A literature review of management practices to support increased biodiversity in intensively managed Douglas-fir plantations

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Contents

I. Introduction

The west side of the Cascade Range in the Pacific Northwest region of the United States is home to highly productive forestland in a mix of public and private ownerships. While public ownerships have been managed predominantly for non-timber objectives in recent years, private ownerships are often comprised of Douglas-fir (*Pseudotsuga menziesii*) plantations that are intensively managed for wood production. T85
hese plantations supply important wood products, but there is also interest in the ability of these lands to provide non-timber values, such as biodiversity, at the same time.

Intensively managed Douglas-fir plantations are characterized by relatively short, clear-cut rotations and the use of genetically superior stock, vegetation control, thinning, and other practices to improve production (Adams et al. 2005). As such, these plantations are very different in structure and function from natural forests, as they tend to lack structural diversity and later seral stages (Hansen et al. 1991, Hayes et al. 2005, Helgerson and Bottorff 2003). Even so, intensively managed plantations still provide forest cover and thus support greater biodiversity than competing, non-forest land uses such as agriculture or development (Hayes et al. 2005, Moore and Allen 1999). More importantly, there are stand-level management changes that can support increased biodiversity in plantations while still achieving wood production and economic goals (Hartley 2002, Moore and Allen 1999). In this report we review the literature to identify a spectrum of practices that support increased biodiversity in intensively managed Douglas-fir plantations.

II. Management practices to support increased biodiversity

Biodiversity is the variety of all life at the genetic, species, and ecosystem scale for a given area (Hunter 1999, Oliver 1992, Patel-Weynand 2002, Reid and Miller 1989). Management approaches for increasing biodiversity should target a broad range of species, as focusing on individual species can be costly and result in management conflicts (Curtis and Carey 1996, Wigley and Loehle 2004). To meet the needs of a broad range of species, structural diversity is needed to provide a variety of habitat elements (Helgerson and Bottorff 2003, Muir et al. 2002). This requires complex three-dimensional canopy attributes and spatial relationships (Franklin and Van Pelt 2004, Helgerson and Bottorff 2003, Ishii et al. 2004, Parker et al. 2004, Spies 1998, Zenner 2004). This report will focus on increasing structural complexity at the stand level, though maximum complexity is ultimately achieved at the landscape scale (Helgerson and Bottorff 2003, Oliver 1992).

Our review on practices to increase complexity will examine ways to promote both vertical (e.g., layers) and horizontal elements of structural diversity. Increased vertical and horizontal structural diversity are noted elements of old-growth forests, and these elements are highly correlated with both increased biological diversity and specific diversity and functions uniquely associated with old-growth systems. However, it is important to note that the immediate creation of one or more elements of structural diversity (e.g., multiple canopy layers, large live and dead trees, gaps, etc.) is not instantaneously translated into conditions suitable for old-growth or late-seral dependent wildlife or epiphytic species; there may be a delay. Structural manipulations merely create the structures suitable for these old-growth or late-seral dependent species; however, these manipulations should greatly shorten the time necessary for occupancy.

One of the most important ways to increase stand-level structural diversity is by thinning. Plantations are usually established at high densities, typically around 435 trees per acre or greater (Scott et al. 1998, Talbert and Marshall 2005, Woodruff et al. 2002). Under these conditions, the canopy quickly closes, and the stand moves into the stem exclusion stage in which the understory vegetation is shaded out (Oliver and Larson 1990). Dense stands in this stage support few wildlife species (Hayes et al. 1997, Oliver and Larson 1990). In addition, many planted and naturally regenerated stands of Douglas-fir are so dense in the stem exclusion stage that stand differentiation is slowed and delaying thinning may result in considerable risk to wind throw (Wilson and Oliver 2000).

Numerous studies have documented the positive effects of thinning on stand structure and biodiversity. Thinning opens up the stand and allows light to reach the forest floor. This provides for better developed understories with greater richness, diversity, and cover (Bailey et al. 1998, Curtis et al. 1997, Thomas et al. 1999, Thysell and Carey 2000). Studies have found that thinned stands have greater herbaceous cover (Carey and Wilson 2001, Muir et al. 2002), greater understory trees and shrubs (Bailey and Tappeiner 1998, Muir et al. 2002, Tappeiner and Zasada 1993), and greater density, survival, and growth of conifer seedlings (Bailey and Tappeiner 1998, Brandeis et al. 2001, DeBell et al. 1997, Muir et al. 2002). These elements provide forage for wildlife. They also allow the stand to develop multiple layers, which increases vertical diversity (Bailey et al. 1998, Bailey and Tappeiner 1998, Muir et al. 2002). To keep the canopy open and minimize the stem exclusion stage, thinnings should be heavy (Beggs et al. 2005) and intervals should be frequent (He and Barclay 2000).

