference dataset were used to create a quantitative management target representing the DFC. Potential management plans could then be assessed to determine whether they achieve the target, producing a structure that was statistically similar to the DFC (Gehringer 2006). Three attributes provided the best discrimination in describing the structure of the reference dataset: stand density in trees per acre (TPA), quadratic mean diameter (QMD), and average height computed using only trees having a diameter at breast height (DBH) greater than 12 in. The distribution of values for these attributes, when considered simultaneously, established a three-dimensional target region. The target region was then refined by identifying a 90 percent acceptance region around the mode (the most likely value of the data distribution) to reduce the influence of the most extreme or outlying data points (fig. 1). An observed stand condition in which the density, QMD, and average height fall simultaneously within the 90 percent target acceptance region would be statistically similar to the DFC reference dataset.

The percentage of time over a 140-year assessment period (assessed at five-year intervals) that the stand structure for a projected management option fell within the target was established as the specific ecological performance criterion for potential management templates. This criterion allowed the selection of template options that achieved the DFC quickly, maintained it until a regeneration harvest, and then quickly re-attained it in the subsequent rotation.

In addition to an ecological criterion, an economic criterion is needed. Soil expectation value (SEV), or bare land value, is the net present value of a complete forest rotation repeated in perpetuity given a target rate of return (Klemperer 1996). This is perhaps the most important single economic criterion, as it measures the economic performance of the initial investment and whether it provides an acceptable rate of return to sustain the land under forest management. Soil expectation value is also relevant for landowners starting with mid-rotation stands, as at some point they will reach the end of a rotation and be faced with the decision of whether or not to continue the template for additional rotations. Soil expectation value was computed using a five percent real cost of money.

ASSESSING TEMPLATE ALTERNATIVES

Using the biodiversity pathway model, we defined a range of alternatives that incorporated repeated heavy thinnings over long rotations to enhance riparian forest structure while providing acceptable economic returns. These alternatives were designed for Douglas-fir stands with mid-high site quality and each alternative was a variation of a base 100-year rotation. This base rotation included three commercial thinnings, the first of which was an early commercial thinning from below to 180 TPA at age 20. Early commercial thinnings are being utilized in lieu of pre-commercial thinnings, given new markets for small diameter wood (Talbert and Marshall 2005). Subsequent thinnings from below to 60 TPA at age 50 and to 25 TPA at age 70 were performed. A clearcut harvest was done at age 100, followed by replanting Douglas-fir to a typical density of 435 TPA (Talbert and Marshall 2005). In order to keep the costs of riparian treatments low, the timing of these entries was chosen to correspond with upland operations, which were assumed to be done on a 50-year rotation with a commercial thinning at age 20 (table 1).

A total of 18 potential template alternatives were generated from which to select those with the best ecological and economic performance as the basis for template development. Each alternative included a 25-ft no clearcut zone to provide for continuous shade and bank stability. One of

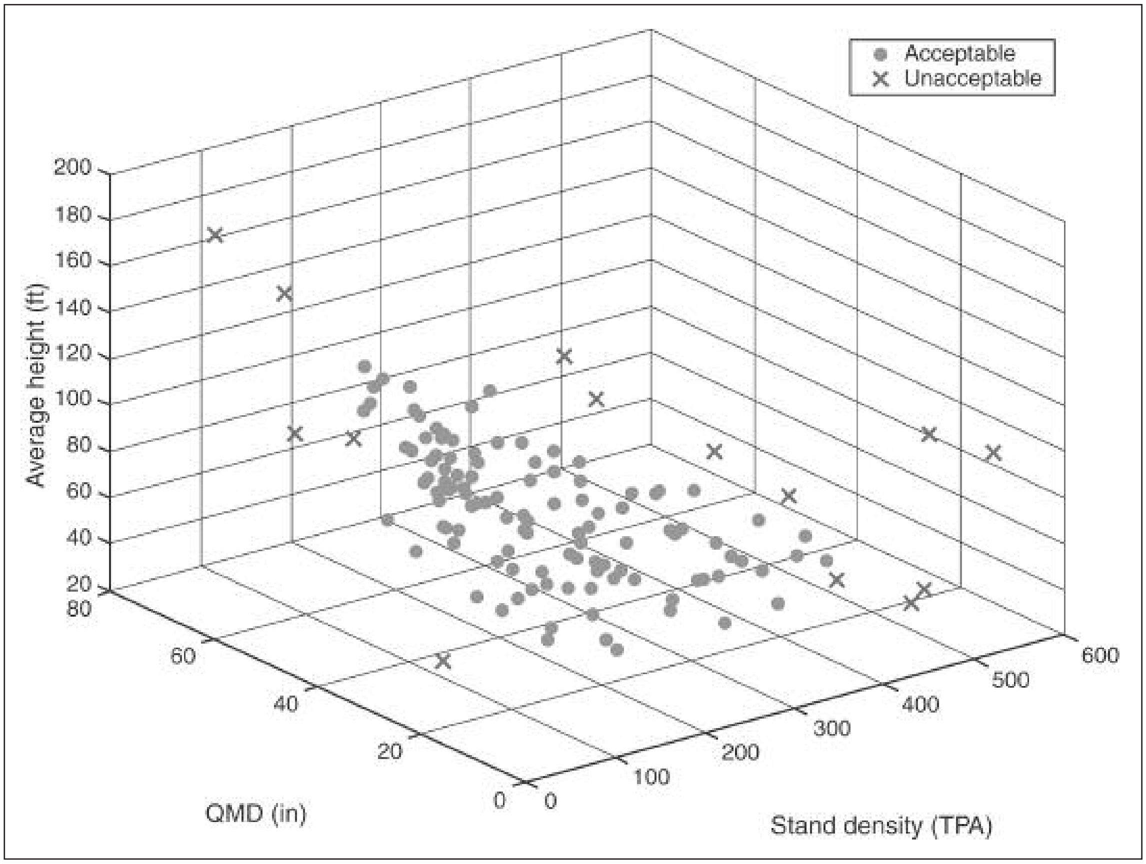

Figure 1—The 90 percent acceptance region of the three-dimensional structure target. The grey dots represent the central 90 percent of the DFC dataset, while the black Xs represent the most extreme ten percent of the data points that are rejected as the outlying values. A stand whose observed attributes fell within the 90 percent acceptance cluster would be statistically similar to the DFC dataset.

three prescriptions was applied in this zone: no action, no entry after thinning to 60 TPA (60-hold), or no entry after thinning to 25 TPA (25-hold). Beyond this bank stability zone, either 25-hold or the full 100-year rotation was applied. There were three total buffer widths used: 50-, 80-, and 113-ft. These widths corresponded to divisions between buffer zones for site class II under the Washington regulations. The total width of the riparian zone was 170 ft, and was based on the site potential tree height for site class II. The portion of the riparian zone beyond the buffer was assumed to be managed with the upland areas (50-year rotation). Specific prescriptions for the 18 alternatives are listed in table 2.

The 18 riparian management alternatives were simulated over time using the Landscape Management System (LMS). Landscape Management System is a program that integrates growth, treatment, and visualization models under a single, user-friendly interface (McCarter et al. 1998). Landscape Management System includes a number of regional variants of publicly available single-tree growth models. The Stand Management Cooperative (SMC) variant of the ORGANON growth model was used to simulate the template options (Hann et al. 1997). Simulations were begun using an initial inventory from a 20-year-old Douglas-fir plantation in southwestern Washington that is representative of a dense plantation approaching its first commercial thinning (fig. 2). The plantation had 472 TPA and a 50-year site index of 120 ft. The simulation length was 140 years for all prescriptions. For prescriptions that included a regen-eration harvest (the 100-year rotation and the 50-year upland rotation), replanting was done to 435 TPA and the rotation repeated as necessary.

Using LMS projections of tree lists, stand structures relative to the target conditions were assessed over time. Each management segment of the riparian area (the bank stability zone, remaining buffer, and the riparian area out-

Table 1—Timeline of riparian entries and corresponding upland operations for the 100-year Douglas-fir rotation defined for potential riparian template options based on the biodiversity pathway approach

Year	Riparian entry	Corresponding upland operation
20	Thin to 180 TPA	Thin to 180 TPA
50	Thin to 60 TPA	Clearcut and replant
70	Thin to 25 TPA	Thin to 180 TPA
100	Clearcut and replant	Clearcut and replant

Table 2—18 potential template alternatives. Each alternative had a 25-ft no clearcut bank stability zone that was thinned to 60 TPA, 25 TPA, or left unthinned. The remaining portion of the buffer varied in width and was either thinned to 25 TPA or managed on a 100-year clearcut rotation

Alternative	Bank stability zone prescription	Remaining buffer prescription	Total buffer width (ft)
1	No action	25-hold	113
2	No action	100-year	113
3	No action	25-hold	80
4	No action	100-year	80
5	No action	25-hold	50
6	No action	100-year	50
7	60-hold	25-hold	113
8	60-hold	100-year	113
9	60-hold	25-hold	80
10	60-hold	100-year	80
11	60-hold	25-hold	50
12	60-hold	100-year	50
13	25-hold	25-hold	113
14	25-hold	100-year	113
15	25-hold	25-hold	80
16	25-hold	100-year	80
17	25-hold	25-hold	50
18	25-hold	100-year	50

side the buffer) was assessed independently, and a weighted average was used to obtain an assessment score. Recognizing that the portions of the riparian area closest to the stream are more critical for key riparian functions such as LWD recruitment, greater weight was given for closer proximity to the stream. To calculate the weights, potential LWD recruitment volume was simulated for the DFC dataset using a model that estimates the expected values for potentially available LWD (Gehringer 2005). The average percent of the cumulative potentially available LWD volume derived using the DFC dataset was then plotted by distance from the stream out to the site potential tree height of 170 ft where 100 percent of the potential LWD volume was included (Meleason et al. 2003) (fig. 3). The weights used for a management segment of a given width and distance from the stream were computed as the proportion of the cumulative potential LWD volume recruitment for the corresponding segment of the cumulative curve.

To assess economic performance, SEV was computed for each alternative using local log prices and treatment

Figure 2—Photo and SVS visualization of the representative inventory used to simulate potential template alternatives. The inventory is from a Douglas-fir plantation in southwest Washington. Photograph taken by Kevin Zobrist.

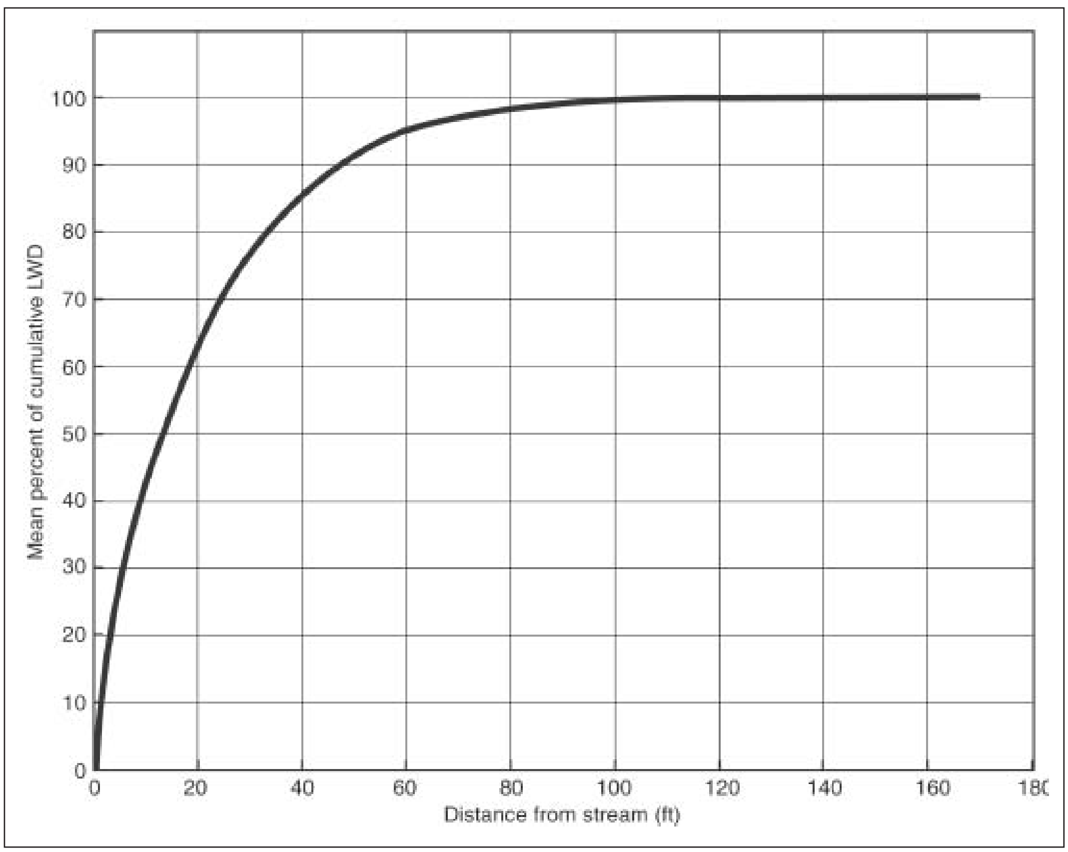

Figure 3—The average percent of the cumulative potential LWD volume recruitment by distance from the stream, based on simulations of potentially available LWD using the DFC dataset.

Table 3—Percent time in target over a 140-year assessment period, along with soil expectation values (SEV) per riparian acre for the no harvest alternative, default regulatory prescription, and 18 potential template alternatives

Alternative	Time in target	SEV/acre
	Percent	*Dollars*
Washington regulations	32.1	(215)
No Harvest	31.0	(800)
1	40.1	(322)
2	46.1	106
3	40.1	(45)
4	45.8	222
5	39.9	207
6	44.1	329
7	64.5	(322)
8	70.5	106
9	64.5	(45)
10	70.2	222
11	64.2	207
12	68.5	329
13	62.1	(322)
14	68.1	106
15	62.0	(45)
16	67.7	222
17	61.8	207
18	66.1	329

Note: Parentheses indicate negative values.

costs[4]. Soil expectation value was calculated from the cumulative economic contribution of each management segment of the riparian area out to the 170-ft site potential tree height as the extremity of the riparian area. The overall economic performance of a stand depends on the combined performance of the riparian and upland areas. However, identifying management alternatives that achieve viable economic returns for the riparian area ensures that riparian areas do not cause a loss of economic viability, even when they comprise a high proportion of a stand.

IDENTIFYING PREFERRED TEMPLATE ALTERNATIVES

The percent time in target over a 140-year assessment period, along with SEV per riparian acre, is summarized in table 3 for the 18 potential template alternatives. The default prescription under the Washington regulations[5] and a no riparian harvest alternative are included as reference points. For riparian templates to be implemented, the performance of the default regulatory option could be considered as a threshold for acceptance since protection should be at least as good as the default regulatory prescription.[6]

The no harvest alternative performed the worst relative to both the DFC and economic criteria. Maintaining a dense stand with no thinning delayed the achievement of the DFC, resulting in a low time in target score. The lack of harvest revenue resulted in a net economic cost per acre, as the only cash flows were the annual overhead costs, which are assumed to apply regardless of whether a harvest occurs. This resulted in a negative SEV (-$800). The regulatory prescription only had a marginally higher time in target score than the no harvest alternative, as the regulatory prescription called for no harvest within 80 ft of the stream– this is the portion of the riparian zone which provides the majority of the potential LWD volume and has a score weight of almost 100 percent (fig. 3). The SEV for the regulatory prescription was negative, as there was not enough harvest revenue to achieve the five percent target rate of return.

All 18 of the potential template alternatives performed better than the regulatory prescription, as the biodiversity thinnings accelerated the development of the DFC, achieving greater time in target scores. Alternatives 1-6 had the lowest time in target scores of the 18 alternatives, as these alternatives did not include any thinning in the first 25 ft, which carries a scoring weight of 0.71 (fig. 3). Economic performance was driven by the total buffer width and whether or not a regeneration harvest was allowed in the area outside the bank stability zone. For the alternatives that did not have a regeneration harvest outside the bank

[4] Average Puget Sound region delivered log prices for 2000 were used, as reported by Log Lines. Logging and hauling costs were based on Lippke et al. (1996) and varied by the average DBH of the harvested trees and whether the harvest was a clear-cut or thinning operation. The early commercial thinning at age 20 was assumed to break even, with no net cost or revenue. Planting costs were assumed to be $0.55/seedling ($239/acre for 435 TPA). Since this template was developed with smaller, non-industrial landowners in mind, relatively high annual overhead costs of $40/acre were used. For larger or industrial landowners, $17/acre were considered appropriate. All financial calculations were done before taxes.

[5] Washington regulations allow several management options. It is assumed that the default option for a clear-cut harvest is "Option 2," which requires a minimum 80-foot no harvest area, followed by retention of 20 conifers per acre greater than 12 inches in DBH out to edge of the riparian zone at 170 feet.

[6] The regulations do not specify a performance standard for riparian protection, but given that the stated intent of the regulations is to develop the DFC, time in target was assumed to be a reasonable criterion.

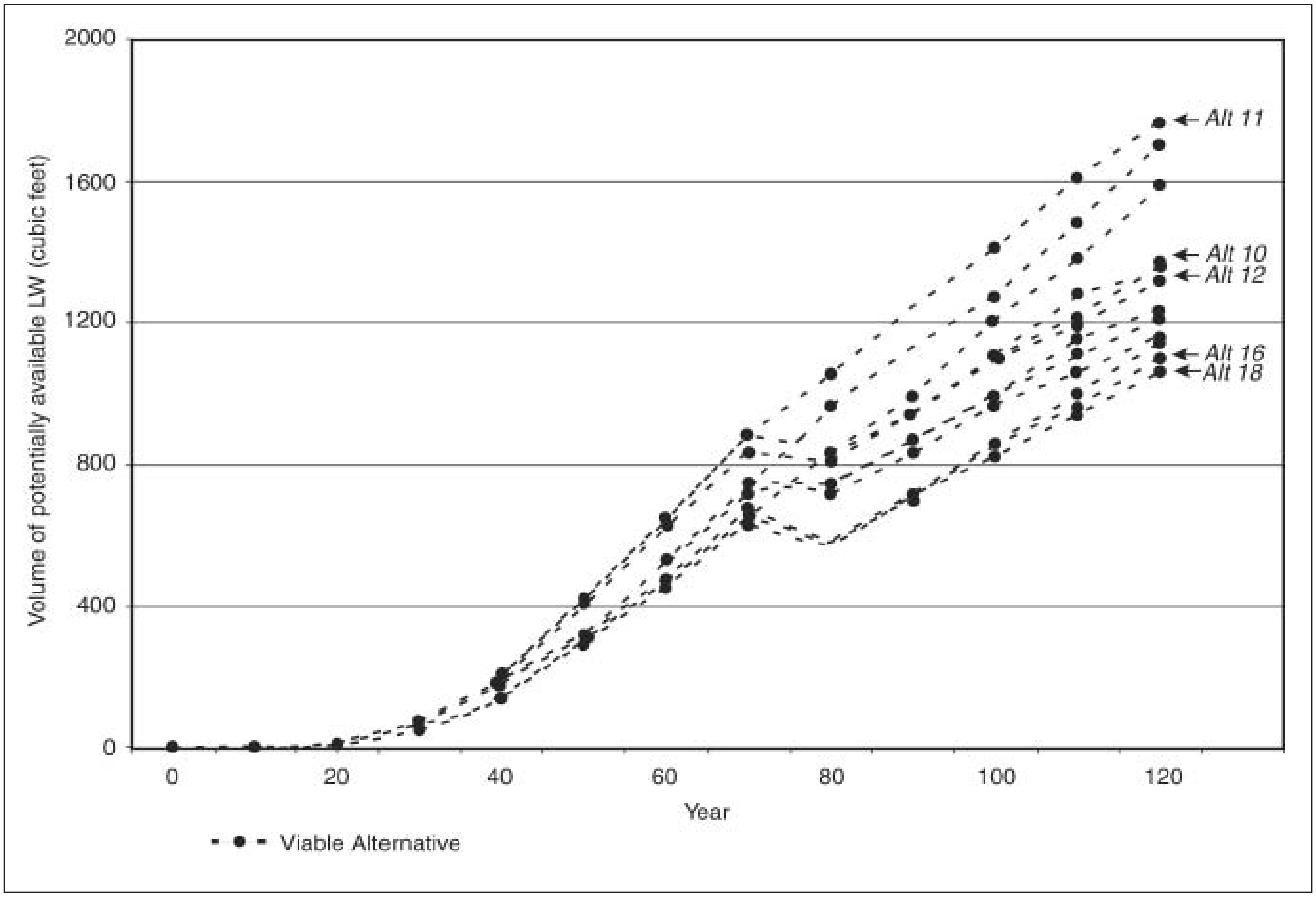

Figure 4—Potentially available LWD volume over time for the 12 viable template alternatives. Alternative 10 had the largest final volume of the four alternatives that performed best in the coarse filter assessment, and alternative 11 had the largest final volume of all viable alternatives.

stability zone (25-hold instead of 100-year), no further harvest was done after the third thinning to 25 TPA, which was assumed to preclude subsequent rotations. As with the no harvest prescription, this resulted in a negative SEV (-$800) for those segments, as the only perpetual cash flows beyond the current rotation were the annual overhead costs.

A total of 12 out of the 18 potential alternatives could be considered as viable template options, having achieved both increased time in target values and the five percent target rate of return (SEV > $0). Alternatives 10, 12, 16, and 18 performed particularly well relative to both criteria. This allowed adding an additional potentially available LWD as a fine filter screening criterion to refine the set of viable options down to one or two preferred alternatives. LWD provides important in-stream functions, and long-term sources of LWD are typically lacking in areas of intensive management (Bilby and Bisson 1998). The potential LWD volume was simulated for the 12 viable template alternatives using a potentially available LWD model (Gehringer 2005). The potentially available LWD volume for each alternative is plotted in figure 4.

