Centuries of Change in Pacific Northwest Forests: Ecological Effects of Forest Simplification and Fragmentation

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Abstract

The forests of the Pacific Northwest have undergone significant changes in the relative proportions of various forest types, including dramatic reductions in certain habitats such as old-growth forests and early successional habitat rich in woody debris. Intensive forest management practices have resulted in the simplification of forest structure through reductions in certain structural elements such as coarse woody debris, snags, and canopies with high spatial variability.

The loss of old-growth forests to timber harvest and land-use conversion has resulted in a condition of fragmentation, creating spatial isolation of remaining patches and significant reductions in interior habitat conditions required by certain organisms. The ecological effects of forest simplification and fragmentation in the Pacific Northwest are reviewed, and management actions to reduce negative consequences are briefly discussed.

I. Introduction

The latter half of the twentieth century marked an increase in awareness of the importance of elements of forest structure at the level of the individual forest stand and at the level of the forest landscape. Two of the most central topics in understanding forestry and the conservation of biodiversity in the Pacific Northwest reflect these concerns: the structural simplification of forest stand structure in forest stands due to timber harvest and regeneration practices, and the fragmentation of formerly contiguous forest patches at the landscape level (Noss 1999). Many of the challenges in the provision of public and private values from the rich forest landscapes of the Pacific Northwest are at least partially rooted in these two processes. I emphasize that the fundamental issue is that of habitat loss (Fahrig 2003) – the degradation of formerly productive habitats or conversion to alternate land uses – and not fragmentation and forest simplification *per se*. Fragmentation and forest simplification are consequences of this overarching problem of habitat loss but with important implications of their own for wildlife habitat and other values. The objective of this chapter is to provide the reader with an understanding of the ecological effects of forest structural simplification and fragmentation. The chapter concludes with a brief review of management methods designed to address the associated impacts.

II. Forest Simplification

Forest simplification is the reduction of compositional and structural diversity from forest stands and landscapes. Compositional diversity is the species richness of plants (trees, shrubs, herbs, cryptogams) and other organisms in a forest stand or landscape. Structural diversity refers to the presence of live trees of different sizes, snags, woody debris, and complex spatial patterns (gaps, dense areas, and variability of tree-to-tree distances). Alteration of natural disturbance regimes (e.g., fire suppression in forests formerly subject to low severity fire), clearcut harvesting, and other practices may lead to simplification of both composition and structure of forest stands (see Figure 1, a structurally complex forest profile, and Figure 2, a structurally simple forest stand).

