CONSERVATION ISSUES

Cattle, Deer, and Elk Grazing of the Invasive Plant Sulfur Cinquefoil

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Natural Areas Journal 28:404–409

ABSTRACT: The role of ungulates as contributors to establishment and spread of non-native invasive plants in natural areas is not well known. The objectives of this study were to document whether or not sulfur cinquefoil *(Potentilia recta* L.) is grazed by ungulates and to quantify the effects of ungulate herbivory on the density and demography of sulfur cinquefoil. Despite reports suggesting sulfur cinquefoil is minimally grazed, our results indicate that substantial grazing of sulfur cinquefoil occurs in a northeastern Oregon natural area. The number of sulfur cinquefoil flowers and seed heads differed significantly ($P < 0.0001$) among all grazing treatments at all sampling periods. Cattle *(Bas Taurus)* grazed sulfur cinquefoil throughout early summer, resulting in smaller plants with few flowers and subsequent seed heads. Sulfur cinquefoil was grazed by deer *(Odocoileus heminous* and *0. virginianus)* and elk *(Cervus elaphus)* primarily in the fall and winter by specifically removing just the seed heads. As sulfur cinquefoil reproduces only by seed and seeds typically fall within 3 m of a parent plant, grazing by ungulates and subsequent deposition of the seeds by endozoochory may explain the establishment of satellite infestations across susceptible natural areas.

Index terms: invasive species, noxious weeds, ungulate herbivory, wildlife habitat

INTRODUCTION

Ungulates have profound impacts on the structure and composition of plant communities (Hobbs 1996). However, the role of ungulates as contributors to the dispersal, establishment, and spread of non-native invasive plants is not well known, especially by means of manipulative experiments (Vavra et al. 2007). Grazing and browsing (hereafter referred to as "grazing") can alter successional patterns and rates when selective foraging favors survival, growth, and reproduction of invasive plants with low palatability, although the impact can differ greatly among ecosystems (Augustine and McNaughton 1998), Ungulates also contribute to invasive plant spread by transporting seeds of invasive plants to uninfested sites through endozoochory (Janzen 1984), which occurs when they consume seeds in one area and later regurgitate or defecate them in another area. Ungulates also transport seeds of invasive plants through epizoochory, in which seeds are carried attached to animal skin, fur, or hooves to another location where the seeds detach (Janzen 1984). Ungulates disturb or alter soils plus trample vegetation, any of which confers advantage to invasive plant seeds that often are adapted for establishment in subsequent openings and bare soil. However, studies in various habitats show that non-native species invade sites with or without livestock grazing (Lacey et al. 1990; Frank et al. 1995; Rambo and Faeth 1999). Other studies have tested the utility of prescribed grazing to reduce biomass and occurrence of invasive plants (Sheley and Petroff 1999).

Sulfur cinquefoil *(Potentilla recta* L.) is a long-lived invasive perennial plant from Eurasia that has become one of the most serious invaders of natural area grasslands in the interior Northwest It reproduces only by seed and a plant can produce 8500 seeds per year (Dwire et al. 2006). In northeastern Oregon, adult sulfur cinquefoil plants produce one to several erect stems which average 45 cm and produce, on average, 107 flowers (Perkins et al. 2006). Sulfur cinquefoil plants begin to bloom in June, and are considered to be in peak bloom approximately the first week of July, and rapidly senesce within a few weeks (Naylor et al. 2005). The mechanism of long distance spread and the occurrence of new satellite infestations of sulfur cinquefoil is unclear because seeds are unwinged and fall within 3 m of an adult (Radosevich et al. 2005; Dwire et al. 2006). Little information is available on use of sulfur cinquefoil by ungulates, although it is thought to be generally avoided by most grazing animals (Rice 1999). Rice (1993, 1999) reports utilization of sulfur cinquefoil by cattle *(Bos Taurus)* was less than 1% on 85 sites studied in Montana where sulfur cinquefoil appeared to be one of the last plants selected. Additional studies report that cinquefoil species *(Potentilla* spp.) generally make up a very small percentage of the diets of grazing animals. In British Columbia, cattle, elk *(Cervus elaphus),* and mule deer *(Odocoileus heminous)* diets averaged 0.4%, 0.2%, and 0.3%, respectively, of cinquefoil species (of which sulfur cinquefoil was a constituent) (Werner and Soule 1976). Campbell and Johnson (1983) found that cinquefoil species comprised

2.5%, 0.3%, 1.3%, and 0.2% of winter, spring, summer, and fall diets, respectively, of mule deer in Washington. Winter diets of elk in New Mexico contained 1.1% cinquefoil species (Rowland et al. 1983). Sulfur cinquefoil has tannin content of 17%-22% dry weight that likely lowers its palatability relative to other species (Werner and Soule 1976; Powell 1996). Even when forage and browse choice is limited, cattle have been reported to graze the bitter-flavored spotted knapweed preferentially over sulfur cinquefoil (Rice et al. 1994). However, Bartuszevige and Endress (2008) found viable sulfur cinquefoil seed in collected ungulate fecal samples.

