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Midcanopy growth following thinning in young-growth conifer forests on the Olympic Peninsula western Washington

Emily J. Comfort [a,*], Scott D. Roberts [a], Constance A. Harrington [b]

[a] Mississippi State University, Department of Forestry, Box 9681, Mississippi State, MS 39762, United States
[b] USDA, Forest Service, Pacific Northwest Research Station, 3625 93rd Ave SW, Olympia, WA 98512, United States

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ABSTRACT

Midcanopy layers are essential structures in "old-growth" forests on the Olympic Peninsula. Little is known about which stand and tree factors influence the ability of midcanopy trees in young-growth forests to respond to release; however, this information is important to managers interested in accelerating development of late-successional structural characteristics. We examined basal area growth response of midcanopy trees following variable-density thinning in an effort to determine the effect of thinning and local environment on the release of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and western redcedar (*Thuja plicata* ex. D. Don) on the Olympic Peninsula in western Washington. Release was measured as the difference between average annual basal area growth over the 5-year prior to thinning and the 3-to-6 year period following thinning. Results indicate that while growth rates were similar prior to thinning (5.4 cm^2 $year^{-1}$in both thinned and unthinned patches) midcanopy trees retained in a uniformly thinned matrix grew significantly more (8.0 cm^2 $year^{-1}$) than those in unthinned patches (5.4 cm^2 $year^{-1}$) for western hemlock and for western redcedar. Crown fullness and crown crowding affected the release of western hemlock in the thinned matrix. Initial tree size, relative age, local crowding and measures of crown size and vigor affected the release of western redcedar in the thinned matrix. Our results indicate that midcanopy western hemlock and western redcedar retain the ability to respond rapidly with increased growth when overstory competition is reduced and the magnitude of response is related to neighborhood variables (intracohort competition, overstory competition, and tree vigor), thus suggest that variable-density thinning can be an effective tool to create variability in the growth of midcanopy trees in young-growth stands. We expect that this rapid response will produce even greater variability over time.

1. Introduction

Forest management practices in the Pacific Northwest for most of the last century have led to the homogenizing of managed, young-growth forest stands and fragmentation of existing old-growth stands (Bolsinger and Waddell, 1993; Tappeiner et al., 1997; Puettmann et al., 2009). Lack of habitat with complex structure similar to old-growth forests is associated with declines in old-growth dependent species, such as the northern spotted owl (*Strix occidentalis caurina* Merriam) (Lamberson et al., 1992; Courtney et al., 2008). Forest managers in the Pacific Northwest are trying to develop management practices to accelerate the transformation of even-aged, young-growth conifer stands into more heterogeneous stands that fill the ecological and aesthetic role of late-successional forests (Franklin et al., 2002; Reutebuch et al., 2004). Although numerous studies have examined the growth of residual canopy trees following thinning (Curtis and Marshall, 1986; Harrington and Reukema, 1983; McComb et al., 1993; Roberts and Harrington, 2008; Swanson and Franklin, 1992), little research has examined the growth of residual midcanopy trees or determined which individual tree and local environmental characteristics influence the ability of these trees to release after thinning treatments. Because the development of midcanopy layers is an important component of old-growth structure (Franklin et al., 1986), a closer examination of the response of midcanopy trees to alternative management practices may offer insight into the longer-term implications and effectiveness of these treatments.

Old-growth forests are typically initiated following catastrophic disturbance events including wildfire and wind storms (Winter et al., 2002; Franklin et al., 2002) by species such as Douglas-fir (*Pseudotsuga Menziesii* (Mirb.) Franco.) often with surviving legacy trees from previous stands. Douglas-fir is a long-lived species (Hermann and Lavender, 1990), so after the onset of canopy closure

* Corresponding author at: Oregon State University, Forest Engineering, Resources, and Management, 265 Richardson Hall, Corvallis, OR 97331, United States. Tel.: +1 541 602 6566.
E-mail address: emily.comfort@oregonstate.edu (E.J. Comfort).

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and initial density-dependent mortality of pioneering trees, the stands can stagnate in the stem-exclusion phase of stand development for long periods of time (Oliver and Larson, 1996).

Small-scale disturbances over time allow shade-tolerant trees such as western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and western redcedar (*Thuja plicata* ex. D. Don) to establish and grow in the understory and midcanopy, while larger scale disturbances allow new cohorts of shade-intolerant species to establish. In the absence of small-scale (non-stand-replacing) disturbance, forests would likely remain structurally simple and be more prone to stand-replacing disturbances (fuel overloads) (Zenner, 2005; Bailey and Tappeiner, 1998).

Manipulating forest structure to mimic disturbance can change the competitive environment for remnant trees, thereby allowing a diverse assemblage of trees to thrive and possibly help to achieve goals of creating old-growth structural complexity (Reutebuch et al., 2004; Zenner, 2004). Because succession in western conifer forests commonly begins with structurally simple stands, young-growth stands are ideal for examining the effects of inducing spatial heterogeneity on the development of late-successional characteristics.