***Figure 1*. Profile of structurally and compositionally diverse old-growth stand**. Artwork by Dr. Robert Van Pelt.

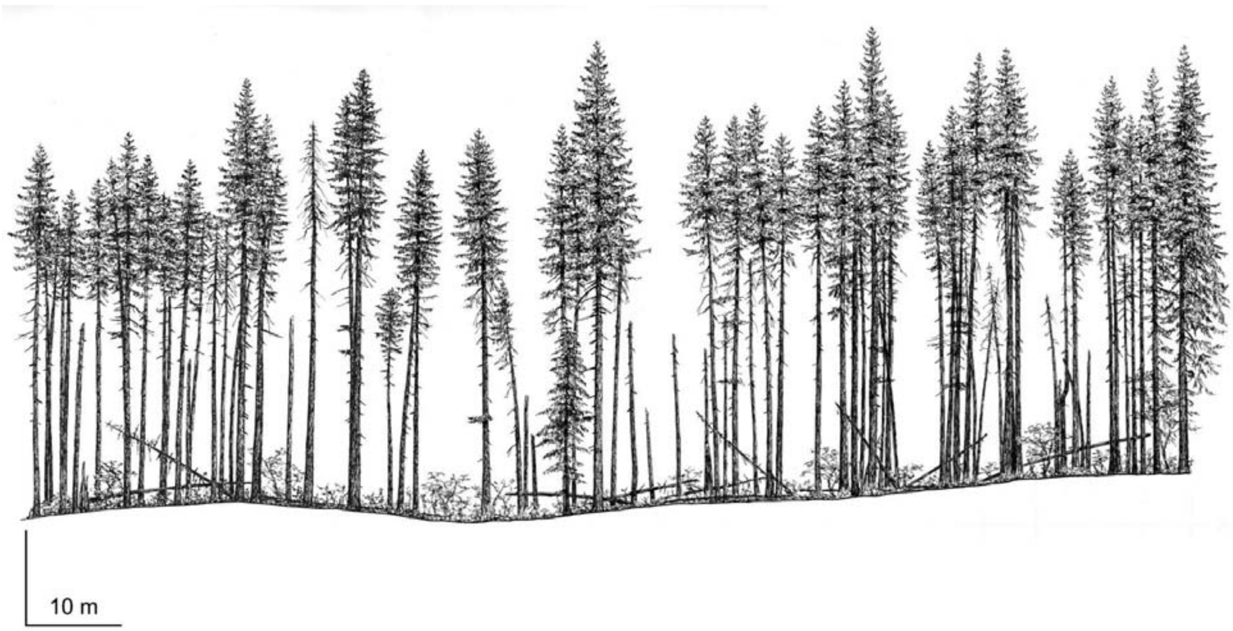

Figure 2. **Profile of young, structurally and compositionally simplified stand**. Artwork by Dr. Robert Van Pelt.

1. Composition

Composition refers to the assemblage of species found on a site. I will use this term to refer primarily to the vegetative composition of a site (trees, shrubs, and herbs). Planting of monocultures following timber harvest, wildfire, or other disturbance in the Pacific Northwest has frequently simplified composition in forest stands by focusing on a few species, mainly pioneer species such as Douglas-fir (*Pseudotsuga menziesii*). Broadleaf tree species such as red alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*), despite providing a number of ecological and even economic benefits, are frequently eliminated from forest stands as a compositional element via the use of herbicides (Smith *et al.* 1997) or selective precommercial thinning (BC Environment 1993). While some broadleaf tree species have increased on regional and landscape scales due to timber harvest and other anthropogenic disturbance (Harrington 1996), local conversion of mixed hardwood and conifer stands to young conifer-dominated stands is a concern (Kennedy and Spies 2004), especially for some species of wildlife such as neotropical migrant birds (BC Environment 1993; Fenger 1996; Bunnell *et al.* 1999). Conversely, hardwood stands that originated in timber harvest, such as dense stands of red alder in coastal areas, often require restoration plantings of conifers to restore certain ecological functions (Berg 1995; Beechie *et al.* 2000). Shade-tolerant tree species (western hemlock, *Tsuga heterophylla*, western redcedar, *Thuja plicata*, and, in the southern part of the region, tanoak, *Lithocarpus densiflorus*) have also declined in frequency in some managed stands due to dense planting of pioneer species and short rotation lengths, which allow insufficient time before harvest for shade-tolerant trees to initiate a cohort in the stand. On the positive side, naturally seeded individuals (volunteers) of non-commercial species have contributed to diversity in managed landscapes, and this contribution may be conserved in at least portions of the stand in thinning and brush control prescriptions. Shrubs such as salal (*Gaultheria shallon*) are also critical elements of stand composition due to functions such as browse and fruit production for wildlife, nesting/denning habitat, and contribution to vertical stratification, and deserve to be addressed in stand management (Bunnell *et al.* 1999; Lindenmayer and Franklin 2002; Hagar 2003). Care should also be taken to preserve the intraspecific, or genetic, diversity of tree species (Silen and Doig 1976; Ledig 1988). Reduced genetic diversity may reduce the ability of tree species to adapt to changing climatic conditions or resist pests or pathogens, with negative consequences for both economic and ecological forest values (Perry 1998). To date, commercial tree breeding programs for the most important species in the Pacific Northwest have utilized thousands of 1st generation parents from different regional seed zones in order to conserve rare alleles while improving growth characteristics (Johnson *et al.* 2001; Johnson *et al.* 2003); however, this is an area where continued research is warranted. Not all compositional simplification occurs through direct management influences. Western white pine (*Pinus monticola*) has been dramatically reduced as a component of forest stands in the Pacific Northwest due to the introduction of the Eurasian white pine blister rust (*Cronartium ribicola*) (Neuenschwander *et al.* 1999). Sudden oak death, a syndrome caused by the fungus *Phytophthora ramorum*, may also reduce compositional diversity in the southern part of the region by reducing or eliminating tree species such as tanoak (*Lithocarpus densiflora*)(McPherson *et al.* 2005).