Of the four alternatives that performed best in the coarse filter assessment, alternative 10 provided the largest level of potentially available LWD volume at the end of the 120-year simulation, with a value of 1,369 ft^3. Alternative 11 also warranted consideration, as it provided the largest level of potentially available LWD at the end of the 120-year simulation of all of the viable alternatives, with a value of 1,761 ft^3. While this alternative did not perform as well as others in the initial template assessment, it still met the minimum criteria, and its higher LWD volume made it a desirable second option.

Two preferred options emerged from the fine filter assessment: alternatives 10 and 11. Both alternatives called for the 60-hold prescription in the 25-ft bank stability zone. Alternative 10 had a wider total buffer width of 80 ft, but

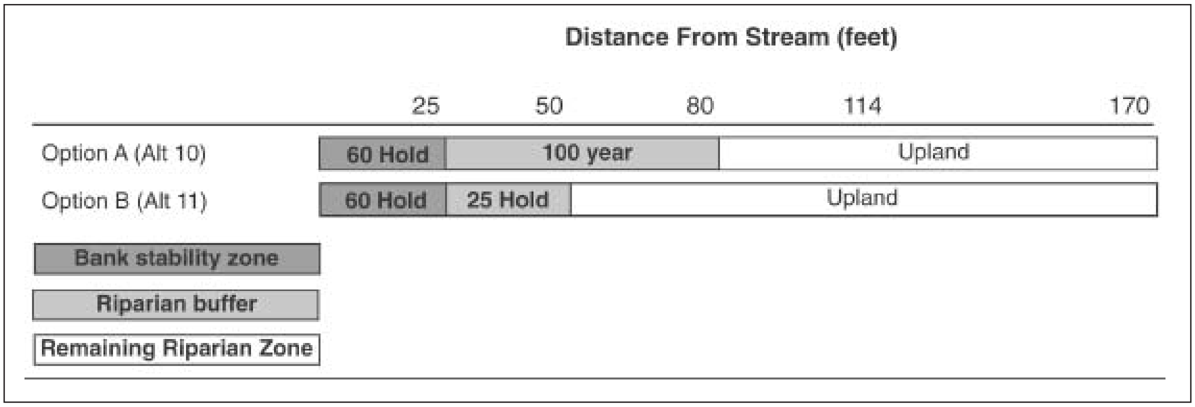

Figure 5—Using the fine filter criterion, two preferred alternatives emerged: alternative 10 and alternative 11. These became Option A and Option B respectively for the template. Option A had a wider buffer but allowed a regeneration harvest outside the bank stability zone, whereas Option B had a narrower buffer but allowed no further entries after the third thinning.

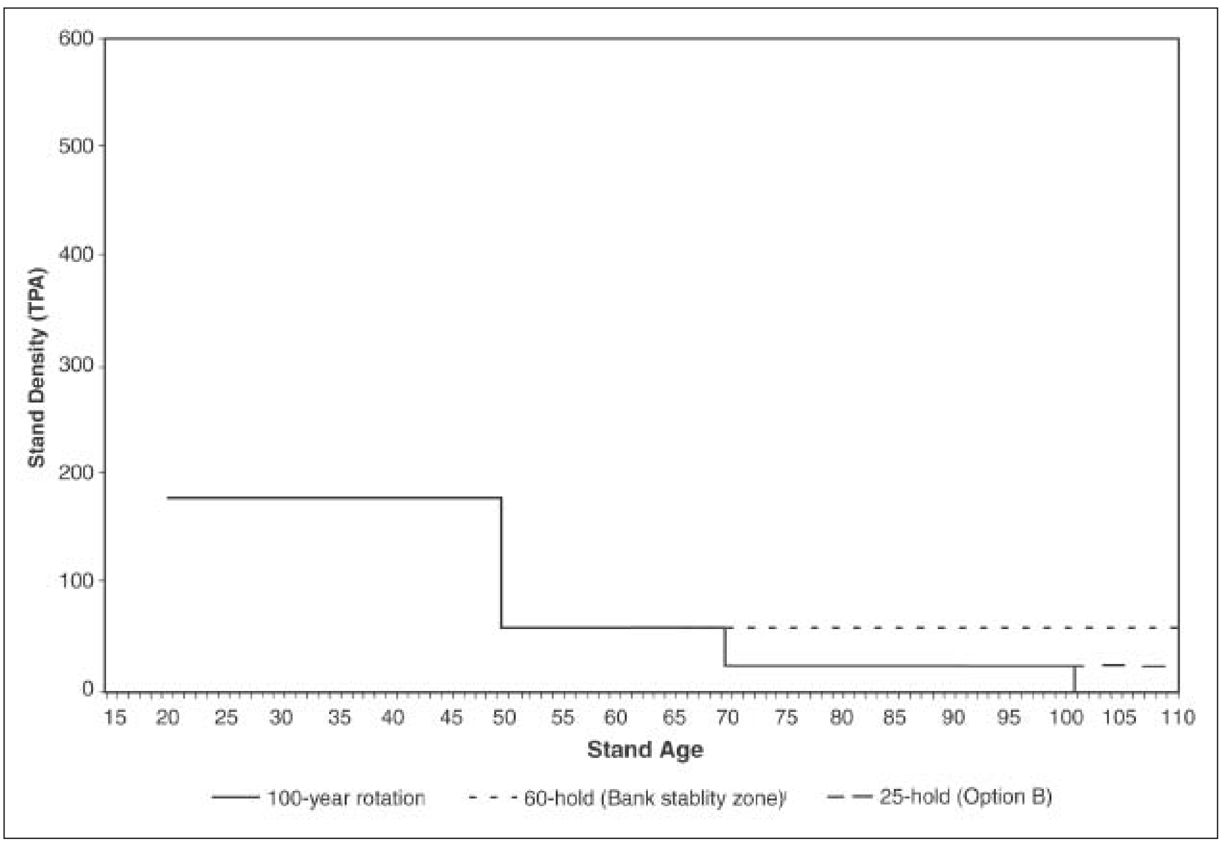

Figure 6—Management diagram for the two template options showing target stand density by stand age. The solid lines show the trajectory of the 100-year rotation, while the dashed lines show the 60-hold density floor for the bank stability zone and the 25-hold density floor for the remainder of the buffer under Option B.

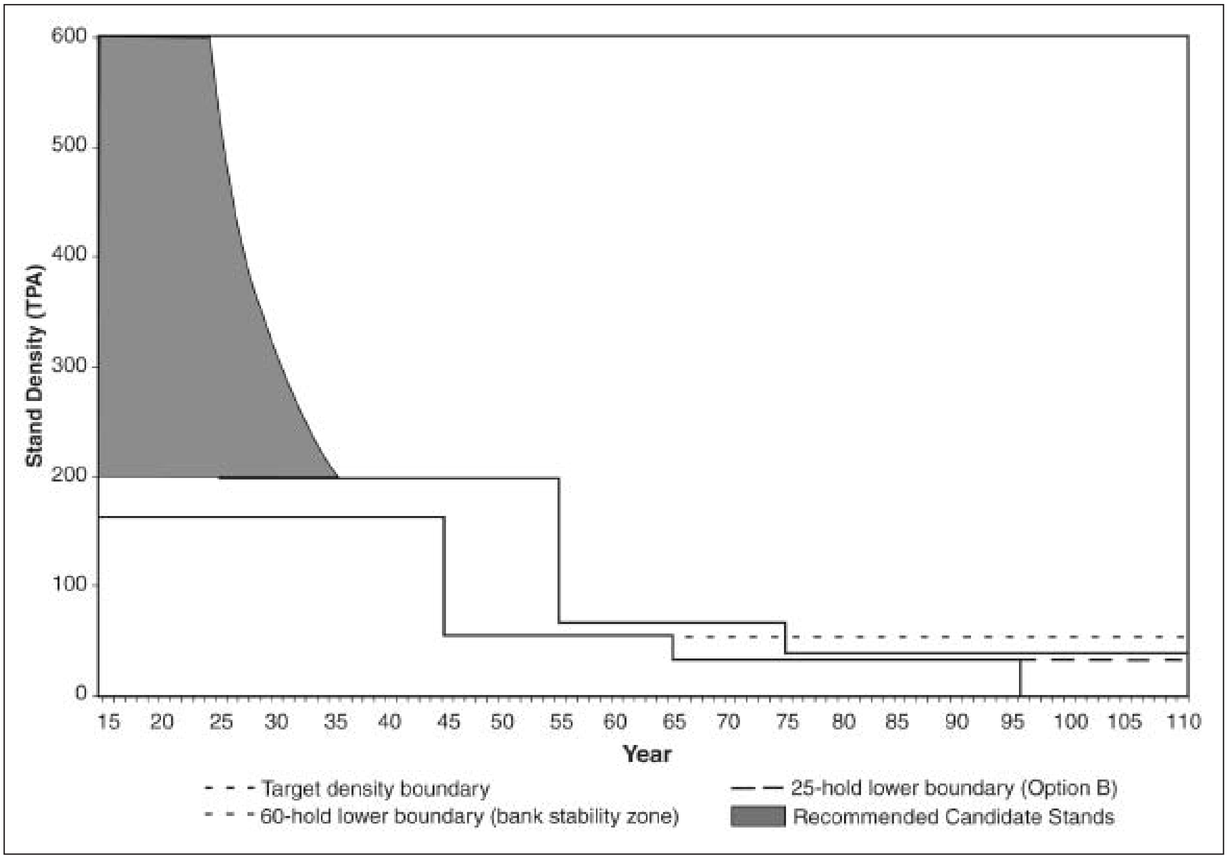

Figure 7—The example management template, with a density range of ± ten percent and a thinning window of ± 5 years for operational and timing flexibility. The shaded region indicates the stand conditions that are best suited for this template. For stands outside of this region, other factors should be considered before applying the template prescription.

allowed a regeneration harvest outside the bank stability zone (100-year prescription). Alternative 11 had a narrower total buffer width of 50 ft but did not allow additional entries after the third commercial thin (25-hold prescription). These alternatives then became Option A and Option B, respectively, in a template that gives landowners a choice between two different approaches (fig. 5).

Stand density targets were plotted by stand age for the two template options in figure 5 to provide a density management diagram (fig. 6). The solid line shows the management trajectory for the 100-year rotation, with the dashed lines showing the 60-hold density floor for the bank stability zone and the 25-hold density floor for the remainder of the buffer under Option B. To refine this prescription into template form, a density range of plus or minus ten percent was added for operational flexibility. Likewise, a 10-year thinning window of plus or minus five years was added for timing flexibility to coordinate with market conditions or other operations. The target density for the third thinning was also increased to 35 TPA, to address concerns that thinning to 25 TPA may be too heavy. The resulting template specifying desired management ranges is shown in figure 7. The shaded area in figure 7 suggests stand conditions which are likely to respond well to the template prescription. Stands beyond this area may be unstable from growing at high densities for too long (Wilson and Oliver 2000) or may not have the capacity to produce a growth response if thinned heavily. Additional factors, such as height/diameter ratio or live crown ratio, should be considered before applying the template prescription to stands beyond the shaded region.

RIPARIAN TEMPLATE APPLICATIONS

The final riparian management template provides useful guidance for landowners in Washington and Oregon who have overstocked riparian stands and wish to pursue an alternative management plan. For mid-high site stands with conditions that are within the candidate region illustrated in figure 7, the analysis suggests that either of the template options could significantly increase the structural similarity to the DFC over a 140-year time period while also providing an acceptable economic return. Both have been rigorously developed and evaluated by assessment procedures. It should be cautioned, however, that this template has not received regulatory approval. Landowners who wish to implement this template should work with the appropriate agencies to ensure that all regulatory requirements are met. Longer-term permits may also be needed to fully implement the template as a long-term riparian management plan.

The template described serves as an important demonstration of an objective, data-driven process that can be used to develop templates for situations in which desired outcomes (economic and environmental) can be quantified. Additional riparian templates can be developed for different site classes or for hardwood stands. A number of upland applications also exist for templates, including their use to increase biodiversity in intensively managed plantations. It is important to recognize that no single template can provide all biodiversity needs. Rather, a range of different template options is needed for application across a landscape, as applying the same management prescription over a broad region will ultimately decrease the landscape heterogeneity, with a subsequent decrease in diversity (Bunnell and Huggard 1999). An effective template should be broadly applicable in order to be useful over a significant number of acres, while at the same time the range of appropriate template application should be limited, recognizing that one size does not fit all. Finally, a degree of template flexibility will always be necessary to accommodate site-specific needs within a regulatory context.

UPLAND HABITAT MODELING: A CASE STUDY

The biodiversity pathways discussed above in the context of riparian management alternatives were originally developed with a greater focus on creating upland habitat for species sensitive to the conditions found in older forests such as the spotted owl. The opportunity exists to treat managed stands to provide wildlife habitat for a wide diversity of both game and non-game species. Many types of wildlife habitat models have been developed that can estimate both habitat quality and quantity based on tree lists and forest structure attributes available from existing forest inventory data. There are direct parallels between biodiversity pathway approaches for uplands management and the challenges faced in development of effective riparian strategies. Treatments can be designed to focus on the objectives of a single species or multiple species of local interest while creating a sustainable, albeit diminished, flow of timber.

We illustrate this with a case study carried out to meet the wildlife mitigation agreement on the Satsop Forest in southwestern Washington (Ceder 2001, Marzluff et al. 2002). This project focused on the habitat needs of five species, using previously defined Habitat Suitability Index (HSI) models and the Habitat Evaluation Procedure (HEP) used by Washington Department of Fish and Wildlife (USDI 1980). The species were chosen to track changes in a variety of habitat types: spotted towhee (*Pipilo erythrophthalmus*) in brush habitats; Cooper's hawk (*Accipiter cooperii*) in mixed hardwood and conifer forests; southern red-backed vole (*Clethrionomys gapperi*) in closed canopy forests; pileated woodpecker (*Dryocopus pileatus*) in mature forests; and black-tailed deer (*Odocoileus hemionus columbianus*), a habitat generalist, across a range of structures. The Landscape Management System (LMS) was used with links to the habitat models to estimate current and future habitat conditions responsive to forest growth and alternative management treatments.

Twenty potential management alternatives for Satsop Forest were developed ranging from a no-management control to 40-year regeneration harvests with varying amounts, timings, and levels of thinning between these extremes. Assessments of each alternative determined the amount of habitat for each species and wood volume that could be produced over an 80-year planning horizon. Results indicated the amounts of available habitats, similar to no management or passive management, that could be created through active management (fig. 8). Cooper's hawk, southern red-backed vole, and spotted towhee habitat values changed relatively little as harvesting increased. In contrast, habitat available for the pileated woodpecker, which is associated with older forest structures, generally decreased with high harvest levels but was increased with some management.

Figure 8 shows that reducing the harvest (and timber revenue) by approximately 50 percent can result in increased woodpecker habitat compared to no harvest at all. When the harvest constraints are large, as in this case to affect increases in woodpecker habitat, the incentive needed for private managers to adopt such management approaches with associated costs will also be large. If costly habitat protections are imposed through regulation in absence of compensation, the likelihood of forest conversions on private lands increases.

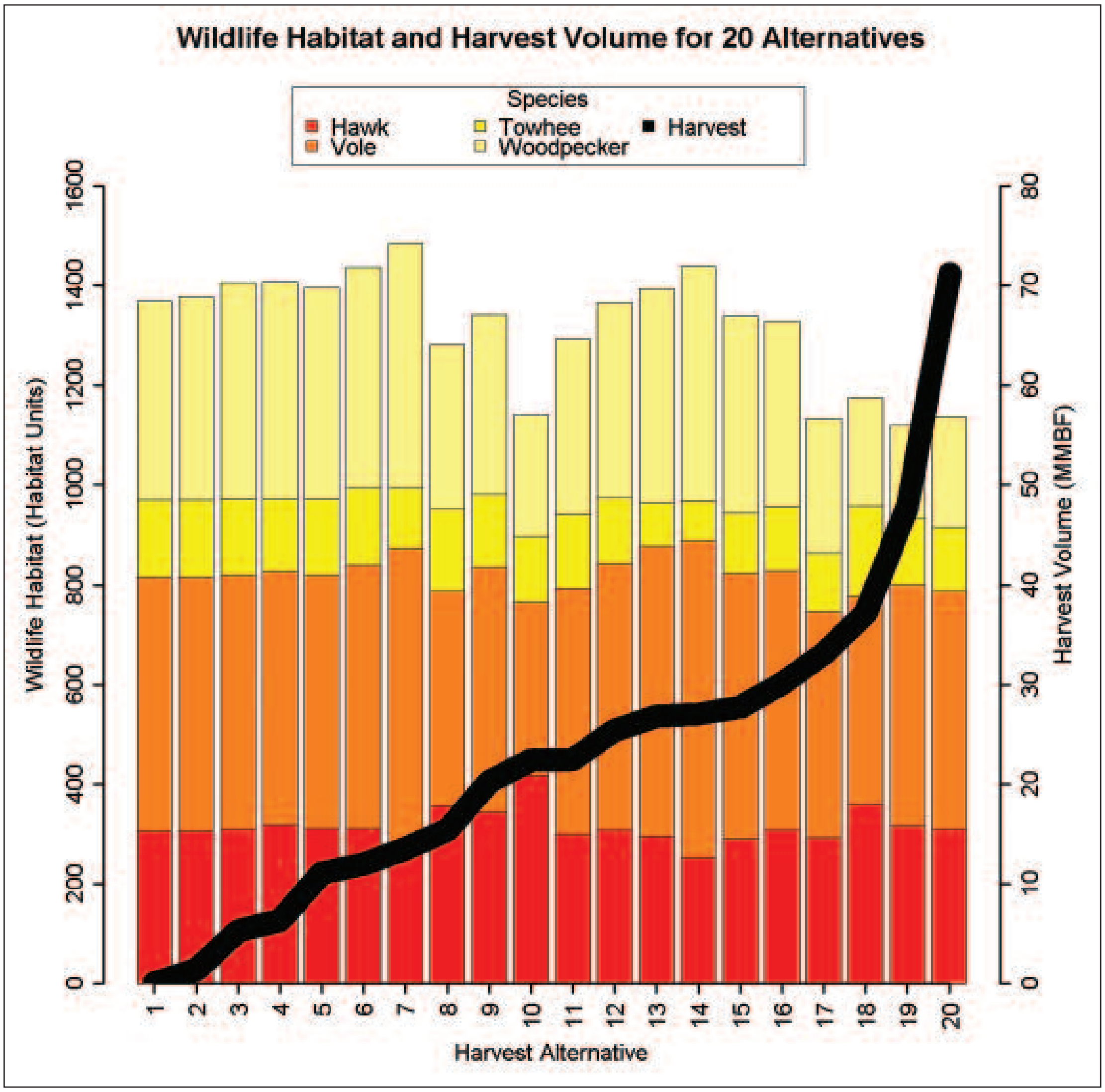

Figure 8—Habitat and volume production for 20 potential 80-year management alternatives for Satsop Forest.

POTENTIAL NEED FOR ECONOMIC INCENTIVES

To determine the costs of increasing habitat is a straightforward process of comparing the landowner return for alternatives that meet the habitat objectives with those that meet commercial objectives. Determining the societal value of meeting the objectives is more complex and currently a difficult political or regulatory decision. As a simplified example, to aid in understanding the cost, a generic biodiversity pathway including three thinnings and a harvest in 100 years produces an SEV of $420 compared to $1000 for a short commercial rotation involving a single commercial thinning (table 4). This $580 loss to the landowner would require an incentive payment of $29 per acre per year to compensate the owner for their loss. While incentives may be needed for biodiversity pathways, the incentives are substantially less than the compensation needed for a no-harvest reserve which for our example is $81 per acre per year even though it cannot achieve the targeted ecological objective as fast as the biodiversity pathway. If the ecosystem service value of achieving the habitat target is at least $29 per acre per year, society should be willing to provide the incentive for the bio-pathway.

HABITAT MODEL USES AND LIMITATIONS

There are many habitat models available that are sensitive to forest structure and hence management treatments such as those developed by Johnson and O'Neil (2001).

Table 4—Soil expectation value (SEV) for commercial and habitat treatments and the incentive needed to offset losses

Treatment	SEV/acre	Incentive/ acre/year
	- - - - - Dollars - - - - - -	
50 yr commercial rotation	1000	0
100 yr biopathway	420	29
No harvest (after stocking)	-615	81

Empirical models can be derived from tree measures, as with the bird population models of Hansen (1995), who generated regression models relating trees per acre in specific diameter classes to bird population. The Washington State Department of Natural Resources has quantified nesting, roosting, and foraging habitats for the northern spotted owl based on tree and snag measures[7].

Models of choice will be dependent upon the region and species of interest. Appropriate models provide managers and planners with the ability to analyze many alternatives quickly while holding all other assumptions constant. This consistency in assumptions provides uniform comparability between simulations so that relative tradeoffs between treatment alternatives can be assessed.

Key limitations to the use of habitat models include the lack of understory models that are compatible with forest growth models and the need for more research to field-verify the target attributes of habitat models. Understory vegetation is a key component for many wildlife species and associated models. Local understory relative to overstory relationships can be developed to derive mean values for understory measures for each forest cover type, as was done for the Satsop Forest project. Lack of regional models, however, increases the cost and complexity of analysis and limits broader application to inform policy decisions. With these limitations in mind, habitat analysis using available modeling capabilities implemented in LMS, or other forest simulation tools, can provide useful predictive capability to assess habitat availability, risks to habitat, and communicate the potential tradeoffs among different treatments and management strategies. Further, in a modeling framework, outputs developed from habitat analysis can be linked to evaluations of economic impacts expected from management alternatives. Other important public values can be assessed as well, such as forest health and carbon sequestration.

CONCLUSIONS

Management alternatives employing thinning treatments have been shown to produce old forest structures more effectively and at a lower cost than no-management reserves or buffers. Such alternatives are needed to meet ecological objectives while supporting an acceptable rate of return to discourage land conversion. Management templates based on an exhaustive analysis of simulation alternatives can simplify the identification of best treatments for practical implementation. Analysis of riparian habitat enhancement opportunities has been shown to benefit from similar modeling methodologies as those developed for upland ecosystem management; however, the assessment of tradeoffs between species of greatest interest, the amount of habitat needed, how much revenue can be foregone, and who pays can become complex. Alternatives are being evaluated for reducing costs of habitat enhancement through thinnings but longer rotations to provide the complexity of older forests will not likely be provided by private managers without incentives to compensate for lost revenues.

