Rangeland Ecology & Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Rangeland Ecology & Management

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

Can Sheep Control Invasive Forbs Without Compromising Efforts to Restore Native Plants?

Eva Masin [a,*], Cara R. Nelson [a], Morgan T. Valliant [b]

[a] Department of Ecosystem and Conservation Science, University of Montana, Missoula, MT 59812, USA
[b] Missoula Parks and Recreation, Conservation Lands Program, Missoula, MT 59801, USA.

ARTICLE INFO

Article history:
Received 23 March 2016
Received in revised form 18 October 2017
Accepted 6 November 2017
Available online xxxx

Keywords:
conservation grazing
forage preference
leafy spurge
restoration
ruminants
sulphur cinquefoil
weeds

ABSTRACT

Domestic sheep *(Ovis aries)* are increasingly being used to control non-native invasive plants in areas where restoration is a management goal. However, the efficacy of sheep grazing depends on both its potential for controlling undesirable plants and its ability to promote natives. To date, few studies have investigated impacts of sheep grazing on native forb recovery in North American grasslands. We assessed the impact of sheep on forbs by measuring the number of stems grazed before and after sheep foraged in western Montana, United States. Sheep grazed a higher percentage of non-native than native forbs (70% vs. 23%, respectively), and number of stems grazed was six times higher for non-natives than natives (48 vs. 5, respectively). Sheep preferentially selected the non-native forbs sulphur cinquefoil and yellow salsify over leafy spurge ($fi = 2.075$; $fi = 0.969$; $fi = 0.969$, respectively), as well as the native forbs white prairie aster ($fi = 1.090$) and blanketflower ($fi = 1.000$). Selection of native forbs was positively correlated with their pregrazing abundance and increased over the grazing period. Our findings indicate that when using sheep to control invasive forbs, appropriate timing and monitoring of grazing are critical for reducing nontarget impacts to native vegetation.

Published by Elsevier Inc. on behalf of The Society for Range Management.

Introduction

Conservation grazing has the potential to rehabilitate plant communities and is increasingly being used as a management strategy in disturbed grasslands (Landgraff et al., 1984; Bangsund et al., 2001). To date, however, studies investigating effects of sheep grazing have focused primarily on invasive plant control (e.g., Landgraff et al., 1984; Olson and Lacey, 1994) rather than ecosystem recovery (but see Gibson et al., 1987; Norton and Young, 2016). Although there are a limited number of investigations on effects on native plant communities, they are restricted in taxonomic and geographic scope. Effects are better documented for grasses (e.g., McIntyre and Lavorel, 1994; Landsberg et al., 2002) than forbs and for Europe, South America, and Australia (Hellström et al., 2003; Cingolani et al., 2005; Evju et al., 2009; Mavromihalis et al., 2013) than North America.

The response of native plants to grazing is known to be variable, with some species increasing in abundance or size (e.g., Gibson et al., 1987; Hellström et al., 2003; Evju et al., 2009) and others declining (e.g., McIntyre and Lavorel, 1994; Landsberg et al., 2002; Austrheim et al., 2008). Plant traits may be an important predictor of response, but previous investigations of the relationship between traits and sheep grazing preferences have not found consistent patterns: Some investigators report that sheep select shorter over taller forbs (Cingolani et al., 2005), whereas others report that sheep avoid short stature species (Diaz et al., 2001; Evju et al., 2009). Similarly, some investigators report that sheep prefer nutrient-rich foods over low-quality options (Villalba and Provenza, 1999), while others report nutrient quality does not have an effect (Schwartz and Ellis, 1981). Additional studies, therefore, are needed to tease apart variation and provide species-level information. Toward that end, we investigated 1) whether sheep preferentially grazed native or non-native forbs, 2) whether pregrazing cover of native or non-native forbs affected their rate of consumption, 3) which forb species (native and non-native) were susceptible to grazing, and 4) whether grazing pressure (% stems grazed) on forbs varied during the grazing season.

