Forest Ecology and Management 310 (2013) 847–856

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Natural forest floor clearings around trees in Jeffrey pine forests reduce tree damage and mortality following wildfire

Sarah E. Dalrymple [a,*], Hugh D. Safford [b,c]

[a] Department of Evolution and Ecology, One Shields Ave, University of California, Davis, CA 95616, USA
[b] USDA-Forest Service, Pacific Southwest Region, Vallejo, CA 94592, USA
[c] Department of Environmental Science and Policy, University of California, Davis, CA 95616, USA

ARTICLE INFO

Article history:
Received 10 July 2013
Received in revised form 14 September 2013
Accepted 17 September 2013
Available online 15 October 2013

Keywords:
Fire
Pinus jeffreyi
Litter accumulation
Fire severity
Tree mortality
Clearing

ABSTRACT

In the western United States, trees in pine-dominated forests historically characterized by frequent, low severity wildfires often support deep litter and duff accumulations due to the fire exclusion policies of the last century. These accumulations at the bases of trees can smolder for long periods of time after the passage of fire, which can result in high temperatures, cambial injury, and subsequent tree mortality. As a result, prescribed fire prescriptions often call for the manual removal of litter and duff from the bases of large trees by raking or other means before fire is applied. Here we report on the presence of naturally formed, circular clearings in the soil surface litter layer that occur around the bases of tree boles in seasonally dry forests dominated by *Pinus jeffreyi* (Jeffrey pine) in eastern California and Baja California (along the eastern edge of the North American Mediterranean-climate zone). We show that such clearings significantly reduce fire severity and tree mortality in surface fires. In the Lake Tahoe Basin (LTB) study area, Jeffrey pine individuals surrounded by clearings experienced much lower bole char heights, and were 1/3 as likely to support crown torching as individuals lacking the clearings; mortality of Jeffrey pine lacking clearings was more than five times higher than individuals surrounded by clearings. Clearings also reduced mortality in incense cedar and white fir. Data from both the LTB and Inyo National Forest (INF) study areas show that clearings are larger and much more common in forests that have recently burned at low severity. In both locations, natural clearings around trees were about four times more common, and existing clearings about three times wider, in recently burned versus long unburned (>60 years) sites. Logistic regression models show that clearing size, specifically the percentage of tree bole surrounded by a clearing, is an important predictor of Jeffrey pine survivorship in low to moderate severity fires, but clearing measures have never been included in previously published assessments of tree survival. We suggest that these previously unreported clearings are important features of Jeffrey pine and related semiarid forests and we recommend that more in-depth studies be made of their occurrence, formation, and ecological relationships.

1. Introduction

In many North American forest ecosystems where fire once occurred frequently, the exclusion of wildfires during most of the 20th century has led to major changes in forest structure, forest composition, and forest fuel loadings (Agee, 1993; Sugihara et al., 2006). As a result, the overall probability of wildfire in these forests has decreased, but increases in forest fuels and forest density have led to higher probabilities of high severity, "stand replacing" events if and when fire occurs (McKelvey and Busse, 1996). This pattern has been particularly evident in the southwestern US and California, where forests historically experienced frequent, low- to moderate-intensity fires (Miller et al., 2009; Dillon et al., 2011). An unfortunate outcome of these trends is the increasing loss of large, old "legacy" trees to fire, even in controlled, prescribed fire scenarios. Many decades of fire suppression have led to thick accumulations of litter, duff (older, partially decomposed litter) and fine woody debris at the bases of such trees, which can smolder for long periods of time after the passage of fire, resulting in a long residence time of damaging temperatures and subsequent cambial injury. The trees that survive this damage will be stressed and may subsequently succumb to bark beetle attack (Covington et al., 1997; Hood, 2010; Kolb et al., 2007).

In western US forests dominated by ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*Pinus jeffreyi*), the common occurrence of deep litter and duff mounds at the base of older trees has led to the recommendation to remove or reduce basal fuels before

* Corresponding author. Present address: Division of Biology, University of Tennessee, Knoxville, TN, USA. Tel.: +1 865 696 4124.
E-mail address: sdalrymp@utk.edu (S.E. Dalrymple).

0378-1127/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.foreco.2013.09.032

conducting prescribed fire, or as a component of fuels treatment practices in preparation for eventual wildfire (e.g., Thomas and Agee, 1986; Covington et al., 1997; Kolb et al., 2007; Hood, 2010). Typically, such removals or reductions involve a raking treatment, where fuel accumulations at the base of trees are physically dragged away from the bole. Several studies have experimentally investigated the effectiveness of raking treatments at reducing tree mortality during prescribed fires. In one of these, Nesmith et al. (2010) found that raking treatments increased survival by 9.6% in sugar pine (*Pinus lambertiana* Douglas), but only when fire intensity was moderate. In two other studies, prescribed fires burned at low intensities and caused little to no mortality, but raking treatments eliminated cambial kill in both ponderosa and Jeffrey pine trees (Hood, 2007; Fowler et al., 2010). In comparison, 17% of unraked ponderosa pine trees had cambial kill (Fowler et al., 2010) and the cambial kill rating in unraked Jeffrey pine trees was between 0.3 and 1.9 (Hood, 2007). In another study, removing fuels from the bases of small-diameter ponderosa pine trees prior to a prescribed fire resulted in a dramatic reduction in mortality (van Mantgem and Schwartz, 2004). Thus there is considerable evidence that manually reduced basal fuel loads can protect both large and small trees from fire damage.