Variable-density thinning (VDT) is an ecologically-based treatment option for increasing structural complexity in mature young-growth stands. The general strategy is to selectively thin adjacent areas within a stand at different intensities. This creates a heterogeneous release of light and nutrient resources across the stand. Trees will presumably respond to the level of thinning in their immediate neighborhood, creating variable growth responses, and leading to greater structural diversity. However, because VDT is a relatively new management approach, little is known about the long-term effects of VDT on growth and development of forest stands. Alternatives to VDT, such as variable retention harvests and variable spatial distributions of thinning at various stand ages (e.g. pre-commercial thinning and mid-rotation thinning) are also being examined (Reutebuch et al., 2004; Carey et al., 1999).

The survival and growth of understory and midcanopy trees are necessary to achieve the structural and spatial heterogeneity associated with "old-growth" forests. However, there is very little information available on the response of these subcanopy trees to the increase in resources available following thinning. This retrospective study examined growth release of residual midcanopy trees measured as change in basal area growth from the 5 years prior to thinning to the 3–6 years following thinning. Specific questions that were addressed include: (1) Did VDT increase the growth rate of residual midcanopy trees in thinned patches relative to unthinned patches? We expected that midcanopy trees that were from the same cohort as the canopy trees may not respond to the thinning with increased growth in the short term (3–6 years). (2) Which tree- and stand-level factors were related to the growth response of midcanopy trees? We expected that ability to respond to the thinning would be related to tree size, vigor and age and the intensity of local competition.

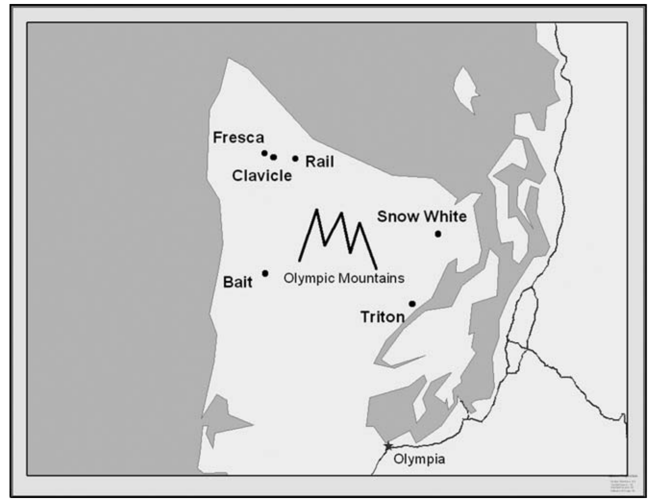

Fig. 1. Locations of the six OHDS blocks used in this study on the Olympic Peninsula in Washington, USA.

2. Methods

2.1. Site description

The Olympic Habitat Development Study (OHDS) is located in the Olympic National Forest on the Olympic Peninsula in western Washington. This joint venture between the Olympic National Forest and the Pacific Northwest Research Station was initiated in 1994 to examine whether management in 35- to 70-year-old even-aged conifer stands could accelerate the development of the compositional and structural characteristics typical of late-successional stands (for more information about the OHDS see Harrington et al., 2005; Roberts and Harrington, 2008).

Eight forest blocks were initially identified on the Olympic Peninsula for use in the larger OHDS study. Six of the blocks (Snow White, Bait, Rail, Fresca, Clavicle, and Triton) had been thinned and were used in this study (Fig. 1). Elevation at the study sites ranges from ca. 150 m to 575 m. Terrain varies from relatively flat to steep. Average annual precipitation ranges from 1950 mm to 3185 mm, occurring mostly during the winter (Harrington et al., 2005) (Table 1). Annual precipitation near Quilcene, WA, located on the east side of the Olympic Peninsula (near Snow White and Triton), averaged 965 mm per year between 1994 and 2005. In contrast, annual precipitation near Forks, WA on the west side of the peninsula (near the other four blocks), averaged 3162 mm per year over the same time interval.

Table 1
Site characteristics by block for OHDS sites used in this study.

Block	Age	Primary tree species	Initial stocking[a]		Elevation	Annual precipitation[b]
			Trees ha^{-1}	$m^2\,ha^{-1}$	m	mm
Rail	56	Douglas-fir, western hemlock	788	50	275	2390
Fresca	56	Sitka spruce, western hemlock	547	72	150	2650
Clavicle	62	Sitka spruce, western hemlock	678	86	475	2100
Bait	46	Douglas-fir, western hemlock	856	69	250	3180
Triton	74	Western hemlock, Douglas-fir, western redcedar	1151	59	400	3050
Snow White	74	Douglas-fir	1592	62	575	1950

[a] Stocking values based on pre-treatment conditions in stem-mapped plots.
[b] Annual precipitation estimates based on the parameter-elevation regressions on independent slopes model (PRISM) (U.S. Department of Agriculture Natural Resources Conservation Service et al., 1999).