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Snag longevity and surface fuel accumulation following post-fire logging in a ponderosa pine dominated forest

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ABSTRACT

In a study of post-fire logging effects over an 8 year period at Blacks Mountain Experimental Forest, salvage logging was conducted at varying levels of intensity after a 2002 wildfire event. In a designed experiment, harvest prescriptions with snag retention levels ranging from 0% to 100% in 15 experimental units were installed. Observations of standing snags and surface fuels were made 2, 4, 6, and 8 years after the fire. Fire-killed snags fell rapidly over time, leading to elevated surface fuel levels in areas where no salvage logging was done. The 1000 h and larger surface fuels were strongly related with basal area retention level, with values ranging from 0–60 Mg ha^{-1} by year eight. However, when expressed as a percent of standing retained biomass, surface fuel accumulation was not related to treatment. In year 8, surface fuel was 81% of retained bole biomass. The retention of snags after this wildfire event provided snags for wildlife foraging and nesting habitat, however most of these snags were lost within 8 years after the fire. White fir snags were more stable than pine and appeared to be used with greater frequency than pine for cavity excavation.

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1. Introduction

Ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson) forests of interior North America, where fire has been excluded for decades, are now prone to high-severity crown fires. Fires in these areas once burned at primarily low to moderate severities under the historic regime of frequent fire (Arno, 2000; Wright and Agee, 2004; Skinner and Taylor, 2006). Tree mortality from fire was often most pronounced in the small size classes of trees and mortality of overstory trees was patchy, restricted to areas with localized build-up of surface fuel. Fire suppression-caused declines in fire activity have reversed in some parts of the western United States, with both the extent of burning (Westerling et al., 2006) as well as the proportion of acres burning at high severity increasing in recent decades (Miller et al., 2009).

High severity crown fires result in high levels of tree mortality, consuming leaves and small branches but leaving the boles largely intact. In the aftermath of such fires, managers often propose the salvage of wildfire-killed trees. Prompt removal of recently killed trees provides financial return and thus facilitates subsequent tree planting and release treatments. Salvage harvesting also has the potential to influence other site resources of interest to forest managers. This activity has the potential to disturb soils (e.g. Brais and Camire, 1998), remove potential wildlife habitat (Blake, 1982; Caton, 1996; Hitchcox, 1996; Morissette et al., 2002), impact natural tree regeneration (Greene et al., 2006), increase loading of fine surface fuels (Donato et al., 2006; McIver and Ottmar, 2007), and modify understory species composition (Purdon et al., 2004). Increasingly, salvage harvesting has been the subject of study to develop a fuller understanding of the consequences of this activity.

1.1. Snag retention and dynamics

The direct effect of salvage harvest is in reducing density of snags on the landscape. In ponderosa pine forests, snags contribute to wildlife habitat (Laudenslayer, 2002a; Farris et al., 2002), and retention of standing dead material may provide important forage and nesting opportunities for numerous species (Scott, 1979). However as these snags fall, they also contribute to elevated surface fuels (McIver and Ottmar, 2007). Managers therefore must find a balance between preserving the habitat value provided by snags while also mitigating the threat posed by excess surface fuels to future fire severity.

The rate at which snags decay and fall is important where decisions are made to retain snags after fire. Yet little is known of snag dynamics in a post fire environment. Some studies have shown that fire-killed snags remain standing for a relatively short period of time (e.g. Raphael and Morrison, 1987; Harrington, 1996). Laudenslayer (2002b) found that fire-killed snags deteriorate at

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approximately twice the rate of trees killed by means other than fire.

Standing snags may retain a substantial amount of biomass that will contribute to surface fuels over time as snags fall. Although large wood is not included in surface fire spread models, it can contribute to fire behavior and fire spread by acting as a source of embers, both directly by lofting from burning snags (van Wagtendonk, 2006), and indirectly through torching of trees preheated by burning of heavy fuels on the forest floor. Presence of coarse woody debris also presents a hindrance to fire suppression (Brown et al., 2003; USDA, 1976). Decomposing snags and logs provide a receptive surface for ignition of spot fires from embers (Stephens, 2004). In addition, fire effects are often related to the amount of fuel consumed (Knapp et al., 2005) and a substantial portion of the fuels consumed by fire may be contained within large logs, especially in areas that have experienced high tree mortality in the recent past. Large fuels increase burnout time, and prolonged heat exposure affects soil porosity and structure (McNabb and Swanson, 1990; Brown et al., 2003).

Concerns about the potential for negative impacts of salvage logging have led to a number of studies of fire salvage effects (McIver and Starr, 2001; Peterson et al., 2009). Unfortunately many of these studies have been unreplicated and/or observational in nature (McIver and Starr, 2001). In addition, salvage logging has in the past traditionally been viewed in black and white terms – either all merchantable material is removed or the stand is not entered at all, leaving few opportunities to study how a gradient in snag densities might influence fuel accumulation and wildlife attributes over time.

