Available online at www.sciencedirect.com
ScienceDirect
Forest Ecology and Management 255 (2008) 3130–3140
Forest Ecology and Management
www.elsevier.com/locate/foreco

Understory vegetation response to thinning and burning restoration treatments in dry conifer forests of the eastern Cascades, USA

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Received 5 October 2007; received in revised form 13 December 2007; accepted 10 January 2008

Abstract

Restoration/fuel reduction treatments are being widely used in fire-prone forests to modify stand structure, reduce risks of severe wildfire, and increase ecosystem resilience to natural disturbances. These treatments are designed to manipulate stand structure and fuels, but may also affect understory vegetation and biodiversity. In this study, we describe prescribed fire and thinning treatment effects on understory vegetation species richness, cover, and species composition in dry coniferous forests of central Washington State, U.S.A. We applied thinning and prescribed fire treatments in factorial design to 12 large (10 ha) management units, and surveyed understory vegetation before treatment and during the second growing season after treatment completion. Many understory vegetation traits changed significantly during the treatment period, regardless of treatment applied, and changes were often proportional to pre-treatment condition. In general, cover declined and species richness increased during the treatment period. Thinning followed by prescribed fire increased species richness, particularly in areas where species richness was low initially. Thinning alone had a similar, but lesser effect. Forb richness was increased by thinning, and shrub richness was increased by the combined thin/burn treatment, but graminoid richness was unaffected. Exotic cover and richness also increased in the combined thin/burn treatment, although they constituted only a very small portion of the total understory. Understory plant cover was not affected by treatments, but did decline from pre- to post-treatment sampling, with cover losses highest in areas where cover was high prior to treatment. Forb cover increased with thinning followed by burning where forb cover was low initially. Burning reduced graminoid cover with or without thinning. Species composition varied within and among treatment units, but was not strongly or consistently affected by treatments. Our study shows that thinning and burning treatments had mostly neutral to beneficial effects on understory vegetation, with only minor increases in exotic species. However, the pre-treatment condition had strong effects on understory dynamics, and also modified some responses to treatments. The maximum benefit of restoration treatments appears to be where understory richness is low prior to treatment, suggesting restoration efforts might be focused on these areas.
Published by Elsevier B.V.

Keywords: Restoration; *Pinus ponderosa*; Ponderosa pine; Exotic species; Thinning; Burning; Species richness

1. Introduction

The prospect of increasingly widespread use of fuel reduction treatments to manage wildfire hazards in fire-prone forests has highlighted the need for a better understanding of the broad range of effects of these treatments on ecosystem structure and function (Allen et al., 2002). Fire exclusion, livestock grazing, and logging practices have combined to alter forest structure and composition and ecosystem functions in many fire-prone forest types of North America over the past century or more (Cooper, 1960; Covington and Moore, 1994; Harrod et al., 1999; Keane et al., 2002; Hessburg et al., 2005). Changes in forest structure and composition have also altered fire regimes, increasing risks of insect and disease outbreaks (Hessburg et al., 2005) and high severity wildfires (Fulé et al., 2002; Fiedler et al., 2003; Hessburg et al., 2005). As concern over large, stand-replacing fires has grown, forest managers have increasingly turned to prescribed fire and fire surrogate treatments such as mechanical thinning to modify forest structure, reduce surface fuels, and thereby reduce risks of severe wildfire (Arno et al., 1995; Covington et al., 1997; Fiedler et al., 2001; Allen et al., 2002). Although intended primarily to manage potential fire behavior and forest health, these treatments could also impact other aspects of forest ecosystems, including understory vegetation diversity, species composition, and cover. The purpose of this study was to

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0378-1127/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.foreco.2008.01.026

evaluate the individual and combined effects of mechanical thinning and prescribed fire on understory vegetation in dry coniferous forests of the eastern Cascade Mountains of Washington State.

Understory vegetation contributes to a wide variety of ecosystem functions (Allen et al., 2002; Kerns et al., 2006) and comprises the vast majority of plant biodiversity (Gildar et al., 2004; Wayman and North, 2007). Thinning and prescribed fire can serve as disturbance processes, modifying understory vegetation by damaging or killing plants, releasing resources, creating establishment sites for colonizing species and expanding populations, and promoting germination of seeds stored in soil and canopy seed banks (Whelan, 1995; Kaye and Hart, 1998; Huffman and Moore, 2004; Gundale et al., 2005). Thinning and prescribed burning may also alter understory vegetation indirectly by altering overstory tree cover and density and their effects on understory microclimate, light, soil water, and nutrient availability. Such overstory–understory interactions have been shown to be important in many fire-prone forest and savanna ecosystems (Moir, 1966; Ffolliott and Clary, 1982; Uresk and Severson, 1989; Riegel et al., 1992; McPherson, 1997; Scholes and Archer, 1997; Naumburg and DeWald, 1999).