Methods

This study was conducted in an intermountain grassland near Missoula, Montana (46.5217° N, 113.5750° W) at 1150 − 1250 m elevation with 35 − 45% slopes, Bigarm gravelly loam soil (NRCS, 2017), 35 cm average annual precipitation (NOAA, 2017), an average annual temperature of 45.9°F, and seasonal temperatures ranging from 47°F to 86°F in June − July (NOAA, 2017). Dominant native grasses include bluebunch wheatgrass *(Pseudoroegneria spicata* [Pursh] A. Love), Sandberg bluegrass (*Poa secunda* J. Prsel.), prairie Junegrass (*Koeleria macrantha*

* Correspondence: Eva Masin (present address), U.S. Dept. of Agriculture Forest Service, RMRS, 5775 W Broadway, Missoula, MT 59801, USA. Tel.: +1 406 880 3989.
E-mail address: emasin@fs.fed.us (E. Masin).

https://doi.org/10.1016/j.rama.2017.11.003
1550-7424/Published by Elsevier Inc. on behalf of The Society for Range Management.

[Ledeb.] Schult.), and Idaho fescue (*Festuca idahoensis* Elmer). Common native forbs include white prairie aster (*Aster falcatus* [Lindl.] G.L. Nesom), milkvetch (*Astragalus* L.), hairy false goldenaster (*Heterotheca villosa* [Pursh] Shinners), silky lupine (*Lupinus sericeus* Pursh), common yarrow (*Achillea millefolium* L.), blanketflower (*Gaillardia aristata* Pursh), prairie sagewort (*Artemisia frigida* Willd.), and wavyleaf thistle (*Cirsium undulatum* [Nutt.] Spreng.). The most common non-native forbs are leafy spurge, sulphur cinquefoil (*Potentilla recta* L.), and yellow salsify (*Tragopogon dubius* Scop.). In 2010, approximately 400 sheep and five goats were allowed to roam and forage. Because 99% of grazing animals were sheep, hereafter, we refer to grazing as "sheep grazing."

Field Measurements

In May 2010, before sheep grazing, we randomly selected 55 2-m-diameter circular plots in a mixed native/non-native plant community. All plots contained a comparable mix of native and non-native species; no single species occurred at >65% cover; and all of the common species used for analyses (see later) were present on ≥ 50% plots. Plots with total cover of leafy spurge >50% were rejected. Within each plot, we measured percent cover of forbs and density of forb stems by species within one randomly selected quarter of the circular plot (hereafter subplot). Nomenclature follows USDA, Natural Resources Conservation Service (2015).

Pregrazing and Control Plots

Sheep grazed an adjacent area heavily infested with leafy spurge for 3 weeks before introduction into the study area. After this conditioning period, 50 plots were available for grazing for 5 weeks (9 June to 19 July 2010); the remaining five controls were protected from grazing by a 1.3-m-high 5 000-volt electric fence.

Grazing Period Assessments

After sheep grazed for 1 week, we estimated percent forb stems grazed within each plot. Subsequent estimates were conducted on a random subset of subplots (including controls) on a weekly basis. At week 6, grazed and ungrazed forb stems were recounted in the same subplot where initial stem density was measured. Due to early desiccation, some less common native forbs were not resampled; these species all occurred at <15% pretreatment frequency and accounted for <12% of total stems (Table 1).

Analyses

Before statistical analyses, variables were assessed for normality. When distributions were non-normal, non-parametric tests were used. Analyses were conducted using SPSS 15.0 (SPSS Inc., 2009). We considered α <0.05 as significant and 0.05 − 0.10 as marginally significant.

Assessing Background-Level Changes

To address whether sheep preferentially grazed native versus non-native forbs, we first assessed background changes (i.e., changes not due to grazing) in percent stems grazed and stem density. This was done by testing for differences between pre-and-post grazing assessments for each response variable (stem density and percent stems

Table 1
Scientific and common names of perennial forbs[1] (ordered according to selection index) on study plots, their origin (native or non-native),[1] functional traits,[2] post-treatment status (grazed or ungrazed), preference,[3] proportion of stems within each species grazed (for species occurring on >15% of the study plots), and frequency pretreatment (% of plots where present).

