Forest Ecology and Management 370 (2016) 56–64

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Post-fire logging produces minimal persistent impacts on understory vegetation in northeastern Oregon, USA

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ARTICLE INFO

Article history:
Received 11 December 2015
Received in revised form 26 March 2016
Accepted 1 April 2016
Available online 5 April 2016

Keywords:
Post-fire logging
Salvage logging
Understory vegetation
Species richness
Biodiversity
Post-fire forest management

ABSTRACT

Post-fire forest management commonly requires accepting some negative ecological impacts from management activities in order to achieve management objectives. Managers need to know, however, whether ecological impacts from post-fire management activities are transient or cause long-term ecosystem degradation. We studied the long-term response of understory vegetation to two post-fire logging treatments – commercial salvage logging with and without additional fuel reduction logging – on a long-term post-fire logging experiment in northeastern Oregon, USA. We sampled understory plant cover and species diversity on 10–11 sampling plots within each of nine experimental treatment units to see if post-fire logging treatments produced any lasting effects on understory plant cover, species diversity, community composition, or exotic species cover. Post-fire logging treatments produced no significant effects on understory vegetation cover, diversity, or community composition 15 years after treatment. We found no significant treatment effects on graminoid, forb, woody plant, or exotic plant cover and species richness, and differences among treatment means were generally small. Differences in treatment means were larger at the individual species level, but were only statistically significant for one native grass, California brome (*Bromus carinatus*), which responded differently to the two logging treatments. Multivariate analysis of understory plant communities across 91 sample plots found two major gradients in understory plant community composition, one correlated with regenerating forest (sapling) density and one correlated with residual overstory tree density, suggesting that initial fire severity (tree mortality) and post-fire regeneration may have greater long-term impacts on post-fire understory vegetation than post-fire logging. This study demonstrates that understory vegetation can be resilient to post-fire logging, particularly when best management practices, like logging over snow, are used to limit damage to soils and understory vegetation. Further research is needed to establish the generality of our results and to identify sources of variability in understory plant community responses to wildfire and post-fire logging. If further research confirms our findings, post-fire logging debates will be able to focus more on how to mitigate short-term disturbance impacts and manage fire-killed trees to meet wildlife habitat, fuel reduction, and economic objectives, and less on concerns over long-term ecosystem degradation.

Published by Elsevier B.V.

1. Introduction

Post-fire forest management commonly requires balancing competing social–ecological resource interests and deciding whether to accept short-term ecological impacts to achieve management objectives. For example, harvesting fire-killed trees quickly after wildfire can provide economic benefits to communities impacted by fire (Prestemon et al., 2006; Lowell et al., 2010), reduce future surface woody fuels (Ritchie et al., 2013; Peterson et al., 2015), hasten forest regeneration through artificial regeneration (Sessions et al., 2004; Newton et al., 2006), and promote long-term carbon sequestration in forest products (Apps et al., 1999; Stockman et al., 2012). However, fire-killed trees (standing and fallen) also provide habitat functions for a wide variety of organisms, influence soil carbon and nutrient cycling processes, and modify soil and surface microclimates for tree seedlings and understory vegetation (Harmon et al., 1986; Smith, 2000; Brown et al., 2003; Boulanger and Sirois, 2007; Hutto, 2008; Marañón-Jiménez et al., 2013). Given recent trends toward larger wildfires

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http://dx.doi.org/10.1016/j.foreco.2016.04.004
0378-1127/Published by Elsevier B.V.

(Westerling et al., 2006; Dennison et al., 2014), there may increasingly be enough fire-killed trees on landscapes after large wildfires to meet wildlife habitat needs and also allow some harvesting to meet other resource objectives. In those cases, post-fire logging decisions will focus more on assessing and balancing the short- and long-term resource costs and benefits.

Logging is a form of disturbance (*sensu* White and Pickett, 1985), so we would expect post-fire logging to alter community structure and the physical environment to some extent. Indeed, previous studies have shown that post-fire logging can increase soil disturbance and erosion, alter the cover and composition of recovering native vegetation, damage natural tree regeneration, and increase surface woody fuels within 2–4 years after fire and logging (Klock, 1975; Stuart et al., 1993; McIver and Starr, 2001; Purdon et al., 2004; McIver and McNeil, 2006; Donato et al., 2006; Keyser et al., 2009; Ritchie et al., 2013; Slestak et al., 2015; Wagenbrenner et al., 2015). Disturbance impacts on forest ecosystems can diminish as ecosystems recover, however, so longer-term impacts of post-fire logging may differ from short-term impacts (e.g., Kurulok and Macdonald, 2007; Ritchie et al., 2013; Peterson et al., 2015). Longer-term studies of post-fire logging impacts are needed to determine whether post-fire logging produces only short-term disturbance impacts or if post-fire logging impacts exceed ecosystem resilience thresholds and alter trajectories of post-fire recovery and succession (Gunderson, 2000; Beschta et al., 2004; Brewer et al., 2012; Kishchuk et al., 2015).

