Available online at www.sciencedirect.com
ScienceDirect
Forest Ecology and Management 255 (2008) 3141–3150
Forest Ecology and Management
www.elsevier.com/locate/foreco

Initial response of conifer and California black oak seedlings following fuel reduction activities in a Sierra Nevada mixed conifer forest

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Received 16 June 2007; received in revised form 27 October 2007; accepted 14 November 2007

Abstract

Forest structure, fuel characteristics, and fire regimes of mixed conifer forests in the Western United States (US) have been dramatically altered since the early 20th century. Fuel treatments have been suggested as a means to limit the size and intensity of wildfires but few experiments are available to analyze the ecological effects of different treatments. The objective of this study is to determine how mechanical, prescribed fire, and mechanical and fire combination fuel treatments affected seedling density by species in a Sierra Nevada mixed conifer forest. The relative influences of stand-level light availability and substrate quality on conifer and black oak seedling densities are assessed. For all species combined, seedling densities increased when the fire only treatment was applied and no change was detected for the other treatments. The fire only treatment as well as the combined fire plus mechanical treatment had the effect of significantly increasing Douglas-fir seedling density. Ponderosa pine seedling densities significantly increased when the fire plus mechanical treatment was applied. California black oak seedling density decreased when the fire only treatment was applied but no change was detected for the other treatments. Previous studies have found a decline in sugar pine and ponderosa pine in dense stands of Sierran mixed conifer forests. The findings reported here corroborate these studies in that current conditions are not conducive to recruitment of ponderosa pine and sugar pine species. Our initial results indicate, that in this case, treatments used to reduce fire hazard may not result in retention or recruitment of California black oak and sugar pine seedlings.

Keywords: Fuel treatments; Prescribed fire; Fire surrogates; Fire hazards; Regeneration; Wildfire

1. Introduction

Forest structure, fuel characteristics, and fire regimes of mixed conifer forests in the Western United States (US) have been dramatically altered since the early 20th century (Kilgore and Taylor, 1979; Biswell, 1989; Skinner and Chang, 1996; Swetnam, 1993; Graham et al., 2004; Stephens and Collins, 2004; Taylor and Beaty, 2005; Moody et al., 2006; Stephens et al., 2007). Sierra Nevada mixed conifer forests have experienced changes in fire regimes during the last 90–100 years; past harvesting practices, introduced pathogens such as white pine blister rust (*Cronartium ribicola* J.C. Fischh. Ex Raben) (van Mantgem et al., 2004), and changing climates are other factors that affect forest structure and potential fire behavior (Millar and Woolfenden, 1999; Millar et al., 2007). These factors have contributed to increased stand densities of shade tolerant species such as white fir (*Abies concolor* Gord. & Glend), incense-cedar (*Calocedrus decurrens* [Torr.] Floren.) and decreased recruitment of ponderosa pine (*Pinus ponderosa* Laws) and sugar pine (*Pinus lambertiana* Dougl.) throughout mixed conifer forests in the Sierra Nevada (Parsons and DeBendeetti, 1979; Beesley, 1996; Ansley and Battles, 1998; North et al., 2002; Taylor and Skinner, 2003; Franklin and Agee, 2003; Romme et al., 2003; Gray et al., 2005; van Mantgem et al., 2004; Schmidt et al., 2006).

Currently over 10 million ha of coniferous forests in the Western US are in moderate or high fire hazard condition classes (NWGC, 2001). Several recent fire policies and initiatives such as the National Fire Plan (USDA–USDI, 2000), 10-year comprehensive strategy (WGA, 2001), and Healthy Forest Restoration Act (USDA, 2004a) have been enacted to address the national US wildfire management problem (Stephens and Ruth, 2005; Husari et al., 2006). All of the statutes emphasize forest thinning, and to a lesser extent,

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0378-1127/$ – see front matter
doi:10.1016/j.foreco.2007.11.009

prescribed fire, as integral tools for reducing high fire hazards in Western US forests. The National Fire and Fire Surrogate Study (FFS) has implemented a series of controlled empirical experiments to study the effects of alternative fuel treatments on vegetation structure, fuel loads, and a suite of other ecological variables at 13 locations across the continental US (Weatherspoon and McIver, 2000). In this paper, we report results from the Blodgett forest FFS study site in the north-central Sierra Nevada, California.

