#872

Rangeland Ecology & Management 69 (2016) 179–184

Contents lists available at ScienceDirect

Rangeland Ecology & Management

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

Effects of Using Winter Grazing as a Fuel Treatment on Wyoming Big Sagebrush Plant Communities☆

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ARTICLE INFO

Article history:
Received 2 October 2015
Received in revised form 14 December 2015
Accepted 21 December 2015
Available online 5 April 2016

Key Words:
Artemisia tridentata
cattle
exclosure
exotic annual grass
fire
fuel treatment

ABSTRACT

More frequent wildfires and incidences of mega-fires have increased the pressure for fuel treatments in sagebrush *(Artemisia)* communities. Winter grazing has been one of many fuel treatments proposed for Wyoming big sagebrush (*A. tridentata* Nutt. subsp. *wyomingensis* Beetle and A. Young) communities. Though fire risk and severity can be reduced with winter grazing, its impact on vegetation characteristics of Wyoming big sagebrush plant communities is largely unknown. We evaluate the effect of winter grazing at utilization levels between 40% and 60% at five sites in southeastern Oregon. Winter grazing was applied for 5–6 yr before measurements. The winter-grazed and ungrazed treatments generally had similar vegetation characteristics; however, a few characteristics differed. The consumption of prior years' growth resulted in less large perennial bunchgrass, perennial forb, and total herbaceous cover and standing crop and litter biomass. Large perennial bunchgrass and perennial forb density and biomass and exotic annual grass and annual forb cover, density, and biomass did not differ between treatments, suggesting that winter grazing is not negatively impacting resilience and resistance of these communities. Shrub cover was also similar between treatments. These results imply that winter grazing can be applied to reduce fine fuels in Wyoming big sagebrush communities without adversely affecting the native plant community. Winter grazing should, however, be strategically applied because the reduction in perennial grass and perennial forb cover with the consumption of prior years' growth may negatively impact the habitat value for wildlife species that use herbaceous vegetation for concealment.

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Introduction

Mega-fires have become increasingly common in the western United States with federal fire-suppression costs averaging approximately $1.5 billion annually from 2005–2014 (NIFC, 2015). For example, southeastern Oregon has had one or more mega-fires in 3 of the past 4 years. Suppression of these wildfires and postfire restoration is expensive with tens of millions of dollars expended per mega-fire. The loss of forage for several years post fire is also an economic hardship on livestock producers, with the majority of some ranches burning in a single fire. Recent mega-fires in the sagebrush steppe have also increased concerns for greater sage-grouse *(Centrocercus urophasianus)* and other sagebrush-associated wildlife, as well as threatened the resilience and resistance of Wyoming big sagebrush (*Artemisia tridentata* Nutt. subsp. *wyomingensis* Beetle and A. Young) plant communities. Fire in these communities has been identified as one of the primary threats to sage-grouse (USFWS, 2013) and can decrease the resilience to disturbance and resistance to exotic annual grass invasion (Chambers et al., 2007, 2014). Presuppression management of fuels is necessary to not only reduce the likelihood, size, and frequency of wildfire in Wyoming big sagebrush communities (Hulet et al., 2015) but also sustain the resilience and resistance of these communities in the absence of fire.

Grazing is a feasible treatment to effectively reduce fine fuels across vast rangelands to reduce fire risk and severity (Davies et al., 2015, in press), though strategically placed fuel breaks or green strips could provide opportunities to limit wildfires and a staging area for suppression (Omi, 1979; Pellant, 1994; Agee et al., 2000). Grazing, however, is not without risk and can be difficult to apply effectively. Improper grazing during the growing season can damage desirable plants and promote exotic annual grass invasion (Daubenmire, 1940, 1970; Mack, 1981; Knapp, 1996; Reisner et al., 2013). Grazing during the growing season can also be challenging because fine fuel production is unknown as plants are still growing, and in some years fuel-reduction goals may not be met because forage production exceeds the amount that can be consumed by available domestic herbivores (Schmelzer et al., 2014) and in other years fuel reductions may not be warranted because of limited forage production. Winter (dormant season) grazing eliminates some of these logistical constraints (Davies et al., 2015) as forage

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http://dx.doi.org/10.1016/j.rama.2015.12.005
1550-7424/Published by Elsevier Inc. on behalf of The Society for Range Management.

production is known and domestic herbivores are often more available, since the other option is often to feed them hay during this time period. Winter grazing can be a valuable tool to manage fine fuels as it reduces the probability of wildfire by reducing fine fuels and increasing fuel moisture during the wildfire season (Davies et al., 2015). It also decreases fire behavior and intensity, rate of spread, and area burned (Davies et al., in press).