In addition to identifying links between thinning and stand structure, studies have also found direct links between thinning and wildlife abundance. Havari and Carey (2000) observed that thinning resulted in more winter birds. Similarly, Hayes et al. (2003) noted that thinning had an overall positive impact on birds, including providing for birds that were otherwise rare or absent. Thinning has also been noted to increase the abundance of small mammals (Suzuki and Hayes 2003, Wilson and Carey 2000).

Thinning can accelerate the development of old forest conditions. This type of structure is particularly desirable for biodiversity, as it is highly complex (Franklin and Van Pelt 2004) and supports a variety of species, some of which depend on late seral structures (Franklin and Spies 1991). This structure is the most lacking on the landscape and difficult to replace (Curtis et al. 1998). Key features of the structural complexity of old forests are large conifers (Zenner 2004). Lower stand densities allow for greater tree diameter growth (Curtis et al. 1997), and early, heavy thinnings can thus accelerate the development of large trees (Beggs et al. 2005, Poage and Tappeiner 2002, Zenner 2004). Indeed, retrospective studies of natural, old-growth stands have found that these stands often developed at much lower densities and over much longer initiation periods than today's dense, intensively managed plantations (Poage and Tappeiner 2002, Tappeiner et al. 1997). Not all old-growth stands developed at low densities, and natural, well-differentiated stands may not need thinning to achieve old forest structure (Winter et al. 2002).

However, the uniform age and spacing of plantations makes them particularly subject to poor differentiation and even stagnation (Oliver and Larson 1990). Repeated, heavy thinnings in these stands can allow them to develop structure similar to natural, old forests in a much shorter time period than would occur if high densities were maintained (Barbour et al. 1997, Busing and Garman 2002, Carey et al. 1999a, Garman et al. 2003, Latta and Montgomery 2004, McComb et al. 1993, Poage and Tappeiner 2002, Tappeiner et al. 1997).

How thinning is done can have a significant impact on its effectiveness towards increasing structural diversity. Thinning can be done from below, which maximizes tree size and canopy height diversity (Busing and Garman 2002) and promotes understory development (Carey and Johnson 1995). Thinning can also be done proportionally, allowing shade-tolerant species to be recruited into the overstory (Busing and Garman 2002). Instead of traditional, uniform thinning, irregular thinning with different densities, unthinned areas, and openings can greatly enhance structural diversity (Curtis et al. 1998, Helgerson and Bottorff 2003). This is also called variable density thinning, which treats alternating areas of usually around 0.25 to 0.5 acres leaving two or more different levels of residual density (Carey and Curtis 1996, Carey and Johnson 1995, Carey et al. 1999b, Carey and Wilson 2001). Variable density thinning is intended to mimic natural forest processes of suppression and mortality to create a structural mosaic and maintain wind stability (Carey et al. 1999b).

In addition to maintaining a mix of different densities, maintaining a mix of different species is also important for creating structural diversity (Curtis et al. 1998, Hayes et al. 1997, Helgerson and Bottorff 2003). Hardwoods are particularly important habitat elements for wildlife, including small mammals (Carey and Johnson 1995) and birds (Hagar et al. 1996, Muir et al. 2002). Maintaining a mixture of different conifer species, especially shade tolerant species, further adds structural complexity by providing different tree sizes, live-crown lengths, and shapes (Zenner 2000). Thinning practices, especially pre-commercial thinnings that typically remove non-crop trees, should be modified to leave a variety of tree sizes and species (Curtis et al. 1998, DeBell et al. 1997). Douglas-fir plantations can even be planted with other species, such as red alder (*Alnus rubra*) or western redcedar (*Thuja plicata*), to develop a multilayered stand (Tappeiner et al. 1997).

Another important way to increase stand-level structural diversity is to retain biological legacies. Retaining biological legacies such as large, live trees, snags, and downed wood can better mimic natural disturbances and give plantations a structure more similar to natural stands (Franklin et al. 2002, Hansen et al. 1991). Variable retention harvests retain some level of these key features at the time of harvest and leave them through the subsequent rotation to enhance structure (Barg and Hanley 2001, Franklin et al. 1997). Variable retention harvests can “lifeboat” species by helping them to tolerate harvest conditions, create habitat features much sooner than would be possible without legacies, and facilitate dispersion (Franklin et al. 1997).