Here we describe circular clearings, free of litter and duff, that occur *naturally* (i.e., without the aid of manual removal) around the bases of some trees in Jeffrey pine forests along the eastern edge of the North American Mediterranean-climate zone (also widely known as the "California Floristic Province"). Throughout the paper we refer to these features as "natural clearings" or simply as "clearings." The width of natural clearings varies, but they usually extend less than 1 m from the tree bole and completely surround the tree (Fig. 1a). No previous study has described these interesting features, but we have observed them in semi-arid conifer forests throughout most of the geographic range of Jeffrey pine, from 40.3°N latitude at the northern edge of the Sierra Nevada, through the southern Sierra Nevada to the Peninsular Ranges of southern California and northern Baja California, Mexico. In most cases, our observations of natural clearings around trees come from forests that recently experienced nonlethal fire, from either low severity wildfire or prescribed burning. These clearings contrast strikingly with fuel accumulations around neighboring trees, which can be many centimeters thick (Fig. 1b). In light of the detrimental effects that accumulated basal fuels can have on trees when fires occur, we hypothesized that trees with these natural clearings should experience lower mortality and lower levels of physical fire damage from natural or prescribed fires.

Following the Angora Fire, which burned >1200 ha of Jeffrey pine-dominated forest in the Lake Tahoe Basin in June 2007, we found evidence that some trees had clearings before the fire occurred. Specifically, we observed rings of unburned soil surrounding the bases of >50% of the trees in burned areas that had previously been "treated" for fuels, where "treatments" involved mechanical and hand thinning, followed by pile burning and/or prescribed burning (Safford et al., 2009). The recognition of these features was facilitated by the strong color contrast between the light gray sand in the rings and the blackened litter layer and soil organic component surrounding them (Fig. 1c); other trees in the same areas were missing this feature entirely (Fig. 1d). We inferred that the rings of unburned soil were the remnants of clearings that had been in place before the fire, and confirmed this assumption after finding clearings around trees in treated areas just outside the fire perimeter as well. The Angora Fire thus provided a unique opportunity to compare the effects of fire between trees with and without natural clearings.

Since no other study has documented or described these natural clearings, another research objective was to determine what causes clearings to form around trees. Based on early observations that linked clearing occurrence with recent fire activity, we focused specifically on the role that fire may play in creating or maintaining clearings. We hypothesized that fire initially creates clearings by consuming (and therefore removing) fuel on the forest floor. Thus we predicted that clearings around trees would be more common and/or larger in recently burned areas.

In this contribution, we document the existence of naturally-occurring clearings in Jeffrey pine forest and briefly describe some of their defining features. We also describe observational studies performed in the Lake Tahoe Basin in the area impacted by a recent wildfire (the Angora Fire), and on the Inyo National Forest, in an area of forest with a history of prescribed fire. The objectives of

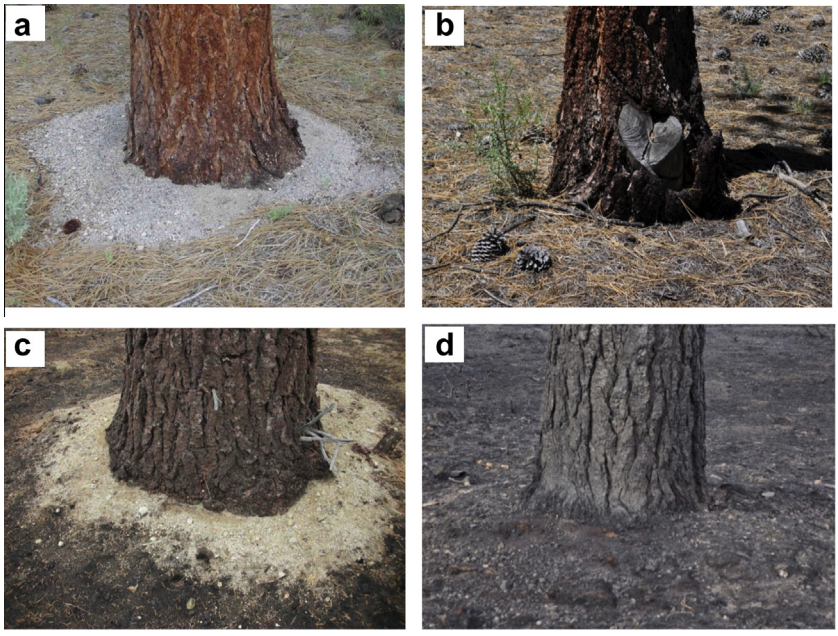

Fig. 1. (a) Tree with a basal clearing in an unburned forest in the Lake Tahoe Basin. (b) Tree with remnants of a basal clearing following the Angora fire. (c) Tree lacking a basal clearing, with several inches of accumulated litter and duff adjacent to the tree trunk. (d) Tree that had no clearing in place, in the aftermath of a fire.