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Pruning high-value Douglas-fir can reduce dwarf mistletoe severity and increase longevity in Central Oregon

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ABSTRACT

Mid- to very large-sized Douglas-fir (*Pseudotsuga menzieseii* var. menziesii) that were lightly- to moderately-infected by dwarf mistletoe (*Arceuthobium douglasii*) were analyzed over a 14-year period to evaluate whether mechanical pruning could eradicate mistletoe (or at least delay the onset of severe infection) without significantly affecting tree vitality and by inference, longevity. Immediate and long-term pruning effects on mistletoe infection severity were assessed by comparing pruned trees ($n = 173$) to unpruned trees ($n = 55$) with respect to: (1) percentage of trees with no visible infections 14 years post-pruning, (2) Broom Volume Rating (BVR), and (3) rate of BVR increase 14 years post-pruning. Vitality/longevity (compared with unpruned trees) was assessed using six indicators: (1) tree survival, (2) the development of severe infections, (3) the development of dead tops, (4) tree-ring width indices, (5) Normalized Difference Vegetation Index (NDVI) from high-resolution multi-spectral imagery, and (6) live-crown ratio (LCR) and increment. Twenty-four percent of the pruned trees remained free of mistletoe 14 years post-pruning. Pruning is most likely to successfully eradicate mistletoe in lightly infected trees (BVR 1 or 2) without infected neighbors. Pruning significantly decreased mean BVR in the pruned versus the unpruned trees. However, the subsequent average rate of intensification (1.3–1.5 BVR per decade) was not affected, implying that a single pruning provides ~14 years respite in the progression of infection levels. Post-pruning infection intensification was slower on dominant and co-dominants than on intermediate or suppressed trees. The success of mistletoe eradication via pruning and need for follow-up pruning should be evaluated no sooner than 14 years after pruning to allow for the development of detectable brooms. Based on six indicators, foliage from witches brooms contribute little to long-term tree vitality since removal appears to have little effect on resources available for tree growth and maintenance. In the severely pruned trees, tree-ring width was reduced for several years post-pruning, but then compensated with larger ring width in later years. Both NDVI and LCR increment were significantly higher for the pruned trees than the control trees, while the development of severe infections and/or dead tops was significantly (5× and 3×) higher for the controls. If possible, multiple indicators of tree vitality should be evaluated. Pruning can be worthwhile even if all the mistletoe is not removed, because mistletoe intensification is delayed. The impact of removing the brooms seems to be minimal, and post-pruning crowns had greater NDVI values.

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1. Introduction

Large, old-growth Douglas-fir trees (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) are highly valued features in Pacific Northwest campgrounds, parks, lakeshores, and other developed recreation areas. In these settings they provide wildlife habitat, shade, beauty, and confer a sense of wonder and tranquility. In many cases along the east slope of the Cascade Range, however, Douglas-fir is infected with dwarf mistletoe (*Arceuthobium douglasii* Engelm.). At high severity levels, *A. douglasii* can greatly decrease the vitality (ability to grow and survive under conditions

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present (Shigo, 1986)) and as a result, the longevity of these trees (Pierce, 1960; Mathiasen et al., 1990; Hawksworth and Wiens, 1996; Mallams, 2008b). Over time, when severely infected trees occur in recreation settings, the quality of the recreational experience may decrease as the large, severely infected trees die.

The principal and only common host of Douglas-fir dwarf mistletoe is Douglas-fir (Hawksworth and Wiens, 1996). Douglas-fir dwarf mistletoe has the greatest latitudinal range (3000 km) of any species in the genus (Hawksworth and Wiens, 1996). It occurs from southern British Columbia to central Mexico. It is common in eastern Washington, eastern Oregon, Idaho, western Montana, Utah, Colorado, Arizona, and New Mexico. Although there are abundant hosts west of the crest of the Cascade Mountains of Oregon, Washington, and British Columbia, *A. douglasii* is infrequent (Hawksworth and Wiens, 1996). It also occurs in southwestern Oregon and is common in northern California (Hawksworth and Wiens, 1996). *A. douglasii* is also characterized by its very small, aerial shoots, making it one of the smallest mistletoes in western North America (mean shoot length = 2 cm) (Hawksworth and Wiens, 1996).

Dwarf mistletoes (including *A. douglasii*) have an explosive seed dispersal mechanism and a sticky/slick seed coat that, together, increase the probability of proper seed placement for successful inoculation and infection. At maturity the seed (with a sticky seed coat) is forcibly ejected from the fruit. In order to successfully colonize a tree, however, the discharged seed must ultimately reach the base of a live needle. The seed coat assists this by being alternatively sticky and then slick. First, the sticky seed coat of the expelled seed increases its probability of adhering to needles that intercept its flight. Second, the seed coat becomes lubricated and slick when moistened by rain and often slides down to the needle base, germinates and sends a rootlet into the tree. Seeds can either re-infect the same tree or infect another tree (Hawksworth and Wiens, 1996).