LITERATURE CITED

Bare, B.B.; Lippke, B.R.; Xu, W.; Oliver, C.D.; Moffet, J.; Waggener, T.R. 1997. Demonstration of Trust Impacts from Management Alternatives to Achieve Habitat Conservation Goals on Washington Department of Natural Resources Managed Lands. Seattle, WA: College of Forest Resources, University of Washington, 60 p. plus Appendices.

Bilby, R.E.; Bisson, P.A. 1998. Function and distribution of large woody debris. In: Naiman, R.J.; Bilby, R.E., eds. River ecology and management: lessons from the Pacific coastal ecoregion. New York: Springer-Verlag: 324-346.

Bunnell, F.L.; Huggard, D.J. 1999. Biodiversity across spatial and temporal scales: problems and opportunities. Forest Ecology and Management. 115: 113-126.

Carey, A.B.; Lippke, B.R.; Sessions, J. 1999. Intentional ecosystem management: managing forests for biodiversity. Journal of Sustained Forestry. 9: 83-125.

[7] Washington Administrative Code (WAC) 222-16-085

Carey, A.B.; Lippke, B.R.; Sessions, J.; Chambers, C.J.; Oliver, C.D.; Franklin, J.F.; Raphael, M.J. 1996. A pragmatic, ecological approach to small-landscape management. Compiled for the Washington Forest Landscape Management Project. Phase II Report. Sponsored by USDA Forest Service and Washington Department of Natural Resources, with support from the faculty of University of Washington and Oregon State University.

Ceder, K.R. 2001. Using silviculture to sustain wildlife habitat: assessing changes and trade-offs in forest habitats using a habitat evaluation procedure within the Landscape Management System. Seattle, WA: College of Forest Resources, University of Washington. 82 p. M.S. thesis.

Chan, S.; Anderson, P.; Cissel, J.; Larsen, L.; Thompson, C. 2004. Variable density management in riparian reserves: lessons learned from an operational study in managed forests of western Oregon, USA. Forest Snow and Landscape Research. 78: 151-172.

Gehringer, K.R. 2005. An individual tree simulation model for estimating expected values of potentially available large woody debris. Seattle, WA: College of Forest Resources, University of Washington. 77 p. http://www.ruraltech.org/pubs/reports/lwd_gehringer/lwd_gehringer.pdf (Accessed July 2005).

Gehringer, K.R. 2006. Structure-based nonparametric target definition and assessment procedures with an application to riparian forest management. Forest Ecology and Management. 223: 125-138.

Hann, D.W.; Hester, A.S.; Olsen, C.L. 1997. ORGANON user's manual. 6th ed. Corvallis, OR: Department of Forest Resources, Oregon State University. 133 p.

Hansen, A.J.; McComb, W.C.; Vega, R.; Raphael, M.G.; Hunter, M. 1995. Bird habitat relationships in natural and managed forests in the west Cascades of Oregon. Ecological Applications. 5: 555-569.

Johnson, D.H.; O'Neil, T.A. 2001. Wildlife habitat relationships for Washington and Oregon. Corvallis, OR: Oregon State University Press. 768 p.

Klemperer, D.W. 1996. Forest resource economics and finance. New York: McGraw Hill. 551 p.

Lippke, B.R.; Sessions, J.; Carey, A.B. 1996. Economic analysis of forest landscape management alternatives: final report of the working group on the economic analysis of forest landscape management alternatives for the Washington Forest Landscape Management Project. CINTRAFOR Special Paper 21. Seattle, WA: College of Forest Resources, University of Washington. 157 p.

Marzluff, J.M.; Millspaugh, J.J.; Ceder, K.R.; Oliver, C.D.; Withey, J.; McCarter, J.B.; Mason, C.L.; Comnick, J. 2002. Modeling changes in wildlife habitat and timber revenues in response to forest management. Forest Science. 48: 191-202.

McCarter, J.B.; Wilson, J.S.; Baker, P.J.; Moffett, J.L.; Oliver, C.D. 1998. Landscape management through integration of existing tools and emerging technologies. Journal of Forestry. 96: 17-23.

Meleason, M.A.; Gregory, S.V.; Bolte, J. 2003. Implications of selected riparian management strategies on wood in Cascade Mountain streams of the Pacific Northwest. Ecological Applications. 13: 1212-1221.

Talbert, C.; Marshall, D. 2005. Plantation productivity in the Douglas-fir region under intensive silvicultural practices: results from research and operations. Journal of Forestry. 103: 65-70.

U.S. Department of Interior [USDI]. 1980. Habitat evaluation procedures 102 ESM. Washington, DC: U.S. Department of Interior Fish and Wildlife Service.

Washington State Department of Natural Resources [WDNR]. 2004. Final environmental impact statement on alternatives for sustainable forest management of state trust lands in western Washington. Olympia, WA: Washington State Department of Natural Resources.

Wilson, J.S.; Oliver, C.D. 2000. Stability and density management in Douglas-fir plantations. Canadian Journal of Forest Research. 30: 910-920.

Zobrist, K.W.; Gehringer, K.R.; Lippke, B.R. 2004. Templates for sustainable riparian management on family forest ownerships. Journal of Forestry. 102: 19-25.

Zobrist, K.W.; Gehringer, K.R.; Lippke, B.R. 2005. A sustainable solution for riparian management. In: Deal, R.L.; White, S.M., eds. Understanding key issues of sustainable wood production in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-626. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 54-62.

ECONOMIC CONSIDERATIONS IN MANAGING FOR OLDER-FOREST STRUCTURE

Greg Latta[1] and Claire A. Montgomery[2]

ABSTRACT

Forest conomists at Oregon State University have been conducting analyses of cost-effective management for older forest structure on private forest land in western Oregon. We describe three studies in this paper: a stand-level study, a forest-level study, and a simulation of forest certification. We also present a case study in which a stand not part of the original study is used to demonstrate how results from the stand-level study can be applied to a typical production forest stand in such a way that generates more complex structure in a relatively cost-effective manner.

KEYWORDS: Management regimes, opportunity cost, older-forest structure.

INTRODUCTION

For several high-profile wildlife species of concern in the Pacific Northwest, old-growth conifer forest is a critical component of habitat. But its area is dwindling. While these forests may once have covered 30 percent to 70 percent of the western Oregon coastal-forested landscape (Teensma et al. 1991, Wimberly et al. 2000), it is estimated that they now account for only about 5 percent (Spies et al. 2002). Concern about this loss has fueled a number of responses that seek to preserve and enhance the area of older forest on production forests of the Pacific Northwest. We believe that, regardless of the goal of a conservation program or the means by which it may be implemented, the more cost-effective it is, the more likely it will be accepted and implemented.

In three recent studies by forest economists at Oregon State University, different aspects of cost-effective active management for stands that are structurally similar to old-growth on private forest land in western Oregon have been explored: (1) stand-level silvicultural regimes, (2) forest-level targets for the area of structurally old forest, and (3) the effectiveness of certification in achieving forest-level targets.

In the first study, Latta and Montgomery (2004) used a random search heuristic and an individual tree simulation model, ORGANON (Hann et al. 1997), to search for cost-effective old forest management regimes for a wide range of stand types that occur on private land in western Oregon. The regimes were required to meet older forest structural criteria, defined by the Oregon Department of Forestry (Oregon Department of Forestry 2001), for 30 years prior to clear-cut harvest. The opportunity cost of managing for older forest structure was estimated for each stand type as the value of forgone timber production under maximum net present value management. Opportunity cost was found to be positively correlated with site quality, stand age, and stocking.

In the second study, Montgomery et al. (2006) examined the use of active management to achieve targets for the area of private forest land in western Oregon that meet these old forest structural criteria within a range of time frames. The idea of area targets is consistent with standards for sustainable forestry that include measures of the extent of area in the full range of forest successional stages (Montreal Process Working Group, http://www.mpci.org, accessed in August 2004). A model of regional timber

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supply was used to search for cost-effective strategies to reach these targets. The model provides a method for quantifying tradeoffs between the area and timing of alternative targets. It was estimated that a target of 20 percent of private forest area that met older forest structural criteria within 95 years could be achieved at an aggregate loss to forest landowners and lumber and plywood manufacturers of $341 million[3]; doubling the area target from 20 to 40 percent could increase cost 3.4 times and extending the time horizon by 25 years could reduce the cost four-fold.

In the third study, Busby et al. (in press) used the same regional timber supply model for western Oregon to simulate the response of private forest landowners to incentives to certify their forest land. In the case of a $35 per acre certification bonus payment, 20 percent of the forest area was certified within a 100-year time horizon; with a $69 per acre certification bonus payment, 60 percent of the area was certified. However, the ecological benefit of certification, measured in terms of forest area meeting older forest structural criteria, was minimal.

In this paper, we use a case study to illustrate how foresters can use the information from these studies, particularly Latta and Montgomery (2004), to meet sustainability objectives related to older forest structure while generating income from timber harvest. In the next section, a case study stand is described. Stand development under three different management regimes is simulated and costs compared. A discussion of factors leading to the type of older forest structural management regime found in the studies follows. The paper concludes with a brief discussion of the trade-offs involved in identifying optimal versus pretty good management regimes.

CASE STUDY

In the Latta and Montgomery (2004) study, management regimes were developed for a range of stands using an optimization algorithm. While forest land managers are unlikely to have access to such a program, it may be possible for them to generalize from the results of that study in order to generate pretty good regimes for the stands they manage.

To illustrate, a 15-year-old, even-aged Douglas-fir stand from Lincoln County, Oregon was selected. This stand was not part of the original study. It was planted using a ten-by-ten ft spacing and it currently has 474 trees per acre, 15 of which are hardwoods (97 percent of normal stocking; USDA Forest Service 2000). The 50-year Douglas-fir site index is 133 and the current quadratic mean diameter is 4.9 in.

Only a brief description of the growth and yield, silvicultural regimes, logging and other costs are provided here. Additional details may be found in Latta and Montgomery (2004).

Silvicultural Regimes

Growth of the case study stand was simulated for 100 years under three different management regimes: one designed to maximize the net present value of timber harvest with no other objective, one designed to maximize the net present value of timber harvest while generating a stand that meets older forest structural criteria within 125 years, and one that set aside the stand in a reserve with no timber management activities allowed. The first two regimes were based on the optimization results published in Latta and Montgomery (2004).

In tables 1 and 2, we show the average values reported in Latta and Montgomery (2004) for number of years to thinning and percent volume removed in up to three proportional thinnings from the optimized management regimes that meet older forest structural criteria within 125 years. In table 1, the regimes are for newly regenerated stands and, hence, years to thinning are stand ages. The regimes are summarized for all stand types, by forest type, by site class, and by ecological region. In table 2, the regimes are for the 834 existing stands that were included in the original study. Average number of thinnings is shown because less than three thinnings were prescribed for some stands. Again, these are summarized for all stand types, by age class, and by stocking level.

Ideally, a land manager, seeking to achieve older forest structural criteria while maximizing the value of the stand, would find the optimal regime for each existing stand using an optimization algorithm. Or, as a second-best strategy, the manager would identify the regime for the stand in the original study that most closely approximates the stand that is being managed. But this study demonstrates how the published results can provide the basis for a pretty good older forest structural regime.

[3] All dollar values in the paper are in 2005 dollars.

Table 1—Silvicultural regimes for achieving older forest structure in 125 years in newly regenerated stands

Prescription Categories	Years until thinning / percent volume removed 1st thinning	2nd thinning	3rd thinning
All stand types	40 yr/63%	59 yr/56%	79 yr/40%
By forest type:			
Douglas-fir	39 yr/63%	57 yr/62%	76 yr/46%
Other conifer	42 yr/63%	63 yr/48%	83 yr/32%
By site index:			
Over 135	33 yr/61%	49 yr/63%	68 yr/52%
115 to 135	39 yr/61%	54yr /60%	76 yr/40%
95 to 115	45 yr/67%	65 yr/51%	85 yr/37%
95 and under	41 yr/60%	66 yr/54%	86 yr/30%
By ecological region:			
West Coast Range	35 yr/61%	56 yr/54%	78 yr/38%
Other Coast Range	40 yr/66%	57 yr/62%	79 yr/34%
West Cascade Range	39 yr/61%	57 yr/55%	75 yr/49%
Klamath	55 yr/65%	73 yr/53%	89 yr/36%

Note: Years until thinning is equivalent to total stand age for regenerated stands.

Table 2—Silvicultural regimes for achieving older forest structure in 125 years in existing stands

Prescription Categories	Thinnings	Years until thinning / percent volume removed 1st thinning	2nd thinning	3rd thinning
All stand types	2.6	18 yr/68%	39 yr/60%	72 yr/42%
By age class:				
20 and under	2.5	31 yr/67%	51 yr/63%	78 yr/42%
20 to 40	2.6	12 yr/68%	34 yr/59%	69 yr/43%
40 to 60	2.6	5 yr/68%	28 yr/58%	68 yr/40%
60 to 80	2.8	4 yr/69%	28 yr/58%	71 yr/36%
over 80	2.9	6 yr/69%	35 yr/56%	67 yr/42%
By percent of normal stocking:				
40 percent and under	2.6	28 yr/67%	50 yr/61%	77 yr/43%
40 to 120 percent	2.6	11 yr/68%	32 yr/60%	68 yr/40%
over 120 percent	2.5	6 yr/68%	28 yr/56%	68 yr/42%

In developing a pretty good older forest structure management regime, a manager could select and average the applicable prescriptions from the categories presented for newly regenerated stands (table 1) and/or older existing stands (table 2). Prescription categories for regenerated stands are: all stand types, forest type, site index, and ecological region (table 1). Similarly, prescription categories for existing stands are: all stand types, age class, and percent of normal stocking (table 2). A manager could then select an applicable prescription, or multiple prescriptions from appropriate categories in tables 1 or 2 and then develop a composite thinning regime by averaging the values for 1) years until thinning and 2) percent volume removed.

To illustrate this process, we show in table 3 the applicable thinning prescriptions from tables 1 and 2 that relate to the case study stand. Activites in table 3 are presented at total stand age. Simply averaging these prescriptions and rounding to the nearest five yields the following prescription: 65 percent volume removed at age 35, 60 percent volume removed at age 55, and 40 percent volume removed at age 80. We also simulated this stand as if it was set aside as a reserve for 100 years and as if it was managed for

Table 3—Silvicultural regimes for the case study stand from tables 1 and 2

Prescription categories (from tables 1 and 2)	Years until thinning / percent volume removed 1st thinning	 2nd thinning	 3rd thinning
Table 1, all stand types	40 yr / 63%	59 yr / 56%	79 yr / 40%
Table 1, forest type, Douglas-fir	39 yr / 63%	57 yr / 62%	76 yr / 46%
Table 1, Site index, 115-135	33 yr / 61%	49 yr / 60%	68 yr / 40%
Table 1, Ecological Region, West Coast Range	35 yr / 61%	56 yr / 54%	78 yr / 34%
Table 2, all stand types	33 yr / 68%	54 yr / 60%	87 yr / 42%
Table 2, age class, < = 20	46 yr / 67%	66 yr / 63%	93 yr / 42%
Table 2, percent of normal stocking 40-120 percent	26 yr / 68%	47 yr / 60%	83 yr / 43%
Averages	36 yr / 64%	55 yr / 59%	81 yr / 41%

Note: Years until thinning is equivalent to total stand age for the case study stand, which is 15 years old at the start of the simulation.

maximum net present value of timber harvest. The latter regimes involves a clearcut timber harvest every 40 years and no thinnings.

Economic Returns

An important aspect of valuing forest stands is accounting for the time value of money. Because returns on forestry investment alternatives occur in varying years and far in the future, the methodology employed in determining the present value of those alternatives is important. To simplify this analysis, we used a simple discounting formula for each of the thinning and final harvest returns for each of the three regimes. The financial value of the growing stock was evaluated at the end of the 100-year time horizon and discounted to present. Because each dollar in 2106 is worth only one third of a penny in 2006, this is a valid approximation of the total stand value.

In table 4, the volume and value of the removals under each of the three regimes are shown, along with the value of the standing inventory at the end of 100 years. These values were discounted using three different interest rates: 4-, 6-, and 8-percent. Log price is an average of #2 and #3 sawlog prices projected for a 50-year base case in a recent western Oregon timber supply study (Adams et al. 2002). Logging costs were computed using equations from Fight et al. (1984) that take volume per acre and average diameter into account. Haul cost was assumed to be $59 per thousand board ft. For the net present value regime, we included a $441 per acre planting cost.

The net present value regime represents the highest return possible to the landowner given the growth, yield and costs associated with the stand. Any deviation from this management is an opportunity cost borne by the landowner; the landowner is giving up income by choosing to manage for some non-market objectives.

The reserve regime generates the highest volume. But it does not generate financial value because it is never harvested. Therefore, the opportunity cost of the reserve option is the total value of the stand under the net present value regime.

The older forest structural regime has heavier than traditional thinning intensities that occur early in the life of the stand and final harvest age is far greater than financial maturity. This reduces the value of the stand from the maximum net present value regime. The heavy thinnings generate value early, but even so, the opportunity cost of older forest structural management is substantial. For example, over 50 percent of the value of the stand is foregone with a discount rate of 6 percent.

Stand Structure

To evaluate whether structural criteria were being met, we used the Stand Visualization System (McGaughey 1997). In figure 1, the stand development at 20-year intervals over the 100-year time horizon is shown for each of the three management regimes. The first 20 years (i.e., to age 35 years) are identical for all three regimes.

At 40 years into the simulation, however, the disparate paths of the three regimes become evident. The 55-year-old reserve stand is very dense and the crowns have receded up the boles of the trees, leaving little live crown per tree. The net present value stand was clearcut at 40 years of age, 25 years into the simulation, leaving a fully stocked 15-year-old stand. The 55-year-old older forest structure stand has been thinned just following the stand representation at 20 years old with a volume removal of 65 percent. The opening up of growing space in the stand has allowed the larger trees to retain lower branches resulting in longer crowns than the reserve stand.

Table 4—Economic returns per acre case study stand for three management strategies

Year	Stand age	Volume removed (mbf)	Logging cost ($/mbf)	Revenue	Discounted value at 4	6	8
					- - - - - - -*Percent* - - - - - - -		
Older forest structure							
2026	35	10.1	146	3,384	1,544	1,055	726
2046	55	12.6	95	4,793	998	466	221
2071	80	6.4	81	2,510	196	57	17
2106	115	62.8	68	25,272	500	74	11
Total	92	35,960	3,239	1,653	975		
Reserve							
2106	115	138.7	60	56,793	1,124	167	26
Net present value							
2031	40	35.5	96	12,998	4,876	3,029	1,898
2071	40	35.5	96	12,998	1,016	294	87
2106	35	24.8	117	8,948	177	26	4
Total	96	34,944	6,069	3,349	1,989		

At 60 years into the simulation, the 75-year-old reserve stand looks structurally much as it did at age 55 years, with a dense single story and short crowns. The largest trees in the stand are just under 28 in diameter at breast height (DBH). The net present value stand is once again 5 years from a regeneration harvest. The older forest structure stand has been thinned again removing another 60 percent volume removal. The understory has the light required for development of a new cohort. The 75-year-old older trees have retained much of their live crown, providing for greater diameter growth. There are just under 5 trees per acre with greater than 32 in DBH.

At 80 years, the 95-year-old reserve stand now has 16 trees per acre larger than 32 in DBH, yet with the dense canopy it has limited ability to generate an understory of any kind. The net present value stand is once again at 15 years of age. The older forest structure stand just received its final thinning, a 40 percent volume removal. The stand has a well-established younger cohort (age <20 years) and still has 6 trees per acres of 95-year-old trees larger than 32 in DBH following the final removals.

Finally at 100 years, the 115-year-old reserve stand has over 30 trees per acre that are larger than 32 in DBH. The largest tree is just under 38 in DBH. Despite its size, there is not much diversity in this stand. The canopy closure is 89 percent, compared to the 51 percent for the older forest structure stand, letting little light down to the forest floor to support understory vegetation. In contrast, the older forest structure stand has at least two distinct cohorts, with over 9 trees per acre greater than 32 in DBH. The largest trees (115 years old) are over 45 in DBH.

DISCUSSION

This case study reinforces silviculturists' concerns that the young fully stocked production forests of today may not develop into the natural old-growth forests we are familiar with if left unmanaged in reserves (Andrews et al. 2005). They may instead develop into dense over-stocked forests with increased risk of fire, insects, and disease. To hasten the development of large trees and multiple cohorts it may be necessary to employ thinning regimes which appear extreme when compared to the traditional commercial or uneven-aged stand removal levels (Tappeiner et al. 1997, Carey and Curtis 1996).

There are several factors leading to the selection of multiple heavy thinnings as a silvicultural pathway to older forest structure. It is notable that the management regimes developed to meet older forest structural criteria while maximizing the financial value of the stand are very similar to management regimes developed by silviculturists who ignored economic criteria (e.g. McComb et al. 1993, Carey and Curtis 1996, Barbour et al. 1997). This is because the silviculture, logging cost dynamics, and economics all push the optimization toward the same type of regime.