2. Structure

Forest structure refers to living and dead elements of a forest stand (live trees, snags, shrubs, soil) and their spatial distribution (patterns of tree stems, horizontal and vertical distributions of foliage, architecture of individual tree crowns, etc.). Old-growth forests in the coastal Northwest typically possess abundant amounts of snags, shade-tolerant tree species, coarse woody debris, large-diameter trees, and complex canopy structures in live trees (Franklin and Spies 1991). Even young stands originating in a fire or windstorm disturbance typically are structurally rich due to abundant live and dead biological legacies from the pre-disturbance stand (Franklin *et al.* 2000; Franklin *et al.* 2002; Lindenmayer and Franklin 2002). In the interior Pacific Northwest, stands of old-growth ponderosa pine (*Pinus ponderosa*) which appear structurally simple actually display structural complexity with respect to tree spatial pattern, woody debris, and snags (Youngblood *et al.* 2004). Decline in the frequency of certain spatial attributes of natural forest stands (in both coastal and interior Pacific Northwest) such as gaps, areas of heavy shade ("anti-gaps"), variability in stem density in horizontal dimensions, and variability in vertical distribution of foliage all have resulted from the imposition of short-rotation, structurally simple management regimes (Hansen *et al.* 1991).

Physical, disturbance-related, and biological impacts of forest simplification can be observed in Pacific Northwestern forests.

3. Physical Processes

Impacts of forest management on hydrological processes are more related to changes in evapotranspiration following timber harvest and the conversion of subsurface flows to surface flows than to forest structure (Ziemer and Lisle 1998). Generally, observable changes in hydrology (e.g., peak flow magnitudes, increases in summer streamflow) are reduced within a few decades of reforestation. However, some elements of forest structure do play a role in forest hydrology. The large canopies of old-growth forests provide a large condensing surface for cloud-borne moisture, which may contribute 30% of the annual precipitation in coastal Northwestern forests (Harr 1982). Light availability in the understory, critical to wildlife-important shrub and herb species, is also more spatially diverse in old-growth forests due to the architecture of the canopy, including gaps in the overstory trees. Structural simplification of forests, when it reduces the availability of coarse woody debris, has the potential to reduce the amount of sediments retained in streams and rivers, thus influencing geomorphic and energetic aspects of Northwestern streamscapes (Sedell *et al.* 1988; Montgomery *et al.* 2003).

4. Disturbances

The frequency, intensity, severity, and extent of disturbances may be influenced by structural simplification. The compositional and structural simplification of forest stands may alter fire behavior, especially if dense plantations or young stands replace a variety of stand structures of varying vulnerability to fire (Cooper 1960; Agee 1993). This is especially important in the interior pine forests of the inland Pacific Northwest. Dense, structurally simplified stands may be more susceptible to windthrow events, especially where stand density has not been managed to provide stable height-diameter ratios (Ruel 1995). Pest and pathogen dynamics are also influenced by compositional and structural simplification. Trees in dense monocultures may experience increased susceptibility to insects such as *Dendroctonus* bark beetles (Coulson and Witter 1984) or defoliators (Coyle *et al.* 2005). *Phellinus weirii*, a prominent root-rot disease of Douglas-fir, makes for a compelling argument for mixed-species regeneration regimes, since western red cedar (*Thuja plicata*), western white pine, and other commercially valuable species are relatively resistant. Off-site plantings in the Pacific Northwest can result in losses in productivity due to pathogens. A good example is the high incidence of Swiss needle cast (*Phaeocryptus gauemannii*) in Douglas-fir plantations in the coastal Sitka spruce zone (Hansen *et al.* 2000). The removal of broadleaf species from forest stands may also increase incidence of fungal disease (Baleshta *et al.* 2005) and insect damage (Almond 2004) in the conifer crop.

