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Shrub removal in reforested post-fire areas increases native plant species richness

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ABSTRACT

Large, high severity fires are becoming more prevalent in Sierra Nevada mixed-conifer forests, largely due to heavy fuel loading and forest densification caused by past and current management practices. In post-fire areas distant from seed trees, conifers are often planted to re-establish a forest and to prevent a potential type-conversion to shrub fields. Typical reforestation efforts promote conifer survival and growth by reducing competing shrub cover, yet the effects of these practices on plant species richness and composition are not well understood. We compared the effects of treatment and time since fire on (1) native and exotic plant species richness, (2) plant community composition, and (3) stand structure. Plots were installed throughout three different aged but proximate fires located in the canyon of the South Fork of the American River in California, 10, 22, and 41 years after fire. All three fires included large patches of stand-replacing fire that had been reforested with conifers as well as unplanted areas. Native plant species richness was significantly higher in planted areas where shrub cover was lower and planted trees successfully established. Native species richness decreased as time since fire increased, but the relationship between shrub control and richness persisted. Exotic species richness was higher on treated sites in the more recent fires, while the opposite was true in the oldest fire. As time since fire increased, understory species composition shifted from a community dominated by annuals and perennials to one dominated by shrubs and shade-tolerant trees. Shrub cover and July soil moisture were the top two factors influencing understory richness levels. Natural regeneration was low in the youngest fire and high in the oldest fire but highly heterogeneous in all three fires. Our study suggests that while retaining some shrub cover for post-fire habitat may be desirable, some level of shrub reduction does favor native plant richness and overall herbaceous cover.

1. Introduction

Sierra Nevada mixed-conifer forests are experiencing an unprecedented increase in the number and size of stand-replacing fires (Miller et al., 2009; Miller and Safford, 2012; Mallek et al., 2013). While fire has always played an integral role in maintaining the structure and resilience of these forests, the increase in fuels and stand density over the past century due to logging and fire suppression (van Wagtendonk and Fites-Kaufman, 2006; Fites-Kaufman et al., 2007; Lydersen et al., 2013; Safford and Stevens, in press) has led to an increase in fire severity – a measure of biomass loss to fire – as well as high-severity patch size, thus increasing the distance to adequate seed sources necessary for forest re-establishment (Bonnet et al., 2005; Donato et al., 2009). In the Sierra Nevada, high intensity fire also initiates the germination and establishment of highly competitive shrub species – especially from the genera *Ceanothus* and *Arctostaphylos* – that quickly become dominant in high burn severity sites and can remain dominant for several decades to a century or more (Cronemiller, 1959; Kauffman and Martin, 1991; Nagel and Taylor, 2005; Lauvaux et al., 2016). As mixed-conifer forests continue to experience large, stand-replacing fires, land managers must determine which silvicultural practices are most effective for promoting forest re-establishment while retaining some shrub habitat and a diverse herbaceous understory.

A major focus of silvicultural methods has long been the maximization of wood production by manipulating developing forest

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tree stocking. To reach desired stocking rates more quickly in post-fire environments, land managers often employ silvicultural techniques that enhance establishment, survival, and growth of desirable tree species (Graham and Jain, 2004). While post-fire reforestation can include a number of management practices (e.g., salvage logging, tree propagation and planting, etc.), tree seedling survival and growth often require early control of competing vegetation (Zhang et al., 2006, 2008; McDonald and Fiddler, 2010). Since the focus of forest management is typically the health and survival of (usually conifer) trees, relatively few studies have focused on how understory species richness and composition are altered by post-fire management practices (DiTomaso et al., 1997; McGinnis et al., 2010; Kayes et al., 2011; Leverkus et al., 2014). In Sierra Nevada mixed-conifer forests, most plant species are found in the understory and herbaceous understory plants are important sources of wildlife, livestock, and human foodstuffs (Weeden, 1996; Potter, 1998, 2005) while also providing other ecosystem services such as ground cover, nutrient cycling, and essential wildlife habitat (Beedy, 1981; Hagar, 2007; Kuhn et al., 2011).