Winter grazing is assumed to be less likely to damage native bunchgrass and perennial forbs than grazing during the growing season when defoliation can place grazed plants at a competitive disadvantage with nondefoliated plants (Caldwell et al., 1987; Briske and Richards, 1995; Holechek et al., 1998). Therefore, herbivory by cattle in the winter is generally anticipated to have limited impacts on native plant communities; however, little information is available to support this assumption. Winter grazing may also affect plant community dynamics through mechanisms other than defoliation. Forage quality during the winter, when herbaceous vegetation is largely dormant, is generally inadequate to meet the nutritional needs of livestock (Coppock et al., 1986; Ganskopp and Bohnert, 2001). To compensate for low-quality forage during the winter, cattle are often fed a supplement high in protein. Alfalfa (*Medicago sativa* L.) hay is a commonly used protein supplement for cattle wintering on rangelands (Vanzant and Cochran, 1994). Alfalfa hay may have a fertilization effect, which would likely favor exotic annuals (Wilson et al., 1996; Brooks, 2003). Unconsumed hay may also increase litter, which has been demonstrated to benefit exotic annual grasses (Evans and Young, 1970). The effects of grazing Wyoming big sagebrush plant communities in the winter are, therefore, largely unknown. This information is critical to properly managing Wyoming big sagebrush steppe plant communities because these plant communities are some of the least resilient sagebrush communities and are exceedingly difficult to restore (Davies et al., 2011; Chambers et al., 2014). In addition, these communities provide critical livestock forage and wildlife habitat in the western United States (Connelly et al., 2000; Davies et al., 2006, 2011).

The purpose of this study was to evaluate the effects of repeated winter grazing by cattle on Wyoming big sagebrush plant communities. We expect that repeated winter grazing with utilization between 40% and 60% will have minimal effects on Wyoming big sagebrush plant communities. However, we speculate that herbaceous perennial vegetation (current and previous years' standing growth) and litter cover will be lower because of the removal of previous years' growth in the winter-grazed compared with ungrazed treatments. If winter grazing is having minimal effects in these plant communities, then exotic annual grass, sagebrush, and annual forb cover and density and the density of perennial herbaceous vegetation will be similar between winter-grazed and ungrazed treatments.

Methods

Study Area

The study was conducted near Diamond, Oregon, United States in northern Great Basin (43°04′N, 118°40′W). Precipitation across the study sites averages 250–280 mm annually (NRCS, 2013). Precipitation mainly occurs in the cool season (winter-spring), and summers are typically dry and hot. Topography was generally flat, and elevation was approximately 1450 m. Study sites were Droughty Loam 11-13 PZ (R023XY316OR) and Sandy Loam 10-12 PZ (R023XY213OR) Ecological Sites (NRCS, 2013). Plant communities were sagebrush-bunchgrass steppe with Wyoming big sagebrush being the dominant shrub at all study sites. The dominant perennial bunchgrasses were Thurber's needlegrass (*Achnatherum thurberianum* [Piper] Barkworth) or Thurber's needlegrass codominant with bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve). Other common bunchgrasses included bottlebrush squirreltail (*Elymus elymoides* [Raf.] Swezey), Indian ricegrass (*Achnatherum hymenoides* [Roem. and Schult.] Barkworth), and Sandberg bluegrass (*Poa secunda* J. Presl.). Cheatgrass (*Bromus tectroum* L.), a naturalized exotic annual grass, was found in low abundance across the study area.