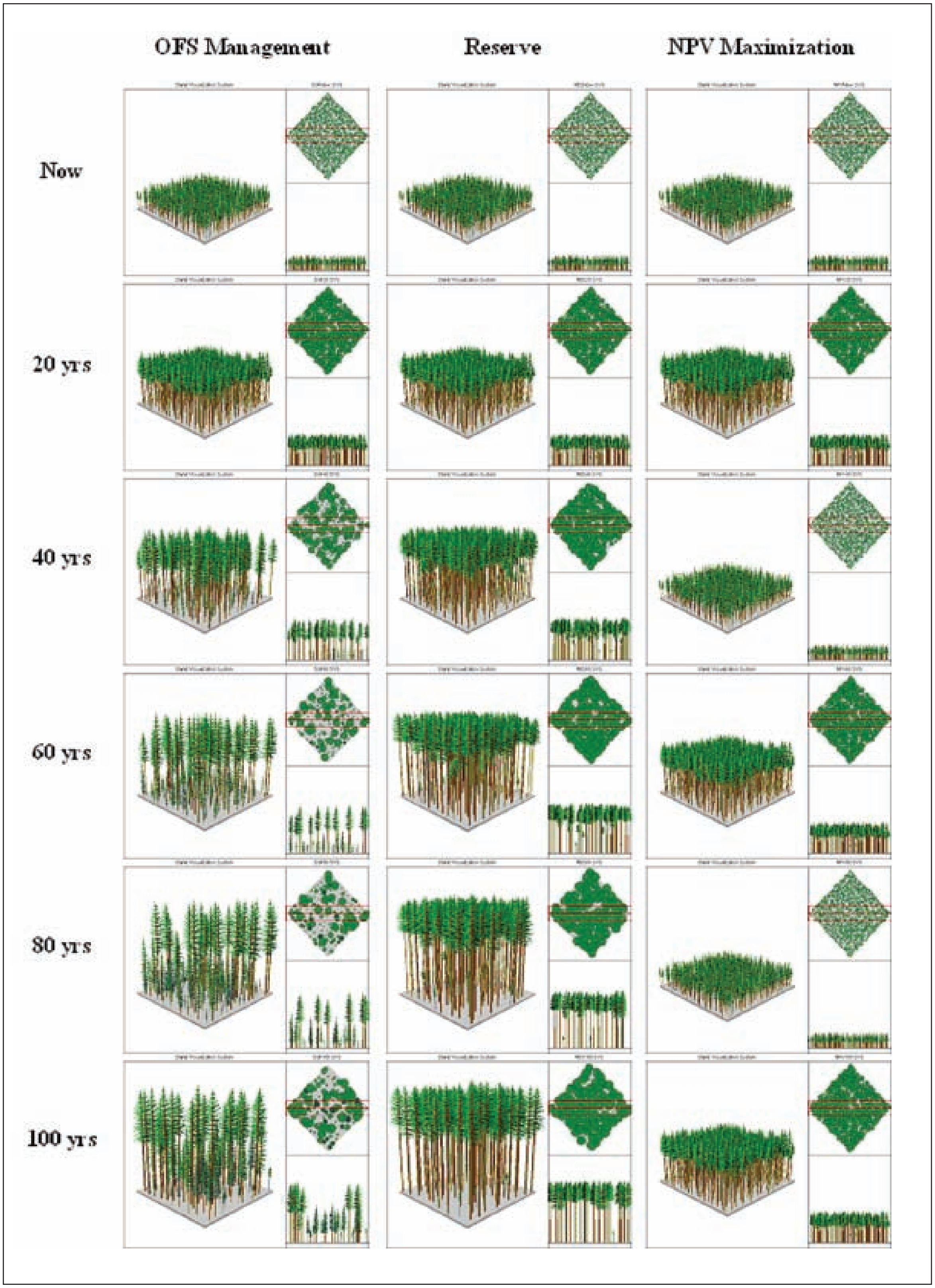

Figure 1—Stand Visualization System representations of the Older Forest Structure (OFS) Management, Reserve, and Net Present Value (NPV) Maximization regimes for the case study stand in 20 year intervals for 100 years.

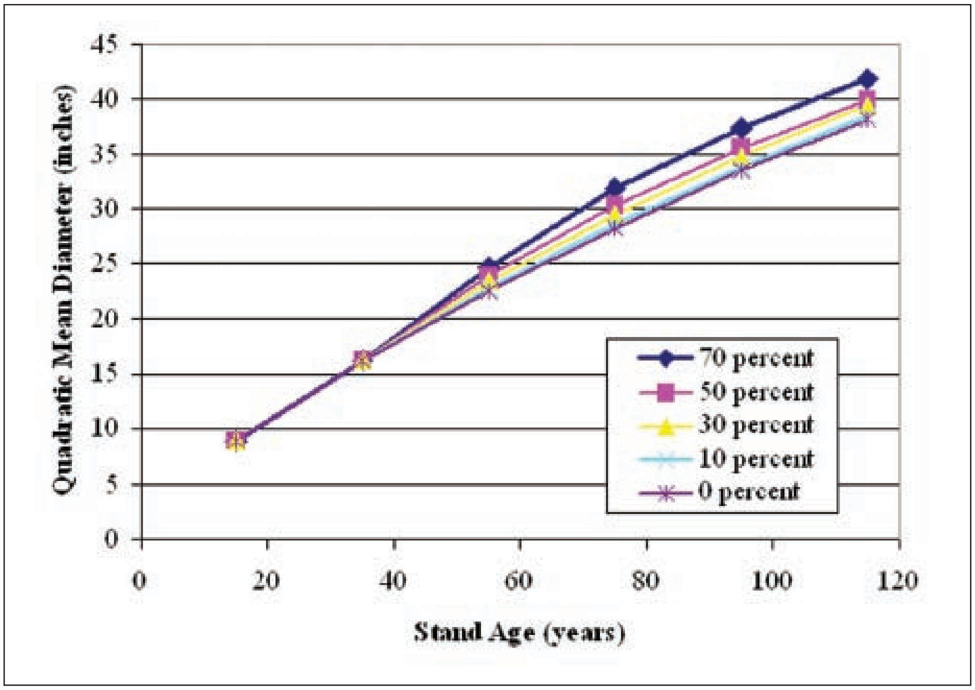

Figure 2—Quadratic mean DBH of the ten largest trees per acre following a thinning at age 35 for a range of % volume removals.

Silvicultural Considerations

Silviculturally, the use of heavy thinning promotes diameter growth and creates openings in which seedlings can survive and ultimately develop into a second story. In crowded stands, encroachment of a tree's growing space causes the shaded limbs to die and eventually fall off. Increasing a tree's growing space by thinning reduces crown recession, which leads to longer and wider crowns over time; larger crowns lead to faster diameter growth. To illustrate, we simulated the diameter growth of the ten largest trees per acre in our case study stand following a thinning of varying intensity administered at age 35 (fig. 2). Diameter growth is increased with each increment in the intensity of the thinning. Note that the effect on diameter growth is greater for an increase from 50 to 70 percent volume removal than it is for an increase from 30 to 50 percent. Also note that the effect of the first 10 percent removal is relatively small; this is because the stands return quickly to being fully stocked after such a light thinning.

A reduction of density may not always lead to such a pronounced change in diameter growth. If the pre-thinning stand does not have enough live crown to respond to the newly opened space, it will require years to develop the leaf area necessary to support increased diameter growth.

Operational Considerations

Operationally, while thinning costs more per unit volume than final harvest, there are economies of scale leading to lower unit costs for heavier thinnings. The logging cost equations used in this study are based on Fight et al. (1984). He found that logging costs are inversely related to both average tree diameter and volume per acre. The reduction in cost as the intensity of thinning increases is due in part to increases in efficiency in felling and yarding and to a lesser extent the spreading of the fixed costs, such as moving equipment in, over a larger volume of removals.

To illustrate, we computed unit logging costs for a range of stand conditions (table 5) and thinning intensities. The stands are fictional uniform stands of 100, 300, or 500 trees per acre with DBH of 10, 12, and 16 in. The stands are described in the left hand side of the table. Logging costs in dollars per thousand board ft for a range of thinning intensities are shown on the right hand side. In general, these costs decrease as the logs get bigger or as the thinning intensity increases.

Economic Considerations

Finally, the time value of money refers to the fact that, all things equal, a dollar today is preferable to a dollar

Table 5—Logging cost variation for differing stand attribute and removal levels

	Stand attributes					Logging cost ($ / mbf) based on percentage of stems removed			
Number of trees	Diameter (in)	Stand density index[a]	Basal area (square ft)	Thousand board ft	Cubic ft	100	70	40	10
100	10	100	55	3	1426	249	265	299	493
300	10	300	164	10	4277	208	221	242	322
500	10	500	273	17	7129	196	203	223	284
100	12	134	79	7	2291	149	159	176	271
300	12	402	236	22	6873	127	132	145	188
500	12	670	393	37	11455	122	125	133	169
100	16	213	140	18	4623	79	84	93	132
300	16	638	419	55	13870	71	73	76	98
500	16	1063	698	92	23117	69	70	73	89

[a] Reineke, L.H. 1933. Perfecting a stand-density index for even-aged forests. Journal of Agricultural Research. 46: 627-638.

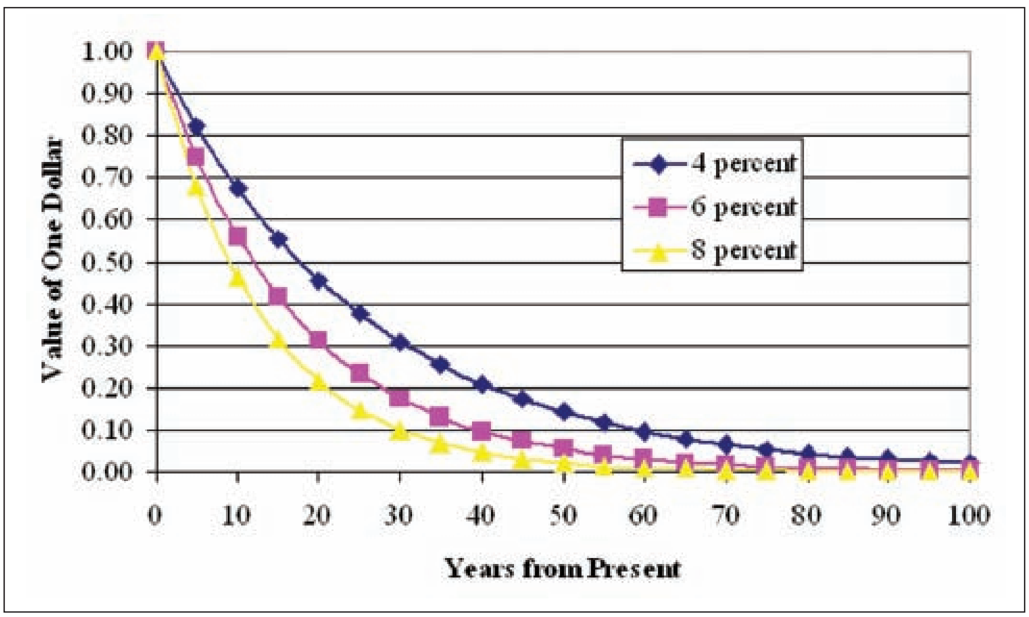

Figure 3—Present value of one dollar received up to 100 years in the future.

received some time in the future. This is an important concept in valuation of a forest investment because the time horizon of forest investment is typically very long. To illustrate the importance of the time value of money, the present value of one dollar received up to 100 years in the future is shown in figure 3 for discount rates of 4-, 6-, and 8-percent. Economic returns, even one rotation out, have very limited value today. Even when considering a rather conservative discount rate of four percent, a dollar 50 years in the future would only be worth fourteen cents today, and at 100 years it would be worth just under two pennies. This discounting gives preference to positive events, such as thinning revenue, happening sooner in the future rather than later.

CONCLUSION

We utilized a case study of a typical young even-aged production forest stand to compare stand development under a silvicultural regime designed to increase the development of older forest structure while minimizing the economic impact to a regime designed to maximize the net present value of the stand. We also compared it to a forest reserve. We based the older forest structure regimes on published results from a study in which least cost old forest structural regimes were identified for a range of stand types on private land in western Oregon. It that study, the opportunity cost of old forest structure (the present value of forgone timber harvest revenue when old forest structural criteria are imposed) was found to average around 30 percent of the maximum net present value of the stands in the study. In our case study, in which we simply applied average values for the timing and intensity of thinnings, the value loss associated with old forest structure was about 50 percent. While it would be nice if, in practice, you could simply go to a table from a published study and find a management regime that would work for a particular stand, we found a potential gain of 20 percent between an optimized regime and a non-optimized regime.

The ideas portrayed in this case study can serve as a rule of thumb in developing a regime to generate old forest structure in an economic way. As any forester knows, though, every stand is a little different, and adjusting for those differences can matter.

ACKNOWLEDGMENTS

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LITERATURE CITED

Adams, D.M.; Schillinger, R.A.; Latta, G.; Van Nalts, A. 2002. Timber harvest projections for private land in western Oregon. Contrib. 37. Corvallis, OR: College of Forestry, Oregon State University. http//fcg.cof.orst.edu/rc/rc37.pdf

Andrews, L.S.; Perkins, J.P.; Thrailkill, J.A.; Poage, N.J.; Tappeiner, J.C. 2005. Silvicultural approaches to develop northern spotted owl nesting sites, Central Coast Ranges, Oregon. Western Journal of Applied Forestry. 20: 13-27.

Barbour, R.J.; Johnston, S.; Hayes, J.P.; Tucker, G.F. 1997. Simulated stand characteristics and wood product yields from Douglas-fir plantations managed for ecosystem objectives. Forest Ecology Management. 91: 205-219.

Busby, G.M.; Montgomery, C.A.; Latta, G.S. [In press]. The opportunity cost of forest certification on private land in western Oregon. Western Journal of Applied Forestry.

Carey, A.B.; Curtis, R.O. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. Wildlife Society Bulletin. 24: 610-620.

Fight, R.D.; Ledoux, C.B.; Ortman, T.L. 1984. Logging costs for management planning for young-growth coast Douglas-fir. Gen. Tech. Rep. PNW-176. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 10 p.

Hann, D.W.; Hester, A.S.; Olsen, C.L. 1997. ORGANON user's manual. 6^{th} ed. Corvallis, OR: Forest Resources Department, Oregon State University. 135 p.

Latta, G.; Montgomery, C.A. 2004. Minimizing the cost of stand level management for older forest structure in western Oregon. Western Journal of Applied Forestry. 19: 221-231.

McComb, W.C.; Spies, T.A.; Emmingham, W.H. 1993. Douglas-fir forests: managing for timber and mature-forest habitat. Journal of Forestry. 91: 31-42.

McGaughey, Robert J. 1997. Visualizing forest stand dynamics using the stand visualization system. In: Proceedings of the 1997 ACSM/ASPRS Annual Convention and Exposition; April 7-10, 1997. Seattle, WA. Bethesda, MD: American Society of Photogrammetry and Remote Sensing. Vol. 4: 248-257.

Montgomery, C.A.; Latta, G.S.; Adams, D.M. 2006. The cost of achieving old-growth forest structure. Land Economics. 82: 240-256.

Oregon Department of Forestry. 2001. Northwest Oregon state forests management plan: final plan. Salem, OR: Oregon Department of Forestry. 501 p.

Spies, T.A.; Johnson, K.N.; Reeves, G.H.; Bettinger, P.; McGrath, M.; Olsen, K. 2002. An evaluation of the compatibility of wood production and ecological integrity in the Oregon Coast Range. In: Johnson, A.C.; Haynes, R.W.; Monserud, R.A., eds. Congruent management of multiple resources: proceedings from the Wood Compatibility Initiative workshop. Gen. Tech. Rep. PNW-GTR-563. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 111-120.

Tappeiner, J.C.; Huffman, D.; Marshall, D.; Spies, T.A.; Bailey, J.D. 1997. Density, ages, and growth rates in old-growth and young-growth forests in coastal Oregon. Canadian Journal of Forest Research. 27: 638-648.

Teensma, P.D.A.; Rienstra, J.T.; Yeiter, M.A. 1991. Preliminary reconstruction and analysis of change in forest stand age classes of the Oregon Coast Range from 1850 to 1940. Tech. Note T.N. OR-9. Portland, OR: U.S. Department of Interior, Bureau of Land Management. 11 p.

USDA Forest Service. 2000. Documentation of inventory procedures and compilation routines: western Oregon. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forest Inventory and Analysis Program. 48 p.

Wimberly, M.A.; Spies, T.A.; Long, C.J.; Whitlock, C. 2000. Simulating historical variability in the amount of old forests in the Oregon Coast Range. Conservation Biology. 14: 167-180.

INTENSIVELY-MANAGED FORESTS

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MANAGING FOR WILDLIFE HABITAT IN INTENSIVELY-MANAGED FORESTS

Ken L. Risenhoover[1] and S. Blake Murden[2]

ABSTRACT

Privately owned timberlands are an essential component of biodiversity conservation in the Pacific Northwest. Despite public perceptions, these areas represent significant amounts of productive habitat that are important to sustaining a large variety of wildlife species. Management goals in working forests differ from those employed on public lands. Private forest lands play an important role in providing the wood products needed by society, and wood production is a primary goal influencing how they are managed. Managed forests provide a variety of young to intermediate stand age classes and provide considerable habitat diversity for species adapted to these conditions. Primary differences between managed and unmanaged forest are the result of differences in the frequency and intensity of disturbance patterns. Although managed stands typically lack the structural diversity present in unmanaged forests, within-stand habitat diversity can be enhanced in managed forests by retaining individual structures such as snags, downed logs and green trees from past rotations. In managed forest landscapes, spatial diversity is a function of the size and distribution of stand age classes produced by the pattern of harvest. Riparian management zones retained at harvest buffer streams and ensure maintenance of important ecological functions. As they develop, riparian areas will contribute late-successional habitat currently unavailable in managed forests and will provide sources of large snags. Riparian areas also will facilitate animal movements and help sustain population viability. For conservation efforts to succeed, it is critical that the public, conservationists, and state and federal agencies gain a greater appreciation of the role privately-owned timberlands play in landscape management.

KEYWORDS: Biodiversity, conservation, Pacific Northwest, retained structures, within-stand diversity.

INTRODUCTION

Foresters and landowners managing private forest lands in the Pacific Northwest face numerous challenges. Principal among these is remaining competitive in a rapidly globalizing market, while at the same time contending with increasing forest practices regulations. World demand for wood and fiber continues to increase and it has stimulated economic development around the world (Haynes 2003, Shifley 2006). World demand also has stimulated markets for alternative building products (e.g., glue-laminated beams and steel studs). Changing supply and demand have, in turn, impacted domestic and export markets, and ultimately, they affect what buyers are willing to pay for logs (Franklin and Johnson 2004). More recently, increasing fossil fuel prices have led to similar increases in logging and transportation costs (e.g., road maintenance and fuels). Collectively, these economic factors and declining log prices reduce profit margins for landowners. Because investment horizons in forestry are long-term compared to other enterprises, they are more risky considering trends in global markets and the political and regulatory uncertainty.

At the same time, timberland owners and managers have experienced a steady increase in the number of regulations governing how forestry practices are carried out in this region. Concerns about threatened and endangered species such as the northern spotted owl (*Strix occidentalis*), marbled murrelet (*Brachyramphus marmoratus*), and most recently, the listing of several declining salmon populations

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have led to additional regulations that have taken lands out of production. The growing human population in the Pacific Northwest has effectively shifted the political agenda in states like Washington and Oregon from rural to urban and has changed public attitudes toward forestry (Johnson and Stankey 2002). Unfortunately, changing social values and political conflict have led to antagonism between people making a living in forestry and other interest groups. As a result, there are a great many misconceptions about modern forest practices.

Fortunately, the science of forestry and its application has advanced considerably during the past 20 years (Hunter 1990, DeBell et al. 1997, Tappeiner et al. 2002). In addition, private timberland owners are taking a more active role in conservation processes and they have voluntarily accepted additional restrictions where credible science has demonstrated the need for additional protective measures. Clearly, the timber industry is concerned about public opinion and desires to reassure the public that they are practicing sustainable forestry. The recent "Forest and Fish Agreement" in Washington (Washington Department of Natural Resources et al. 1999) is one example of this process.

In our opinion, the majority of private timberland owners are in this business for the long haul. They are in touch with the land they manage and they have an appreciation for natural resources. Their reputations as good land stewards are important to them and practicing responsible forestry is a source of pride. However, because many private timberland owners do not employ wildlife biologists, they may not fully comprehend the objective of the rules governing forest practices. Landowners would benefit from assistance aimed at helping them to better understand the scientific basis for forest practice regulations and to help them to know how they can integrate conservation practices into their own management program.

In this paper, we discuss the role private forest lands have in wildlife management and biodiversity conservation. In addition, we suggest a way of thinking about challenges confronting forest landowners, and suggest ways they can improve their own practices to benefit biodiversity on their ownership while minimizing impacts to forest operations. It is important that foresters and landowners adopt the philosophy that if they do a better job of applying effective conservation measures, they will succeed in sustaining wildlife populations and thus, prevent the need for additional regulations in the future. That would be a "win-win" situation for both timberland owners and biodiversity conservation and should be the goal of landowners and conservationists.

The Role of Managed Forests in the Conservation Process

So how do we jumpstart the process needed to help create this "win-win" scenario for landowners and natural resource managers? First, society needs to recognize and better understand the role private timberlands play in biodiversity conservation. How do the goals for managing privately-owned timberlands differ from those used to manage public lands? As stated above, the primary management goal for any private timberland owner is the production of wood products. In the Pacific Northwest, working forests play an important role in providing the wood products needed by society. They also are an important part of local and regional economies, especially in rural areas. Gebert et al. (2002) reported Oregon's primary and secondary wood and paper products industry employed nearly 75,000 workers who earned an estimated $2.8 billion in annual income in 1998. It is estimated that the United States utilizes more than one-third of the industrial wood produced around the globe, although it has only 5 percent of the world's population (Oregon Forest Resources Institute 2003). Like many other developed countries around the world, the United States must import wood to meet its growing demand for wood products. However, because the environmental standards regulating harvest and forest management in other parts of the world are lower than they are in the Pacific Northwest, there is a growing concern that we may be, in effect, shifting the burden of environmental responsibility elsewhere (Oregon Forest Resources Institute 2003, Shifley 2006). Thus, production forests in the Pacific Northwest are very important and, without them, the public would be left further dependent on imports to meet society's current and future demands for paper and wood products.