In this study, we assessed possible long-term effects of post-fire logging treatments on understory vegetation recovery and succession by surveying understory vegetation cover and diversity on a previously established post-fire logging experiment. Our study was conducted 18 years after the wildfire and 15 years after logging treatments were completed. We assessed vegetation recovery in terms of understory plant cover, community composition, and species richness, asking if post-fire logging treatments produced persistent effects on understory plant cover and diversity, exotic plant cover and diversity, or plant community composition that were still detectable 15 years after treatment. Based on previous studies, we hypothesized that logged sites would support lower plant cover and plant species diversity than unlogged sites. However, we also anticipated that post-disturbance vegetation recovery processes would reduce or eliminate at least some of the impacts commonly observed shortly after treatment, helping us to identify areas of persistent negative impacts.

2. Materials and methods

2.1. Site description

The study area is located within the area burned by the 1996 Summit Fire, which burned about 16,000 ha in northeastern Oregon, USA (McIver and McNeil, 2006; McIver and Ottmar, 2007). Soils are mostly rocky, clay-loam to clay soils, but some soils also have a layer of Mt. Mazama ash (McIver and McNeil, 2006; McIver and Ottmar, 2007). Slopes in the study area ranged from 10 to 25 percent, with south to southwest aspects (McIver and Ottmar, 2007). Mean daily temperatures range from −2 °C in January to 18 °C in July, while mean annual precipitation is about 520 mm, much of which falls as snow between November and April (PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu/explorer/, accessed on October 20, 2015).

The study area supports dry coniferous forests that were historically dominated by ponderosa pine (*Pinus ponderosa*), but with some Douglas-fir (*Psuedotsuga mensiezii*) and grand fir (*Abies grandis*) trees also present (McIver and McNeil, 2006). Historically, dry ponderosa pine forests in the region burned frequently and at predominantly low severity, with mean fire return intervals of 14–16 years reported for the period 1687–1900 (Heyerdahl et al., 2001). Like many dry coniferous forests in the region, reductions in fire frequency and extent and increases in logging and cattle grazing likely altered forest structure and fuels during the 20th Century, combining to produce denser stands with smaller trees and higher surface fuel loads than were typical historically (Hessburg and Agee, 2003; McIver and Ottmar, 2007). These altered stand structural conditions promote higher fire severity. Of the 8103 ha of the Summit Fire that burned on the Malheur National forest, 72% burned at high severity (>80% of overstory trees killed; McIver and Ottmar, 2007).

2.2. Experimental design and treatments

The original post-fire logging study included four treatment blocks with three treatment units per block. These 12 treatment units ranged in size from 6 to 16 ha. Treatment blocks were located in separate drainages, each with a perennial stream. We limited our sampling to the first three treatment blocks (9 treatment units) of the original study because the fourth block (Wray Creek) re-burned in the 2008 Sunshine wildfire. Ponderosa pine was the dominant overstory species in two of the treatment blocks. In the third block, ponderosa pine and Douglas-fir were codominant in one treatment unit, while Douglas-fir and grand fir were codominant in the other two units (McIver and Ottmar, 2007).

Three experimental treatments (control, commercial logging, and commercial plus fuel reduction logging) were randomly assigned to one treatment unit in each of the treatment blocks, using a complete randomized block design (McIver and Ottmar, 2007). The control treatment was not logged after fire. The commercial post-fire logging treatment called for removing about 2/3 of the dead merchantable trees, but leaving at least 17 snags/ha greater than 30 cm DBH. The commercial plus fuel reduction logging treatment called for removing most dead merchantable trees (retaining at least six snags/ha greater than 30 cm DBH) and also removing most non-merchantable small trees (10–29 cm DBH). The commercial logging treatment was designed to reflect typical logging operations, with retention of some wildlife snags, while the commercial plus fuel reduction logging treatment was designed to remove merchantable material and reduce residual woody fuel mass and future wildfire severity. Logging was conducted between October 1998 and August 1999, and was limited to periods with frozen or dry ground to minimize soil compaction and disturbance. Commercial treatment units were entered once (commercial timber sale), while fuel reduction treatment units were entered twice (commercial timber sale followed by a service contract to remove smaller trees). McIver and Ottmar (2007) provide additional details about the logging methods and subsequent forest regeneration activities.

2.3. Data collection

The original experiment used a grid of permanent sample plot centers (hereafter, grid points) placed at 50-m intervals in each treatment unit, leaving at least a 50-m buffer around the treatment unit boundary. Because of size differences, treatment units contained 14–47 grid points. For this study, we randomly selected 10–11 grid points from each unit for understory vegetation sampling in summer 2014. At each selected grid point, we established two parallel 10-m sampling transects, four meters apart and oriented parallel to the slope contour, thereby delineating a 40-m^2 (4-m by 10-m) rectangular sampling plot centered on the grid point.

We assessed plant cover, by species, using the line-point intercept (LPI) method, with LPI sampling points placed at 20-cm