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Review

Perpetuating old ponderosa pine

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Abstract

We review current knowledge about the use of management treatments to reduce human-induced threats to old ponderosa pine (*Pinus ponderosa*) trees. We address the following questions: Are fire-induced damage and mortality greater in old than younger trees? Can management treatments ameliorate the detrimental effects of fire, competition-induced stress, and drought on old trees? Can management increase resistance of old trees to bark beetles? We offer the following recommendations for the use of thinning and burning treatments in old-growth ponderosa pine forests. Treatments should be focused on high-value stands where fire exclusion has increased fuels and competition and where detrimental effects of disturbance during harvesting can be minimized. Fuels should be reduced in the vicinity of old trees prior to prescribed burns to reduce fire intensity, as old trees are often more prone to dying after burning than younger trees. Raking the forest floor beneath old trees prior to burning may not only reduce damage from smoldering combustion under certain conditions but also increase fine-root mortality. Thinning of neighboring trees often increases water and carbon uptake of old trees within 1 year of treatment, and increases radial growth within several years to two decades after treatment. However, stimulation of growth of old trees by thinning can be negated by severe drought. Evidence from young trees suggests that management treatments that cause large increases in carbon allocation to radial xylem growth also increase carbon allocation to constitutive resin defenses against bark beetle attacks, but evidence for old trees is scarce. Prescribed, low-intensity burning may attract bark beetles and increase mortality of old trees from beetle attacks despite a stimulation of bole resin production.

Keywords: Bark beetle; Forest management; Fire; *Pinus ponderosa*; Prescribed burn; Restoration; Thinning

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1. Introduction

Much of past forestry research has focused on obtaining information to increase the efficiency of wood commodity production. Consequently, the majority of past silvicultural research has been directed at treatments to hasten regeneration and improve the growth and wood properties of young trees (Smith et al., 1997; Nyland, 2002). Large, old trees were rarely included in this research agenda.

Interest in using silviculture to perpetuate the vigor and longevity of existing old trees is growing. This interest has arisen from the recognition that old trees are rare on the landscape (Bailey and Ide, 2001; Sesnie and Bailey, 2003), are a living testimony of past disturbance and climate change (e.g., Speer et al., 2001; Soulé and Knapp, 2006), provide unique wildlife habitat (Reynolds et al., 1992; Kelly et al., 1993; Humes et al., 1999; Mazurek and Zielinski, 2004; Molina et al., 2006), sequester carbon over centuries (Harmon et al., 1990), and provide spiritual inspiration to many people (Ostlund et al., 2005). In, dry, fire-prone, forests of the western U.S., Fiedler (2000) recommended that stands containing old trees receive priority for fuel-reduction treatments because of their rarity and ecological importance, and because they are currently threatened by fire, competition stress, drought, and associated bark beetle attacks. This review focuses on old ponderosa pine (*Pinus ponderosa*), the dominant species of these forests (Hardin et al., 2001).

Definitions of old-growth ponderosa pine forests vary among authors and agencies, yet all emphasize the existence of old trees (Kaufmann et al., 1992). For example, attributes of old-growth ponderosa pine forests include containing trees with a diameter at breast height (DBH) greater than 41 cm and at least 200 years old in the Front Range of the Rocky Mountains, DBH greater than 41 cm and at least 160 years old in the Black Hills, South Dakota, and DBH greater than 46 cm and at least 160 years old in Arizona and New Mexico (Mehl, 1992). The mean age of ponderosa pines in old-growth stands in Arizona and New Mexico is about 279 years, with the oldest known tree 742 years old (Swetnam and Brown, 1992). In southern Oregon, mean age of ponderosa pine in two mixed confer stands ranged from 230 to 315 years, with the oldest tree over 400 years (Agee, 2003; Perrakis and Agee, 2006). In Montana, mean age of ponderosa pine in old-growth mixed conifer stands ranged from 179 to 374 years with the oldest tree over 450 years (Arno et al., 1995, 1997; Keeling and Sala, unpublished data). Trees older than about 400 years in remote unlogged areas are rare, perhaps because of extensive mortality from severe drought in the late 1500s (Swetnam and Brown, 1992). In addition to age, crown characteristics differ between old and younger, but mature trees. Height growth is slow in old trees producing a flattened crown top compared to the more conical crown top of younger trees with more rapid height growth (Keen, 1936; Bond, 2000). In this review, we use the term ‘‘old’’ to refer to ponderosa pines that are at least 160 years old or have a DBH greater than 40 cm, and the terms ‘‘young’’ or ‘‘younger’’ to refer to trees that are less than 160 years of age or have a DBH less than 40 cm.

Old ponderosa pine in areas historically subjected to frequent low-severity fire regimes is currently threatened by several factors that are distinct from the logging that reduced their abundance over the past 150 years. The first of these factors is wildfire. Recent increases in wildfire activity and severity in the western U.S. that often kill old pines have been linked to temperature increases since the mid 1980s (Westerling et al., 2006) and fuel accumulation resulting from a century of fire exclusion (Habeck, 1994; Arno et al., 1995, 1997; Covington et al., 2001; Keane et al., 2002; Fulé et al., 2004; Moore et al., 2004). The increase in fuels due to fire exclusion, however, appears to be less predictable in old-growth forests of the northern Rocky Mountains relative to drier forests of the southwestern U.S. (Keeling et al., 2006). Increasing evidence also suggests that historic logging disturbance may also promote regeneration and increase fuel accumulation in the long-term beyond that caused by fire exclusion (Minnich et al., 1995; Kaufmann et al., 2000). In ponderosa pine forests where current fire regimes are clearly outside the historic range of variability, wildfire severity and frequency are expected to increase in the future in the western U.S. as temperatures rise and relative humidity decreases (Brown et al., 2004). Restoration treatments, consisting of thinning or prescribed burning to reduce fuels and modify fuel structure, have been recommended to reverse the current trend of large, stand-replacing wildfires (e.g., Covington, 2000; Fiedler, 2000; Fulé et al., 2001; Allen et al., 2002; Fitzgerald, 2005).

A second threat to old ponderosa pine is competition with mid- or under-story trees. This threat may be natural, or non-anthropogenic, in some mixed-species higher elevation forests containing ponderosa pine whose fire regime does not deviate much from historic variability (Brown et al., 1999; Schoennagel et al., 2004), but is of anthropogenic origin in regions where fire exclusion has increased tree density beyond its natural range of variability. For instance, increased tree density in the understory and in former openings and meadows over the last century of fire exclusion has increased competition between old and younger trees in some areas (Biondi, 1996; Feeney et al., 1998; Stone et al., 1999; McDowell et al., 2003). The use of silvicultural treatments to reduce competition stress on old trees is a relatively new idea (Harrington and Sackett, 1992;