Branch infection by dwarf mistletoe results in a malformation of the branch commonly called a "witches' broom." *A. douglasii* is characterized by the development of massive witches' brooms (Tinnin and Knutson, 1980; Tinnin et al., 1982; Mallams et al., 2005). Compared to uninfected branches, dwarf mistletoe infections produce larger-diameter branches with twice as many twigs that are 50% longer. Consequently, broomed branches may weigh 2.5 times that of healthy branches (Tinnin and Knutson, 1980). Brooms accumulate dead foliage, lichens, water, snow, and ice, and may weigh >65 kg each, and thus are more prone to breakage (Hadfield, 1999; Filip et al., 2014).

The preferred method of rating dwarf mistletoe infection severity in Douglas-fir is broom volume rating (BVR), based on the volume of witches' brooms (Tinnin, 1998). An alternative rating system is the Six-Class Dwarf Mistletoe Rating (DMR, Hawksworth, 1977), which is based on visible plants and the number of infected branches and their abundance in crown thirds. The small shoot size and characteristic dense brooming make DMR difficult for rating *A. douglasii* infection severity. Comparisons between the two ratings, however, show very little difference (Mallams, 2008a) and although a DMR of 0 means there is no mistletoe on the tree, a similar rating using the BVR system simply means there are no witches' brooms.

Witches' brooms caused by Douglas-fir dwarf mistletoe are often highly resistant to self-pruning that would naturally occur and therefore both affect the normal pattern of biomass/foliage allocation (Hawksworth and Wiens, 1996) and water balance (Fisher, 1983). Abnormal growth patterns (including dead tops and branches) and major changes in the biomass allocation are the result. Foliage on infected Douglas-fir has lower water use efficiencies (WUE) than non-infected branches or trees. This decrease in WUE is accompanied by increases in leaf area, water uptake, and transpiration (sap flux) (Sala et al., 2001), provided there is enough available water to support this increase. Although amounts vary among studies, there is a consistent decline in tree growth and survival as infection severity increases from moderate (BVR rating of 3 or 4) to severe (BVR rating of 5 or 6) (Pierce, 1960; Filip and Parks, 1987; Wicker and Hawksworth, 1988; Mathiasen et al., 1990; Filip et al., 1993). Significant declines in radial bole increment (measured at 1.4 m from ground level on the uphill side of the tree) in larger trees usually begin at moderate infection severity levels. Severely infected trees exhibit dramatic growth reductions, sometimes less than half that of a healthy tree (Pierce, 1960; Wicker and Hawksworth, 1988; Filip et al., 1993). In addition to trees killed by dwarf mistletoe, breakage of large brooms and decayed dead tops can pose safety hazards to visitors in developed recreation sites (Hadfield, 1999). Management treatment(s) that arrested or delayed mistletoe intensification would be useful to managers and the public if the treatments improved longevity and structural integrity of these valuable trees.

The objective of this study is to refine current operational guidelines for mechanical pruning of dwarf mistletoe infected branches in larger Douglas-fir. These guidelines will address where and when it is likely that we can:

1. Remove all infected branches and brooms for the foreseeable future.
2. Significantly slow the increase in infection severity over time without seriously compromising the vitality and, by inference, the longevity of the tree.
3. Evaluate an approach that compares multiple indicators of vitality/longevity (e.g. survival, tree-ring width, BVR, and Normalized Difference Vegetation Index [NDVI]) between pruned and unpruned trees over the study period.

2. Methods

2.1. Study area

Suttle Lake and Scout Lake are located on the east slope of the Cascade Range in central Oregon in a moist mixed-conifer forest (1070 m elevation). The plant association for most of the area is White Fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.)-Grand Fir (*A. grandis* (Dougl. ex D. Don) Lindl.)/Twinflower (*Linnaea borealis* L.) (ABCO-ABGR/LIBO2) (Simpson, 2007). Average annual precipitation ranges from 33 to 150 cm (1960–2012). The shoreline of Suttle and Scout Lakes, where study trees are located, are managed by the USDA Forest Service (Sisters Ranger District, Deschutes National Forest), and there are several campgrounds, day-use recreation sites, a lodge and cabins, boat launching sites, and a hiking trail surrounding the lakes.

Douglas-fir dominates the overstory shoreline vegetation, although there are also ponderosa pine (*Pinus ponderosa* Douglas ex C. Lawson), white fir, Engelmann spruce (*Picea engelmannii* Parry ex Engelm), and western white pine (*Pinus monticola* Douglas ex D. Don). While there is a mixture of sizes and ages, old, large Douglas-fir are abundant. Dwarf mistletoe is distributed among all size classes of Douglas-fir. The Douglas-fir and white fir were severely defoliated by western spruce budworm (*Choristoneura freemani Razowski*) from 1985 to 1993. The Link Fire burned to the edge of the study area in 2003. The trees selected for study were not burned.

2.2. Study trees and pretreatment data

In 1998–99, stands surrounding Suttle Lake and Scout Lake were surveyed for larger diameter Douglas-fir infected with dwarf mistletoe that would be suitable for pruning; specifically trees