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Variable density thinning promotes variable structural responses 14 years after treatment in the Pacific Northwest

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ABSTRACT

Young stands are commonly assumed to require centuries to develop into late-successional forest habitat. This viewpoint reflects the fact that young stands often lack many of the structural features that define late-successional habitat, and that these features derive from complex stand dynamics that are difficult to mimic with forest management. Variable density thinning (VDT) is a silvicultural strategy designed to accelerate development of late-successional habitat by applying a variety of harvest intensities within a stand. Previous reports indicate that VDT has had initial success increasing growth and regeneration. However, few studies have examined the effects of VDT at longer time scales. Here, we report 14-year growth response of residual trees in the thinned and unthinned VDT sub-treatments in five young mixed-conifer stands located on the Olympic Peninsula in western Washington. Our objectives were to investigate whether thinning has accelerated the recruitment of large trees (> 80 cm dbh), recruitment of shade-tolerant species into the mid-story (40–65 cm), or development of longer crowns relative to the unthinned sub-treatment. In addition, we investigated whether the basal area distribution in the combined VDT sub-treatments has become more diverse compared to the unthinned sub-treatment. The response to thinning varied consistently across the diameter size class gradient. Thinning was ineffective at stimulating growth of upper canopy trees (65–80 cm). In this size class neither diameter growth nor crown length increased significantly compared to trees in unthinned patches. Further, only one stand has reached the restoration benchmark for large tree density. In contrast, thinning significantly increased diameter growth and crown length among trees in the mid-story (40–65 cm) and shade-tolerant species in the future mid-story (20–40 cm). Higher rates of recruitment into the mid-story were also observed from shade tolerant species growing in the thinned (34%) compared to unthinned (19%) patches, with two stands reaching the restoration benchmark for shade-tolerant mid-story density. Clear trends in basal area diversity and evenness have yet to develop in either the combined or unthinned sub-treatments. Collectively, our results demonstrate that VDT has partially accomplished its objectives. Although thinning has not yet accelerated recruitment of large trees, it has accelerated the advancement of shade-tolerant species into the mid-story and the development of deeper crowns among trees in smaller size classes. In addition, differing rates of diameter growth among smaller diameter trees in the various VDT sub-treatments suggest that increases in structural diversity may be developing more quickly than in untreated stands.

1. Introduction

Forest restoration has become an increasingly common forest management objective, particularly on public lands. Throughout much of western North America, restoration efforts have focused on reversing forest succession to offset decades of fire suppression (Covington, 2000; Allen et al., 2002; Baker and Shinneman, 2004). One notable exception to this regional trend can be found in the Pacific Northwest (PNW), where accelerating the formation of late-successional structural attributes is a restoration priority (Bolsinger and Waddell, 1993; Franklin and Norman Johnson, 2012).

Interest in restoring late-successional structure on federal land is largely driven by concerns over declining late-successional wildlife habitat and biodiversity (Carey and Harrington, 2001; Spies et al., 2010). Of particular concern is the relative structural simplicity of forests managed for wood production. Late-successional structural attributes often lacking in stands managed for timber production include: large canopy trees (> 80 cm in diameter), diversity of tree size-classes,

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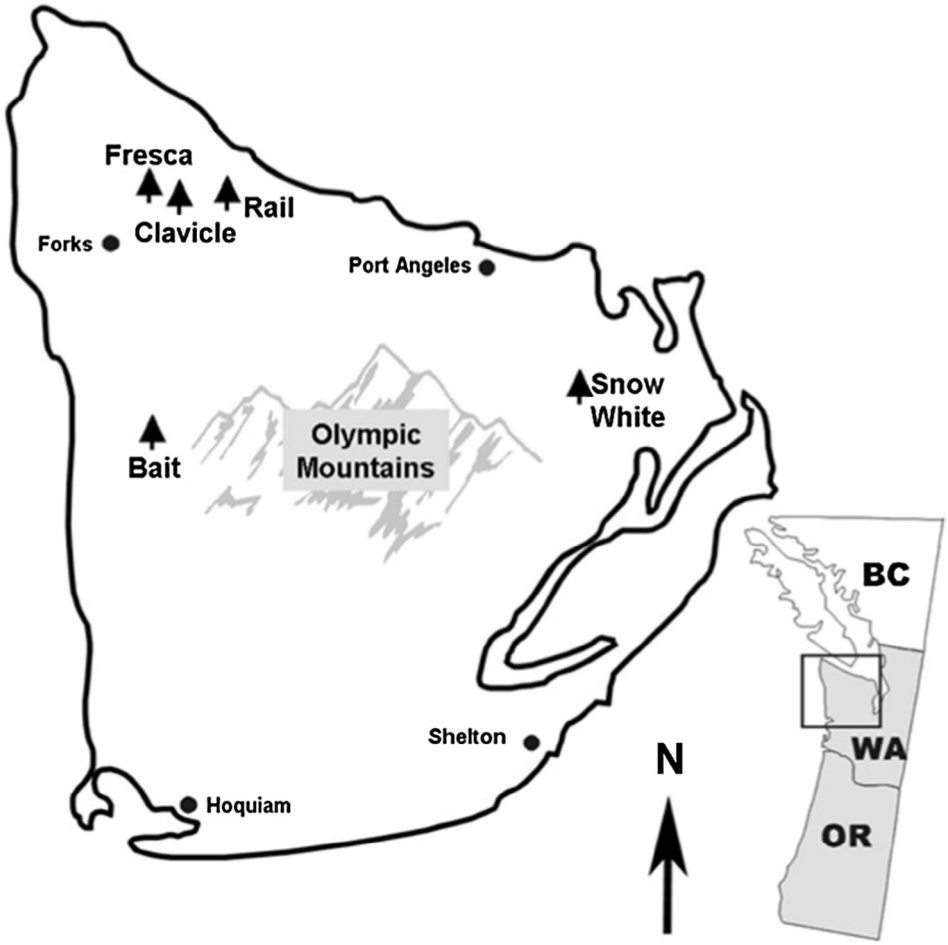