5. Biological Effects

The process of forest development is often impacted in ways that are not immediately apparent. Natural succession and forest development following wildfire frequently included a relatively protracted period of regeneration of seral pioneers (Franklin *et al.* 2002). The result was a structurally and floristically diverse early successional phase characterized by rich songbird, insect, and browsing mammal habitat. This phase is strongly truncated by forest management practices that aim for relatively quick crown closure by conifers following timber harvest. Productivity and growth are also influenced, both positively and negatively, by the process of simplification. Reducing competition from non-commercial species of trees and shrubs may certainly increase harvest volume in many situations (Oliver and Larson 1996; Smith *et al.* 1997). However, maintaining a species mixture may increase stand yield, especially if one of the species has root symbionts which convert atmospheric nitrogen into forms usable by plants (Miller and Murray 1978; Perry 1994) or reduces disease incidence in the primary crop tree (Baleshta *et al.* 2005). The reduction of coarse woody debris such as snags and logs means that a key source of nutrients has been removed (Harmon *et al.* 1986; Maser *et al.* 1988)

While a review of the effects of simplification on wildlife is beyond the scope of this article, it is known that the loss of certain forest structures, especially coarse wood, can have disproportionate impacts on certain wildlife species. Woodpeckers, such as the pileated woodpecker (*Dryocopus pileatus*), require large-diameter snags for nesting and feeding (Mannan *et al.* 1980). Many invertebrates utilize woody debris during all or some of their lifecycle (Harmon *et al.* 1986). Anadromous fish such as salmon (*Oncorhynchus* spp.), economically and ecologically important to the region, also benefit from habitat creation and maintenance related to woody debris that enters the aquatic environment (Cederholm *et al.* 1997; Roni and Quinn 2001; Johnson *et al.* 2005). Small mammals and amphibians, which are often dependent on snags, coarse woody debris, and forest shrubs, may decline as a result of the loss of these features (Maser *et al.* 1988). Structures related to or caused by diseases and parasites, such as dwarf mistletoe "brooms" (dense, deformed branches in tree crowns), are often important nesting structures (Hawksworth and Wiens 1996). Late-successional specialists are especially affected by loss of structures associated with mature forest. For example, arboreal rodents, which are prey for numerous late-successional predators such as the northern spotted owl and fishers (*Martes pennanti*), often decrease in areas subjected to forest structural simplification (Carey *et al.* 1992; Carey 2000). Forest simplification may even influence forest health in unforeseen ways. Vespulid wasps, for example, are important predators of native and non-native insect herbivores (Steward *et al.* 1988; Donovan 2003), but often use woody debris and other structures for nesting (Roush and Akre 1978). Loss of woody debris in stands and landscapes may compromise their ability to prevent outbreaks of insect herbivores.

III. Forest Fragmentation

Large, infrequent disturbances that create large forest patches are characteristic of many temperate forest ecosystems (Foster *et al.* 1998), and the coniferous forests of the Pacific Northwest are no exception (Hemstrom and Franklin 1982). Historically, fires west of the Cascade crest occurred when significant east wind events coincided with low fuel moisture conditions of the late summer and early fall (Agee 1993). Under these conditions, hundreds of thousands of acres might burn, setting the stage for the establishment of a large and contiguous cohort of forest trees. Winter windstorms, such as the 1920 windstorm on the southwest Olympic Peninsula, also could create relatively large and contiguous forest patches (Kramer *et al.* 2001). Even small windthrow patches created at different times over decades may coalesce, creating larger patches that comprise a significant portion of the landscape (Harcombe *et al.* 2004). Interior pine forests consisted of complex fire-created mosaics (Hessburg *et al.* 2005), but presented large patches of forest with a broadly similar physiognomy (Franklin and Dyrness 1973).

Dispersed-patch clearcutting over the past 150 years in the Pacific Northwest has tended to interrupt the relatively contiguous large patch-dominated pattern of many of the region's forest landscapes (Lehmkuhl and Ruggiero 1991; Ripple *et al.* 1991; Spies *et al.* 1994). The emergent spatial property produced by this type of harvesting is described by the term fragmentation (see Figure 3).