There are two spatial approaches to variable retention harvests: leaving retention evenly dispersed throughout the stand or aggregating it in clumps. Dispersed retention provides retention throughout the stand, but it also poses some operational challenges and hazards. Aggregated retention has fewer operational challenges and allows for protection of elements like snags, sensitive areas, and undisturbed areas (Barg and Hanley 2001, Franklin et al. 1997). A mix of aggregated and dispersed retention can achieve good results for both biodiversity and timber production (Franklin et al. 1997). In addition to protecting existing snags and downed wood as part of a retention strategy, these features may also need to be artificially created in stands that are lacking dead wood (Barbour et al. 1997, Curtis et al. 1998, DeBell et al. 1997, Franklin et al. 2002, Garman et al. 2003).

Retaining buffers to protect riparian areas from harvest impacts is another important practice when managing for biodiversity. Riparian forests are areas of high diversity of both species and ecological processes (Naiman et al. 1993, 1998). Riparian areas not only provide habitat for obligate species that depend on them, but they provide significant habitat for generalist species as well (Carey and Johnson 1995, Kelsey and West 1998). Because of the high diversity and important habitat provisions of these areas, riparian protection can play a significant role and should be a priority for providing for biodiversity on the landscape (Carey and Johnson 1995, Naiman et al. 1993). Leaving riparian buffers can also help meet legacy retention needs (Franklin et al.1997).

Additional management activities such as underplanting, fertilization, and pruning can also be used to improve structural diversity in plantations. Underplanting in gaps or thinned areas may be needed to help establish multiple layers (Barbour et al. 1997, Brandeis et al. 2001, DeBell et al. 1997, Thysell and Carey 2000). Fertilization can hinder understory development by accelerating canopy closure (Thomas et al. 1999). However, applying fertilizer to individuals or groups rather than uniformly can promote differentiation and greater vertical diversity (Curtis et al. 1998, DeBell et al. 1997). Pruning can also be applied variably to add diversity and allow more light to reach the forest floor (DeBell et al. 1997). Relatively early pruning, coupled with thinning, can create increased space for birds to fly within the stand. In addition to structurally altering the treated stand, this intermediate operation may enhance the ability of young stands to serve as connectors between older, more structurally diverse stands.

Ultimately, practices to increase biodiversity in intensively managed plantations will be most effective in conjunction with longer rotations. Longer rotations are necessary to accommodate pathways that use multiple thinnings to increase structural diversity. Even though thinning and legacy retention can greatly accelerate the development of complex, old forest conditions, it still takes around 100 years to develop these conditions (Carey et al. 1999a, Latta and Montgomery 2004, McComb et al. 1993). Typical commercial rotations of Douglas-fir range from 30 to 50 years (Adams et al. 2005).

Longer rotations also have significant landscape-level benefits. Long rotations can help balance the distribution of age classes on the landscape by allowing for the development of later seral stages, whereas short rotation management limits stands to only the early seral stages with the majority of stands being in the stem exclusion stage (Curtis 1997, Curtis and Carey 1996, Curtis et al. 1998). Longer rotations would also reduce the amount of land harvested each year, minimizing the level of major disturbance on the landscape (Curtis 1997, Franklin et al. 1997).

III. Biodiversity pathways

The practices described above can be combined to create "biodiversity pathways" for forest management. Biodiversity pathways begin with legacy retention at the time of harvest, less intensive site preparation to conserve downed wood and other forest floor substrates, and planting at wider spacing. Successive variable density thinnings are done over longer rotations. These thinnings are heavier than traditional commercial thinnings and favor multiple species. The goal of biodiversity pathways is to minimize the dense stem-exclusion stage and accelerate the development of old forest structure and function to support increased biodiversity (Carey and Curtis 1996, Carey et al. 1996).

Simulations of biodiversity pathways for western hemlock forests of the Olympic Peninsula in Washington predicted that 98% of potential ecosystem health would be achieved and that 30% of the landscape would be in late seral conditions within 100-120 years. In comparison, timber production pathways did not achieve desired conditions because rotations were too short. It took at least 180 years for the desired conditions to be achieved under the no action alternative, leaving much of the landscape in a prolonged stem exclusion stage in the meantime (Carey et al. 1996, Carey et al. 1999a). Using the same principles, biodiversity pathways could also be developed for intensively managed Douglas-fir plantations as an overall strategy for supporting increased biodiversity in both riparian and upland areas.

