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Estimating economic impact of black bear damage to western conifers at a landscape scale

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ABSTRACT

Black bear (*Ursus americanus*) damage to trees in the Pacific Northwest is common, although volume and economic losses are unknown. Common measures to quantify bear damage to conifers at large scales rely solely on aerial estimates of red tree crowns (caused by complete girdling) and broad assumptions about stand characteristics. We surveyed 122 vulnerable stands in the Coast Range and western Cascades of Oregon using both aerial surveys and ground surveys. Then, we modeled 4 damage scenarios (Salvage; Total Loss; Root Disease; and Combined Damage) with the Forest Vegetation Simulator (FVS) growth and yield model and the Fuel Reduction Cost Simulator (FRCS). Damage polygons, digitized in real time from aerial surveys identifying red (dead or dying) tree crowns, overestimated bear damage by approximately 5-fold due to misclassification with root disease, and failed to detect partially peeled trees that contributed to economic loss. Damage polygons assessed from the air generally did not include red crowns, and were a mean distance of 58.8 m (SE = 8.8) from damage polygons' outer edges to the nearest red crown. We accounted for mortality and volume losses from partially girdled trees that did not show red crowns in our Salvage scenario, whereas we assumed that all bear-peeled trees resulted in complete loss in the Total Loss scenario. At the landscape scale, economic loss was ≤0.35% of net present value under both damage scenarios, while processing bear damage trees (Salvage) was the most efficacious option. At the landscape scale, our worst-case scenario (Total Loss) resulted in an estimated loss of $56/ha to bear damage, 10-fold less than a previously reported estimate of $585/ha. Root disease was a more prevalent damage agent than bear damage but did not affect net present value at harvest. The majority (92%) of bear damage observed in ground surveys was older (> 2 yrs) and existed at a low frequency (1.5 bear damaged trees/ha) and severity across the landscape. Our results suggest that black bear damage is not uniformly distributed and that perceived impact varies with spatial scale. On-the-ground monitoring of the status of bear damage across the western Oregon landscape will identify hot spots of severe peeling and provide an understanding of these changes over time.

1. Introduction

Wildlife damage is an ongoing concern for forest resource management. Among vertebrate species, black bears (*Ursus americanus*) are perceived to have the greatest economic impact to young western conifers because bears usually damage the largest, most vigorously growing trees within the most productive stands (Kimball et al., 1998a; Schmidt and Gourley, 1992). Following winter dormancy, common food sources for black bears (e.g., *Rubus* spp., *Vaccinium* spp.) are scarce, requiring them to find additional sources of energy (Ziegltrum, 2004). In spring, black bears find this energy by peeling away bark to consume the sugar-rich phloem and cambial tissues (hereafter vascular tissues) of vigorously growing conifers (Radwan, 1969). In the Pacific Northwest, the most common conifer foraged is young Douglas-fir (*Pseudotsuga menziesii*), particularly within the 15–40 year age range (Flowers, 1987). Damage is typically concentrated at the base of trees where the quality of wood is greatest, and where the majority of the tree's wood volume is concentrated (Schmidt and Gourley, 1992). However, some black bears climb and peel trees where secondary metabolites are less concentrated (Kimball et al., 1998c), and bark is thinner and easier to peel (Schmidt and Gourley, 1992). Full girdling results in tree mortality, while partially girdled trees possess degraded wood quality and are more susceptible to disease, insect infestation (Kanaskie et al.,1990), and windfall (Witmer et al., 2000). Thus,

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impacts to timber stands from black bear damage can be substantial, especially since many stands are damaged by black bears for multiple years in a rotation (Kline et al., 2018). Based on field measurements, Kline et al. (2018) estimated that black bear damage at the stand scale resulted in a 4–46% loss of net present value in stands that were identified as having severe black bear damage. However, to our knowledge, there are no studies that have used field-based methods or growth and yield modeling to assess such economic losses at the landscape or regional scale (Taylor et al., 2014).

Currently, black bear damage in commercial timber stands is only assumed to result in substantial economic loss across scales. Historically, standard damage frequency estimates at the landscape scale have relied on damage detection through aerial surveys (Hartwell and Johnson, 1987). Trees that die as a result of bear damage typically show an observable change in foliar color from green to red by the following spring. Such red crowns can be detected remotely by air or from distant viewpoints on the ground. Red crowns are a potential index for extrapolating the total amount and economic impact of black bear damage at a specific period in time (Hartwell and Johnson, 1987).

In western Oregon, aerial surveys have been conducted annually by Oregon Department of Forestry (ODF) and the U.S. Forest Service (USFS) since 1987 to detect red (dead or dying) crowns and document tree mortality from black bears in western Oregon. Trained observers in fixed-wing aircraft digitize polygons in real-time to draw boundaries around red crowns (i.e., damage polygons). Boundaries vary in size and rules for number of red crowns per polygon are standardized among observers. These surveys are currently the only estimate of damage amounts over a large geographic area (Kanaskie et al., 2001), covering approximately 3.1 million ha each year (Flowers et al., 2014). However, aerial surveys for black bear damage focused on detecting red crowns are an annual estimate of trees completely girdled by black bears only the previous year, and do not estimate partial peeling or cumulative damage. Additionally, the aerial damage surveys have been ground verified twice since they began, revealing various weaknesses in their accuracy including misclassification with other mortality agents (Kanaskie et al., 1990, 2001).