Forest management goals in working forests are different from the goals that direct management decisions on public lands (fig. 1). Management priorities for public lands set aside as parks or wilderness areas often are related to protecting and conserving pristine, unique or otherwise sensitive areas and the fauna and flora that typically inhabit those areas. Public lands managed by the U.S. Department of Agriculture, Forest Service and the U.S. Department of Interior, Bureau of Land Management in the past have been managed for multiple uses that included human recreation, the conservation of wildlife and natural resources, but also management of renewable natural resources such as timber. At the other extreme end of this spectrum are private timberlands managed intensively for

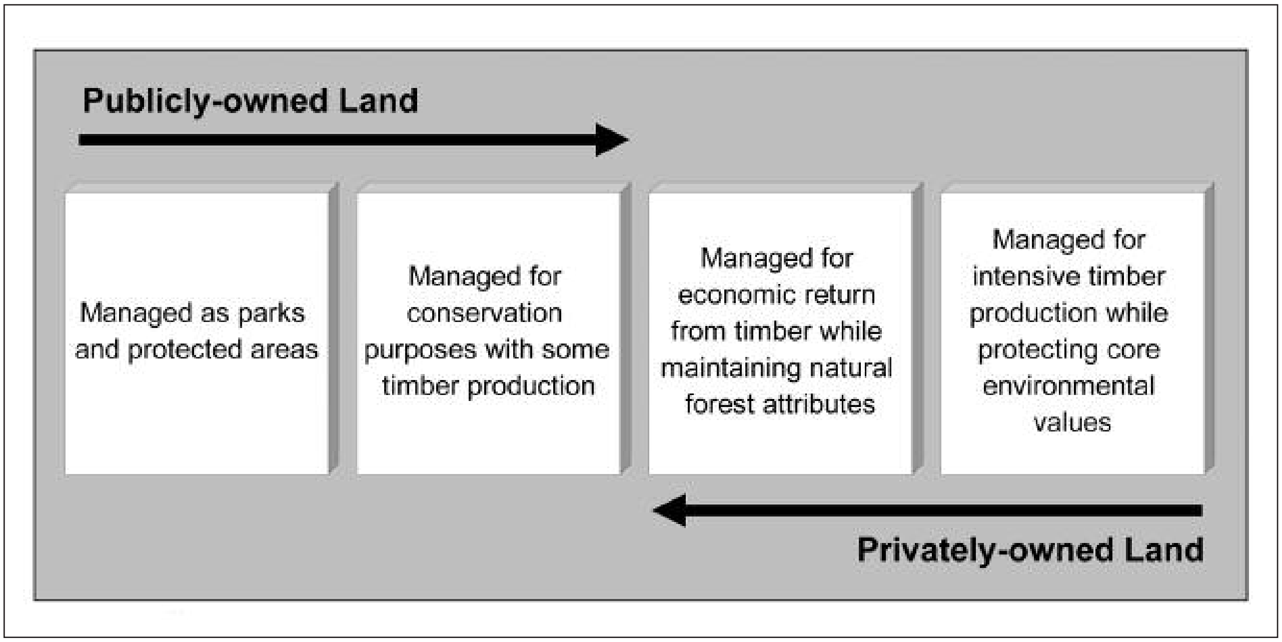

Figure 1—A comparison of management goals relating to public and private forestland ownership (Phillips 2002}.

production of wood fiber and other commercially-important products. Examples of this circumstance might include poplar (*Populus* spp.) plantations or Christmas tree plantations. Generally, under these circumstances the frequency and intensity of management activities may ultimately limit the ability of these areas to support certain wildlife species and native plants. Finally, there are those lands that are managed principally for timber production, but that are managed less intensively. When managed well, these forests have the potential to contribute essential habitat for sustaining wildlife populations and biodiversity.

To remain competitive, private timberland owners must be able to produce a reliable supply of a product that is in demand in the world market. Their competitiveness and survival is dependent on their profit margin and their ability to produce a valuable product that can be sold in the world market. In the Pacific Northwest that product is mostly Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) saw logs. Douglas-fir is a native tree species that is prized as an excellent building material due to its structural qualities (Megraw 1986). It is well-adapted to the climate and moisture conditions in the temperate forest region. However, Douglas-fir is shade intolerant and it requires direct sunlight to grow. When grown in even-aged stands the trees grow quickly and tend to be free of limb knots and other undesirable characteristics that reduce their value. There are efforts and research underway to develop alternative approaches to growing Douglas-fir using single-tree and group selection harvest techniques (Carey et al. 1996, Curtis 1997, Franklin et al. 1997). Although they may prove successful in regenerating structurally-complex, uneven-aged forest stands using these methods, the wood produced with these methods may be relatively low grade and would be more difficult to market.

In the face of economic uncertainty, forest landowners may be encouraged to consider selling off portions of their lands to developers, or converting them to other more profitable uses. Working forests that are producing a valuable commodity are less likely to be converted to an alternative land use. In Washington, conversion from forestry to alternative land uses has been identified as one of the biggest threats to biodiversity (Washington State Department of Fish and Wildlife 2005). The loss of private timber lands jeopardizes our region's ability to meet society's growing demand for wood products (Haynes 2003). While timber production on private forestlands has remained relatively stable, there has been a 96 percent reduction in harvest on federal lands between 1989 and 2001 (Oregon Forest Resources Institute 2003). Declines in harvest on federal lands during this period were related to changes in management priorities associated with needs for endangered species.

Although lands managed to maximize profits in the forest industry may be less than ideal for wildlife, these lands, nevertheless, have an important function in biodiversity conservation. Recently, conservationists have realized that a reserve system alone will most likely be insufficient to sustain all wildlife populations (Wilcove 1989, Hansen et al. 1991, Lindenmayer and Franklin 2002). Thus, private lands play an important support role in the conservation process, and it is important that public agencies carefully consider the potential negative consequences any new regulations might have on the economic viability of private timberland owners (Forest and Fish Report 1999).

Differences Between Managed and Unmanaged Forests

What are the principal differences between managed and unmanaged forests? The biggest differences, in terms of wildlife habitat, are the degree of structural complexity present within the stand. Unmanaged forests often contain a greater diversity of tree sizes, including some that may be very old (200 plus years) and very large. Mature forests often have a multi-layered canopy including a well-developed understory of shrubs and young trees. They typically contain an abundance of snags and downed logs of all sizes. In contrast, managed forests typically are younger, and within any given stand, the trees are more uniform in height and diameter. Managed forests often lack a significant understory component if they have not been thinned. Snags typically are scarce, primarily due to worker safety concerns, and downed wood also may be less abundant.

Many of the structural differences between managed and unmanaged forests can be explained by differences in the frequency and intensity of disturbance in these forest settings (Hansen et al. 1991, Lindenmayer and Franklin 2002). In unmanaged forests, stand initiation occurs naturally following a catastrophic disturbance such as fire. In these settings, succession advances rapidly from the herbaceous plant and shrub phase to the seedling tree phase as shade intolerant conifers become established and begin to coalesce, and shade out, other shade-intolerant vegetation. Vertical tree growth continues rapidly until stand canopy closure occurs as trees reach maturity. If undisturbed, dominant trees in these stands may continue to grow and survive for hundreds of years. Hansen et al. (1991) reported that the average interval between catastrophic natural disturbances for stands in Mount Rainier National Park was 435 years. During this long succession of growth, within-stand diversity is created by the occurrence of low to intermediate intensity disturbance events such as individual tree mortality (e.g., disease, insect infestation, breakage or wind-throw), geological processes (e.g., slope failures and landslides), windstorms, or small-scale fires. Within-stand diversity also is increased by the in-growth of shade tolerant species in the forest understory. Stand development is essentially the same in managed forests although additional efforts are made to ensure the initiation of a fully-stocked stand. However, most of the processes that create within-stand diversity are interrupted by harvest when rotation age is attained. Thus, the frequency of disturbance in managed forests (i.e., harvest) occurs at intervals that are determined by local site conditions, the tree species being grown, and current market demands. Forest management typically shortens the duration of the early successional stages that precede tree canopy closure and eliminates the late successional stages (Franklin and Maser 1988).

In unmanaged forests, the spatial pattern of landscape-level diversity between stands often is a function of topographic features and how they interact with disturbance factors such as fire. Historically, fires were fairly prevalent in the Pacific Northwest, and they create a natural mosaic of varying stand ages across the landscape (Agee 1993, Hansen et al. 1991). In contrast, the size and spatial arrangement of stand age classes in managed forests is a function of the spatial occurrence and size of harvest activities. The average clearcut size in private timberlands in Washington is typically less than 60 acres (Washington Forest Protection Association 2003). Because only a relatively small portion of the overall landscape is harvested each year (1-4 percent), and because rotation cycles generally are 50 years or more, managed forest landscapes can be characterized as steady-state shifting mosaics of stand age classes (Bormann and Likens 1979). Despite these differences, managed forests contribute significantly to wildlife conservation. Although they may not provide the entire range of stand conditions present in unmanaged forests, they occupy a substantial portion of the overall landscape. In Oregon and Washington there are an estimated 18.4 million acres of privately-owned managed forests (Washington Forest Protection Association 2003, Oregon Forest Resources Institute 2003). Managed forests provide a variety of young to intermediate stand age classes, and thus, provide considerable habitat diversity for species adapted to these conditions. Brown (1985) reported that managed forest stands were capable of supporting an estimated 277 of the 460 vertebrate species believed to occur in the forests of western Washington and Oregon. Bunnell et al. (1997) investigated the consequences of forest management on terrestrial forest-dwelling vertebrates and concluded that current forest practices posed no immediate threat to any of the 300 terrestrial vertebrate species in Oregon forests.

Although habitat conditions in managed forests may be less than optimal for certain wildlife species, they remain productive areas for species adapted to the conditions that occur in managed forests. Where it has been shown that management practices negatively impact species

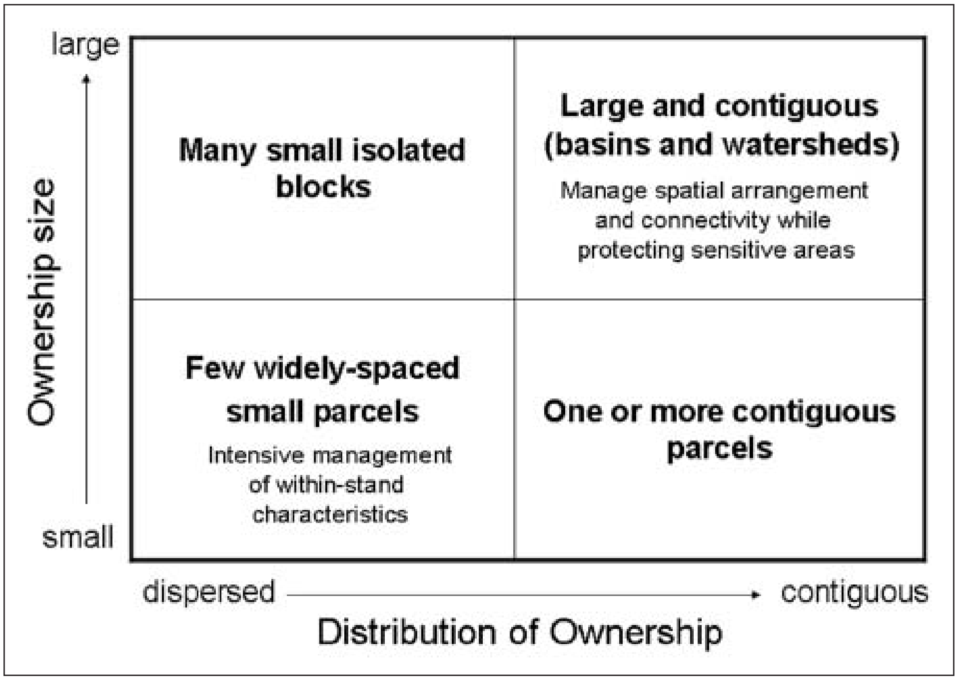

Figure 2—The influence of ownership size and distribution on landowner options for managing forested lands to enhance biodiversity.

or ecological processes, federal and or state regulations have been created to ensure the protection of public resources. As our understanding of ecological processes and species-habitat relationships improves we may identify further conflicts between management for timber production and wildlife. Thus, it is important that managers seek creative solutions to reduce or eliminate these potential problems themselves. If the conflicts cannot be resolved it is very likely that they may lead to new regulations in the future.

Sustaining Biodiversity in Managed Forests

Private timberland owners have a responsibility to maintain the integrity of the public resources occurring within their ownership. Aside from their responsibilities as stewards of the land, it is in their best interest to contribute where possible to the achievement of biodiversity conservation goals. Within the constraints of timber production goals, landowners and managers should be continually striving to identify and improve management practices to reduce negative impacts on wildlife and their habitats. To demonstrate their commitment to the public and to show that they are practicing sustainable forestry, the majority of industrial timberland owners have elected to participate in third-party forestry certification programs such as the Sustainable Forestry Initiative (SFI) and the Forest Stewardship Council (FSC) (Hobbs et al. 2002). A major portion of the principles in SFI and FSC certification standards specifically address biodiversity conservation (Forest Stewardship Council 2004, Sustainable Forestry Board 2005). Adherence to these standards has stimulated industrial timberland owners to seek out innovative ways to incorporate biodiversity conservation measures into their standard operating procedures and to initiate monitoring activities. Lindenmayer and Franklin (2002) identified four primary areas where private timberlands can contribute to biodiversity conservation. These include: 1) supporting wildlife populations, 2) maintaining the integrity of aquatic systems, 3) protecting sensitive areas and unique or imperiled fauna and flora, and 4) facilitating the movement of animals through the landscape (i.e., connectivity).

Because management actions are typically applied at the stand level, often it is the individual forest stand that becomes the focal unit when trying to increase habitat diversity in managed forests. However, ownership size (total acres), and the distribution of parcels under management (i.e., contiguous or dispersed), ultimately determine the set of options available to managers for improving spatial habitat diversity (fig. 2). If an ownership is large and contiguous, opportunities may exist to manipulate the location and timing of harvest units to improve the interspersion of stand ages. However, if ownership is relatively small, or if it is made up of small, disjunct parcels, there will be few opportunities to improve the spatial diversity of forest cover at the landscape scale. Management for biodiversity conservation in mixed ownership situations is challenging because goals and constraints differ between owners, and because they are only a part of the overall landscape neighborhood. There is little that can be done to improve landscape spatial diversity without the cooperation of your neighbors. Under this ownership scenario, management efforts should focus on manipulating within-stand conditions to create greater structural complexity within the stand. Unfortunately, much of the scientific literature available to guide decision-making at the landscape scale is primarily relevant to large and contiguous ownerships (Hunter 1990, Noss et al. 1997). Although the area managed may be relatively small, and unlikely to provide all the specific habitat needs of certain species, that does not mean that the ownership is not contributing to the welfare of that species. Small landholdings are just as important to the overall success of biodiversity conservation in the landscape matrix and their individual roles should be to try to provide whatever habitat features they can in support of the needs of the population occupying the landscape.

Managing Within-Stand Structural Diversity

In even-aged managed forests, within-stand structural diversity is generally low because trees are relatively homogeneous in composition, size and stature. Thus, structural diversity can be enhanced by retaining as many individual structures or legacy features as possible from previous stands. Individual structures include green recruitment trees and wildlife reserve trees purposely left behind during harvest, standing dead or partially dead trees (i.e. snags), tall stumps, downed logs and other woody debris. Green recruitment trees are living trees that will continue to grow in diameter during the next rotation. They often are retained in clusters along waterways or in areas with unstable slope conditions and where they are least likely to interfere with stand management or harvest operations. Occasionally individual trees are left scattered throughout the unit or around groups of snags. Very large diameter green trees (i.e., legacy trees), retained from the previous rotation, provide distinctive structural features that are rare in managed stands and that are especially valuable for birds of prey (i.e., nest platforms, roosts, hunting perches). Wildlife reserve trees are standing, defective trees that often have large limbs and the structural elements (mistletoe brooms and multiple tops) needed to support nesting and denning.

Eventually green trees die and become snags (a standing dead, or partially dead tree), or they are wind-thrown and become a downed log. Snags and downed logs are especially important habitats for wildlife nesting and foraging, and they are utilized by a wide variety of species (Hunter 1990). Johnson and O'Neil (2001) reported 93 vertebrate species were associated with snags in Pacific Northwestern forests. Snags also provide essential habitat requirements for cavity-using species. Between 25 and 30 percent of the vertebrates found in most forest types in the Pacific Northwest use cavities in snags for reproduction or roosting (Bunnell et al. 1999). Snags typically are less abundant in forests managed for wood production (Risenhoover and Murden 2006). This is partially due to issues associated with retaining snags at time of harvest. The majority of snags in working forests are considered safety hazards to workers and must be removed during harvest operations to eliminate potential safety risks to workers (Washington State Department of Labor and Industries 2004). In an attempt to compensate for this snag deficiency, several industrial forest landowners are experimenting with different ways of artificially creating snags (Huss et al. 2002, Kroll 2005). However, this research is preliminary, and it remains uncertain what wildlife species will use created snags or how long they persist during the rotation.

A second means of increasing structural diversity in managed forests involves the use of silvicultural prescriptions. Precommercial thinning frequently is applied to reduce tree density in young stands (10-15 year old). Thinning densely stocked young forest stands can encourage shrub regeneration and accelerate the development of herbaceous ground cover (Muir et al. 2002). Commercial thinning of mid-rotational age classes can release dominant trees and encourage the development of understory shrubs and saplings. Hayes et al. (2003) showed that thinning increased stand use by certain bird species in western Oregon. However, thinning in managed forests is not without constraints as the cost of thinning may exceed profits realized depending on markets and logging cost.

Development of structural diversity within a forest stand requires planning, knowledge of local site conditions, and the availability of existing legacy features. The development of inventories of existing structures within stands can be used to facilitate the development of retention strategies that minimize the impact to the operation while maximizing benefits to wildlife.

Maintaining the Integrity of Aquatic Systems

In the Pacific Northwest, concerns about declining salmon stocks and water quality have led to new regulations governing forest practices (Knudsen et al. 1999). As a result, fish-bearing streams in forested areas are now protected by riparian management zones (i.e., strips of forest adjacent to streams). These riparian management zones act to buffer streams and to ensure maintenance of important ecological functions such as water quality, bank stability, large wood inputs, and nutrient inputs (Naiman and Bilby 1998, Verry et al. 2000).

Riparian management areas provide other important functions as well. First, the green trees retained in these buffers can continue to grow over time and eventually provide mature forest habitat distributed over approximately 10-15 percent of the landscape (Forest and Fish Report 1999). As they continue to grow and develop, these riparian stands eventually will contribute some of the late-successional forest age classes that currently are not available in managed forests. Second, because the riparian areas will not be harvested, they provide places for large snags to develop and to provide for the needs of cavity-dependent wildlife without risking worker safety. Finally, riparian corridors and associated habitats will become the backbone of basins and will facilitate movements and can provide connectivity for wildlife throughout the entire watershed network. Gene flow allowed by this connectivity will help maintain population viability and sustain biodiversity.

Ecologically Sensitive Sites and Rare or Unique Habitats

Some wildlife species are already rare or they have a limited distribution on the landscape. Some species have evolved to have such limited tolerances that they do not respond well to disturbance or habitat changes associated with forest practices. The conservation of these species often requires protection or securing of specific resource sites, such as nesting areas, or avoiding disturbing them during critical times of the year (i.e., nesting and brooding). In forest practices these situations are usually dealt with by setting aside areas and precluding timber harvest, or restricting forest management activities during certain times of the year.

Protecting and maintaining the function of ecologically sensitive sites such as seeps, springs, caves, talus slopes, cliffs, and rock outcrops are best accomplished by excluding equipment use in and around these areas and by applying buffers to maintain site integrity. These areas can contain rare plants and animals, or they may provide unique habitat features for a variety of wildlife species. Unique and rare habitats often are important for nesting, roosting, foraging, and breeding habitats for a large number of wildlife species (Oregon Natural Heritage Program 2003, Washington State Department of Natural Resources 2003). Unique and rare habitats include oak woodlands, aspen stands, natural meadows, forested and non-forested wetlands, bogs, or fens. These areas usually are not ideally suited for timber production.

Sustaining the Future

Private timberlands are an essential component of biodiversity conservation. Despite public perceptions, these areas contribute habitat that sustains large numbers of wildlife and they are important for "keeping common species common." Private forest lands are also playing a greater role in sustaining harvestable surpluses of many of the regions big game species which depend on early forest successional stages for forage. For conservation efforts to succeed, it is critical that the public, conservationists, and state and federal agencies gain a greater appreciation of the role privately-owned timberlands play in the landscape they occupy. The goals for the management of privately-owned forests cannot be to recreate past conditions. Instead working forests will continue to be places focused on the production of wood products. However, private lands can continue to provide productive habitats for a wide variety of wildlife and help to sustain regional biodiversity.

There have been major improvements in forest management practices over the past several decades that are promoting sustainable forestry. The current set of regulations governing forest practices in the Pacific Northwest is designed to protect public resources and to maintain biodiversity while also considering the need to maintain a viable forest industry. Private timberland owners are in the process of implementing these new guidelines and are working on improving their management practices. However, there will continue to be opportunities for improvement. We need sound science to guide management decision making. We need to be continually challenging our assump-tions about what is good for wildlife and not forget that regulations often have unintended consequences (Holling and Meefe 1996). Research will be necessary to determine the effectiveness of our current management practices at maintaining biological diversity within managed landscapes. With additional understanding comes an opportunity to continue to develop new and creative solutions to further increase the compatibility of forest management and conservation efforts.

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LITERATURE CITED

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Washington, DC: Island Press. 493 p.

Bormann, F.H.; Likens, G.E. 1979. Pattern and process in a forested ecosystem. New York: Springer-Verlag, Inc. 253 p.

Brown, E.R. 1985. Management of wildlife and fish habitat in forests of western Oregon and Washington. R6-F&WL-192. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 332 p.

Bunnell, F.L.; Kremsater, L.L.; Wells, R.W. 1997. Likely consequences of forest management on terrestrial, forest-dwelling vertebrates in Oregon. Rep. M-7. Vancouver, BC: Centre for Applied Conservation Biology, University of British Columbia. 130 p.