In addition to the direct impacts of snag removal on standing biomass, it is also possible that retained snag stability is influenced by salvage logging. Russell et al. (2006) reported a shorter half-life for snags in salvaged areas than those in unsalvaged areas.

1.2. Objectives

In this study we characterized the transition from fire-killed snags to surface fuel, over time, for a range of post-fire salvage intensities in a pine-dominated forest. This gradient in snag densities was produced with a post-fire thinning from below, producing plots with standing basal area ranging from zero (complete salvage) to 100% (unsalvaged), with intermediate levels in between. Thinning from below meant that plots with the lowest snag density also generally had the largest average snag size. While salvage, for economic reasons, often focuses on removing the largest most valuable trees, these same snags also are believed to provide the best wildlife habitat both in terms of use by cavity nesting birds and snag longevity. Thus, intermediate removal treatments maintaining some large snags might be envisioned as a compromise treatment for landscapes being managed to provide multiple resource benefits.

Our objective in this study was to (1) quantify the dynamics of standing snags and large surface fuel accumulation over time in relation to varying levels of post-fire salvage in a ponderosa pine-dominated forest, (2) quantify the dynamics of fine fuels post-fire salvage, and (3) evaluate cavity excavation among retained trees.

2. Methods

2.1. Study site

The study was established in a burned area at Blacks Mountain Experimental Forest (BMEF) in the southern Cascade Range of northeastern California (40.72°N latitude, 121.17°W longitude). Elevations range from 1700 to 2100 m. The climate is montane Mediterranean characterized by warm, dry summers and cold, wet winters. Annual precipitation ranges from 231–743 mm and falls primarily as snow from November to May.

The area sampled was dominated by ponderosa pine (60–80% by basal area) with a mix of white fir (*Abies concolor* (Gord. & Glend.) Lindl. Ex Hildebr.) incense-cedar (*Calocedrus decurrens* (Torr.) Florin) and, infrequently, Jeffrey pine (*Pinus Jeffreyi* Balf.).

2.2. The Cone Fire

The Cone Fire burned 565 ha on BMEF in late September 2002. Fuel moisture during this late-season burn was low. A weather station 6 miles northwest of the ignition point recorded 2% for 10- and 100-h fuels and 5% for 1000-h fuels during the fire. Relative humidity was recorded at 6% with winds gusting to 51 km h^{-1}.

In the area of the burn with no prior fuel treatment, the stem density at the time of the burn averaged 1700 ha^{-1}, with a quadratic mean diameter of approximately 16 cm (Table 1). The elevated stem densities observed are consistent with the effects of an extended period of fire exclusion in interior pine stands of northern California (Skinner and Taylor, 2006). Indeed, fire history data for Blacks Mountain clearly show that fire has been almost non-existent on the landscape over the last 100 years (Data on file, PSW Research Station).

Approximately 5 years prior to the burn, some areas of the Experimental Forest were treated with a combination of thinning and prescribed fire (Oliver, 2000) and these areas were subject to low severity fire with very limited spread (Ritchie et al., 2007). However, the areas with no recent fuel-reduction treatments were subject to a high-severity crown fire, with few surviving trees. This portion of the Cone Fire without prior experimental fuel reduction treatments was subject to a post-fire salvage harvest to remove both merchantable and un-merchantable snags. The application of a post-fire salvage harvest afforded the opportunity to evaluate treatment effects.

2.3. Post-fire treatments

The salvage prescription in the Cone Fire called for complete removal of all trees with no green foliage remaining. The post-fire salvage operations began 12 months after the fire, the delay was due to the requirements of the National Environmental Policy Act (NEPA) in effect for National Forest lands. NEPA requires the development and review of a detailed planning document prior to any treatment implementation. Salvage operations for the experiment were concluded by November 2003.

The salvage area of 442 ha, including the study units, was combined with a unburned thin from below of 300 ha elsewhere on the forest for a combined removal of 33 Mg ha^{-1} (green weight) in sawtimber and 27.13 Mg ha^{-1} in non-sawtimber (chips). The timber sale was awarded at a bid price of $352,437 in September of 2003. The salvage area outside of the study plots was subjected to a complete removal of all snags. Because our experimental treatments are part of a larger sale, it is not possible to draw conclusions about the economic viability of any of our intermediate salvage treatments.

Table 1
Stand mean densities (with s.e.) by tree size in the experimental area prior to the Cone Fire.

	Diameter class (cm)			
	2–15	15–30	30–45	45+
Trees ha^{-1}	1192 (86)	438 (30)	54 (7)	20 (4)
Basal area m^2 ha^{-1}	8.4 (0.56)	15.1 (1.08)	5.3 (0.67)	5.2 (1.26)