Rangeland Ecology & Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Rangeland Ecology & Management

journal homepage: http://www.elsevier.com/locate/rama

Original Research

Vegetation Response to Juniper Reduction and Grazing Exclusion in Sagebrush-Steppe Habitat in Eastern Oregon☆

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ARTICLE INFO

Article history:
Received 23 August 2017
Received in revised form 17 November 2017
Accepted 21 November 2017
Available online xxxx

Keywords:
Artemisia tridentata
fuel loads
grazing effects
habitat restoration
juniper removal
medusahead

ABSTRACT

Western juniper expansion is one of the largest threats to conserving sagebrush steppe ecosystems in the northwestern United States. Juniper expansion has degraded the sagebrush steppe by altering fire regimes and outcompeting shrubs and herbaceous vegetation for limited resources. We characterized the effect of juniper removal in a severely degraded sagebrush steppe habitat for 3 yr following juniper cutting. In addition, we measured the effect of low-intensity seasonal grazing on plant community recovery through cattle exclusion treatments. We monitored plant community composition (exotic annual grasses, preferred grasses, preferred forbs, and shrubs); fuel loads; and juniper recruitment in a factorial design of juniper removal and grazing exclusion. We found that although there were significant differences between cut and uncut juniper treatments, there were no consistent trends across all 3 yr. Our results suggest that other factors, such as timing of precipitation, may also have strong short-term effects on plant community composition. We detected no significant grazing effects during the study period, suggesting the current grazing regime is appropriate for the area. The cutting of juniper increased total fuel loads and herbaceous fuel loads. Compared with open interspace, a twofold increase in juniper seedlings and saplings was detected beneath juniper piles, which will act as sources for future juniper encroachment.

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Introduction

The sagebrush (*Artemisia* spp.) steppe is currently threatened due to altered fire regimes, a legacy of historical overgrazing, understory invasion of non-native annual grasses, and the expansion of juniper (Noss et al., 1995; Knick et al., 2003; Davies et al., 2011). In the northwest range of big sagebrush steppe, the largest potential threat, western juniper (*Juniperus occidentalis*), has vastly expanded its range at a rate that is historically unprecedented (Miller et al., 1994; Miller and Wigand, 1994). This expansion has contributed to the degradation of sagebrush steppe ecosystems at mid to high elevation across western North America, primarily by decreasing the frequency of fire (Miller and Rose, 1999) and outcompeting shrubs and other understory plants for limited resources (Miller et al., 2000; Roundy et al., 2014b). Altered fire regimes further contribute to ecosystem degradation through increased erosion of top soils via runoff (Pierson et al., 2007, 2010) and by creating conditions congruent for exotic plant invasions (Brooks et al., 2004).

In eastern Oregon, <3% of western juniper are presettlement trees (i.e., >120 years old) (USDA-BLM, 1990) and the area of juniper woodland has increased from approximately 600 000 ha in the 1930s to 2.6 million ha in the 1990s (Azuma et al., 2005). This increase in junipers along with its cascading effects has negatively impacted some wildlife populations (see Bombaci and Pejchar, 2016 for a review), leading many sagebrush-dependent plant and animal species to be labeled as species of conservation concern (Dobkin and Sauder, 2004; Wisdom et al., 2005; Baruch-Mordo et al., 2013). Additionally, improper grazing management and the invasion by non-native grasses such as cheatgrass (*Bromus tectorum* L.), medusahead (*Taeniatherum caput-medusae* [L.] Nevski), and ventenata (*Ventenata dubia* [Leers] Coss.) have further decreased wildlife habitat (Miller and Eddleman, 2001; Rottler et al., 2015). In response to the loss of sagebrush steppe ecosystems, land managers have deployed approaches to restore ecological communities affected by these altered disturbance factors and regimes. Reduction of juniper density, specifically killing or mechanically removing post-settlement juniper trees, has been one commonly used management action, and short-term recovery (<3 yr) in juniper reduction treatments has recently been well studied. Increased soil water and nitrogen

☆ This project was funded by the Oregon Dept of Fish and Wildlife through Federal Aid in Wildlife Restoration (Pittman-Robertson) Grant F16AF00342.

