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Thinning and chipping small-diameter ponderosa pine changes understory plant communities on the Colorado Front Range

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ABSTRACT

Novel fire mitigation treatments that chip harvested biomass on site are increasingly prescribed to reduce the density of small-diameter trees, yet the ecological effects of these treatments are unknown. Our objective was to investigate the impacts of mechanical thinning and whole tree chipping on *Pinus ponderosa* (ponderosa pine) regeneration and understory plant communities to guide applications of these new fuel disposal methods. We sampled in three treatments: (1) unthinned forests (control), (2) thinned forests with harvested biomass removed (thin-only), and (3) thinned forests with harvested biomass chipped and broadcast on site (thin + chip). Plots were located in a ponderosa pine forest of Colorado and vegetation was sampled three to five growing seasons following treatment. Forest litter depth, augmented with chipped biomass, had a negative relationship with cover of understory plant species. *In situ* chipping often produces a mosaic of chipped patches tens of meters in size, creating a range of woodchip depths including areas lacking woodchip cover within thinned and chipped forest stands. Thin-only and thin + chip treatments had similar overall abundance and species richness of understory plants at the stand scale, but at smaller spatial scales, areas within thin + chip treatments that were free of woodchip cover had an increased abundance of understory vegetation compared to all other areas sampled. Relative cover of non-native plant species was significantly higher in the thin-only treatments compared to control and thin + chip areas. Thin + chip treated forests also had a significantly different understory plant community composition compared to control or thin-only treatments, including an increased richness of rhizomatous plant species. We suggest that thinning followed by either chipping or removing the harvested biomass could alter understory plant species composition in ponderosa pine forests of Colorado. When considering post-treatment responses, managers should be particularly aware of both the depth and the distribution of chipped biomass that is left in forested landscapes.

1. Introduction

Fuels reduction treatments are becoming widespread on federal, state, and local lands across the western United States. Fire hazard reduction treatments continue to be completed throughout the ever-expanding wildland–urban interface to reduce the risk of home, property, and infrastructure damage from wildfire. Also, managers are increasingly prescribing forest restoration treatments in many western forests to return them to a more ecologically appropriate and sustainable condition; many of these forests have experienced dramatic increases in the density of small-diameter trees and in the occurrence of large stand-replacing wildfires due, in part, to a century of fire suppression. In *Pinus ponderosa* (ponderosa pine) forests, fire hazard reduction and forest restoration are often compatible goals that can be achieved by removing small trees and by reinstating natural fire cycles (Allen et al., 2002; Kaufmann et al., 2003). Management options for reducing stem densities remain limited, however. Strict air quality regulations and the risk of fire escape restrict the use of prescribed fire, and a dearth of markets for small-diameter timber makes traditional harvesting practices economically impracticable.

To overcome these barriers to implementing fuels treatments, a variety of novel management techniques that dispose of small-diameter trees by shredding (masticating) or chipping harvested biomass *in situ* are now commonly applied throughout conifer forests of North America (Six et al., 2002; Stephens and Moghaddas, 2005; Fettig et al., 2006; Glitzenstein et al., 2006). According to a 2005 survey of forest managers, chipping and

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mastication treatments impact tens of thousands of acres each year in Colorado alone (S.G. Resh, U.S. Forest Service Rocky Mountain Research Station, personal communication). Whole tree chippers are one of the most widely available forestry tools used for mulching small-diameter trees, yet little information is available on the ecological impacts of broadcast chipping in wildland settings.

Thinning and chipping biomass on site reduces stem densities and ladder fuels in a manner similar to other mechanical fire mitigation treatments, but the impact of simultaneously opening the tree canopy and adding chipped woody debris to the forest floor is likely to have unique impacts on conifer regeneration and understory vegetation. Understory plant community responses to thinning treatments likely depend on how much of the overstory canopy cover is removed. Mitchell and Bartling (1991) found that understory vegetation production increased as ponderosa pine canopy cover decreased along the Front Range of Colorado. In other ponderosa pine forests, thinning has been found to increase the abundance and species richness of herbaceous understory vegetation (Naumburg and DeWald, 1999; Laughlin et al., 2006; Metlen and Fiedler, 2006), but not always (Metlen et al., 2004). By facilitating recovery of the herbaceous layer, thinning often helps to achieve restoration objectives in many ponderosa pine forests (Covington et al., 1997; Allen et al., 2002). However, thinning operations that remove all harvested material from the site typically reduce ground cover of litter and duff and increase the amount of exposed soil within the treatment area, creating favorable habitat for many aggressively colonizing understory herbaceous plants, including non-native invaders (Dodson and Fiedler, 2006). Given the prevalence of non-native species in lower elevation *P. ponderosa* forests prior to restoration treatments (Fornwalt et al., 2003), it is imperative that managers understand how non-native species respond to new management practices.

