



Plant community response to prescribed fire varies by pre-fire condition and season of burn in mountain big sagebrush ecosystems



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ABSTRACT

Artemisia tridentata ssp. *vaseyana* ecosystems evolved with periodic fire, but invasive grasses, conifer encroachment, fire suppression, and climate change have resulted in altered fire regimes and plant communities. Post-fire increases in invasive annual grasses such as *Bromus tectorum* and reductions in native vegetation are common across the sagebrush steppe. Where fire has been excluded though, there are increases in the native tree *Juniperus occidentalis*, which outcompetes the native understory. We applied prescribed fire in spring and fall at three sites (native-dominated, *B. tectorum*-dominated, and *J. occidentalis*-dominated). We documented 65% survival of *A. tridentata* following fall burns and 33% survival following spring burns in native-dominated plots, with evidence of post-fire sprouting in *Purshia tridentata* and *Tetradymia canescens*. At the *B. tectorum*-dominated site, shrub cover was reduced to <1%. Fires at the *J. occidentalis* site were discontinuous, resulting in ~50% mortality of trees and shrubs, with little resprouting. Native herbaceous vegetation persisted following fires, with no increases in *B. tectorum*. There were higher plant survival rates following fall fires and native-dominated sites than in spring burns or where exotics dominated. These results show that burn season and prefire condition are important considerations when evaluating management alternatives in *A. tridentata* ssp. *vaseyana* ecosystems.

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1. Introduction

Fire is a critical part of ecosystem function in the vegetation communities of the sagebrush steppe (Miller et al., 2013). Anthropogenic alterations including urbanization, domestic livestock grazing, fire suppression, and introduction of exotic plants, however, have modified plant community assemblages and altered disturbance regimes (Miller and Eddleman, 2000; West, 2000). Additionally, increasing pressure to protect late-successional habitats for sagebrush-obligate species (Dahlgren et al., 2015; Murphy et al., 2013) and a rapidly changing climate further complicate fire management and planning efforts (Westerling et al., 2006).

Prior to Euro-American settlement, fires occurred approximately every 15–25 years in *Artemisia tridentata* ssp. *vaseyana* communities, and were often stand-replacement events (Miller and Rose, 1995). Lightning-ignited fires were common in late summer. In addition, indigenous groups used fire to maintain

desirable native food plants, for increased crop productivity, and to manage game species (Griffin, 2002; Shinn, 1980). Following settlement of the western United States by Euro-Americans, fire was used excessively, and combined with the introduction of livestock, resulted in degraded rangelands (Young and Blank, 1995). In response to these practices, policies were established by the early 1900's discouraging planned ignitions and requiring the suppression of wildfire (Clark and Starkey, 1990).

Plant community composition is impacted by altering fire regimes, as species better adapted to the new regime – often invasive and early successional species – thrive in the altered environment. In the sagebrush steppe, two circumstances arising from altered fire regimes are prevalent. Low elevation areas with low resilience due to low precipitation and warm soil moisture regimes (Miller et al., 2013) which were overgrazed by domestic livestock or otherwise degraded became susceptible to invasion (Chambers et al., 2007, 2014) by *Bromus tectorum* and other invasive grasses (Boyte and Wylie, 2016). These grasses have increased the potential for fires by providing a continuous, dry fuel source and lengthening the fire season (Paysen et al., 2000). Increased disturbances increase susceptibility to exotic invasion, and perpetuate a cycle of positive

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feedbacks between increased invasion and frequent fire (D'Antonio and Vitousek, 1992).

In contrast, fire return intervals in higher elevations of the Great Basin have been lengthened by fire suppression and removal of fine fuels by domestic livestock grazing (Burkhardt and Tisdale, 1976; Miller and Tausch, 2000). Prior to Euro-American settlement, expansion of *Juniperus occidentalis* (western juniper) is believed to have been limited by frequent fires, drought, and competition with grasses (Kilgore, 1981). Fire exclusion by suppression and reduction of fine fuels due to livestock grazing have contributed to expansion because young junipers (<3 m) do not often survive fire (Bunting, 1984). A fire return interval of ~50 years, longer than that often reported for this mesic end of the sagebrush steppe, is frequent enough to limit juniper expansion (Burkhardt and Tisdale, 1976). The current rate of *J. occidentalis* encroachment into bunchgrass and sagebrush sites exceeds rates of expansion from the 5000 years preceding (Miller and Wigand, 1994). Restoration in this ecosystem may require incorporating fire's natural role to maintain native plant communities and return structure and function to the ecosystem (Davies et al., 2011).

Plant species in the Great Basin have developed strategies to persist within the natural fire regime (Ellsworth and Kauffman, 2010; Wroblewski and Kauffman, 2003). Re-introduction of fire into intact *A. tridentata* ssp. *vaseyana* systems may maintain or restore native composition and structure (Pyle and Crawford, 1996). However, where invasive grasses are a dominant ecosystem component and anthropogenic influences have resulted in the loss of native species, fire may perpetuate or increase invasive dominance (Chambers et al., 2007), at least in the short term (Ellsworth et al., 2016; Miller et al., 2013).

