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Seasonal burning of juniper woodlands and spatial recovery of herbaceous vegetation

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ABSTRACT

Decreased fire activity has been recognized as a main cause of expansion and infilling of North American woodlands. Piñon-juniper (*Pinus-Juniperus*) woodlands in the western United States have expanded in area 2–10-fold since the late 1800s. Woodland control measures using chainsaws, heavy equipment and prescribed fire are used to restore big sagebrush (*Artemisia tridentata* Nutt.) steppe plant communities and reduce woody fuel loading. Immediate objectives in the initial control of piñon-juniper are; (1) recovery of perennial herbaceous species to restore site composition, structure and processes (resilience) and resist invasion and dominance by invasive annual grasses (resistance) and (2) reducing woody fuel accumulations. Spanning a 7 year period (2006–2012), we compared herbaceous recovery following cutting and prescribed fire on three sites in mid and late succession western juniper (*Juniperus occidentalis* spp. *occidentalis* Hook.) woodlands in southeast Oregon. Treatments were untreated controls, partial cutting followed by fall broadcast burning (SEP), clear-cut and leave (CUT), and clear-cut and burn in winter (JAN), and spring (APR). Cover of herbaceous species was measured in three zones; interspace, litter mats around tree stumps (stump), and beneath felled trees. In interspace zones of all treatments, comprising between 51% and 63% of site areas, perennial bunchgrasses dominated two sites and co-dominated with invasive annual grasses at one site after treatment. Burning in the JAN treatments, when fuel moisture and relative humidity were high and temperatures cooler, reduced disturbance severity in stump and felled tree zones, which maintained perennial herbaceous understories and prevented or limited the presence of invasive annuals. Burning felled juniper in SEP and APR treatments resulted in moderate to high fire severity in stump and felled tree zones. At two sites, these fires consumed all fuel up to the 1000-h fuel class, largely eliminated herbaceous perennials, and created islands within treatments that enhanced annual grass invasion and dominance. To maintain or boost site resilience and resistance following control of late successional woodlands, reducing piñon-juniper fuels by burning in winter provides managers with a low-impact option for conserving sagebrush steppe.

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1. Introduction

Semi-arid lands occupy 12.2% of the terrestrial world and many have been significantly altered as a result of land use demands, herbivory, altered fire regimes, invasive species, environmental changes, and woodland expansion (FAO, 1989; UNSO/UNDP, 1997). Woodland expansion and infilling in grasslands, shrublands and savannahs are problematic due to reductions in herbage for livestock and wildlife habitat modification, which may be detrimental to wildlife populations and diversity (Brown and Archer, 1989; Burrows et al., 1990; MacDonald and Wissel, 1992; Van Auken, 2000; Davies et al., 2011). In North American, reduced fire frequency has been recognized as a main cause of woodland development (Burkhardt and Tisdale, 1976; Archer et al., 1988; Miller and Wigand, 1994; Miller and Rose, 1995). Prescribed fire and mechanized treatments are used to eliminate trees to maintain or restore grass and shrub ecosystems (Owens et al., 2002; Miller et al., 2005; Teague et al., 2010; Roundy et al., 2014).

Piñon-juniper (*Pinus-Juniperus*) expansion in the western United States has caused widespread conversion of riparian, sagebrush (*Artemisia tridentata* Nutt.) steppe, and other upland communities to conifer woodland (Miller et al., 2005). In the northern Great Basin and Columbia Plateau, western juniper (*Juniperus occidentalis* ssp. *occidentalis* Hook.) woodlands have increased from 0.3 million to nearly 4 million ha the past 120–150 years (Miller et al., 2005; Johnson and Miller, 2008). Potential undesirable effects of woodland development include greater soil erosion and

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reduced water infiltration (Reid et al., 1999; Pierson et al., 2007; Petersen et al., 2009), loss of wildlife habitat (Noson et al., 2006; Reinkensmeyer et al., 2007), and reduced shrub and herbaceous diversity and productivity (Miller et al., 2005; Coultrap et al., 2008; Bates et al., 2005, 2011).

Thus, control of expanding woodlands is an important management action that conserves sagebrush steppe and other plant communities (Davies et al., 2011). Eliminating the influence of piñon-juniper by prescribed fire or mechanical methods is a straightforward task, however, recovery of desirable herbaceous species is influenced by several factors including the woodland successional phase, the method of tree control and treatment of woody fuels, post-treatment floristics, and other site characteristics (e.g. soils, climate) (Miller et al., 2005; Condon et al., 2011; Bates et al., 2013, 2014). Site characteristics are important for forecasting resilience and resistance especially when impacted by disturbances and stressors including fire, drought and invasive species (Chambers et al., 2014a,b). Areas with higher precipitation, cooler temperatures, and intact native plant communities tend to regain their structure and ecological processes (resilience) after disturbance or stressor events, and are better able to retain these attributes (resistance) compared to drier–warmer areas and those with less intact plant communities (Chambers et al., 2015). Severe disturbances can reduce resilience and resistance and may cause a shift from desirable to undesirable plant communities dominated by invasive weeds (Bates et al., 2013). It is vital that managers tailor selection and application of woodland control treatments appropriate to an area to result in successful plant community recovery.