Empirical studies of thinning and prescribed fire effects on understory vegetation have produced mixed results. For example, thinning has increased species richness (Wienk et al., 2004; Metlen and Fiedler, 2006) and reduced species richness (Metlen et al., 2004) in dry coniferous forests. Similarly, prescribed fire has increased species richness (Huisinga et al., 2005), reduced species richness (Fulé et al., 2005; Collins et al., 2007), or had no significant effect (Metlen et al., 2004; Metlen and Fiedler, 2006). Treatment effects on understory plant cover can also vary among graminoids, forbs, and shrubs, suggesting differences in tolerances to disturbance (Metlen et al., 2004; Metlen and Fiedler, 2006; Moore et al., 2006; Collins et al., 2007). Treatment effects may be realized over different time scales, as vegetation may be highly resilient to some disturbance impacts (Metlen and Fiedler, 2006), while other treatment effects may cause slower but persistent changes in vegetation structure and composition (McConnell and Smith, 1970). Understory vegetation responses to treatment likely depend on pre-treatment site conditions (Fulé et al., 2005), disturbance season and intensity (Emery and Gross, 2005; Knapp et al., 2007), and the degree to which overstory stand structure is modified (McConnell and Smith, 1970; Abella and Covington, 2004).

Recently, invasion by exotic plants has been increasingly emphasized as a threat to dry forest restoration success (Harrod, 2001; Sieg et al., 2003; Keeley, 2006). Thinning and prescribed fire may facilitate exotic species invasions by disturbing existing vegetation, exposing mineral soil, facilitating the spread of propagules, reducing shading, and increasing soil resource availability (Hobbs and Huenneke, 1992; Davis et al., 2000; Harrod, 2001; Leishman and Thomson, 2005; Keeley, 2006). Indeed, experimental studies have confirmed that thinning and burning treatments in dry forests can lead to increases in exotic species (Griffis et al., 2001; Wienk et al., 2004; Fulé et al., 2005; Dodson and Fiedler, 2006; Collins et al., 2007), although this is not universally the case (Fulé et al., 2002; Fornwalt et al., 2003; Metlen et al., 2004; Knapp et al., 2007). Further research is needed in dry coniferous forests to distinguish understory responses that are relatively consistent from those that are limited to certain regions, forest types, or sites.

The Fire and Fire Surrogates (FFS) network study was initiated in 1999 with 13 sites established in fire-prone forests throughout the U.S. to address the effects of fuel reduction and forest restoration treatments on ecosystem attributes. Understory vegetation responses have already been documented in eastern Oregon (Metlen et al., 2004; Youngblood et al., 2006), Montana (Metlen and Fiedler, 2006; Dodson and Fiedler, 2006) and California (Collins et al., 2007; Knapp et al., 2007). Here, we examine the effects of thinning and prescribed fire restoration treatments, applied alone and together, on understory vegetation in ponderosa pine/Douglas-fir forests of the eastern Washington Cascades at the Mission Creek FFS site. Specific research questions were:

(i) Do treatments significantly alter understory plant species richness, total cover, or species composition?
(ii) Do treatment effects vary for major plant life-forms (graminoids, forbs, and shrubs)?
(iii) Do treatments increase the abundance (species richness or cover) of exotic plant species?

2. Methods

2.1. Study sites

The Mission Creek study area is located in the eastern Cascade Range of Washington State at approximately 47°25′N latitude and 120°32′W longitude and is managed by the Okanogan-Wenatchee National Forest. Study sites are within the Mission and Peshastin Creek watersheds west of Cashmere, Washington. Forests are dominated by ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) with grand fir (*Abies grandis*) present to abundant in some stands. Common understory species include *Carex geyeri*, *Calamagrostis rubescens*, *Symphoricarpos albus*, *Spiraea betulifolia* and *Rosa* spp. (*Rosa gymnocarpa*, *Rosa nutkana* and *Rosa woodsii*). Soil parent material is primarily non-glaciated sandstone intermixed with some shale and conglomerate (Tabor et al., 1982). Typical soil types found in the area include Haploxerepts, Haploxerolls, Argixerolls, and Haploxeralfs (Soil Survey Staff, 1995).

The climate features warm, dry summers and cool, wet winters. Long, dry summers create extended periods with low fuel moisture and high wildfire potential. Similar nearby forests within the Wenatchee National Forest burned every 6–7 years prior to Euro-American settlement, but mean fire return intervals have increased considerably during the past century (Everett et al., 2000). The nearest weather station with complete records for the duration of the study (Plain, about 32 km north of the study site) has about 68 cm of precipitation annually with