Bunnell, F.L.; Kremsater, L.L.; Wind, E. 1999. Managing to sustain vertebrate richness in forests of the Pacific Northwest: relationships within stands. Environmental Reviews. 7: 97-146.

Carey, A.B.; Elliott, C.; Lippke, B.R.; Sessions, J.; Chambers, C.J.; Franklin, J.F.; Oliver, C.D.; Raphael, M.J. 1996. A pragmatic, ecological approach to small-landscape management. Washington Forest Landscape Management Project. Final rep. No. 2. Olympia, WA: Washington Department of Natural Resources. 99 p.

Curtis, R.O. 1997. The role of extended rotations. In: Kohm, K.A.; Franklin, J.F., eds. The science of ecosystem management: creating a forestry for the 21st century. Washington, DC: Island Press: 165-170.

DeBell, D.S.; Curtis, R.O.; Harrington, C.A.; Tappeiner, J.C. 1997. Shaping stand development through silviculture practices. In: Kohm, K.A.; Franklin, J.F., eds. The science of ecosystem management: creating a forestry for the 21st century. Washington, DC: Island Press: 141-150.

Forest Stewardship Council. 2004. FSC principles and criteria for forest stewardship. Bonn, Germany. 11 p.

Franklin, J.F.; Johnson, K.N. 2004. Forests face new threat: global market changes. Issues in Science and Technology. 20: 41-48.

Franklin J.F.; Maser, C. 1988. Looking ahead: some options for public lands. In: Maser, C.; Tarrant, R.F.; Trappe, J.M.; Franklin, J.F., tech. eds. From the forest to the sea: a story of fallen trees. Gen. Tech. Rep. PNW-GTR-229. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 153 p.

Gebert, K.M.; Keegan, C.E., III; Willits, S.; Chase, A. 2002. Utilization of Oregon's timber harvest and associated direct economic effects, 1998. Gen. Tech. Rep. PNW-GTR-532. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16 p.

Hansen, A.J.; Spies, T.A.; Swanson, F.J.; Ohmann, J.L. 1991. Conserving biodiversity in managed forest: lessons from natural forests. Bioscience. 41: 382-392.

Hayes, J.P.; Weikel, J.M.; Huso, M.M.P. 2003. Response of birds to thinning Douglas-fir forests. Ecological Applications. 13: 1222-1232.

Haynes, R.W., tech. coord. 2003. An analysis of the timber situation in the United States 1952-2050. Gen. Tech. Rep. PNW-GTR-560. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 254 p.

Hobbs, S.D.; Hayes, J.P.; Johnson, R.L.; Reeves, G.H.; Spies, T.A.; Tappeiner, J.C. 2002. Moving toward sustainability. In: Hobbs, S.D.; Hayes, J.P.; Johnson, R.L.; Reeves, G.H.; Spies, T.A.; Tappeiner, J.C.; Wells, G.E., eds. Forest and stream management in the Oregon Coast Range. Corvallis, OR: Oregon State University Press: 242-259.

Holling, C.S.; Meefe, G.K. 1996. Command and control and the pathology of natural resources management. Conservation Biology. 10: 328-337.

Hunter, M.L. 1990. Wildlife, forests, and forestry: principles of managing forests for biodiversity. Englewood Cliffs, NJ: Prentice-Hall Inc. 370 p.

Huss, M.J.; Bednarz, J.C.; Juliano D.M.; Varland D. E. 2002. The efficacy of inoculating fungi into conifer trees to promote cavity excavation by woodpeckers in managed forests in Western Washington. In: Laudenslayer, W.F.; Shea, P.J.; Valentine, B.E.; Weatherspoon, C.P.; Lisle, T.E., tech. coordinators. Proceedings, symposium on the ecology and management of dead wood in Western forests. Gen. Tech. Rep. PSW-GTR-181. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 777-794.

Johnson, D.H.; O'Neil, T.A., eds. 2001. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press. 736 p.

Johnson, R.L.; Stankey, G. 2002. Forest and stream management in the Oregon Coast Range: socioeconomic and policy interactions. In: Hobbs, S.D.; Hayes, J.P.; Johnson, R.L.; Reeves, G.H.; Spies, T.A.; Tappeiner, J.C.; Wells, G.E., eds. Forest and stream management in the Oregon Coast Range. Corvallis, OR: Oregon State University Press: 7-30.

Knudsen, E.E., D.D. MacDonald, C.R. Steward. 1999. Setting the stage for a sustainable Pacific salmon fisheries strategy. In: Knudsen, E.E.; Steward, C.R.; MacDonald, D.D.; Williams, J.E.; Reiser, D.W., eds. Sustainable fisheries management: Pacific Salmon. Boca Raton, FL: Lewis Publishers: 3-13.

Kroll, A. J. 2005. Personal communication. Wildlife biologist, Weyerhaeuser Company, P.O. Box 9777, Federal Way, WA 98063-9777.

Lindenmayer, D.B., and J.F. Franklin. 2002. Conserving forest biodiversity: a comprehensive multiscaled approach. Washington, DC: Island Press. 351 p.

Megraw, R.A. 1986. Douglas-fir wood properties. In: Oliver, C.D.; Hanley, D.P.; Johnson, J.A., eds. Douglas-fir: stand management for the future. Contrib. No. 55 Seattle, WA: Institute of Forest Research, University of Washington: 81-96.

Muir, P.S.; Mattinly, R.L.; Tappeiner, J.C.; Bailey, F.D.; Elliott, W.E.; Miller, J.C.; Peterson, E.B.; Starkey, E.E. 2002. Managing for biodiversity in young Douglas-fir forest of western Oregon. Biological Science Report USGS/BRD/BSR-2002-0006. Corvallis, OR: U.S. Geological Survey, Biological Resources Division. 76 p.

Naiman, R.J.; Bilby, R.E., eds. 1998. River ecology and management: lessons from the Pacific coastal ecoregion. New York: Springer-Verlag. 705 p.

Noss, R.F.; O'Connell, M. A.; Murphy, D.D. 1997. The science of conservation planning. Washington, DC: Island Press. 246 p.

Oregon Forest Resources Institute. 2003. Forest fact book: answers to frequently asked questions about forest and forestry in Oregon. Portland, OR: Oregon Forest Resources Institute. 30 p.

Oregon Natural Heritage Program. 2003. Oregon natural heritage plan. Salem, OR: Department of State Lands. 167 p.

Phillips, C. 2002. Presentation to the Western Wildlife Program. Portland, OR: Fall meeting of the National Council for Air and Stream Improvement.

Risenhoover, K.L.; Murden, S.B. 2006. Robert B. Eddy Tree Farm HCP effectiveness monitoring report 2001-2005. Tech. Rep. RD-06-01. Tumwater, WA: Port Blakely Tree Farms. 165 p.

Shifley, S.R. 2006. Sustainable forestry in the balance. Journal of Forestry. 104: 187-195.

Sustainable Forestry Board. 2005. Sustainable forestry initiative standard: 2005-2009 edition. Arlington, VA: Sustainable Forestry Board.16 p.

Tappeiner, J.C., II; Emmingham, W.H.; Hibbs, D.E. 2002. Silviculture of the Oregon Coast Range. In: Hobbs, S.D.; Hayes, J.P.; Johnson, R.L.; Reeves, G.H.; Spies, T.A.; Tappeiner, J.C.; Wells, G.E., eds. Forest and stream management in the Oregon Coast Range. Corvallis, OR: Oregon State University Press. 172-190.

Verry, S.E.; Hornbeck, J.W.; Dolloff, C.A., eds. 2000. Riparian management in forest of the Continental Eastern United States. Boca Raton, FL: Lewis Publishers. 402 p.

Washington State Department of Fish and Wildlife. 2005. Washington's comprehensive wildlife conservation strategy. Olympia, WA: Washington Department of Fish and Wildlife 778 p.

Washington State Department of Labor and Industries. 2004. Safety standards for logging operations. Chapter 296-54 WAC. Olympia, WA: Division of Occupational Safety and Health, Washington Department of Labor and Industries. 149 p.

Washington State Department of Natural Resources et al. 1999. Forest and fish report. Olympia, WA: Washington Department of Natural Resources. 177 p. Online at http://www.dnr.wa.gov/forestpractices/rules/forestsandfish.pdf. (Date accessed unknown).

Washington State Department of Natural Resources. 2003. State of Washington natural heritage plan. Olympia, WA: Washington Department of Natural Resources. 64 p.

Washington Forest Protection Association. 2003. Forest facts & figures. Olympia, WA: Washington Forest Protection Association. 16 p.

Wilcove, D.S. 1989. Protecting biodiversity in multiple-use lands: lessons from the US Forest Service. Trends in Ecology and Evolution. 4: 385-388.

PROACTIVE MANAGEMENT CONSIDERATIONS FOR WILDLIFE HABITAT TO ENSURE PROFITABILITY

Malcolm R. Dick, Jr.[1]

ABSTRACT

Proactive management of wildlife habitat begins with understanding forestland ownership and the goals of the landowner. There exist five broad classes of forestland owners: industrial, non-industrial, state, federal and tribal. All owners have different objectives, resulting in different amounts and qualities of habitat. Each landowner class brings its own wildlife benefits and challenges.

Several principles are suggested to begin the journey for proactive management of wildlife habitat on western Washington's forestlands.

- All forestland is managed regardless of the owner or manager.
- Natural resource managers must embrace the art of the possible.
- Asphalt produces little wildlife habitat.
- We must keep our eye on the prize.
- People should be encouraged to own forestland.
- Good science is critical to effective habitat management.
- Landscape planning is a next generation habitat management tool.

The above principles reflect the viewpoint of many land managers. While not complete or the only list that could be developed it is worthy of examination by all wildlife managers as a window into the minds of the habitat owners or managers.

KEYWORDS: Habitat ownership, diverse landowner goals, habitat management principles.

INTRODUCTION

I am a non-scientist and my topic is non-scientific. My background includes political science, but with knowledge gleaned from a lifetime associated with forests, forestry and the issues involved in forest management. My dad's forestry career began in 1939 and ended in 1980, spanning two careers in forest management and forestry education. I came along in 1945 and by 1950, knew that I wanted to follow in his footsteps, which I did. It has been a fascinating journey not to be missed.

Washington has grown, during my life, from two million to over six million people (OFM 2006). The place where I shot my first deer now has houses on it; my favorite duck hunting areas are covered with more houses or freeway. The adjacent dairy farm where a close friend lived now is a freeway interchange. Thousands upon thousands of acres of forestland have been converted to other uses, burned, or devastated by epidemic insect and disease problems, while we argue about mollusks in tiny streams, perennial stream initiation points and the basal area left in stream corridors. We are fiddling while Rome burns, my friends.

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My words may annoy some of you. If, however, just one of you says, “Hmmmm. This guy might have a point,” I will have achieved my goal of causing you to think about the road ahead.

LAND OWNERSHIP AND MANAGEMENT PHILOSOPHY

A long-time associate of my father, and a darn good forester, once told me, “Our job (as corporate foresters) is to make a profit for the company. We are not here to be ‘socially responsible;’ we are not here to provide amenities other than those required by law. We are here to ensure the company meets shareholder expectations. Period.”

I did not fully agree with the statement but he had a point. If a manager governs land in a manner that does not achieve landowner goals, the company will not survive, the agency will not survive, and to a degree, the land will not survive in its current form. It is tempting to lump land on which trees grow as being the same, managed the same, producing the same products and amenities. Land ownership is much more complex. One of our first goals, then, is to understand landowner objectives and problems land managers face in achieving their ownership objectives.

Industrial Forestlands

Industrial forestlands comprise about a fifth of the total forestland base in Washington (WFPA 2005). Many people perceive these lands solely are managed to produce income; forests are clear-cut and then planted, cornrow style, acre after acre. The perception is only partly true.

These lands are managed to produce revenue. They also produce thousands of products society demands and uses every day. The revenue generation process creates jobs, pays taxes, maintains open space and creates a healthy environment while the economy benefits. Industrial forestland is not ideal for all wildlife species but a wide range of species can and do make a good living on these lands. Strict forest practices regulations ensure protection and maintenance of certain habitat types and high water quality.

Pressures on these lands are multiple and substantial: there is pressure to produce products and revenue on an ever-decreasing productive land base. There is pressure to convert the lands to other uses, pressure from neighbors who do not want “their” trees cut, and pressure from those who think industrial lands have an obligation to produce amenities these lands may not be able to produce and still achieve the owners’ goals. More than one landowner has said, “To heck with it,” and left the region. Those who remain recognize social responsibilities associated with forestland management, i.e., “pressures,” but are struggling to find the ability to meet revenue expectations, while concurrently meeting society’s demands.

Non-industrial Forestlands

Non-industrial forestlands comprise fifteen percent of the state’s forestland base (WFPA 2005). Ownership is characterized by thousands of small parcels, closer to urban centers, under significant pressure from developers, various tax burdens, and general urban expansion. Non-industrial landowners manage their lands for a variety of goals but a major purpose almost universally is income generation.

The typical non-industrial landowner fiercely protects his or her land and gives it up only under duress. We must keep in mind that much of this land will change hands over the next generation and the new owners may or may not live on the land. Landowner education will become increasingly important.

This forestland ownership component provides critical forested wildlife habitat where it is needed most of all. We should do all in our power to encourage its retention.

Washington State Forestlands

State of Washington forestlands cover more than 2 million acres of Washington, most of which is in western Washington (WFPA 2005). The lands are held in trust for specific beneficiaries in a unique fiduciary relationship between the State and these beneficiaries. Beneficiaries closely watch revenue production, in the same manner as corporate shareholders watch their investments. Benefi-ciar-ies have the ability to divest themselves of these lands if revenue production falls or management expenses rise to unacceptable levels. The Habitat Conservation Plan of the Washington State Department of Natural Resources, among other land management instruments, ensures recognition and protection for a wide variety of fish and wildlife species.

State trust lands face the same pressures as private forestlands, and, additionally, are subject to the vagaries of a state legislature filled with people who, as a body, have little understanding of resource management.

USDA Forest Service Lands

Non-wilderness lands of the USDA Forest Service cover an additional quarter of Washington’s forests (WFPA

2005). Forest Service land managers face their own set of intense pressures. Let me paraphrase something I wrote several years ago:

> *Today's National Forests are in conflict with themselves. Insects devour vast areas, recreationists trample stream banks, shoot each other, overwhelm sanitation facilities. Each tree scheduled for harvest is fought over as if it were the last Douglas fir in existence. Roads are poorly maintained due to lack of funds and budgets continue to decline. Perhaps worst of all is the complete, profound inability of Forest Service professionals to do their job. If they aren't stopped by administrative appeals or lawsuits, their own process stops them nearly as fast. Glaciers move faster.*

Forest Service lands are "growing" old growth and provide significant old-growth habitat but little early-seral forest habitat. The downside is that with the cessation of timber harvesting on federal lands, species dependent on early-seral forest, such as deer, elk, and certain predators are forced to relocate or perish.

Tribal Forestlands

Tribal lands comprise less than ten percent of the forested land base. Washington's Native American reservations are managed by and for tribal interests that range from revenue production, religious significance, wildlife habitat management, and food and small products, e.g. basket weaving materials, cedar bark, etc.

Wildlife enhancement, particularly for larger species (deer, elk, and bear) is an important tribal goal on most reservations. While tribes reserve the right to manage their lands for their own goals, the wildlife benefits of such management should not be overlooked.

So there you have it: five landowner groups provide distinctly different habitat types and habitat management opportunities in different locations in western Washington, and the entire state, for that matter. Each brings its strengths and weaknesses but the land base exists for diverse habitat management opportunities.

PROACTIVE MANAGEMENT ACTIONS

The bulk of this meeting has been spent discussing technical aspects of wildlife habitat management. I would like to explore social, economic and political aspects of the issues involved in habitat management on Washington's forestlands through several principles that could lead resource managers, including wildlife habitat managers, to be more effective.

All Forestland Managed

All forestland is managed, regardless of the owner or manager. The time of Lewis and Clark is past. That includes wilderness and National Parks. Every acre in this country is under guidance from a body that decides what does or does not happen on that acre.

The idea that we can, or even should, recreate vast stretches of untrammeled wild lands is archaic. We natural resource managers now are in the business of managing lands and all the critters and plants that call them home. The sooner we embrace this concept, the sooner we can concentrate on holistic wildlife habitat management on today's land base for tomorrow's citizens.

Embrace the Possible

We must embrace the art of the possible. Most species will make the transition from 1806 to 2006. Some will not. The northern spotted owl (*Strix occidentalis*), for instance, will not survive in much of its range. The barred owl (*Strix varia*) out competes it in almost every category of life. Charles Darwin wins this round.

Spending copious amounts of time, money and energy on saving species that cannot be saved is an exercise in futility. At some point, we must recognize and accept the inevitable ascent or descent of any given species, as it copes with life, including human occupation or use of its habitat.

A companion issue is the federal Endangered Species Act (ESA), which discourages wildlife habitat creation or enhancement in working forests. Landowners are punished for having certain wildlife habitat via severe land use restrictions. We must reward landowners for creation and enhancement of critical wildlife habitats. ESA revisions that embrace such changes will better protect landowners and wildlife.

Asphalt and Wildlife

Asphalt supports little wildlife. We all need to work at keeping forestlands growing trees versus strip malls, subdivisions, etc., where possible. Concurrently, we must accept that not every forested acre will survive as forested habitat.

Each forested acre need not – cannot – provide habitat for all creatures. All forestlands contribute to wildlife habitat. A deer, bear or neo-tropical migrating bird, for example, could not care less if trees grow in rows as long as he or she can eat, sleep and procreate. It is important that we assess how each land ownership class fits into the big picture and how these lands can contribute to overall wildlife needs, while meeting the landowners' or managers' goals.

Keep Our Eyes on the Prize

We must keep our eyes on the prize. We waste substantial energy analyzing trivia. The angst created by attempts to determine at what point stream flow begins, for example, and endless arguments over what diameter of trees to harvest on federal lands, lawsuits, appeals and crippling process all detract from the land manager's ability to manage the land. This happens as we watch thousands of acres of forest disappear from fire, land conversion, insects and disease. Keep in mind when the land manager's time, energy and resources are soaked up with trivia, important stuff does not get done.

Forestlands Incentives

There should exist incentives to own forestland. Forestland owners can accrue significant net worth in forestlands, including, but not limited to lands suitable for development. Various proposals to modify estate tax standards invariably stall in Congress. That is a tragedy for wildlife; here is why:

A local family recently was forced to sell two substantial parcels of managed forestland to pay a deceased family member's estate tax. Those forests were habitat in an area that needs forested habitat. The now former habitat will host houses, not by choice but by need. This is but one example of a problem that is more common than you might think. We need a new paradigm on how we approach keeping forestland growing trees and habitat.

Good Science as a Wildlife Management Solution

Good science is a critical piece of the wildlife management solution. You undoubtedly are aware of the controversy over an Oregon State University study that made certain conclusions about the impacts of timber salvage on conifer regeneration on federal land. Study results were plausible but methodology was suspect. That the study was rushed into the public's eye, with inadequate review did not help. Everyone associated with the study got a black eye, regardless of the study's ultimate fate.

Natural resource managers need credible science produced by qualified scientists. There are many forms of science and many levels of qualifications. We must define "credible science," different levels of science, different types of science and the qualifications of those we call, "scientists." This is a festering issue that must be resolved sooner rather than later. The credibility of all resource managers and natural resource scientists is on the line.

The Next Generation

Finally, landscape planning is a key next generation wildlife management tool. Wildlife habitat is both temporal and spatial, ever changing over time and space. The ESA has driven us into a corner in which we increasingly manage for single species on discrete pieces of real estate. Until we look at the landscape as a whole, and wildlife as a complex assortment of creatures, we will have missed an important element in our responsibilities as natural resource managers.

SUMMARY

The easy part of any job is enumerating problems and potential solutions as I have done above. It is much harder to actually do something about it, but as Confucius is reputed to have said 2500 years ago: "The journey of a thousand miles begins with the first step."

The issues discussed represent the thoughts of a significant number of people who control and manage forested habitat. As such, my list is worth your perusal, regardless if you agree with the issues involved.

Perhaps the next step in this thousand-mile journey is to agree on a common set of problems we need to solve in our quest to manage land to produce products and revenue and jobs, plus a variety of wildlife. We have begun that journey with today's conversations.

LITERATURE CITED

Washington State Office of Financial Management Population Statistics [OFM]. 2006. Current and historical data sections. Olympia, WA: Access Washington State and Government Official Web Site. http://www.ofm.wa.gov/pop/coseries/default.asp (Accessed 20 July 2006).

Washington Forest Protection Association [WFPA]. 2005. Forest facts and figures. Olympia, WA: Washington Forest Protection Association. 13 p. http://www.wfpa.org/pages/brochure.html (Accessed 20 July 2006).

WORKSHOP SYNTHESIS

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MANAGING FOR WILDLIFE HABITAT IN WESTSIDE PRODUCTION FORESTS: A WORKSHOP SYNTHESIS

Pete Holmberg[1]

ABSTRACT

Two major themes emerged from workshop presentations regarding combining wildlife habitat and revenue objectives in Westside production forests. The first theme was that a substantial, albeit fragmented, base of multi-disciplinary knowledge exists, as was clearly displayed at the workshop. This knowledge base could serve foresters well in managing for combined revenue and wildlife habitat objectives in Westside production forestry. On the other hand, the significant knowledge base is partly counter-balanced by notable difficulties, including social credibility of the forestry profession and regulatory responsibilities for ecosystems that are without central governmental focus. The workshop's second major theme was a diminishing profit potential for forest landowners exacerbated by environmental law and rule enforcement that can be counterproductive. This contributes to Westside forest land conversion, particularly urbanization and real estate development. Thus, land use conversion is thought to pose possibly the single greatest threat to general wildlife habitat. Habitat creation and management efforts will not be relevant if they do not include plans to reverse forest land conversion. To achieve this, a system based on incentives is suggested.