Experimental Design and Measurements

The effects of winter grazing by cattle on plant community characteristics were evaluated using a randomized complete block design with five blocks. Treatments were winter-grazed or ungrazed 50 × 50 m plots. Exclosures were 50 × 100 m in size and separated from the grazed plot by a 10-m buffer. The five blocks differed in vegetation and site characteristics, but treatment plots within blocks did not differ, except sagebrush density was greater in the grazed compared with ungrazed treatment before applying treatments (see Results). The ungrazed treatment was applied by constructing exclosures in ~ 800- to 1000-ha pastures in the fall of 2009. Blocks were located in areas that had a sagebrush overstory, had relatively intact herbaceous understory, were large enough for both treatments to occur on the same site characteristics, and were at least 100 m from a road to limit road effect. Exclosures were six-strand barbwire fences. Grazing was applied at the pasture level using cattle rotated among pastures between November and early April. Grazing was applied at the pasture level to be applicable to management scenarios. Utilization was between 40% and 60% based on forage biomass (Davies et al., 2015) and applied for 5–6 years before measurements. For additional information on grazing see Davies et al. (2015). Cattle were fed 2.7–4.5 kg of alfalfa hay per individual every other day as a protein supplement because the rangeland forage base during the winter is inadequate to meet their nutritional needs (Coppock et al., 1986; Ganskopp and Bohnert, 2001). Location where alfalfa hay was fed was different each feeding and dispersed across the pasture.

Vegetation cover and density, species richness, soil biological crust, bare ground, and litter cover were measured in June 2009 (pretreatment) and in June of 2014 and 2015. Four parallel 45-m transects spaced at 10 m were established in each plot. Herbaceous foliar cover and density were measured by species in 0.2-m^2 quadrats that were spaced at 3-m intervals along each 45-m transect, resulting in 15 quadrats per transect and 60 quadrats per plot. Herbaceous cover by species was estimated on the basis of markings that divided quadrats into 1%, 5%, 10%, 25%, and 50% segments. Herbaceous foliar cover estimates included current and previous years' standing growth. Total herbaceous cover was determined by summing species cover. Bare ground, soil biological crust, and litter cover were also estimated in the 0.2-m^2 quadrats. Density by species was determined by counting all plants rooted in the 0.2-m^2 quadrats. Shrub cover was measured by species using the line-intercept method (Canfield, 1941) along each 45-m transect. Shrub canopy gaps < 15 cm were included in cover estimates. Shrub density was measured by species by positioning a 2- × 45-m belt transect over each 45-m transect. Shrubs were counted if they were rooted in the 2- × 45-m belt transect. Species richness was determined from herbaceous and shrub density measurements. Biomass was measured in June of 2014 and 2015 by clipping herbaceous vegetation by functional group in 25 randomly located 1-m^2 quadrats in each treatment plot. Biomass data was not collected before treatments. Ground litter was also collected in the 1-m^2 quadrats. Clipped vegetation was oven dried for 72 hours, separated into current year's and previous years' growth, and then weighed. Standing crop was the summation of all herbaceous vegetation (current and previous years' growth) still standing.

Statistical Analyses

Repeated measures analysis of variance (ANOVA) with the mixed models procedure in SAS v. 9.2 (PROC MIXED SAS Institute, Inc., Cary, NC) was used to determine the effects of winter grazing on repeatedly measured plant community characteristics. Year was the repeated variable, treatment was considered a fixed variable, and block and block-by-treatment interactions were treated as random variables in analyses. Appropriate covariance structure was selected using Akaike's Information Criterion (Littell et al., 1996). Data that violated assumptions of ANOVAs were square root transformed. Nontransformed data (i.e., original data) were presented in the text and figures. ANOVA in SAS v. 9.2 was used to determine the effects of winter grazing on characteristics that were not repeatedly measured (i.e., pretreatment data). Herbaceous cover, density, and biomass were grouped into five groups for analyses: large perennial bunchgrasses, Sandberg bluegrass, perennial forbs, exotic annual grasses, and annual forbs. Sandberg bluegrass was analyzed individually because it develops earlier, is smaller in stature (James et al., 2008), and responds differently to disturbances than other native bunchgrasses in this ecosystem (McLean and Tisdale, 1972; Winward, 1980; Yensen et al., 1992). Large perennial bunchgrass group was composed of native bunchgrasses. Means were reported with standard errors (mean + S.E.) and considered different at $\alpha = 0.05$.