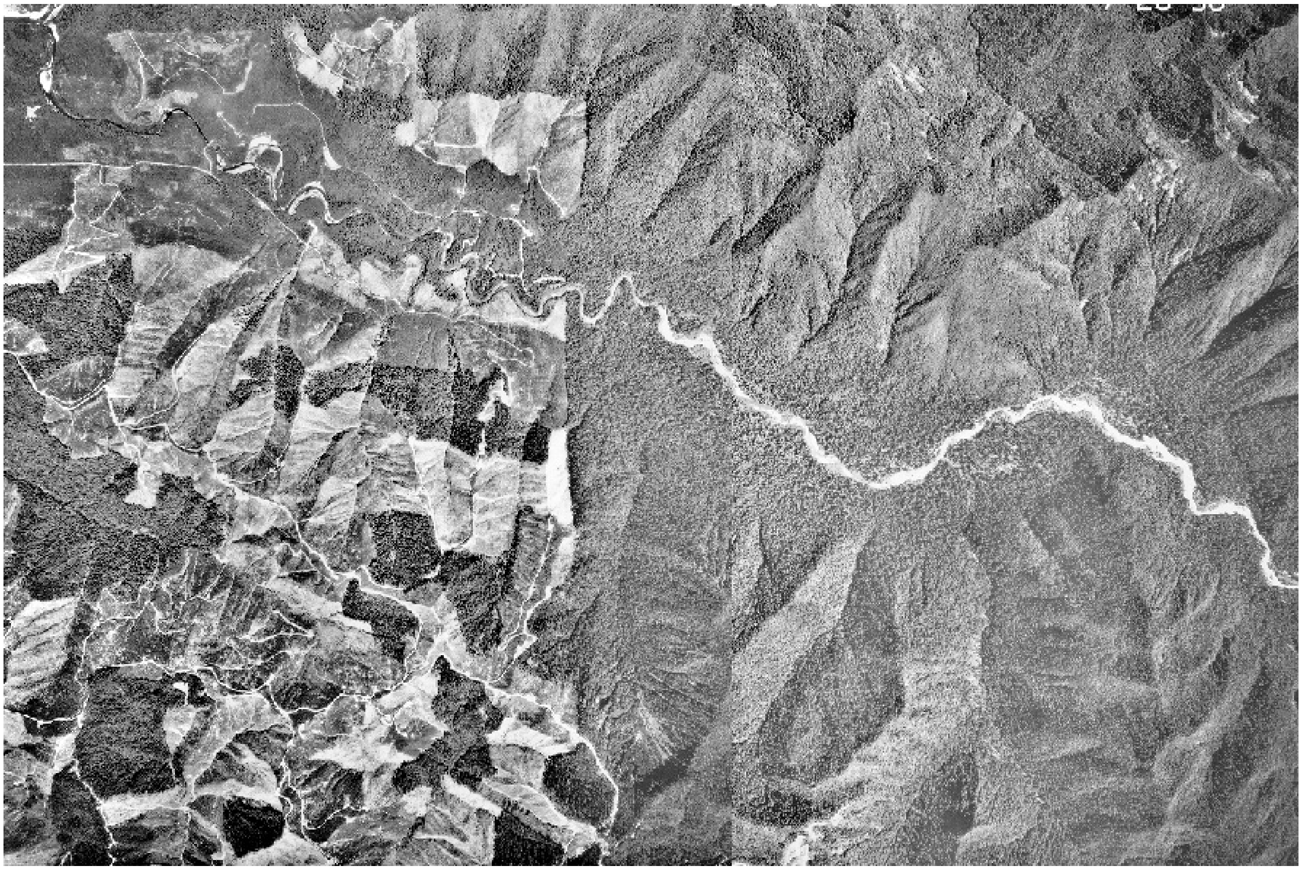

Figure 3. **Forest fragmentation due to road construction and timber harvest on managed timberland contrasts with the old-growth forest matrix (right) within park boundaries.** Western Olympic Peninsula, Washington, 1994.