The first theme poses the question why foresters still seem to have problems credibly managing for multiple objectives when substantial interdisciplinary knowledge exists and is generally available. I suggest a method to synthesize complex arrays of scientific knowledge into a logical decision format. The decision format is for execution of activities in the present to achieve long-term, large-area multiple objectives. A silvicultural system is suggested to deliberately manage stand cohorts that correspond to objectives while recognizing their silvics. A key to this is to correlate landscape, stand-rotation, and stand-activity objectives and take advantage of site-specific characteristics. This system will increase transparency of decisions for the public, which should help build a constructive dialog between the public and land managers.

KEYWORDS: Silviculture, wildlife, prescription, cohort, multiple objectives, financial analysis.

INTRODUCTION

The purpose of this paper is to bring out and integrate workshop themes with other relevant research and to synthesize these into potential solutions where apparent shortfalls exist. The paper's scope is defined accordingly. Thus, I will first summarize the major points of scientific knowledge brought out at the workshop and integrate other relevant scientific knowledge. I will then synthesize the combined body of knowledge, highlighting apparent voids which I will attempt to fill with some observations and suggestions. Specifically, I will offer some thoughts regarding the need for a deliberate methodology in establishing clear, structured objectives at stand-activity, stand-rotational, and landscape-perpetual scales and in linking planning and execution.

WORKSHOP PRESENTATIONS

General

There were two major themes at the workshop. The first and by far most prevalent of these addressed the science,

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techniques, and field craft to manage forests for multiple wildlife habitat and financial objectives. The second theme, mentioned by several speakers and possibly the most fundamental to sustainability of forested wildlife habitat, concerned the unintended consequence of environmental laws and rules that contribute to accelerated conversion of forest lands to more lucrative uses.

Keynote Address: How We Got to Where We are Today

Perceptions of the role of managed forests as wildlife habitat are changing (Aubry 2007). A historical review of the last one hundred years shows a repeating pattern of progress in which solutions are devised, and after some decades of increasing disregard they are rediscovered with a new twist. Thus, in the early 1900s, Theodore Roosevelt established the doctrine of "wise use" of natural resources. Wise use implied, as a public trust, using science to ensure a balance between resource extraction and replenishment. Later, in the 1930s Aldo Leopold initiated wildlife habitat management in the United States by advocating scientific solutions to increase carrying capacity for game species and later for all vertebrates and associated niches. Over time, key turning points in thinking about wildlife management crystallized. In 1979, Jack Ward Thomas precipitated a public realization of the importance of managing forest biodiversity on spatial scales. In 1987, Jerry Franklin and others presented the idea of landscape ecology and planning. A couple of years earlier, in 1985, the idea of extending protection to entire riparian systems, including headwaters, began and gradually took hold through the 1990s. Concurrently, beginning in the early 1980s, old growth forests began to be recognized as possibly unique habitats for key wildlife guilds. Jerry Franklin and others introduced the idea of "new forestry" as "kinder and gentler" forestry that would better accommodate ecological values than tree farm forestry while allowing for the extraction of commodities. This idea gave rise to managing for late-seral habitat including previously unrecognized stand cohorts such as snags, green multi-rotational trees, and coarse woody debris. In other words, we have rediscovered silviculture as the tool to achieve multiple objectives in managed forests! This involves managing at multiple—harvest unit, landscape, and micro-site—scales. The last turn in the path of progress is the emergent realization that old growth and the landscape scale may not be as important for most species of wildlife as initial hypotheses indicated. Never-theless, some species, the northern spotted owl (*Strix occidentalis caurina*) in particular, depend on old-growth landscapes.

Synopsis of Presentations

There are many positive trends in wildlife habitat management. Although nascent knowledge tends by nature to be compartmentalized, there is an over-riding trend towards inter-disciplinary communication and knowledge integration. This is evidenced through an emerging core of inter-disciplinary scientific consensus. Scientific disciplines that interact with forestry (wildlife, ecology, etc.) acknowledge that silvicultural manipulation is a preferable, if not the only, practical option for deliberate and accelerated recovery of otherwise rapidly vanishing niche structures essential for key wildlife guilds. Silviculturists are devising regimes and landscape approaches that accommodate, indeed are often based on, scientifically derived arrays of discrete and measurable stand parameters that describe key wildlife habitats. Yet, there is an apparent reluctance to apply this knowledge towards actual results on the ground in managing for both wildlife and revenue objectives in a highly competitive world market, a market that puts our forests at risk of land-use conversion.

Integration of Multiple Disciplines into Silvicultural Solutions at the Stand Level to Enhance Structural Elements

There is advocacy by wildlife scientists for accelerating habitat development through silvicultural means (Hagar 2007). In particular, there is interest in promoting thinning techniques that create variable densities, develop more than one canopy, and nurture stand cohorts such as large down woody debris (LDWD), snags, wildlife trees, and hardwoods whose seeds are forage for the predator food base, indeed for a variety of species.

Furthermore, scientists are combining inter-disciplinary research findings into silvicultural techniques and field craft to design regimes that incorporate wildlife habitat objectives (Harrington and Tappeiner 2007). This is done by both leaving key older stand cohorts at final harvest of the present stand, as well as by selecting regimes for the new stand that nurture habitat along with financial revenue. These approaches, tailored to site productivity and developed through growth and yield modeling, are used to compare and analyze regime alternatives for multiple objectives, such as a specific wildlife habitat as well as probable future revenue. Rigorous financial analysis can portray alternatives of both rotational investment value as well as cash-flow alternatives. The outcome is the ability to develop and select the regime that best addresses both wildlife and financial objectives.

Silviculture at the Landscape Level

We are entering a new era of silviculture practice in which refined stand analysis techniques will be incorporated with management at the landscape level (Brodie et al. 2007). Landscape management is crucial in that it addresses issues (such as wildlife habitat) at the multi-stand scale where cumulative effects for the particular issue can be addressed. This approach resolves a wide interdisciplinary area of contention created by the outdated, but too often prevalent notion among traditional foresters that issues are mainly resolvable within forest stands or harvest units.

Landscape analysis is a hierarchical approach in which stands attaining certain conditions become the building blocks to address the particular issue for which the landscape was designated. By using habitat needs of the northern spotted owl as a keystone species (i.e., its stand and landscape habitat requirements encompass or exceed those of other species),[2] scientists are able to simulate regimes that integrate equitable revenue generation with accelerated development of quality habitat first at the stand level, and then through time retaining a desired proportion of the landscape in the desired stand condition. Although time-value-of-money analyses suggest a positive revenue flow, there is recognition of a tangible reduction in revenue as a price for providing ecosystem services.

Opportunity Cost of Managing for Wildlife

More specifically as to risk and market competitiveness, there is a body of research addressing vital economic nuances that are hidden if one restricts consideration to broader averages (Latta and Montgomery 2007). This body of statistical knowledge indicates that viability, indeed economic survival, of forest landowners is largely related to opportunity cost (i.e., the unrealized benefit, or cost, of adopting a less profitable alternative as compared to another, more profitable alternative) of sub-optimal financial practices. Thus, growth and yield stand modeling combined with financial analyses indicate a 50 percent reduction in value when comparing longer wildlife habitat regimes with short and revenue-oriented rotations, although both types of regimes generally have positive investment values. Notably, the research also indicates a 20 percent increase in value of longer wildlife habitat regimes that optimize the dual attainment of specific habitat conditions with financial revenue as compared to non-optimal regimes. In other words, the significant opportunity cost associated with incorporation of wildlife habitat objectives indicates a strong need for optimization in selecting and executing regimes.

Proactive Forest Management for Disparate Socio-Political and Economic Demands

There is common but not yet universal recognition that forests must be managed in accordance with standard principles to be socially viable (Dick 2007). Some of these principles are: forest management objectives that are well thought out and balanced against each other, doing essentials first and well (as contrasted with being distracted by trivia); social recognition that economics largely determine whether or not forestlands will remain as such or be converted to urban uses; reliance on objective science versus politically or popularly motivated agendas portrayed as science; and landscape management of ecosystems. The hub of these principles, without which other principles are arguably moot, is to retain current forestland as forest. To that end, some environmental laws and rules are counterproductive in that they have the unintended consequence of contributing to forestland use conversion into more profitable real estate development. Thus the mantra, "asphalt makes poor wildlife habitat." Recognizing the need for environmental protection laws, an enforcement system based on incentives may be a viable alternative to the current approaches which are often financially punitive.

Managing Non-Industrial Private Forest Land for Wildlife

The major workshop theme of financially feasible forest management for wildlife habitat was explored from the socio-political aspect by several speakers. Specifically, several presentations focused on the significant portion of the forest land base in western Washington that is made up of non-industrial private forests (NIPF) and larger private forest businesses.

The following statistics put the issue into perspective (Bottorff 2007):

- NIPF accounts for 19 percent or 2.6 million acres of forestland in Washington, most of which is highly productive (generally western Washington) and often managed for both "wildlife" and timber.
- NIPF at present accounts for 30 percent of timber volume harvested in Washington.
- The average size of an NIPF holding is just under 40 acres.
- Over one-half of NIPF owners are older than 55 years.

This data strongly implies that wildlife habitat managed on a landscape level is generally not a consideration for the portion of western Washington forestland in NIPF

[2] Although applicability of the concept of keystone species may be limited (Aubry 2007, Thomas and Bunnell 2002), it is useful in the context cited.

holdings. However, the ability to sustain species that are currently not threatened is considered substantial but may be in jeopardy with continued land use conversion. Notably, NIPF wildlife management amounts to actions that benefit the most species if not necessarily those currently most threatened. Although they are necessarily limited to stand level management, beneficial actions that were suggested include:

- Retention, distribution, and creation of snags and wildlife trees.
- Retention or creation of coarse woody debris.
- Promotion of certain species of understory vegetation, especially mast-producing trees and shrubs.
- Forage seeding.
- Variable density thinning.
- Hydrologic restoration.

The implication of forest landowner demographics is clear. The average forest landowner is of retirement age and may need the proceeds from land use conversion to finance retirement plans. This further implies accelerating dissipation of an already fragmented land base. Additionally, marginalization of this significant contributor to the lumber market will likely increase pressures for higher production rates—i.e., lower tolerance for creating wildlife habitat—on the remaining forestland base.

Riparian Forest Restoration on Private Forest Land

There is a body of statistical indicators that suggest significant and unnecessary financial penalties to NIPF landowners under current riparian rules (Lippke et al. 2007). While it is obvious that early old-growth harvests in the lowlands resulted in serious ecological regression in many riparian habitats, there are also abundant indicators that correctly applied silvicultural science, techniques, and field craft are the fastest way to restore riparian forest habitats to functional levels. Non-industrial private forest landowners have until recently, through a series of thinnings modeled on biodiversity pathways, been able to accelerate the long road back to desired old-forest structure in riparian zones while protecting short-term riparian function and maintaining a modest economic return. However, recent adoption of expanded stream classification rules have caused a 143 percent increase in the area requiring protection (i.e., the area in which silvicultural intervention and harvest is largely precluded) on NIPF lands and a 133 percent increase on industrial forestlands. In terms of soil expectation value, calculated financial decrements from expanded, and conceivably sub-optimal, riparian protection range from 22 to 54 percent. Thus, financial impacts of new rules raise serious questions as to the continued economic viability of forestland in private ownership. Mean-while, young even-aged stands subjected to new riparian rules are unlikely to attain late seral conditions without the now-precluded silvicultural intervention.

Forest Landowners Managing for Multiple Objectives

Private forestlands have a disproportionately important role in sustaining wildlife habitat and biodiversity conservation (Risenhoover and Murden 2007). The problem of sustaining an adequate forestland base for these purposes must be assessed against the vital issue forestland owners face in being competitive in a world-wide market place for timber. The scope of factors to consider in devising realistic solutions is comprehensive:

- Worldwide timber market competition constrains previously common profit margins.
- Forestland owners are, by and large, committed to long-term good stewardship but may lack sophistication in devising financially equitable solutions to effectively balance multiple objectives.
- There are limits to types of habitat that intensively managed forests can economically accommodate.
- There are guiding principles that can be used to devise financially equitable solutions:
    - Enhance existing stand structural diversity.
    - Maintain integrity of aquatic systems.
    - Recognize and protect ecologically sensitive sites and rare or unique habitats.
    - Keep common species common.

Thus, pertinent extension and education services are vital in helping forest ownership to be a financially desirable pursuit and thereby conserving the forestland base.

Ecosystem Management

Integration of all pertinent eco-functions, rather than compartmentalized approaches, is vital in managing forests (Kimmins 2007). This mandate is sharpened through demographic trends and inevitably increasing social pressures. Forestry should perhaps therefore be redefined as "the art (skill), practice, science, and business of managing forest stands and landscapes to sustain an ecologically possible and socially desirable balance of values over appropriate spatial and time scales." New responsibilities of the forestry profession are (1) to change the way in which a forest is managed as the desired balance of values and environmental services (the forest provides) and (2) to reject current practices and resist proposed new practices that are inconsistent with the ecology and sociology of the desired values and services over ecologically appropriate temporal and spatial scales. A fundamental recognition is that our forests have developed as ecosystems driven by disturbance on grand spatial and sporadic, perhaps climate-driven, temporal scales. In modern times, human society—its values, needs, and desires, whether related to factual information or not and wittingly or not—is increasingly asserting its influence on ecosystems and their management. The forester's responsibility is to intercede on the side of science and reason to safeguard social, economic, and ecological sustainability of forest ecosystems. This process involves establishing balanced long-term objectives for all values associated with the forest while also communicating with stakeholders to establish social credibility and be knowledgeable of markets. A universal trap to avoid is to view the forest in stasis, as stable snapshots frozen in time. The alternative concept of "ecological theater" is suggested. In this concept there is a central understanding that a forest ecosystem is akin to a slow-moving theater or movie in which change is continual. However, the theater adheres to a script, i.e., ecological limitations and drivers, and output varies with manipulation or stochastic occurrences. The social authorizing environment coupled with market drivers are potentially fatal stumbling blocks to the whole concept of ecological management if decisions are not made with appropriate ecological limitations and drivers in mind.

OTHER RELEVANT INFORMATION

Unintended Consequence of Environmental Legislation: Reduction of Forestland Base

A recent Denman Forestry Issues Lecture at the University of Washington comprehensively addressed underlying reasons for the dramatic conversion of forestland to urban uses over the last several decades in the Puget Sound basin (College of Forest Resources, University of Washington 2005). Contributing to land-use change, i.e., real estate development and urbanization, are rules for environmental and forest practices that are financially punitive in nature. The resulting high costs and risks associated with maintaining land as working forests contribute to forest owner's pursuit of land-use change. Society needs to effectively address the connection of regulation to land use conversion, and the consequent impacts on wildlife habitat.

Classical Silviculture

Classical silvicultural system categories, such as clearcut, seed tree, and shelterwood (nomenclature that also describes final harvest systems), may be useful as theoretical points of reference. However, the over-riding principle of ecosystem management compels site-specific stand objectives to govern the rotational prescription in accordance with silvical and ecological factors rather than forcing it into stale and old silviculture dogma (Weetman 1996, Kimmins 2007). The case is magnified when integrating wildlife habitat with revenue objectives into high-production Westside forests. Specifically, designing site-specific innovative activities beyond rote repetition of standardized techniques is the current direction for field forestry.

Cohort Management and Associated Silvicultural Harvest Techniques in Managing for Revenue and Wildlife

The advent of new forestry (Swanson and Franklin 1992) and biodiversity pathways (Carey 2003a) set the stage for using silvicultural techniques to effectively produce habitat along with revenue. To do this, techniques for thinning and final harvest must represent the best possible methods to attain the stand-rotation objectives.

A foundational concept is that different objectives rely on different key cohorts.[3] Keying on cohorts may be thought of as a new silvicultural system based more on intent for future conditions than a snapshot that reflects transient appearance. Stand cohorts disregarded in single-objective classical forestry, and some of which only materialize after a long period of time (wildlife trees, snags, LDWD, and mast-producing hardwoods), have vital importance for wildlife such as the northern spotted owl. By managing these as well as commercial cohorts, wildlife habitat may be created along with revenue. Simulations clearly show that retaining these multi-rotational cohorts at final harvest significantly accelerates attainment of habitat for the new rotation. By retaining or creating these cohorts, risks associated with low stand vigor, such as insect and disease epidemics as well as to some extent, blow-down, are largely bypassed (WDNR 2004).

Two silvicultural techniques specifically combine to support a silvicultural system of cohort management and address creation of wildlife habitat: a final harvest system referred to as "variable retention harvest" (Franklin et al. 1997) and a thinning treatment referred to as "variable density thinning" (Carey 2003b, Harrington et al. 2005). As emphasized in the sustained harvest calculation of Washington State Department of Natural Resources (WDNR), older stand cohorts are deliberately left as a part of a variable retention harvest in order to expedite the stand's development into functional habitat (WDNR 2004).

[3] A cohort is a group of individuals or vital statistics about them having a statistical factor in common, such as (but not restricted to) age class (Helms 1998).

These cohorts are later deliberately replenished in conjunction with variable density thinnings in the new stand. Thus, final harvest of previous stands is the first step to create habitat in new stands.

Variable retention harvest removes commercial cohorts but leaves cohorts (or groves of cohorts) that cannot be quickly recreated and are needed for habitat. Routinely, these cohorts consist of a few wildlife trees, snags, LDWD, and mast-producing hardwoods per acre. Retained cohorts may be clumped into refugia (small groves), either to protect leave trees or to expedite restoration of eco-function.

Variable density thinning has different descriptions, but all enhance habitat. Both the "skips and gaps" approach (Harrington et al. 2005) and the approach using mosaics modeled after structurally complex forest stands (Carey 2003b) deliberately foster openings and unthinned areas while variable thinning covers most of the area. These related techniques afford the opportunity to retain closer spacing around shade tolerant cohorts, widen it around shade intolerant cohorts, comply with state safety rules by not thinning around snags, and allow the logger sufficient landing space and some boost in revenue by harvesting occasional openings as well as being allowed to forego some hard-to-reach areas. Variation is implemented on a scale of approximately 0.5 to 5 acres. Outside of skips and gaps, relative density (RD) is varied 10 to 15 points (Curtis 1982). Often in two-species stands, variability in RD can be attained by thinning to a constant stand basal area but varying leave-tree preferences between, for example, western hemlock and Douglas-fir due to propensity of small-diameter western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and relatively larger-diameter Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco. var. *menziesii*), as alluded to in figure 1.

The mast-producing hardwoods, vine maple (*Acer circinatum* Pursh) and bigleaf maple (*Acer macrophyllum* Pursh), do not have to be felled, yarded, and disposed of in many cases. Release of crop trees and enhanced revenue are feasible with this kind of thinning. Washington State Department of Natural Resources uses the illustration in figure 1 in its internal training manual for thinning to illustrate a side- and overhead-view of a stand after variable density thinning (Holmberg et al. 2006).

SYNTHESIS

General

In view of presentations at the workshop and other relevant information, it would appear that sufficient scientific information exists to manage for both revenue and wildlife habitat objectives in Westside production forests. Nevertheless, there is a common hesitancy to do so. Doubtless, some of this trepidation has to do with sailing uncharted investment waters; concerns most likely also relate to being overwhelmed by the material to be mastered and the idea of reconciling objectives that may seem contradictory to each other. I will attempt to demonstrate how this confounding complexity may be organized in order to design optimal silvicultural treatments in the present that steer stand development towards stand-rotational and landscape objectives. A fundamental realization that should motivate execution to rise above generalities of long-term, large-area plans is that execution, as contrasted to paper plans, is irreversible. A quest for state-of-the-art professional performance is therefore to use site-specific characteristics and possibilities to full advantage.