IV. Economic considerations

When considering management practices to support increased biodiversity, it is important to also consider the economic impacts. Intensively managed Douglas-fir plantations on private ownerships are business enterprises for which landowners expect some level of economic return. Practices to increase biodiversity are unlikely to be successfully implemented on these ownerships if they are cost prohibitive. Unfavorable economic returns can even motivate landowners to convert their forestland to non-forest uses (Murphy et al. 2005). There is already concern about recent trends in forestland conversion in the Pacific Northwest (MacLean and Bolsinger 1997, WADNR 1998). Maintaining favorable economic returns should be a key component of strategies to increase biodiversity on intensively managed plantations, as forest conversion is the worst scenario for biodiversity.

The practices described above do have associated economic trade-offs. Heavy thinnings can result in lower economic returns, as growing space is not as fully utilized (Carey et al. 1999a, Hayes et al. 1997, Lippke et al. 1996). Variable retention harvesting increases logging costs and retention can impact the growth of the subsequent rotation, which decreases wood production (Franklin et al. 1997). Long rotations result in perhaps the most significant costs, as delaying harvest revenues until further in the future significantly discounts the present value of those revenues relative to management costs (Carey et al. 1999a, Latta and Montgomery 2004, Lippke et al. 1996). Some even suggest that shorter rotations are necessary if plantations in the Pacific Northwest are to remain economically competitive (Talbert and Marshall 2005).

Heavier biodiversity thinnings do have some economic benefit in that more wood is removed sooner, which can offset some present value losses. There is also some speculation that heavier thinnings and longer rotations will produce larger, higher quality wood later in the rotation that will be of higher value and thus further offset costs (Carey et al. 1999a, Lippke et al. 1996). However, more open-grown trees can also have more branches, so the overall impact on quality is unclear (Latta and Montgomery 2004). Also, more recent evidence suggests that lost price premiums have reduced the incentive to produce large logs (Talbert and Marshall 2005). Thus, high quality wood production should not be relied upon as a solution to offset biodiversity costs.

Economic incentive programs may be a cost-effective way of encouraging landowners to implement measures to increase biodiversity. Incentives can include direct financial assistance as well as educational and technical assistance. Awarding financial incentives competitively can ensure efficient allocation (Johnson 1995, Lippke et al. 1996). Regardless of whether the costs of biodiversity are borne by private landowners or by the public through cost-sharing, efforts will be most successful if the costs are minimized (Latta and Montgomery 2004). Management strategies that balance biodiversity needs with economic returns can and should be pursued.

V. Summary

Changes in stand-level management practices can support significantly increased biodiversity in intensively managed Douglas-fir plantations in the Pacific Northwest. The key to providing for a diversity of species and processes is to develop more diverse and complex stand structures. Using heavy, repeated thinnings minimizes the dense stem exclusion stage, stimulates the understory, and accelerates the development of complex, old forest structure. Favoring multiple species and sizes when thinning can enhance structural diversity. Variable density thinning, which creates a mosaic of different densities along with unthinned patches and small openings, also works well for enhancing structural diversity.

When harvesting, biological legacies such as large, live trees, snags, and downed wood should be retained to mitigate harvest impacts and provide structure for the new stand. Retention can be left dispersed throughout the stand, in aggregate clumps, or a combination. Riparian areas should be protected, as these are areas of particularly high diversity. Underplanting, selective fertilization, and pruning can also be used to add structural complexity. All of these strategies work best over longer rotation that allow enough time for complex structure to develop and minimize cumulative harvest impacts on the landscape.

These different practices for increasing structural complexity and biodiversity can be combined into overall management strategies called biodiversity pathways. Examinations of biodiversity pathways for coastal hemlock forests have been promising, and similar pathways can be developed for Douglas-fir plantations. There are economic costs to these pathways that must be considered in order to ensure successful adoption by private landowners and minimize unintended consequences such as forest conversion. Competitive incentive programs using both education and financial assistance can offset private costs. Identifying management strategies that target both biodiversity and competitive economic returns will likely be the most successful regardless of who bears the costs.

Metric equivalents

When you know:	Multiply by:	To find:
Acres	0.4047	Hectares
Trees per acre (TPA)	2.471	Trees per hectare

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