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https://doi.org/10.1016/j.rama.2017.11.004
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Please cite this article as: Dittel, J.W., et al., Vegetation Response to Juniper Reduction and Grazing Exclusion in Sagebrush-Steppe Habitat in Eastern Oregon, Rangeland Ecology & Management (2017), https://doi.org/10.1016/j.rama.2017.11.004

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availability has been linked to increased preferred vegetation (e.g., native perennial grasses and forbs) cover and biomass compared with that of exotic grasses (Bates et al., 2000, 2002; Eddleman, 2002). A recent study (Williams et al., 2017) from the SageSTEP project (McIver and Brunson, 2014) found that juniper removal increased tall grass cover without increasing cheatgrass cover but did not affect shrub cover 3 and 6 yr post treatment. However, a previous study by Miller et al. (2014) on the same cut plots did not find any difference in perennial grass and forb density in the first 3 yr after treatment, suggesting vegetation response is delayed.

Grazing management in the sagebrush steppe has varied considerably through time. Early postsettlement grazing by European settlers was characterized by inappropriately high stocking rates, resulting in degraded rangelands across much of the sagebrush steppe (Covington et al., 1994). In 1934, the Taylor Grazing Act initiated regulation of livestock on public lands to prevent further degradation. Beginning in the 1940s, rotational grazing, seasonal rest periods, and reduced stocking rates were implemented to improve range quality. Modern grazing practices continue to improve in order to balance the needs of wildlife, native vegetation communities, and the socioeconomics of livestock production, and thus management regimes range widely in type, intensity, seasonality, and therefore, impacts to vegetation communities and wildlife habitats (Strand et al., 2014). Because domestic livestock grazing continues across the sagebrush steppe and overlaps with areas of juniper expansion and subsequent treatment, data are critically needed to fully understand the potentially interactive effects of grazing and juniper reduction treatments on invasion/recovery dynamics between annual grasses and native plants. The current lack of long-term data and of data on potential interactions may be resulting in the inappropriate management of juniper (Belsky, 1996).

The purpose of this study was to determine the individual and interactive effects of juniper reduction and exclusion of cattle grazing over multiple years on a degraded sagebrush steppe community. To achieve this, we collected plant community data 1 yr before treatment and for 3 yr following juniper treatment. We hypothesized that the combined effect of juniper reduction and elimination of cattle grazing would result in the largest increases in native plants, while the controls (no juniper cutting and grazing allowed) would show no difference in or continued degradation of the plant community when compared with pretreatment data. Furthermore, we hypothesized that intermediate treatments (no juniper reduction but grazing eliminated or juniper reduction but grazing allowed) would show intermediate levels of native rehabilitation. As second-tier objectives of this study, we monitored the biomass (fuel load) of herbaceous material and juniper duff within our study plots each year, as well as juniper recruitment to quantify the effects of management treatments on fire potential and future juniper reencroachment. We hypothesized that that biomass would be highest in ungrazed and cut plots due to the increase of plants and shrubs, and we expected ungrazed-uncut plots would have no change in biomass post treatment. Lastly, we hypothesized that downed juniper skeletons would protect juniper seedlings from the elements and herbivory, as well as provide microsites of higher soil moisture, thus increasing density of seedlings underneath them than in the open (between-tree) interspace.