Understanding the effects of mechanical and prescribed fire-based fuel treatments on conifer and hardwood recruitment is essential for long-term ecosystem management. Seedling establishment, the first stage of recruitment following a disturbance such as a fuel treatment, is fundamental in influencing stand dynamics and shaping future species composition and structure. As stands develop following treatments, so will associated effects on wildlife habitat, resilience, resistance to disturbance, and future seed sources. Multiple environmental factors interact to influence the timing and patterns of understory vegetation in Sierra Nevada forests (North et al., 2005; van Mantgem et al., 2006; Collins et al., 2007). At least two key abiotic factors influencing regeneration and hence future forest composition and structure in Sierra Nevada forests are the availability of germination substrate and sunlight (Oliver and Dolph, 1992; Gray et al., 2005). At Blodgett forest in the central Sierra, substrate and light availability are altered to varying degrees depending on the choice of silvicultural practice and the details of implementation. While each of the overstory species present can typically regenerate to some degree under a wide variety of silvicultural methods, species are thought to have different regeneration responses to some methods versus others (Laacke and Fiske, 1983). Numerous stand-level studies have indeed revealed general patterns of regeneration responses that allow managers to coarsely predict how species will respond to a given choice of traditional regeneration method (Burns and Honkala, 1990a).

Effects of traditional even and un-even aged silvicultural treatments and reserve (no active management) treatments have been previously studied at Blodgett Forest Research Station (Olson and Helms, 1996). None of these treatments were designed specifically for reduction of fire hazard nor included the use of prescribed fire for reduction of surface fuels (Stephens and Moghaddas, 2005c). Stand-level studies of fuel treatments are still needed to predict patterns of seedling regeneration following modern fuel reduction treatments proposed for broad implementation across Western US forests. Although not traditionally considered to be a regeneration treatment, these fuel treatments will nevertheless have a profound effect on regeneration and hence future stand composition and structure.

The objective of this study is to determine how four different experimental fuel treatments affected seedling density by species and to describe the relative influences of stand-level light availability and substrate quality on seedling densities. The four treatments include: (1) mechanical thinning and mastication, (2) prescribed fire, and (3) a combination of mechanical thinning, mastication, and prescribed fire, and (4) controls (no treatment). We tested for treatment effects at 4 years post-treatment.

2. Methods

2.1. Study area

This study was performed at the University of California Blodgett Forest Research Station (Blodgett forest), approximately 20 km east of Georgetown, California. Blodgett forest is located in the mixed conifer zone of the north-central Sierra Nevada at latitude 38°54′45″ N, longitude 120°39′27″ W, between 1100 and 1410 m above sea level, and encompasses an area of 1780 ha. Mixed conifer forests cover 3.2 million ha (7.8%) of California's land base (CDF, 2003). Tree species in this area include sugar pine, ponderosa pine, white fir, incense-cedar, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), and California black oak (*Quercus kelloggii* Newb.). Species present in minor abundance include tan oak (*Lithocarpus densiflorus* (Hook. & Arn.) Rehder), bush chinkapin (*Chrysolepis sempervirens* (Kell.) Hjelmg.), and Pacific madrone (*Arbutus menziezii* Pursh). Experimental units were very similar in terms of stand structure and species composition. Prior to treatment, there were no significant differences in species composition, quadratic mean diameter, tree density, surface fuel loads, and canopy cover between treatment types (Stephens and Moghaddas, 2005a).

Soils at Blodgett forest are well-developed, well-drained Haploxeralfs (Alfisols), derived from either andesitic mudflow or granitic/granodiorite parent materials (Hart et al., 1992; Moghaddas and Stephens, 2007). Cohasset, Bighill, Holland, and Musick are common soil series. Soils are deep, weathered, sandy-loams overlain by an organic forest floor horizon. Common soil depths range from 85 cm to 115 cm. Slopes across Blodgett forest average less than 30%.

Climate at Blodgett forest is Mediterranean with a summer drought period that extends into the fall. Winter and spring receive the majority of precipitation which averages 160 cm (Stephens and Collins, 2004). Average temperatures in January range between 0 °C and 8 °C. Summer months are mild with average August temperatures between 10 °C and 29 °C, with infrequent summer precipitation from thunderstorms (averaging 4 cm over the summer months from 1960 to 2000) (Stephens and Collins, 2004). Precipitation during the study (2003–2006) varied between 62% and 150% of the average 42-year rainfall record at UC Blodgett forest.

Fire was a common ecosystem process in the mixed conifer forests of Blodgett forest before the policy of fire suppression began early in the 20th century. Between 1750 and 1900, median composite fire intervals at the 3–5 ha spatial scale were 6–14 years with a fire interval range of 2–29 years (Stephens and Collins, 2004). Forested areas at Blodgett forest have been repeatedly harvested and subjected to fire suppression for the last 90 years reflecting a management history common to many forests in California (Laudenslayer and Darr, 1990; Stephens, 2000) and elsewhere in the Western US (Graham et al., 2004).