While opening forest canopies tends to promote vigorous understory growth, adding chipped biomass to the forest floor litter layer may reduce light and substrate availability, limiting opportunities for germination and growth of new propagules (Knapp and Seastedt, 1986). On the other hand, chipped biomass may increase soil moisture retention and moderate seasonal and diurnal variation in soil temperatures (Gower et al., 1992; Greenly and Rakow, 1995), which creates more favorable growing conditions for plants that are able to establish. Over time, the addition of chipped material to the forest floor is likely to change the understory plant community composition as individual species uniquely respond to its presence. After the eruption of Mt. St. Helens in 1980, Antos and Zobel (1985a,b) found that the ability to reproduce vegetatively was an important characteristic of plants that were successful following burial from tephra and volcanic ash. Additionally, Lezberg et al. (1999) found that rhizomatous species may be able to persist in dense coniferous forests over long periods of time better than species that lack the ability for vegetative spread. These studies suggest that the simultaneous disturbances of adding chipped biomass to the forest floor and opening up the tree canopy may create a unique set of circumstances inhibiting some species and favoring others in the understory community.

We examined conifer regeneration and responses of understory plant communities to thinning and spreading chipped biomass in ponderosa pine forests three to five years following treatment in the Front Range of Colorado. We hypothesized that thinned stands with harvested biomass removed, where light levels and exposed mineral soil favor regeneration, would contain more ponderosa pine seedlings than other treatments. We also expected that thinning would increase the cover and species richness of understory vegetation under each fuel disposal method compared to unthinned forests, and that increasing woodchip depths would decrease cover and species richness of understory vegetation. Finally, in thinned and chipped treatments we expected unique plant community assemblages compared with other treatments, characterized by increased relative cover and richness of rhizomatous species and reduced non-native species abundance.

2. Methods

2.1. Study site

This study was conducted at the Heil Valley Ranch (HVR), which is owned and managed by Boulder County Parks and Open Space. The forested, 1992 ha property is located approximately 5 km northwest of Boulder, Colorado (Fig. 1a). Climate is characterized by generally cool and dry winters with warm summers. Average minimum January temperature at the city of Boulder weather station (1672 m elevation) is −6.3 °C, with average highs of 7.5 °C. July is the warmest month with average maximum temperatures of 30.9 °C and lows of 14.8 °C. Average annual precipitation is 486 mm and the wettest months are April and May. Precipitation is relatively well distributed throughout the growing season from early spring through late fall (WRCC, 2008), with summer and fall precipitation dominated by short and often intense rain events. Soft surface recreational trails and an improved dirt road that is restricted to infrequent motorized travel by Boulder County employees are located within the study site at the HVR.

2.2. Study design

Boulder County acquired the HVR property in 1994 and subsequently designated a contiguous block of 141 ha of forest for future thinning, with the dual purposes of creating a large fire break and restoring historic forest structure. To facilitate implementation of the thinning project by private contractors, Boulder County divided the 141 ha into ten smaller stands ranging in size from 7 ha to 30 ha. Stand boundaries were established with regard to recreational trails and existing road access. The thinning prescriptions for all thinning treatments stipulated removal of all ponderosa pine individuals under 15 cm diameter at breast height (DBH). The thinning treatments differed by stand only in the fate of the removed biomass, which was determined by contractor preference and capabilities.

All thinning was implemented via chainsaw felling and hand crew or all-terrain vehicle skidding. In treatments where biomass was chipped, felled trees were fed through a Morbark Hurricane 18 WCL brush chipper (Morbark, Inc., Winn, Michigan) or similar model brush chipper towed by a pickup truck or ATV, and broadcast throughout the stand to an average depth of 7.5 cm and no greater than 15 cm. In treatments where biomass was removed from the site, ATV or hand skidding was used to forward logs to designated landings where they were locally chipped or hauled away. Stands were treated between 2000 and 2004.

Stands selected for study were at least three years post-treatment at the time sampling was initiated in 2005. Stands were classified into three treatment categories: (1) unthinned stands (*control*); (2) thinned stands with harvested biomass removed from the site (thin-only); and (3) thinned stands with harvested biomass chipped and distributed on the site (thin + chip). Pre-thinning forest conditions and environmental characteristics were similar throughout all stands selected for study (Chad Julian, Boulder County Parks and Open Space, personal communication), characterized by even aged forests strongly dominated (>95%) by