There are five main processes of land transformation (Forman 1995): perforation, dissection, fragmentation, shrinkage, and attrition. Perforation refers to the loss of initial patches from within the matrix of an undisturbed landscape. Dissection occurs when narrow linear corridors, such as roads or power line right-of-ways, are introduced into that matrix (Trombulak and Frissell 2000). Fragmentation occurs when disturbed or harvested patches accumulate in the landscape to the point of spatially coalescing, thus creating isolated patches of native forest stands. Shrinkage refers to the decrease in area of the remaining patches without changing connectivity significantly. And finally, attrition is the loss of isolated remaining patches. All five of these processes have been, and are active in the natural forests of the Pacific Northwest. The dissected topography and diverse disturbance regimes of western North America have created noticeable heterogeneity in many western pre-settlement landscapes (Hejl *et al.* 2002). However, when the dominant observable pattern in forest landscapes is related to timber harvest (Spies *et al.* 1994), physical and biological impacts on timber production, wildlife, watershed properties and other entities may be expected.

The ecological effects of fragmentation in Pacific Northwest forests involve both physical, disturbance-related, and biological conditions and processes. It is critical to remember that these effects may be positive, neutral, or negative, depending upon the process, organism, or emergent value being considered. It must also be considered that the effects of forest fragmentation in the

Pacific Northwest may vary from those observed in other regions, since the disturbed matrix is mostly comprised of plantations or stands of native tree species, and not agricultural land, urban development, or other highly contrasting land use (McGarigal and McComb 1995; George and Dobkin 2002).

1. Physical Processes

The physical conditions within an interior forest patch reflect the insulating effects of a forest overstory. Low light levels are typical, often ranging from 1-10% of ambient insolation (Parker *et al.* 2002). Humidity is frequently higher due to plant evapotranspiration, and shade from the overstory. The boundary layer effect of the overstory induces reduced windspeeds in the forest vertical profile, as trees dissipate the kinetic energy inherent in wind (Venäläinen *et al.* 2004). The presence of an overstory, often with several layers of shade-tolerant tree species, also creates a somewhat buffered environment which experiences less variation in micrometeorological variables such as light level, temperature, and air moisture when compared with the extremes encountered in an open area (Chen and Franklin 1992; Brosofske *et al.* 1997).

2. Disturbances

Alteration of landscape pattern has been shown to influence the behavior of disturbances in the forests of the Pacific Northwest, especially windthrow and fire. Fragmentation in landscapes due to forest harvest, road construction or other activities increases the amount of edge inherent in a landscape, which in turn may increase the risk of windthrow due to the exposure of previously protected trees to storm-force winds (Franklin and Forman 1987; Burton 2002). Clearcutting across a large portion of the landscape may also decrease boundary surface roughness and increase maximum windspeeds, again leading to increased rates of windthrow (Venäläinen *et al.* 2004).

Fragmentation may influence fire intensities and spread dynamics. West of the Cascades, the probability of ignition and probability of spread following ignition increases with the amount of harvested area in the landscape (Franklin and Forman 1987). Natural or harvest-related fragmentation of coniferous forest with interspersed broadleaf stands or avalanche tracks, however, may have a firebreak effect, thus reducing fire spread (Harrington 1991) or changing the landscape orientation of fire disturbance patches (Dorner *et al.* 2002).

3. Organisms

Organisms are impacted in a number of ways by fragmentation, and not only by the direct loss of habitat. There are two primary influences of fragmentation (independent of habitat loss) on organisms: 1) edge effects and 2) isolation of suitable habitats (Noss and Cooperrider 1994). Most of the emergent impacts of fragmentation are related to these two influences. Edge effects, broadly defined, are the influences of one patch type on a neighboring patch type (Forman 1995; Turner *et al.* 2001). Isolation of suitable habitats can increase the risks and costs associated with dispersal, reproduction, and foraging (for animals) for many organisms.

Reproduction of organisms may be affected by the loss of interior habitat associated with fragmentation (Yahner 1988). For example, nest predation by habitat generalists such as crows and ravens may increase with an increase in landscape edge (Andren 1992; Raphael *et al.* 2002;

Marzluff 2004). Brood parasitism by cowbirds (*Molothrus* spp.), while an important factor in the decline of songbirds in the agricultural landscapes of the eastern United States (Wilcove 1985; Faaborg 2002), remains a relatively minor factor in most forest ecosystems of the coastal Pacific Northwest (Manuwal and Manuwal 2002).