To date, only 2 studies have estimated economic loss to black bear damage at broad scales (Nolte and Dykzeul, 2002; Taylor et al., 2014). Although informative, these estimates lacked stand assessments and were derived solely from aerial surveys of red crowns using broad assumptions of average tree age, economic value per tree, and tree density. Kline et al. (2018) was the first known study to integrate forest growth and yield models, harvest simulations, and present value models in quantifying black bear damage. They also improved estimates by including stand assessments and accounting for trees that were damaged but not killed (Kline et al., 2018). In this study, our objective was to improve our knowledge of the potential impacts of black bear damage at large scales by expanding upon this conceptual framework and methodology (Kline et al., 2018). This study builds upon such previous research (Nolte and Dykzeul, 2002, Taylor et al., 2014) by: (1) evaluating the accuracy of the black bear damage portion of the aerial forest health surveys for western Oregon, (2) accounting for volume loss and gain at the landscape scale, and (3) incorporating tools and techniques commonly used in forest valuation, such as growth and yield models, harvest simulators, and present value models into black bear damage assessments.

2. Methods

2.1. Study area

The study area included 122 intensively managed Douglas-fir stands on private land in the western Cascades and Coast Range of Oregon (Fig. 1). The Western Cascades ecoregion extends down-slope from the Cascade Mountains summit to the foothills of the Willamette, Umpqua, and Rogue valleys, and spans the entire length of the state of Oregon, from the Columbia River to the California border (ODFW, 2006). The mild maritime climate is characterized by cool, wet winters and hot, dry summers (Immell et al., 2013). Elevation ranges from sea level to 3500 m. Average annual rainfall is 107–226 cm and average snowfall above 1220 m is 18–592 cm (ODFW, 2006). This ecoregion is almost entirely forested by conifers. Douglas-fir is the most common tree species below 1220 m, often mixed with western hemlock (*Tsuga heterophylla*) as a co-dominant. At higher elevations, dominant tree species include Pacific silver fir (*Abies amabilis*), mountain hemlock (*Tsuga mertensiana*), or subalpine fir (*Abies lasiocarpa*). Other common conifers include western redcedar (*Thuja plicata*), grand fir (*Abies grandis*), and noble fir (*Abies procera*) (ODFW, 2006). Understory vegetation is comprised of vine maple (*Acer circinatum*), salal (*Gaultheria shallon*), rhododendron (*Rhododendron macrophyllum*), swordfern (*Polystichum munitum*), vanilla leaf (*Achlys triphylla*), Oregon oxalis (*Oxalis oregano*), and twin flower (*Linnaea borealis*, Immell et al., 2013).

The Coast Range ecoregion extends from the Pacific coast eastward through the coastal forest to the border of the Willamette Valley and Klamath Mountains. The area is comprised of rugged, mountainous terrain with steep slopes and deep river and creek drainages. Elevation ranges from sea level to 1250 m. Climate is maritime with mild, wet winters and cool, dry summers (Cushman and McGarigal, 2003), and an average annual precipitation of 152–249 cm (ODFW, 2006). The forest overstory is dominated by Douglas-fir, western hemlock, and red alder (*Alnus rubra*). Western redcedar and bigleaf maple (*Acer macrophyllum*) are also common. Common understory vegetation include salmonberry (*Rubus spectabilis*), salal, vine maple, Oregon grape (*Berberis* spp.), huckleberry (*Vaccinium* sp.), and swordfern (Cushman and McGarigal, 2003).

Approximately 45% of western Oregon forestland is managed by federal agencies (OFRI, 2013). Approximately 30% falls under large private industrial ownership, and 18% falls under small private ownership (OFRI, 2013). The remaining 7% is managed by ODF and other nonfederal public entities (OFRI, 2013).

2.2. Data collection

We accessed black bear damage data from ODF and USFS aerial forest health surveys conducted in 2014–2015 (http://www.oregon.gov/ODF/ForestBenefits/Pages/ForestHealth.aspx). Trained observers recorded black bear damage from fixed-wing aircraft in early summer, as this is the optimal time to detect changes in foliar color among injured western conifers (Flowers et al., 2014). Flights followed a grid pattern 300–500 m above the ground with flight lines 6.5 km apart (Flowers et al., 2014). Observers recorded damaged areas by drawing curvilinear polygons on a digital sketch mapping system (Flowers et al., 2014). The resulting polygons designated approximate damage boundaries, and were coded with suspected damage agent and an estimated of number of trees affected. Areas of mature (> 30 cm dbh) Douglas-fir with red crowns in tight groups were coded as Douglas-fir beetle mortality, while all other red crowns were coded as bear damage unless an obvious alternative cause was evident (Kanaskie et al., 2001).

We obtained stand-scale spatial and relational data from cooperating forest landowners, and integrated those data with aerial survey data of black bear damage for 2014–2015 in a geographic information system (GIS). We randomly selected 35 stands in the western Cascades and 35 stands in the Coast Range (70 stands each year for 2 years; 140 stands total) that overlapped with a surveyed black bear damage polygon and were within the most common age range of vulnerability for black bear damage (11–34 years). After removing 8 stands because of access issues, and 10 aerial images that contained no red crowns to verify on the ground, 122 of the 140 sample stands were surveyed.

Sampling to assess wildlife damage influences extrapolation of damage estimates to the larger area (Engeman, 2002). In order to maximize the efficiency of establishing the ratio of actual black bear peeling