Site-Specific Silvicultural Application

First, there are a number of foundational concepts to consider when designing site-specific silvicultural treatments with multiple objectives to be executed in the present. They are:

1. Planning intent—a primary influence of strategic and other large-area, long-term planning in designing a silvicultural treatment for a stand is the strategically desired, general end state at the stand level.
2. Objectives at landscape, stand-rotational, and stand-activity levels—landscape objectives are best expressed as a proportion of the landscape to be in a specified stand condition (habitat quality, merchantable value, etc.) at any one point in time; stand-rotational objectives attain that same specified stand condition for individual stands, and each objective is defined by an array of discrete and measurable threshold targets. Stand-activity objectives are immediate stand conditions achieved by activities.
3. Threshold targets—objectives are defined by arrays of discrete and measurable threshold parameters referred to as threshold targets (e.g.; for a habitat objective, threshold targets might be quadratic mean diameter, dominant tree height, level of competition in the stand, trees per acre, number of snags per acre of a certain minimum size, LDWD per acre, etc.; and for a revenue objective of maximizing net economic benefit, threshold targets might be a minimum investment return per acre, a maximum investment allowance per acre over the rotation, etc.).
4. Linking objectives—objectives at the landscape, stand-rotation, and stand activity level must be demonstrably linked, so that an activity can be clearly shown

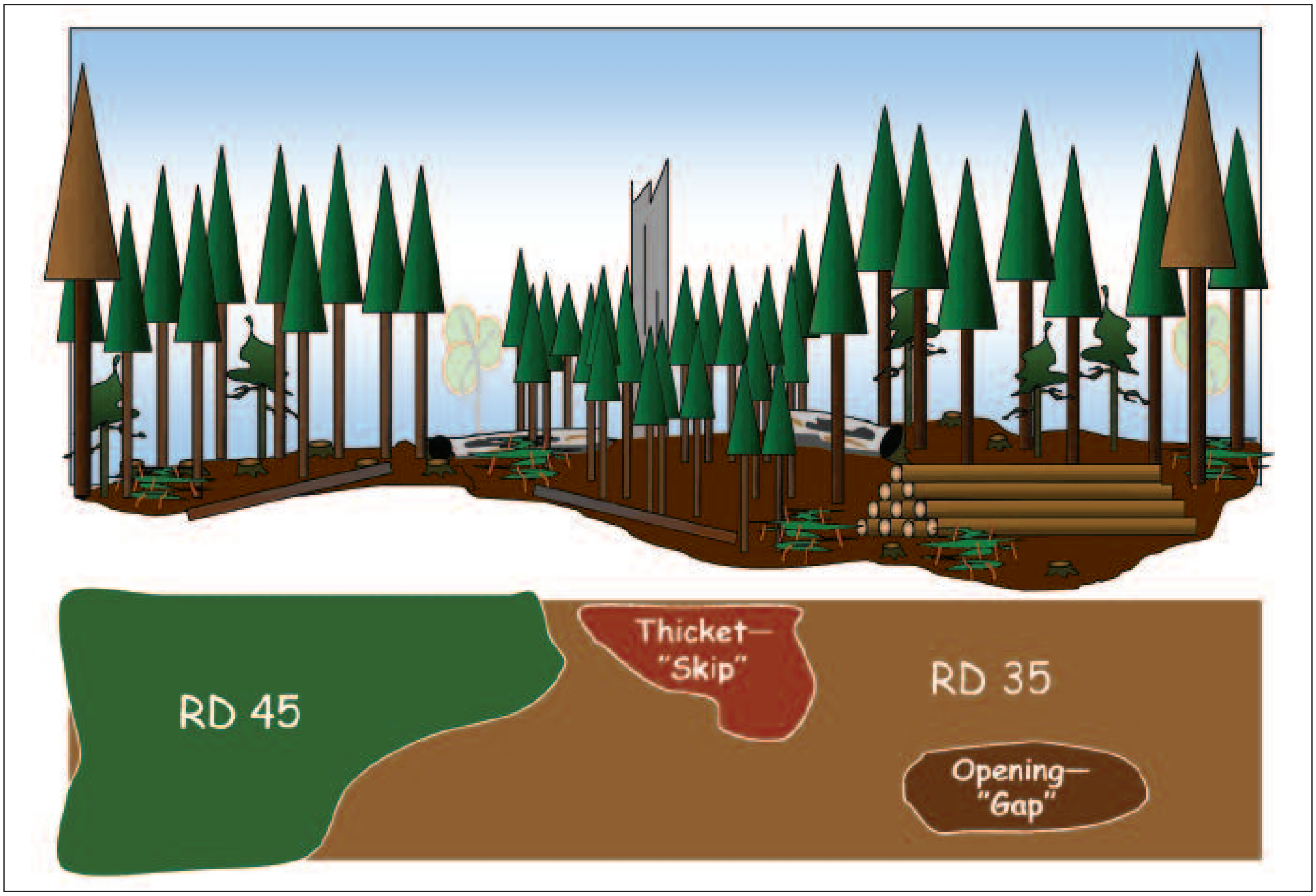

Figure 1—Example of a variable density thinning. In the side view (upper image), there are different densities between the left and right sides of the stand, some suppressed understory and mast-producing trees are deliberately retained as are some logs, a thicket is left around the snag, the two larger wildlife trees at each margin have been converted to snags, and sufficient landing space–a stand opening–is indicated by the log deck. Furthermore, natural regeneration is evident in openings that, if tended in future entries, will produce a scattered lower canopy. In the overhead view (lower image), two relative densities (RD; Curtis 1982) are indicated for a majority of the stand. Openings and thickets together constitute around 15 percent of the stand area. Variations in RD of 10 to 15 points and openings and thickets should generally occur on a scale of 0.5 to 5 acres.

to be the best option for redirecting stand development towards stand-rotational and landscape objectives.

5. What a landscape is—a useful definition of landscape is an area whose extent and shape is defined by a particular issue, e.g., visual landscape: an area as seen from a travel route or vantage point; northern spotted owl landscape: an area on which nesting pairs and their juvenile offspring depend for survival and proliferation (nesting areas plus a surrounding territory for roosting and foraging).

6. Why we consider landscapes—we consider landscapes because we need to reconcile the requirements imposed by the issues they represent, and these issues are resolvable only at the scales that define them.

7. Refining an activity prescription through use of products of planning—the products of long-term, large-area planning useful in guiding site-specific activities are rotation age, generally acceptable techniques, and likelihood of financial equity; foresters should understand how these planning products were developed and thus be able to justify their application or modification at the site-specific level.

8. Managing objective-driven stand cohorts—wildlife habitat depends on forest stand cohorts such as snags, wildlife trees, and LDWD which are managed on a multi- or non-rotational basis; meanwhile,

Table 1—Stand-rotation objectives and their threshold targets

- Attain sub-mature habitat for the northern spotted owl:
  - o A canopy composed of trees of the dominant, co-dominant, and intermediate crown classes of which at least 30 percent are conifer species
  - o A relative density (Curtis 1982) of at least 50 for trees 4 inches diameter at breast height (DBH) and larger
  - o Tree density of between 115 and 270 trees per acre for trees 4 inches DBH and larger
  - o Dominant and co-dominant trees at least 85 feet in height
  - o At least 3 snags or cavity trees per acre at least 20 inches DBH
  - o At least 5 percent of the ground covered with large down woody debris
- Maximize net revenue, as consistent with other objectives:
  - o A bare land value for the rotation of at least $0 per acre at a discount rate of 4 percent
  - o A maximum investment for the rotation of a cumulative sum of $500 per acre

commercial cohorts are generally managed on a rotational basis; when modeling commercial stands, noncommercial cohort volume must be subtracted from predicted volumes, usually as a function of the area they occupy.

9. Utilization of silvicultural techniques adapted to attain site-specific objectives—these include primarily species mixtures and densities in planting and thinning, micro-site preparation and vegetation management, variable density thinning, and variable density final harvest.

An Illustrative Example

To illustrate how these concepts might be applied, let us imagine a fairly typical category of intensively managed forestland west of the Cascades: a forest stand in the western hemlock-western swordfern (*Polystichum munitum* (Kaulf.) Presl.) plant association group. The plant association group implies a high productivity site, average 50-year site index of 127 ft, and a high potential for salmonberry (*Rubus spectabilis* Pursh) in openings, if at all present under a forest canopy.

Let us assume the owner of our common but imaginary stand has recently adopted a landscape objective to sustain sub-mature habitat for the northern spotted owl over at least 50 percent of the landscape. The landowner has additional landscape objectives to maximize annual harvest from the local block as well as to maximize revenue from the same block, but both must first be consistent with constraints imposed by the first objective.

The landowner's harvest schedule indicates a final harvest is due for the particular stand we are now looking at. This poses the questions for current and near-current activities: how should the stand be harvested, and how should it be reforested to best attain stand-rotation objectives? For our particular stand, the landscape objectives in the previous paragraph translate into stand-rotation objectives for the new stand (1) to attain sub-mature habitat and sustain it for a period yet to be determined, (2) to maximize stand volume and or value over time, (3) to maximize net revenue, and implied but not stated, (4) to sustain forest health.

The average rotation age required to sustain sub-mature habitat over 50 percent of the landscape may be approximated by first determining the time it takes for the stand to enter the habitat window, i.e., when all threshold targets for sub-mature habitat are met. Threshold targets for sub-mature habitat are listed in table 1. Stand modeling indicates that if LDWD, snags, and snag candidates (wildlife trees) are left in sufficient numbers at final harvest of the current stand, the new stand will enter the habitat condition window at a stand age of 35 years for this specific site. Rotation age that is consistent with all stand objectives can now be estimated, sufficient for financial analysis, through the formula:

Rotation age = Stand age when entering the habitat window ÷ Proportion of the landscape that may at any one time not be in the specific habitat that is targeted

In our example, rotation age = 35 ÷ (100% - 50%) = 70 years. Let us suppose we discovered scattered salmonberry under the present stand canopy. The plant association group indicates this presence will develop into a competitive brush sere when exposed to direct sunlight soon after final harvest. Thus, there is a need to control the salmonberry to ensure survival of planted conifer seedlings.

Although the climax sere for this plant association is dominated by western hemlock, Douglas-fir and western redcedar (*Thuja plicata* Donn ex D. Don) are also well-suited. In addition, Briggs (1999) found that Douglas-fir planted at 12-ft spacing will produce knots of 1.5 inches and smaller, indicating #2 sawlogs or better quality in time.

We now have sufficient information to test silvicultural activity prescriptions for final harvesting the present stand and reforesting the new.

The final harvest activity prescription to test is for a variable retention harvest in which the requisite snags, snag candidates (wildlife trees), and LDWD are left as legacies in small groves. In addition to the eight required standing snags and trees, we leave an additional four large live trees per acre to account for progression from standing live, to snag, to LDWD. The test for this activity prescription is fairly simple: will fewer leave-tree schemes lengthen or shorten the period before return on silvicultural investments? The answer is certain to be that it is best from a financial investment standpoint to provide sufficient legacies and thereby ensure the shortest possible rotation. In this case, we made a subjective judgment that 12 legacies per acre would be prudent.

The reforestation activity prescription to test is to plant a mixture of seedling stock types of 1+1 for Douglas-fir, plug+1 for western hemlock, and a lesser cohort of plug+1 for western redcedar after a ground herbicide site preparation treatment (lesser brush and slash concentrations will be spared as browse protected planting spots for western redcedar). The Douglas-fir and western redcedar both have high potential future value for different markets, while the western hemlock with a modest potential for future value will offset epidemic potential of Douglas-fir pests. Browse inhibitor application at the nursery is specified for both western redcedar and Douglas-fir; deer browse for our area has in the past been moderate.[4] The proposition is that a species mix is an effective measure to prevent pest epidemics, and that a mixture provides opportunities to exploit market niches as they may occur for different species and products.

After several simulation runs with different planting densities and thinning regimes, the silvicultural stand-rotation prescription in table 2 was chosen. This regime (1) has the best probable progression to attainment of stand rotational wildlife and revenue objectives; (2) provides reforestation and site preparation prescriptions for near-present execution that reasonably minimize the probability precommercial thinning will be needed while maximizing the probability of success for the earliest commercial thinning thought safely merchantable; and (3) provides density-related decision nodes to be scheduled in the corporate database at which junctures the stand-rotation prescription may be altered, should objectives change in the interim.

Additional simulations revealed an opportunity cost on the order of $600 per acre for a 70-year rotation without western redcedar versus a shorter 40-year rotation. However, the site-specific opportunity to include a western redcedar cohort to the 70-year rotation added approximately $300 to bare land value (BLV),[5] thus halving the opportunity cost (a higher harvest value assumption for western redcedar—see table 2—would have further reduced the opportunity cost). A western redcedar cohort would not appreciably increase the value of a shorter 40-year rotation; western redcedar requires the 70-year rotation to gain superior value (as well as to develop into an intermediate canopy suitable for roosting). Meanwhile, an intensively managed 100-year rotation attained high-quality nesting habitat at 75 years but caused a halving of bare land value (BLV) as compared to the 70-year rotation with a western redcedar cohort. Both the value enhancement from the western redcedar cohort in the 70-year rotation and the rapid deterioration in investment value caused by a "stretch" objective of high quality nesting habitat in a longer 100-year rotation are similar to findings of Latta and Montgomery (2007).

SUMMARY

We have demonstrated a process to fine-tune activities in the present to serve multiple objectives and long-term intent by using concepts from current science in concert with site-specific opportunities. We used an example with both revenue and wildlife habitat objectives and demonstrated how enhanced value could accrue by capitalizing on

[4] WDNR's Webster Forest Nursery charges approximately one cent per seedling for an application that lasts in the field for around 3 months.

[5] $BLV = NFV \div [(1 + i)^{n} - 1]$. BLV is bare land value and NFV is net future value i.e., the net of all real value costs and revenues, each compounded until the end of the rotation. $NFV = \sum FV$ wherein $FV = V \div (1+i)^{n}$). V is the value of an investment or revenue; i is the compounding rate; and n is the number of years in the rotation. Expressed differently, BLV is the net present value (NPV) of an infinite number of successive, identical rotations ($NPV = \sum PV$ with $PV = V \div (1 + i)^{n}$). Thus, because its investment period always is infinity, BLV, unlike NPV, is suitable for comparing investment value of differing lengths.

Table 2—Silvicultural prescription summary for a 70-year rotation that manages sub-mature habitat for the northern spotted owl in concert with landscape objectives

Year of occurrence from present	Event and associated activity prescription[a]	Cash flow (2006 dollars)
-1	VRH Prior Stand, leaving approx. 12 legacies/acre (snags, wildlife trees) and LDWD	NA
0	Manual herbicide site prep. avoiding micro-sites suitable for hiding from browse WRC to be planted	-$100
1	Plant a mix of 150 1+1 DF, 150 P+1 WH, and 60 P+1 WRC w/ browse inhibitor/acre	-$200
4	Manual herbicide vegetation management	-$100
12	Monitor for PCT—if projected, subtract $65 from BLV	-$1
35	Enter habitat window; stand is now estimated to meet or exceed all threshold targets for sub-mature habitat	
28	VDT from RD 65 to RD 45, removing equal amounts of DF and WH but leaving WRC; harvest 9.4 MBF/acre at $150/MBF	$1,410
53	VDT from RD 65 to RD 50, removing equal amounts of DF and WH, leaving WRC; harvest 10.8 MBF/acre at $250/MBF and leaving 3 MBF as snag and LDWD replenishment	$2,700
70	Pre-harvest 10 MBF/acre WRC at $750/MBF; VRH, leaving 10 MBF/acre as snags, wildlife trees, and LDWD while harvesting 39.2 MBF/acre of 2-saw or better DF and WH at 375/MBF	$22,200

Results

- Bare land value (BLV)[b] at 4 Percent Discount Rate: $1,983 (exceeds $0 threshold)[c]
- Approximate internal rate of return[d]: 7.65 percent (exceeds 4 percent threshold)
- Total investments: $401/acre (within $500/ac maximum threshold)

[a] Abbreviations used in the table have the following meaning: DF (Douglas-fir), LDWD (large down woody debris), MBF (thousand board feet), RD (relative density; Curtis 1982), VDT (variable density thinning), VRH (variable retention harvest), WH (western hemlock), and WRC (western redcedar),

[b] BLV = NFV ÷ $[(1 + i)^n - 1]$. BLV is bare land value and NFV is net future value i.e., the net of all real value costs and revenues, each compounded until the end of the rotation. NFV = $\sum FV$ wherein FV= V ÷ $(1+i)^n$). V is the value of an investment or revenue; i is the compound interest rate; and n is the number of years in the rotation. Expressed differently, BLV is the net present value (NPV) of an infinite number of successive, identical rotations. NPV= $\sum PV$ with PV = V ÷ $(1 + i)^n$.

[c] The BLV gain is approximately $300 from planting and marketing western redcedar as a separate sort at final harvest

[d] Internal rate of return, IRR, is the discount rate for which NPV = $0 (for longer rotations, NPV approaches BLV).

particular opportunities in site-specific execution of silvicultural activities. We also illustrated potential opportunity costs incurred by ambitious wildlife objectives in a rotation that nevertheless generated positive revenue. It appears that such opportunity costs, even in the case of positive financial profit, may affect land use. We cannot disregard the possibility that alterations to regimes required to accommodate wildlife habitat objectives may have negative effects on competitive positioning in a worldwide marketplace as it affects conversion of forestland to other uses. It is also unclear to what extent opportunity cost of medium-length and more complex rotations may be offset by decreased risk to forest health and market opportunities offered by a diverse inventory of standing wood. It is therefore plausible, as alluded to in the above example with the western redcedar cohort, that innovation realized through site-specific execution at all stages of a rotation may convey financial gains routinely foregone in minimum-length intensive monocultures.

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LITERATURE CITED

Aubry, K.B. 2007. Changing perceptions of the role of managed forests as wildlife habitat in the Pacific Northwest. In: Harrington, T.B.; Nicholas, G.E., tech. eds. Proceedings, Managing for wildlife habitat in Westside production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 3-17.

Bottorff, J. 2007. Wildlife habitat management practices on private non-industrial forestlands. In: Harrington, T.B.; Nicholas, G.E., tech. eds. Proceedings, Managing for wildlife habitat in Westside production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 61-64.

Briggs, D. 1999. Modeling number and size of branches in young coastal Douglas-fir plantations as affected by silvicultural treatment. http://www.cfr.washington.edu/research.smc/newsletter/IUFRO3rdqtr99.htm [Access date unknown].

Brodie, A.W.; Bowering, M.; Jaross, W.; Reimer, D.; Lu, B. 2007. Combining management goals of wildlife habitat conservation and revenue on Washington State Trusts. In: Harrington, T.B.; Nicholas, G.E., tech. eds. Proceedings, Managing for wildlife habitat in Westside production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 67-80.

Carey, A.B. 2003a. Biocomplexity and restoration of biodiversity in temperate coniferous forest: inducing spatial heterogeneity with variable-density thinning. Forestry. 76(2): 127-136.

Carey, A.B. 2003b. Managing for wildlife: a key component for social acceptance of compatible forest management. In: Monserud, R.A.; Haynes, R.W. Johnson, A.C., eds. Managing forest ecosystems–compatible forest management. Kluwer Academic Publishers: Dordrecht. The Netherlands: 401-428.

College of Forest Resources, University of Washington. 2005. Keeping our northwest forest landscape green. Denman Forestry Issues Series. lecture.http://www.uwtv.org/programs/displayevent.aspx?rID=2799&fID=558 [Access date unknown].

Curtis, R.O. 1982. A simple index of stand density for Douglas-fir. Forest Science. 28: 92-94.

Dick, M.R. 2007. Proactive management considerations for wildlife habitat to ensure profitability. In: Harrington, T.B.; Nicholas, G.E., tech. eds. Proceedings, Managing for wildlife habitat in Westside production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 117-120.

Franklin, J.F.; Berg, D.R.; Thornburgh, D.A.; Tappeiner, J.C. 1997. Alternative silvicultural approaches to timber harvesting: variable retention harvest systems. In: Kohm, K.A.; Franklin, J.F., eds. Creating a forestry for the 21st Century: the science of ecosystem management. Washington, DC: Island Press: 111-139.

Hagar, J.C. 2007. Key elements of stand structure for wildlife in production forests west of the Cascade Mountains. In: Harrington, T.B.; Nicholas, G.E., tech. eds. Proceedings, Managing for wildlife habitat in Westside production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 35-48.

Harrington, C.; Roberts, S.; Brodie, L. 2005. Tree and understory responses to variable-density thinning in western Washington. In: Peterson, C.E.; Maguire, D.A., eds. Proceedings, balancing ecosystem values: innovative experiments for sustainable forestry. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 97-106.

Harrington, T.B.; Tappeiner, J.C., II. 2007. Silvicultural guidelines for creating and managing wildlife habitat in Westside production forests. In: Harrington, T.B.; Nicholas, G.E., tech. eds. Proceedings, Managing for wildlife habitat in Westside production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 49-59.

Helms, J. A., ed. 1998. The dictionary of forestry. Bethesda, MD: The Society of American Foresters, 5400 Grosvenor Lane.

Holmberg, P. 2006. Red alder—regeneration and stand initiation: techniques and field craft as related to final returns on early investments. In: Deal, R.L.; Harrington, C.A., eds. Red alder: a state of knowledge. Gen. Tech. Rep. PNW-GTR-669. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 137-143.

Holmberg, P.; Aulds, B.; Christiansen, D.; Dickson, L.; Jaross, W.O.; McFadden, G. [N.d.]. Thinning forest stands, east- and westside—an inter-active self-study and reference pamphlet. Manuscript in preparation. On file with: P. Holmberg, Washington State Department of Natural Resources, 1111 Washington Street SE, Olympia, WA 98504.

Kimmins, J.P. 2007. Forest ecosystem management: miracle or mirage? In: Harrington, T.B.; Nicholas, G.E., tech. eds. Proceedings, Managing for wildlife habitat in Westside production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 19-31.

Latta, G.; Montgomery, C.A. 2007. Economic considerations in managing for older-forest structure. In: Harrington, T.B.; Nicholas, G.E., tech. eds. Proceedings, Managing for wildlife habitat in Westside production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 95-104.

Lippke, B.; Zobrist, K.W., Ceder, K. 2007. Issues and alternatives associated with private forest wildlife and riparian habitat management. In: Harrington, T.B.; Nicholas, G.E., tech. eds. Proceedings, Managing for wildlife habitat in Westside production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 81-94.

Risenhoover, K.L.; Murden, S.B. 2007. Managing for wildlife habitat in intensively-managed forests. In: Harrington, T.B.; Nicholas, G.E., tech. eds.. Proceedings, Managing for wildlife habitat in Westside production forests. Gen. Tech. Rep. PNW-GTR-695. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 107-116.

Thomas, J.W.; Bunnell, F. 2002. Objectives and principles for developing comprehensive plans for forest biodiversity conservation. In: Lindenmayer, D.B.; Franklin, J.F., eds. Conserving forest biodiversity: a comprehensive multiscaled approach. Washington, DC: Island Press: 41-53.

Washington State Department of Natural Resources [WDNR]. 2004. Final environmental impact statement on alternatives for sustainable forest management of state trust lands in western Washington. Olympia, WA: Washington State Department of Natural Resources.

Weetman, G.F. 1996. Are European silvicultural systems and precedents useful for British Columbia silviculture prescriptions? FRDA report, ISSN 0835-0752; 239. Victoria, BC: Canada-British Columbia Partnership Agreement on Forest Resource Development: FRDA II: Canada Ministry of Forests. 26 p.

METRIC EQUIVALENTS

When you know:	Multiply by:	To find:
Degrees Fahrenheit (°F)	(F-32) x 0.556	Degrees Celsius (°C)
Inches (in)	2.54	Centimeters (cm)
Feet (ft)	.3048	Meters (m)
Acres (ac)	.4047	Hectares (ha)
Trees per acre	2.471	Trees per hectare
Square feet per acre (ft^2/ac)	.2296	Square meters per hectare (m^2/ha)
Thousand board feet (MBF)	.0024	Cubic meters (m^3)
Fluid ounces	.0296	Liters (L)
Gallons	3.78	Liters (L)

ENGLISH EQUIVALENTS

When you know:	Multiply by:	To find:
Degrees Celsius (°C)	(C*9/5) +32	Degrees Fahrenheit (°F)
Centimeters (cm)	.3937	Inches (in)
Meters (m)	3.2808	Feet (ft)
Kilometers (km)	0.6214	Miles (m)
Square meters per hectare (m^2/ha)	4.3560	Square feet per acre (ft^2/ac)

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