Results

Pretreatment

Before treatment, large perennial bunchgrass, Sandberg blue grass, exotic annual grass, perennial forb, and annual forb cover and density did not differ between treatments (data not shown; $P > 0.05$). Bare ground, litter, soil biological crust, and sagebrush cover also did not differ between grazed and ungrazed treatments (data not shown; $P > 0.05$). Sagebrush density was greater in the grazed compared with the ungrazed treatment ($P = 0.033$). Sagebrush density averaged 0.48 ± 0.08 plants·m^{-2} and 0.27 ± 0.05 plants·m^{-2} in the grazed and ungrazed treatments, respectively. Species richness did not differ between treatments (data not shown; $P = 0.711$).

Post Treatment

Large perennial bunchgrass cover was 1.5-fold greater in the ungrazed than the grazed treatment (Fig. 1; $P = 0.048$). Sandberg bluegrass and exotic annual grass cover did not differ between treatments (see Fig. 1; $P = 0.292$ and 0.496). Perennial forb cover was 2.3-fold greater in the ungrazed compared with the grazed treatment (see Fig. 1; $P = 0.048$). Annual forb cover was similar between ungrazed and grazed treatments (see Fig. 1; $P = 0.492$). Total herbaceous cover was 1.2 times greater in the ungrazed compared with the grazed treatment (see Fig. 1; $P = 0.011$). Bare ground, litter, and soil biological crust cover did not differ between grazed and ungrazed treatments (see Fig. 1; $P = 0.077$, 0.427, and 0.402). Sagebrush and total shrub cover were similar between treatments (see Fig. 1; $P = 0.251$ and 0.387). The interaction between treatment and year was not significant for any measured cover response variables ($P > 0.05$).

Large perennial bunchgrass density did not differ between the grazed and ungrazed treatments (Fig. 2; $P = 0.366$). Sandberg bluegrass density was 1.5-fold greater in the grazed compared with the ungrazed treatment (see Fig. 2; $P = 0.015$). Exotic annual grass, perennial forb, and annual forb density did not differ between treatments (see Fig. 2; $P = 0.675$, 0.487, and 0.175). Sagebrush and total shrub density were 1.4 and 1.3 times greater in the grazed compared with the ungrazed treatment (see Fig. 2; $P = 0.044$ and 0.022). Species richness was similar between treatments (see Fig. 2; $P = 0.871$). The interaction between treatment and year did not influence the response of density variables ($P < 0.05$).

Large perennial bunchgrass biomass was similar in ungrazed and grazed treatments (Fig. 3; $P = 0.501$). Biomass of Sandberg bluegrass was 1.3 times greater in the ungrazed compared with the winter-grazed treatment (see Fig. 3; $P = 0.040$). Exotic annual grass, perennial forb, and annual forb biomass did not differ between treatments (see Fig. 3; $P = 0.872$, 0.100, and 0.440). Standing crop and litter biomass were 1.8- and 3.0-fold greater in the ungrazed compared with the winter-grazed treatment (see Fig. 3; $P = 0.029$ and < 0.001). The interaction between treatment and year was not significant for any measured biomass response variable ($P > 0.05$).

Discussion

Repeated winter grazing does not appear to negatively impact the resilience to disturbance and resistance to exotic annual grass invasion