Connectivity for the dispersal of forest-dependent organisms may decrease as fragmentation of the original forest matrix increases, resulting in the isolation of individuals and populations. The rate of successful dispersal of juvenile spotted owls (*Strix caurina*), for example, decreases in fragmented landscapes, thus influencing long-term population viability (Doak 1989; Miller *et al.* 1999). Less well-known, but still ecologically important, organisms may also decrease in fragmented landscapes. Certain epiphytic lichens, such as the nitrogen-fixing *Lobaria oregana*, encounter dispersal problems across early-successional habitats, a primary reason why they predominantly occur in old-growth forests (Sillett *et al.* 2000). Edge effects may also reduce the amount of area available in a landscape for organisms such as birds (Lehmkuhl and Ruggiero 1991), lichens (Rheault *et al.* 2003), certain understory plants (Nelson and Halpern 2005), and bryophytes (Nelson and Halpern 2005).

Fragmentation may increase food availability for some species, while decreasing it for others. Black-tailed deer (*Odocoileus hemonius columbianus*) and Roosevelt elk (*Cervus elaphus* var. *rooseveltii*) frequently benefit from increased fragmentation, since this process creates ideal dispersion of browse-rich clearcuts in close proximity to mature forest (escape terrain and thermal cover)(Nyberg and Janz 1990). In the southern portion of the range of the northern spotted owl, naturally occurring fragmentation provides access to both foraging habitat (shrub communities supporting dusky-footed woodrat) and roosting/nesting habitat (late-successional conifer communities)(Folliard *et al.* 2000). In the northern part of the range of the spotted owl, however, fragmentation reduces efficiency in the ability of owls to locate prey, primarily the northern flying squirrel (*Glaucomys sabrinus*)(Carey *et al.* 1992).

An increase in landscape connectivity or permeability for exotic/generalist species or pathogens due to fragmentation may impact native species, such as in the case of woodland caribou in the interior Northwest. Landscape fragmentation due to dispersed-patch clearcut harvest has allowed white-tailed deer (*Odocoileus virginianus*) to expand into the geographic range of the caribou and subsequently transmit a lethal meningeal brainworm to the vulnerable caribou (Holmes 1996). While still debated, forest fragmentation may have contributed to the range encroachment of the eastern barred owl (*Strix varia*) into the range of the northern spotted owl (*Strix caurina*)(Peterson and Robins 2003).

IV. Future Management

Regardless of the landowner's objectives, the issues of forest structural simplification and fragmentation merit attention in any land management plan. Even if maximizing financial return is the sole management goal, fragmentation and simplification-related concerns such as windthrow, disease and soil fertility (e.g., loss of nitrogen-fixing species) must be addressed. And if wildlife and other concerns are to be addressed, then stand structure and landscape pattern are equally important as timber productivity.

1. Stand Level Management

Stand level management to reverse forest simplification may be done at several important phases in the rotation. During the regeneration phase, the planting of tree species mixtures instead of monoculture (including incorporation of volunteer regeneration of hardwoods) and the incorporation of small gaps in the planting prescription will help to increase both compositional and structural diversity (Carey and Curtis 1996). The maintenance of mature trees across the landscape as seed sources also may diversify forest composition (Beach and Halpern 2001). Intermediate treatments may include commercial thinning, preferably using variable-density methods to create horizontal heterogeneity in the stand (Carey and Johnson 1995; Carey and Curtis 1996; Lindenmayer and Franklin 2002), and the deliberate creation of snags and/or decadent trees (trees with injuries to branches, tops, or boles which create habitat features) (DeBell *et al.* 1997). The timing and design of the regeneration harvest also is critical to structural and compositional diversity within the stand. Extended rotations, when combined with other silvicultural measures, allow the development of a number of structures uncommon in the short-rotation plantation setting (Curtis 1997). These include large-diameter trees, snags, and coarse woody debris. Retention of various structural elements at the time of harvest is also a useful strategy to enrich the regenerating stand (Franklin *et al.* 1997). Silvicultural techniques at the stand level may also influence landscape function. For example, creation of “closed edges”, in which trees of various sizes and shrubs decrease penetration of light, wind, and other exterior influences (Matlack 1993; Matlack and Litvaitis 1999), may be useful in increasing the effective interior habitat of a patch in managed landscape. Riparian buffers, wetland buffers, and retention of forest cover on areas of unstable soil are already required by law (WAC 222-30 2005), and some of these areas may be expected to develop late-successional characteristics in time, thus diversifying within-stand structure.