Season of burn may be an important determinant of plant response to fire. Most naturally ignited fires in the sagebrush steppe coincide with frequent dry lightning during summer and early fall, but most prescribed fires are set late in the fall, after fuel moisture increases and likelihood of fire escape is reduced (Miller et al., 2013). Further, it is expected that fires that occur in the fall, after the active growing season, result in less direct mortality than growing season fires because live, moist plant tissue is more subject to heat-induced mortality than dormant tissue (Wright and Klemmedson, 1965). Direct comparisons between seasonal impacts of fire on individual plant species and plant communities are difficult and conclusions often inconsistent due to the confounding impacts of fire intensity and severity, weather conditions before and during prescribed burns, and the logistical challenges of implementing prescribed burning during the active fire season (Kauffman and Martin, 1990; Pyle and Crawford, 1996; Wright and Klemmedson, 1965). Where direct comparisons between seasons of burn have been made (i.e., Ellsworth and Kauffman, 2010; Pyle and Crawford, 1996; Wright and Klemmedson, 1965), results are highly variable and focus on individual plant mortality rather than plant community response. In this study, we quantified the differences in plant community composition following spring and fall prescribed fire treatments in sites differing in fire and disturbance history, elevation, and pre-fire plant composition, but all mapped as the same *A. tridentata* ssp. *vaseyana* plant community type (Erhard, 1979). The response of landscapes to fire is dependent upon on the condition of the site, the existing plant composition, and the soil seedbank which will generate postfire vegetation (Davies et al., 2008; Ellsworth and Kauffman, 2013). Our objective was to quantify vegetation compositional shifts following spring and fall prescribed fire in *A. tridentata* ssp. *vaseyana* ecosystems in different ecological conditions: 1) native-dominated- little past fire suppression or anthropogenic degradation 2) *B. tectorum*-invaded- intensive historic use and increase in fire frequency and 3) juniper-dominated- light historic land use but with successful fire suppression. We

hypothesized: 1) at all sites, fire would reduce woody species resulting in a postfire dominance of herbaceous vegetation; 2) native forbs and perennial bunchgrasses would respond more favorably to prescribed fires in the pristine and juniper dominated sites than in the *B. tectorum*-invaded site; 3) fall fires will result in increased cover of perennial bunchgrasses and native forbs than spring fires; and 4) more shrub cover will be retained after fall fires than spring fires due to increased heterogeneity of burn response during cooler weather. To test these hypotheses, we applied three prescribed burn treatments (spring, fall, unburned control) in a randomized block design in each of the three sites of differing ecological condition (native, *B. tectorum*-invaded, and juniper-dominated).

2. Methods

2.1. Study site

The study sites were located within the Lava Beds National Monument, California, 77 km southeast of Klamath Falls, Oregon. This area ranges in elevation from 1228 m along the shore of Tule Lake in the northeast to 1725 m at the southwest corner (Erhard, 1979). The climate is cool and semi-arid, with an average annual precipitation of 39 cm (Miller et al., 2003) and a mean temperature range from -1° C in January to 20° C in July. Most natural fires occur from July to September, when dry thunderstorms often coincide with high temperatures and low fuel moisture contents. The geology of the monument is unique, with basaltic lava flows and cinder cones scattered across the landscape. The monument is located on the north face of Medicine Lake shield volcano, which has erupted periodically over the last 500,000 years, and most recently erupted approximately 1100 years BP. Soils are of volcanic origin, shallow with basaltic outcrops (Erhard, 1979).

Five experimental blocks were established at each of three sites (Gillems Camp, Fleener Chimneys, and Merrill Caves; Fig. 1) at the Lava Beds National Monument. Sites were mapped as the same *Artemisia tridentata* ssp. *vaseyana* community type (Erhard, 1979) but with different land use histories and current species composition. Fleener Chimneys (pristine site) was dominated by native perennial grasses and forbs, with predominately *A. tridentata* ssp. *vaseyana*, *Tetradymia canescens* and *Purshia tridentata* in the overstory. There was a significant lava flow between this site and water, which likely limited historic domestic grazing. Merrill Caves (juniper-dominated site) was characterized by an overstory of *J. occidentalis*, with mostly native forbs and bunchgrasses in the herbaceous layer, and a reduction in the shrub layer. This site was also far away from surface water but close to the Monument headquarters, necessitating fire suppression in the area for structure protection. Gillems Camp (*B. tectorum*-invaded site) was located near the historic shore of Tule lake, had a history of degradation by domestic livestock grazing, and was dominated by *B. tectorum* and native bunchgrasses with a sparse cover of woody vegetation, principally *Ericameria nauseosa* (grey rabbitbrush).

We employed a randomized block design at each site to conduct the experiments. Each block (5 per site) contained three plots (each a minimum size of 0.25 ha) in which a spring and a fall prescribed fire treatment as well as an unburned control were randomly assigned. For each combination of site and season of burn, there were five replicate burn plots for a total of 30 burn plots (plus 15 unburned controls). There was a 5-m burned buffer around all burned plots.

Spring burns at Fleener Chimneys and Gillems Camp were conducted in June 2003. Due to weather constraints during 2003, spring burns at Merrill Caves were not conducted until June, 2004. Fall burns at all sites were conducted in November 2003. Each fire

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