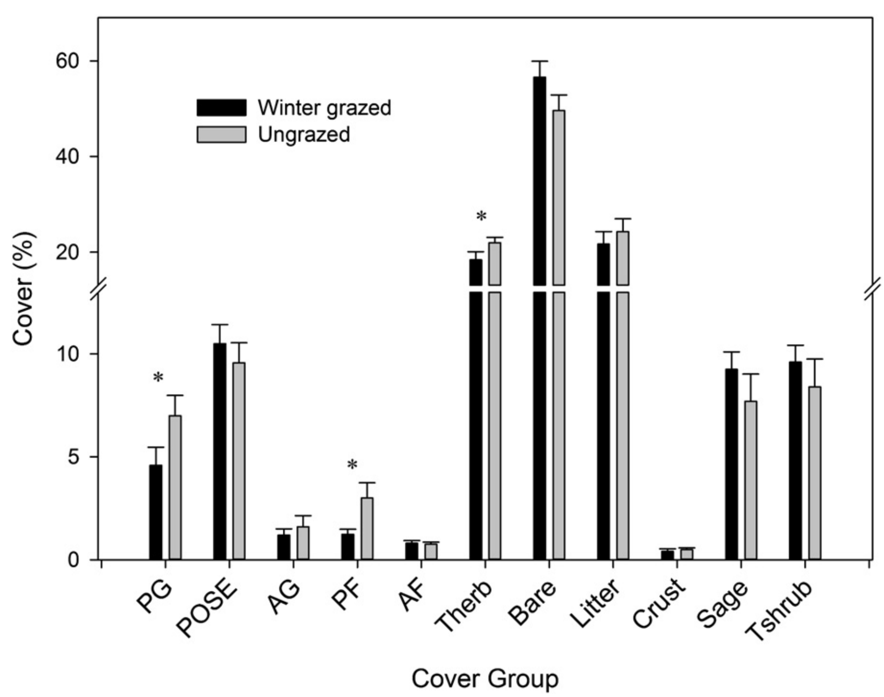

Figure 1. Cover (mean + S.E.) of different cover groups in winter-grazed and ungrazed treatments. Data summarized from 2014 and 2015. PG indicates large perennial bunchgrasses; POSE, Sandberg bluegrass; AG, exotic annual grasses; PF, perennial forbs; AF, annual forbs; Therb, total herbaceous vegetation; Bare, bare ground; Litter, ground litter; Crust, soil biological crusts; Sage, Wyoming big sagebrush; Tshrub, total shrub. Asterisk (*) indicates difference between means ($P \leq 0.05$).

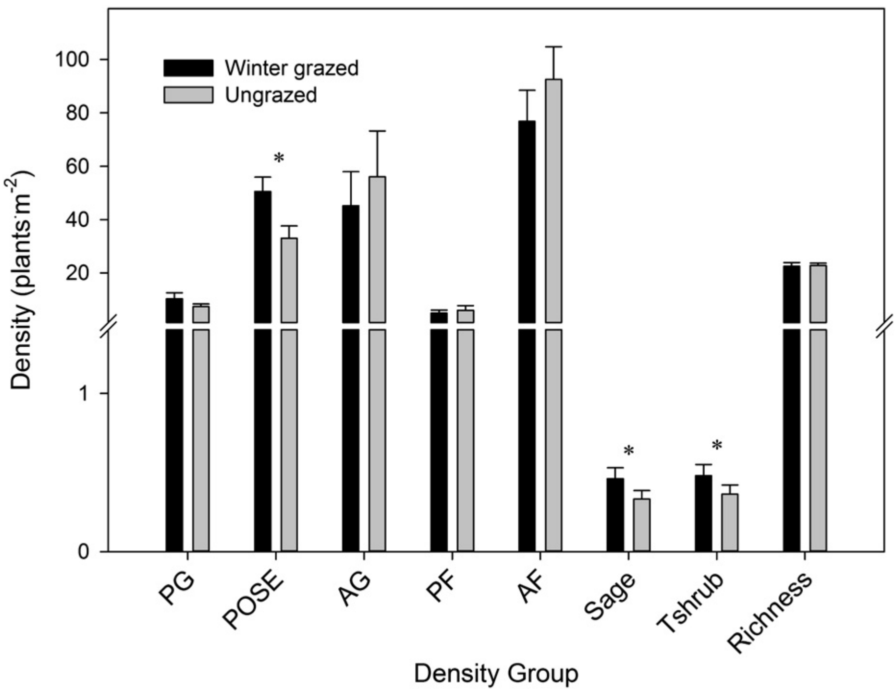

Figure 2. Density (mean + S.E.) of different density groups in winter-grazed and ungrazed treatments. Data summarized from 2014 and 2015. PG indicates large perennial bunchgrasses; POSE, Sandberg bluegrass; AG, exotic annual grasses; PF, perennial forbs; AF, annual forbs; Sage, Wyoming big sagebrush; Tshrub, total shrub; and Richness, species richness. Asterisk (*) indicates difference between means ($P \le 0.05$).