Fig. 1. Area map of the Olympic Peninsula in northwestern Washington showing locations of the five study sites on the Olympic National Forest where wind damage was assessed following variable-density thinning. Circles indicate locations of major towns on the Olympic Peninsula.

coarse woody debris (CWD – down wood and snags), variation in crown structure, and the development of a shade-tolerant mid-story (Franklin and Spies, 1991; Spies, 2004; Zenner, 2004; Bauhus et al., 2009). While all of these attributes typically develop naturally over time, considerable interest has been given to testing management practices which may accelerate the successional process (Curtis and Carey, 1998; Franklin et al., 2002; Reutebuch et al., 2004; Carey, 2006; Curtis et al., 2017).

Thinning has been shown to accelerate tree growth (Mitchell, 2000; Marshall and Curtis, 2002), suggesting that it may be applied to hasten both stand and individual tree growth. Traditional forms of low thinning, however, have been focused on stand growth rather than structural diversity (Nyland, 1996). Natural restoration processes may even be delayed by traditional forms of thinning, particularly low thinning, as these treatments tend to homogenize stand structure, limit CWD input, and remove snags (Nyland, 2003; Larson and Churchill, 2008). Variable density thinning (VDT), on the other hand, is a silvicultural strategy designed to stimulate forest growth while promoting late-successional forest structure (Carey, 2003, 2006). Unlike thinning for wood production, VDT distributes resources unevenly within a stand by creating canopy gaps and gradients of stand density (Carey, 2003; Comfort et al., 2010). The goal of these treatments is to encourage horizontal and vertical heterogeneity within the stand. For example, high resource environments such as thinned areas or canopy gaps are created to encourage rapid tree growth, crown retention and expansion, regeneration, and a more diverse herbaceous vegetation layer (Puettmann et al., 2016). Conversely, unthinned patches are retained resulting in slower individual tree growth, crown contraction, and higher mortality, thus encouraging the creation of snags and greater inputs of CWD to the forest floor. The intended effect of these varying treatments is to produce a more structurally complex stand, consistent with the defining characteristics of late-successional forests in the region (Franklin and Spies, 1991).

Initial reports on the effectiveness of VDT have varied among structural attributes and ecological processes. Diameter growth has been shown to positively respond to VDT at the stand level (Davis et al., 2007; Dodson, 2012), in the mid-story (Comfort et al., 2010), and among individual trees located in proximity to harvest gaps or skid trails (Roberts and Harrington, 2008; O'Hara et al., 2010; Dodson, 2012). Natural regeneration, crown length expansion, and herbaceous layer species richness and diversity have also been shown to increase following gap creation or VDT (Thysell and Carey, 2001; Ares et al., 2010; Dodson, 2012; Curtis et al., 2017). In contrast, growth rates amongst the largest trees have been largely unresponsive to thinning (Dodson, 2012), at least initially, raising questions over whether these trees are experiencing a delayed response or whether more intensive thinning is required to stimulate growth (Maguire et al., 2006; Davis et al., 2007). Similar questions exist surrounding the impact of VDT on forest structure. Dodson (2012) report higher BA variation in plots treated with VDT. However, in a longer-term study, Kuehne et al. (2015) found no significant improvement in structural heterogeneity following VDT. Finally, long-term questions regarding growth dynamics, tree size class diversity, and crown response to VDT remain unanswered, as few studies have reported results beyond the first decade following treatment (Kuehne et al., 2015).

In this report, we examine late-successional structural development in five relatively young second-growth mixed-conifer stands on the Olympic Peninsula in western Washington 14 years following VDT. We focus on the development of main- and mid-canopy structural diversity, and therefore limit our analysis to trees in those canopy strata at the