2. Management at Landscape Level

One of the most important elements of a landscape-scale management plan that maintains biodiversity is the identification and appropriate management of areas of special ecological significance in the landscape, such as wetlands (Lindenmayer and Franklin 2002). The maintenance of some of these types of areas is already required by law in some states, as in areas of unstable soils. Planning of timber harvest to minimize fragmentation and maintain connectivity between mature forest patches is also important (Harris 1984). The study of natural disturbance at large spatial and temporal scales has served as the informational basis for the design of biologically sensitive management regimes on federal lands, such as in the Blue River Strategy in the Willamette National Forest (Cissel *et al.* 1999). In this demonstration, historic fire regimes and landscape patterns have provided a basis for a long-term forest management program that both produces commodity values and maintains structurally diverse, spatially connected forest stands. Technology such as Geographic Information Systems and remote sensing greatly aid the modern forest manager in accomplishing objectives of this type (Sample 1994).

Since fragmentation and similar processes operate at spatial scales that frequently exceed the size of most single ownerships, coordination between landowners, government agencies, tribes, and others is often critical to the conservation of biological diversity (Grumbine 1990). Opportunities for creating large areas of contiguous habitat exist especially on federal lands and lands adjacent to them. For example, the Washington State Department of Natural Resources, as a part of their Habitat Conservation Plan for western Washington, is creating a spatially explicit timber management plan in the Middle Fork of the Snoqualmie Valley to place habitat management areas adjacent to reserves on neighboring federal lands, thus increasing total contiguous habitat (McClelland 2003).

As the ecological impacts of fragmentation and simplification become clearer, managers may even reconsider current forest management policy, such as maximum clearcut size regulations, which tend to promote fragmentation. It might be suggested that mimicry of fire disturbance of a whole watershed (with the proper incorporation of biological legacies, especially near aquatic resources) followed by a long rotation would combat both fragmentation effects and the cumulative effects of constant harvest activity within the watershed. A final precautionary note for management on the landscape scale is to refrain from applying a given management technique in all possible locations.

V. Discussion and Conclusions

There is no question that significant challenges exist in addressing the effects of forest simplification and fragmentation, especially on small private holdings. The public lands of the Pacific Northwest (National Park Service, U.S. Forest Service, Bureau of Land Management, and state agencies, among others) currently possess the bulk of responsibility of maintaining forest biodiversity in the region. However, many private forest lands are also in a position to contribute to this long-term goal through management pathways that provide both economic and ecological objectives (Carey *et al.* 1999). These private lands face significant challenges, such as the long-term financial realities of forestry and burdensome taxes and regulations (Stinson 1998). Private landowners must be engaged and supported in order to facilitate and encourage their participation in addressing the ecological impacts of fragmentation and forest simplification.

Another very significant challenge involves the industrial capacity necessary for proper forest ecosystem management. Many of the region’s forest stands are currently in a young, dense, and structurally simplified condition, and will not produce many of the desired values in the absence of well-designed and professionally executed forest treatments. A healthy forest industry, along with the operational capacity that it embodies (including a skilled work force and the processing of by-products of forest restoration activities, such as small diameter timber from thinnings), must be maintained to ensure the implementation of ecosystem management (Franklin 2003).

Finally, the scientific community must take on a leadership role in providing the information necessary to design biologically-sound management regimes for scales ranging from the stand to the landscape. Further research into region-specific impacts of simplification and fragmentation is necessary in order to design effective and sustainable management pathways.

In addressing forest simplification and fragmentation, the natural resource community is embarking on a new frontier of challenge, and broad perspectives and cooperation shall prove critical to a resolution that benefits both humans and forest ecosystems in perpetuity.

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