of Wyoming big sagebrush plant communities. The density and annual biomass of large perennial bunchgrasses were similar between winter-grazed and ungrazed treatments, suggesting that resilience and resistance were also similar between treatments. Maintaining the density and productivity of large perennial bunchgrasses is critical because they are one of the most important plant functional groups for resilience to disturbance and resistance to exotic annual grass invasion (Chambers et al., 2007; Davies, 2008; Davies et al., 2011). In addition, large perennial bunchgrasses dominate the understory in these plant communities (Davies et al., 2006; Davies and Bates, 2010) and their resource acquisition patterns overlap greatly with exotic annual grasses (James et al., 2008). Large perennial bunchgrass cover was less in the winter grazing compared with the ungrazed treatment, but this is an effect of herbivory removing prior years' growth, not an indicator of reduced resource use by perennial bunchgrasses. Native perennial forb cover, density, and biomass responses were similar to large perennial

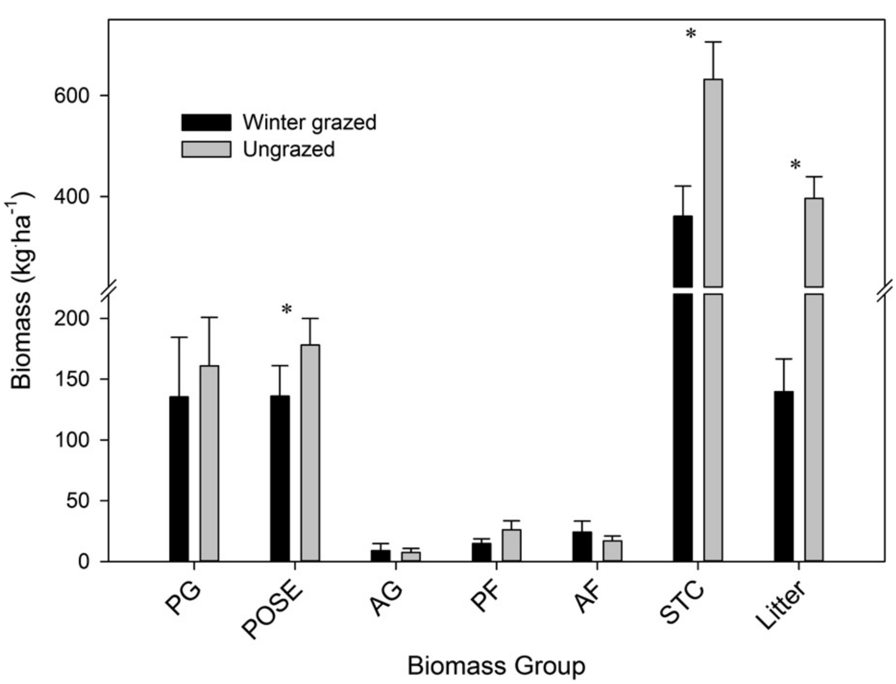

Figure 3. Biomass (mean + S.E.) of different biomass groups in winter-grazed and ungrazed treatments. Data summarized from 2014 and 2015. PG indicates large perennial bunchgrasses; POSE, Sandberg bluegrass; AG, exotic annual grasses; PF, perennial forbs; AF, annual forbs; STC, standing crop; Litter, ground litter. Asterisk (*) indicates difference between means ($P \le 0.05$).

bunchgrasses, likewise suggesting that winter grazing is not negatively impacting these plant communities.

The density of Sandberg bluegrass, however, was 50% greater in the winter-grazed compared with the ungrazed treatment. Though Sandberg bluegrass is known to increase with improper grazing (McLean and Tisdale, 1972), our data suggest that grazing is not causing a shift from large perennial bunchgrass to Sandberg bluegrass. Sandberg bluegrass biomass was less in the grazed compared with the ungrazed treatment, and large perennial bunchgrass biomass, as well as density, were similar between treatments. Thus, winter grazing appears to result in smaller, higher density of Sandberg bluegrass plants, but resource use by Sandberg bluegrass (as evident by biomass production) may be less. The greater density of Sandberg bluegrass with winter grazing is therefore likely inconsequential but may warrant longer-term evaluation.