Two objectives in the initial control of piñon-juniper woodlands are; (1) recovery of native perennial herbaceous species to maintain or restore site structure and processes, and resist invasion and dominance by exotic annual grasses, and (2) mitigation of fuel accumulations during or following woodland treatment (Miller et al., 2005; Huffman et al., 2009; O'Connor et al., 2013). Moderating disturbance severity and treating woodlands in earlier successional phases when accumulations of woody biomass are lower are the best means of achieving these objectives (Miller et al., 2005; Baughman et al., 2010; Chambers et al., 2014a, 2015; Bates et al., 2013). In later successional phases use of fire alone to control trees is riskier because the increase in woody biomass generates fires of greater severity than the historic regime and may increase the risk of weed dominance because of high mortalities of native herbaceous perennials (Tausch, 1999; Bates et al., 2006, 2011, 2013; Condon et al., 2011). Therefore, these woodlands are often mechanically cut, anchor chained, or shredded. Downed trees are commonly treated by various fuel reduction methods including dormant season (October–March) and early spring burning and burning of machine or hand piled trees. In the event of wildfire, fuel treatments reduce fire intensities, rate of spread, and scorch heights (Stephens, 1998; O'Connor et al., 2013). Three distinct zones are created from juniper cutting; interspace areas, areas beneath felled trees, and juniper litter mats surrounding the stumps. The arrangement and treatment of woody fuels often results in differing spatial and temporal recovery of vegetation (Vaitkus and Eddleman, 1987; Bates and Svejcar, 2009; Haskins and Gehring, 2004). Dormant season burning of piñon-juniper appears to offer the best combination for reducing woody fuels and maintaining desirable vegetation (Bates and Svejcar, 2009; O'Connor et al., 2013; Bates et al., 2014). However, comparisons of vegetation response to fuel treatments across sites as well as spatial and longer-term herbaceous recovery have been limited in piñon-juniper woodlands.

We evaluated the spatial response of herbaceous life-forms to seasonal burning of mechanically cut western juniper over a 7-year period (2006–2012) in three distinct plant communities in eastern Oregon. Our expectations were that; (1) herbaceous cover would increase in response to cutting and burning trees and (2) the various treatments would result in understory compositional differences among interspace, beneath felled trees, and litter mat zones. We were interested in the temporal dynamics of the response and the potential for treatments to cause a shift from desirable native perennials to invasive annuals.

2. Methods and materials

2.1. Study sites

In 2006, three study sites were located in southeast Oregon; two on Steens Mountain (Bluebunch, Fescue), 80 km south of Burns and one site at the Northern Great Basin Experimental Range (NGBER), 57 km west of Burns. The Bluebunch and Fescue sites were Phase 3 woodlands as juniper was the dominant vegetation. The NGBER site was a late Phase 2 woodland because trees co-dominated with shrub and herbaceous plants. Woodland phase was classified using criteria developed by Miller et al. (2000, 2005).

The Bluebunch site (42°56′10″N, 118°36′30″W) was located on a west aspect (slope 15–22%) at 1550 to 1600 m. The plant association was basin big sagebrush/bluebunch wheatgrass-Thurber's needlegrass (*A. tridentata* Nutt. spp. *tridentata* (Rydb.) Beetle/*Pseudoroegneria spicata* (Pursh) A. Löve – *Achnatherum thurberianum* (Piper) Barkworth). The ecological site is a Droughty Loam 11–13 (280–330 mm) PZ (precipitation zone) (NRCS, 2006, 2010). Prior to treatment, juniper canopy cover averaged 26% and tree density (>1.5 m tall) was 246 trees ha^{-1}. Sagebrush cover was less than 1%. The interspace was 95% bare ground. Perennial bunchgrasses and Sandberg's bluegrass (*Poa secunda* J Pres.) were the main understory species. The criteria developed by Chambers et al. (2014a,b, 2015) indicates that this site has moderate resilience and resistant scores because it is relatively warm and moist, has shallow soils, and the understory, though comprised of perennial grasses, had an evident presence of invasive annual grasses and forbs.

The Fescue site (42°53′25″N, 118°34′18″W) was an east facing slope (20–45%) at 1650–1730 m (Fig. 1). The plant association was mountain big sagebrush/Idaho fescue (*A. tridentata* Nutt. spp. *vaseyana* (Rydb.) Beetle/*Festuca idahoensis* Elmer). The ecological site was a North Slope 12–16 (304–406 mm) PZ. Juniper canopy cover averaged 31% and tree density averaged 289 trees ha^{-1}. Sagebrush cover was less than 2%. The interspace was 60% bare ground and Idaho fescue and perennial forbs were understory dominants. Criteria developed by Chambers et al. (2014a,b, 2015) indicates that this site has high resilience and resistant scores because it is relatively cool and moist, has deep-loamy soils, and an understory mainly comprised of deep-rooted perennial bunchgrasses and forbs.

The NGBER site (43°29′42″N, 119°42′33″W) was on a northeast slope (10–20%) at 1455–1480 m. The plant association was mountain big sagebrush/Idaho fescue and the ecological site was identified as a Droughty Loam 11–13 PZ. Prior to treatment, juniper canopy cover was 18% and tree density was 195 trees ha^{-1}. Sagebrush cover averaged 3 ± 0.9%. The interspace was 60% bare ground and Idaho fescue and perennial forbs were the main herbaceous species. The criteria developed by Chambers et al. (2014a,b, 2015) indicates this site has high resilience and resistant because it is relatively cool and moderately moist, has moderately deep loamy soils, and the understory was comprised of perennial bunchgrasses and forbs.

Precipitation in the northern Great Basin occurs mostly from late fall into spring. Water year precipitation (1 October–30 September) at the NGBER averaged 284 mm the past 75 years and during the study ranged from 182 to 335 mm. Water year