Species	Origin	Functional traits *height, leaves phenology*	Status	Selection index $fi = \sigma i/\mu i$	Mean % grazed σi	Frequency (%) μi
Potentilla recta, L., Sulphur cinquefoil	Non-native	Tall, tender late flowering	Grazed	2.075	83	40
Aster falcatus, Lindl., White prairie aster	Native	Tall, tough late flowering	Grazed	1.09	60	55
Gaillardia aristata, Pursh, Blanket flower	Native	Tall, tender early flowering	Grazed	1.000	17	17
Tragopogon dubius, Scop., Yellow salsify	Non-native	Tall, tender early flowering	Grazed	0.969	31	32
Euphorbia esula, L., Leafy spurge	Non-native	Tall, tender early flowering	Grazed	0.872	68	78
Astragalus, L., Milkvetch	Native	Short, tender late flowering	Grazed	0.588	10	17
Lupinus sericeus, Pursh., Silky lupine	Native	Tall, tender early flowering	Grazed	0.520	13	25
Achillea millefolium, L., Common yarrow	Native	Tall, tender early flowering	Grazed	0.400	10	25
Heterotheca villosa, (Pursh), Shinners Hairy false goldenaster	Native	Short, tough late flowering	Ungrazed	–	–	63
Cirsium undulatum, (Nutt.) Spreng., Wavyleaf thistle	Native	Short, tough late flowering	Ungrazed	–	–	17
Artemisia frigida, Willd., Prairie sagewort	Native	Tall, tough late flowering	Ungrazed	–	–	13
Taraxacum officinale, F.H. Wigg, Common dandelion	Non-native	Short, tender early flowering	Grazed	–	<1	13
Species	Origin	Functional traits	Status	Selection index[2] $fi = \sigma i/\mu i$	Mean % grazed σi	Frequency (%) μi
Erigeron pumilus, Nutt., Shaggy fleabane	Native	Tall, tender early flowering	Grazed		<1	7
Delphinium bicolor, Nutt., Little larkspur	Native	Short, tough early flowering	Ungrazed	–	–	5
Lomatium, Raf., Desert parsley	Native	Short, tender late flowering	Grazed	–	<1	4
Plantago patagonica, Jacq., Woolly plantain	Native	Short, tender late flowering	Ungrazed	–	–	3
Centaurea stoebe, L., Spotted knapweed	Non-native	Short, tough late flowering	Grazed	–	<1	3
Linaria dalmatica, (L.), Mill. Dalmatian toadflax	Non-native	Tall, tender late flowering	Grazed	–	<1	2
Sisymbrium altissimum, Tall tumble mustard	Non-native	Tall, tender early flowering	Grazed	–	<1	2
Antennaria rosea, Rosy pussytoes	Native	Short, tender early flowering	Ungrazed	–	–	1
Arabis holboellii, Hornem., Holboell's rockcress	Native	Short, tough early flowering	Ungrazed	–	–	1
Helianthus annuus, L., Common sunflower	Native	Short, tough late flowering	Ungrazed	–	–	1
Monarda fistulosa, L., Wild bergamot	Native	Short, tough late flowering	Ungrazed	–	–	1
Penstemon Schmidel, Beardtongue	Native	Short, tough late flowering	Ungrazed	–	–	1
Cirsium vulgare, (Savi) Ten., Bull thistle	Non-native	Tall, tough late flowering	Ungrazed	–	–	1

[1] Nomenclature and origin: USDA PLANTS Database.
[2] Functional traits: tall ≥ 30 cm, short ≤ 30 cm; tender = easily bruised, tough = leathery or waxy.
[3] Forage selectivity index: Manly et al. (2002).

Please cite this article as: Masin, E., et al., Can Sheep Control Invasive Forbs Without Compromising Efforts to Restore Native Plants?, Rangeland Ecology & Management(2017), https://doi.org/10.1016/j.rama.2017.11.003