Similar density, biomass, and cover of exotic annual grasses and annual forbs between winter-grazed and ungrazed areas also suggest that winter grazing is having minimal effects on the native plant community. Detrimental grazing would result in increases in exotic annuals as more resources become available with reductions in grazing-sensitive perennial vegetation (Daubenmire, 1940, 1970; Mack, 1981; Reisner et al., 2013). The lack of an exotic annual grass response indicates that winter grazing applied at the level in this study is not decreasing the resistance of Wyoming big sagebrush communities to exotic annual grass invasion and dominance. This is imperative because increasing exotic annual grass dominance decreases biodiversity (Davies, 2011) and promotes more frequent fires that can result in the development of an annual grass-fire cycle (D'Antonio and Vitousek, 1992; Brooks et al., 2004; Balch et al., 2013).

Sagebrush, a key habitat component for sagebrush-associated wildlife (Mason, 1952; Wallestad et al., 1975; Shipley et al., 2006), was unaffected by winter grazing. Sagebrush density was greater in the plots that were scheduled for winter grazing before treatment application and remained greater in these plots after applying winter grazing for 5−6 years compared with the ungrazed treatment. Sagebrush cover did not differ before treatment application or after treatment application, further indicating that winter grazing was not impacting sagebrush. Other research has similarly found well-managed grazing by cattle has little if any impact on sagebrush (Courtois et al., 2004; Davies et al., 2009, 2010). However, heavy spring grazing can decrease the herbaceous component of these plant communities, likely reducing competition for resources, and thereby increasing sagebrush cover (Laycock, 1967). Thus, our results suggest that grazing at 40%−60% utilization levels when herbaceous vegetation is largely dormant does not alter the competitive relationship between herbaceous vegetation and sagebrush.

Though winter grazing largely has minimal impacts to the native plant community and has been demonstrated to reduce fire risk and severity (Davies et al., 2015, in press), its potential effects to wildlife need to be considered. Decreases in perennial herbaceous cover, as well as less standing crop biomass and litter, with winter grazing were expected because grazing removes prior years' growth, and other research (Davies et al., 2010; Kerns et al., 2011; Bates and Davies, 2014) has also generally reported similar results when comparing grazed with ungrazed areas. However, these effects may influence habitat quality for some wildlife species because herbaceous cover is often an important habitat component for sagebrush-associated wildlife (Johnson and Anderson, 1984; Connelly et al., 2000; Gabler et al., 2001). For instance, less large perennial bunchgrass and perennial forb cover in the winter-grazed area may reduce the nest success of ground-nesting birds such as sage-grouse (Gregg et al., 1994; Connelly et al., 2000), even though these results are not necessarily indicative of decreases in resilience or resistance of the plant community. Wildlife habitat needs, therefore, should be accounted for when deciding when and where winter grazing will be applied for fuel management. However, not grazing in winter and retaining fine fuels could increase the likelihood of a fire in the following summer and this could substantially impact habitat for these species.

Management Implications

In general, vegetation characteristics were similar between the winter-grazed and ungrazed treatments. The few differences detected were not indicative of a negative impact or an artifact of a pretreatment difference. This suggests that Wyoming big sagebrush plant communities with minimal cheatgrass and an understory dominated by perennial bunchgrasses are resilient to repeated winter grazing applied at levels similar to those employed in this study. Winter grazing, therefore, can be applied as a fuel treatment that will likely have minimal to no adverse effects to the native plant community. Unlike our experimental application of repeatedly applying winter grazing to assess its risk of negatively impacting the native plant community, we are not advocating applying winter grazing every year as it would probably be most beneficial after above-average herbaceous production and because repeated application may negatively impact sagebrush-associated wildlife. Reductions in hiding cover (i.e., less herbaceous cover) could negatively impact sagebrush-associated wildlife and should be weighed against benefits of fine fuel reductions before initiating winter grazing as a fuel treatment. Strategic application of winter grazing will be necessary to achieve fuel management goals, be logistically feasible for livestock producers, and create a diversity of habitat characteristics across the landscape.

Acknowledgments

We are grateful that the Roaring Springs Ranch allowed us to conduct this research project on their property, assisted in the construction of exclosures, and provided logistical support. Data collection and management by Urban "Woody" Strachan and summer students and temporary employees were greatly appreciated. We also appreciated thoughtful reviews of earlier versions of the manuscript by Vanessa Schroeder and Brenda Smith.

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