Competition for water and light is one of the main factors determining the future stand dynamics of a burned landscape (Halpern, 1989; Vilá and Sardans, 1999; Royo and Carson, 2006; DeSiervo et al., 2015). Initially, availability is high following stand-replacing fire (Noble and Slatyer, 1977; Grime, 1977), but as vegetation becomes denser, competition increases. Many shrub species consume high levels of soil water (Royce and Barbour, 2001), often outcompeting herbs and small trees in the initial years after disturbance. Where seed sources are available and sites remain disturbance free, growing trees can eventually overtop competing shrubs to create a low light and low soil moisture environment which reduces the abundance of shrubs and other species in the understory (Schoonmaker and McKee, 1988). Common management practices such as post-fire logging, herbicide application and grubbing (hand removal of competing plants) can greatly modify these competitive dynamics and have a significant long-term influence on the developing forest and its understory community (McDonald and Everest, 1996; Nagel and Taylor, 2005; Bataineh et al., 2006; Abella and Springer, 2015). While shrubs may be strong competitors with regenerating trees, they were certainly not absent in pre-Euroamerican settlement forests (average shrub cover in such forests has been estimated at 15–30% [Knapp et al., 2013; Safford and Stevens, in press]) and shrubs provide important ecological services such as habitat provision for small mammals and birds (Converse et al., 2006; Humple and Burnett, 2010) and some species are major nitrogen fixers (Delwiche et al., 1965; Oakley et al., 2006).

We conducted a field study to determine how post-fire reforestation affects understory plant species richness and composition in areas that were severely burned and reforested at three different times in the past. We hypothesized that vegetation control in reforestation areas would increase both native and exotic species richness through its positive effect on light and water availability. Since post-fire reforestation in California encompasses a suite of components that are almost always carried out in concert our study aimed to measure the outcome of the treatment regime rather than each element separately. To do this we compared the effects of treatment and time since fire by looking at three categories of plant responses: (1) richness of native and exotic plant species, (2) understory plant community composition, and (3) characteristics of overstory stand structure. The three fires selected for this study occurred within 25 km of each other, burned predominantly in mixed-conifer forest and were 10, 22 and 41 years old at the time of study, providing insights into three different temporal stages of post-fire development.

2. Methods

2.1. Study area

Our study was conducted in the Eldorado National Forest (ENF), which is located in the central Sierra Nevada (Fig. 1) of California. Elevation of the study area ranged from 1365 m to 2075 m. The climate is Mediterranean with cold, wet winters and warm, dry summers. Annual precipitation in the area ranges from 100 cm to 180 cm, with most of it falling between October and April as rain or snow, depending on the elevation (National Climatic Data

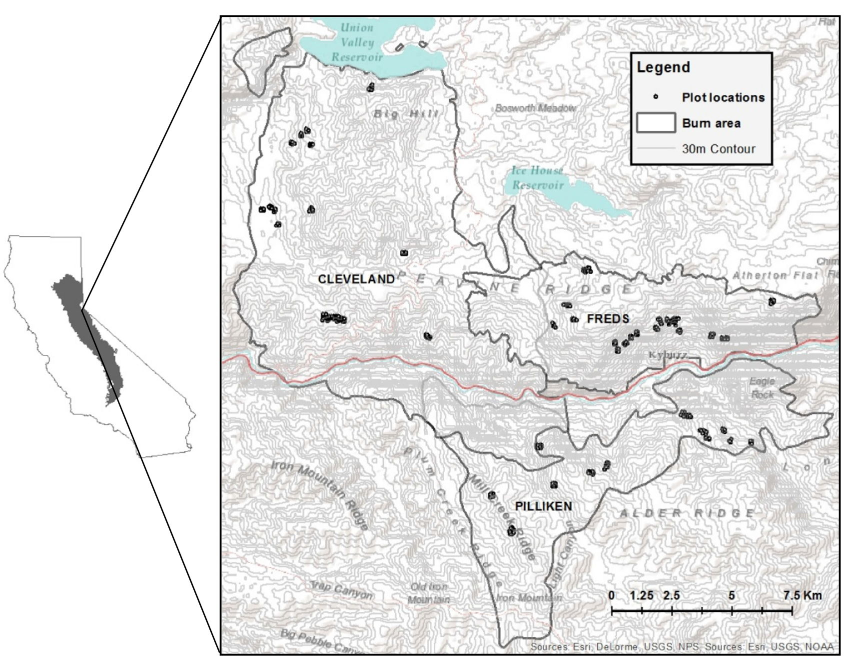

Fig. 1. Location of study sites in the Eldorado National Forest, CA, with the three studied fires identified.