Methods

Study Location

This study was conducted from 2012 to 2016 in the Phillip W. Schneider Wildlife Area (PWSWA) during the months of May and June. The PWSWA is 21 014 ha of primarily sagebrush-steppe habitat owned by the ODFW and located between the Ochoco and Malheur National Forests just south of Dayville, Oregon. Our study site was located in the Flat Creek area at the northeast portion of the PWSWA (~119.45 E, 42.42 N) in the foothills of the Aldrich Mountains at approximately 1 750 m. The study site has a semiarid climate with a 30-yr mean precipitation of 43.22 cm annually (PRISM Climate Group, 2004). During the study period, annual precipitation was 43.18 cm in 2012, 48.18 cm in 2014, 40.37 cm in 2015, and 37.97 cm in 2016 (PRISM Climate Group, 2004). Historically, this site would have been occupied by a sagebrush steppe plant community composed of big sagebrush (*Artemisia tridentata* Nutt.), low sagebrush (*Artemisia arbuscula* Nutt.) antelope bitterbrush (*Purshia tridentata* [Pursh] DC.), green rabbitbrush (*Chrysothamnus viscidiflorus* [Hook.] Nutt.), rubber rabbitbrush (*Ericameria nauseosa* [Pall. Ex Pursh] Nesom and Baird), lupine (*Lupinus* L. spp.), fescue (*Festuca* L. spp.), bottlebrush squirreltail (*Elymus elymoides* [Raf.] Swezey), and various wheatgrasses (*Elymus* L. spp. and *Pseudoroegneria* [Nevski] Á. Löve spp.). However, the PWSWA was historically overgrazed and most wildfires were suppressed (Oliver et al., 1994; Powell, 2008). This resulted in juniper expansion, spread of invasive grasses, and significant loss of topsoil (Oregon Department of Fish and Wildlife, 2006), leaving the site in phase II of juniper succession, in which shrubs and trees codominate the landscape, with a thinning shrub layer (Miller et al., 2005). Currently, ODFW is implementing a deferred rest-rotation grazing program within the two pastures of the Flat Creek area. Both pastures are about 800 ha and together allow for 13.3 ha per animal unit month (AUM). Flat Creek was last rested in 2013. Cattle have been allowed to graze during parts of May-June in both pastures every year since, but precise dates vary yearly. The study site includes several species of planted non-natives (crested wheatgrass; *A. cristatum,* small burnet: *Sanguisorba minor*); invasive grasses (cheatgrass, medusahead, and ventenata); and encroaching western juniper. In 2011 ODFW designated the Murderer's Creek Unit as a Mule Deer Initiative unit where ODFW wanted to focus efforts on improving mule deer populations (Oregon Department of Fisheries and Wildlife, 2011). Within the Murderer's Creek Unit, PWSWA was identified as critical wintering range for mule deer and in response ODFW is actively attempting to improve the wildlife area in efforts to reestablish viable wintering habitat for mule deer and other sage-steppe—dependent species while maintaining grazing and recreational uses of the land.

Experimental Design and Data Collection

In 2012 ODFW created six, 1-ha blocks within the study site, averaging 226 m between each block (min = 150 m). Blocks were placed nonrandomly, so they had similar north-facing aspects and slope (~4%). Blocks were initially divided in half (50 × 100 m), with one-half being fenced (ungrazed) and the other half remaining open (grazed). The exclosures were made with barbed wire fencing and were approximately 1.25 m in height. Barbed wire keeps cattle and resident feral horses out of the study plots but does not prevent mule deer *(Odocoileus hemionus)* or elk *(Cervus canadensis)* from entering. The blocks were then divided again (creating 50 × 50 m plots), in which all juniper were mechanically felled (cut) in one-half while in the other juniper were allowed to remain (uncut). Juniper cutting occurred March—April 2013 with chainsaws, and trees were left where they fell. This created four treatment plots within each block: grazed-cut (GC), grazed-uncut (GUC), ungrazed-cut (UGC), and ungrazed-uncut (UGUC) for a total of 24 study plots, with 6 replicates (1 per block) of each treatment type. Plots were randomly assigned within each block.

Within each plot, a single permanent 30-m transect was established in 2012 by randomly selecting a starting point and then semirandomly selecting a compass direction (i.e., transects could not exit the plot) to determine the end point. Start and end points were marked with 1.27-cm rebar stakes. These transects were used to collect annual reference data on percent cover of herbaceous and woody plants and approximate the number of shrubs within the plot, shrub cover, amount of downed woody material, and biomass. In May to early June of each sample year, we estimated point cover by recording the species of plants intersected by the transect at 0.5-m intervals and then divided by 60 (total number of points along the transect; Elzinga et al., 1998). Plants

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