Despite reports suggesting that sulfur cinquefoil is minimally grazed, we observed evidence of substantial ungulate grazing on sulfur cinquefoil plants in infested rangelands in northeastern Oregon. Our observations were made in the course of conducting rangeland restoration research that includes vegetation sampling within a cattle-excluded area. After one year of cattle exclusion, considerable differences in plant density and growth form were observed between sulfur cinquefoil plants located inside and outside the cattle fence. We also frequently noticed native ungulates grazing in our research area that excluded cattle, as the fence is not an impediment to deer *(0. heminous* and O. *virginianus)* and elk. Ross and Wikeem (2002) documented effects of grazing exclusion on sulfur cinquefoil in a study in southeastern British Columbia that excluded both livestock and wildlife grazing with an exclosure constructed in 1951. They reported that no sulfur cinquefoil was recorded in the area until 1991, and then it occurred only in the grazed area outside the exclosure. Other reports suggest that grazing does not influence sulfur cinquefoil spread and state that it rapidly invades bluebunch wheatgrass (Pseudoroegneria spicata (Pursh) A. Love) rangeland "that is in good condition and properly grazed" (Rice 1993). The objectives of this case study were to quantify the direct and indirect effects of cattle and native ungulate herbivory on the density and demography of sulfur cinquefoil. Specifically we evaluated whether grazing by cattle, deer, and elk directly affects sulfur cinquefoil by altering size or reproductive ability and if grazing is likely to indirectly affect the density and reproductive capability of sulfur cinquefoil by influencing competing plants. Based on results from this study, we discuss specific mechanisms by which the establishment and spread of sulfur cinquefoil may be influenced by ungulate herbivory.

METHODS

Study Site and Treatments

The study was conducted within the Oregon Department of Fish and Wildlife, Wenaha Wildlife Management Area in northeastern Oregon near Troy (elevation: 1000 m). The Wenaha State Wildlife Area is characterized by a matrix of ponderosa pine *(Pinus ponderosa* P. & C. Lawson) and Douglas-fir *(Pseudotsuga menziesii* (Mirbel) Franco var. *menziesiii* stands, abandoned agricultural fields, and perennial bunchgrass plant communities. The current land management objectives for the area are to provide winter habitat for big game (deer, elk, bighorn sheep *(Ovis canadensis)* and habitat for game birds such as turkey *(Meleagris gallopavo)* and chukar *(Alectoris chukar)*. In addition, seasonal grazing of cattle (50 cow/calf pairs) is permitted from mid May through July. The study site was once in agricultural production, but farming practices have been abandoned for over 25 years. The site is dominated by non-native species. Sulfur cinquefoil is most abundant and other non-native species include smooth brome *(Bromus inermis* Leyss.), intermediate wheatgrass *(Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey), Kentucky bluegrass *(Poapratensis* L.), Canada bluegrass *(Poa compressa* L.), bulbous bluegrass *(Poa bulbosa* L.), and cheatgrass *(Bromus tectorum* L.). Besides sulfur cinquefoil, the most abundant forbs at the site are native tarweeds *(Madia exigua* (Sm.) Gray and *Madia glomerata* Hook.). Sparsely occurring are other native forbs, such as silky lupine *(Lupinus sericeus* Pursh), common yarrow *(Achillea millefolium* L.), and slender cinquefoil *(Potentilla gracilis* Dougl. ex Hook). Native grasses are infrequent and include bluebunch wheatgrass and Idaho fescue *(Festuca idahoensis* Elmer).

Using fenced exclosures, treatments consisted of three variations of ungulate grazing: (1) ungrazed, (2) deer and elk grazing only, and (3) cattle, deer, and elk grazing. The deer and elk grazed area was constructed in early May 2003 and fenced a 60-m x 90-m area (5400 m^2) with a combination of smooth and barbed wire designed to exclude cattle. Within the deer and elk grazed area, three 24 m^2 mesh wire exclosures 3.5 m high were constructed in 2003 at randomly assigned locations to exclude all ungulate grazing. Exterior to the exclosures was the extant herbivory (cattle, deer, and elk) treatment. Visual assessment of the area determined that all treatments represented a similar plant community, topography, and soils.

Vegetation Sampling

We evaluated vegetation within nine 0.24 m^2 sampling quadrats at intervals along six transects in each of three grazing treatments at three different times during the growing season of 2004. Evaluations were conducted in early May before current year cattle grazing and when sulfur cinquefoil plants were in a rosette or early bolt stage with a portion of previous year stems still attached (late June during cattle grazing and when sulfur cinquefoil was just starting to flower and in August after cattle were removed and sulfur cinquefoil was senesced). Every sulfur cinquefoil plant located within the quadrat was examined, and the number and height (cm) of stems (whether or not the stem had been grazed) and the number of flowers or seed heads were recorded. In addition, in August; the percent cover of sulfur cinquefoil in plots was estimated and half of the quadrates were clipped to a 2-cm stubble and the vegetation was sorted into life forms (sulfur cinquefoil, other forbs, and grasses). All herbage was oven dried at 50 °C for 72 hours and then weighed to estimate aboveground plant biomass.

Data Analysis

Data were analyzed using one-way analysis of variance models in SAS (PROC GLM) for a series of response variables over three sampling periods (May, August, and October 2004). In some cases, the assumption of equal variances was not met; therefore, a Welch's ANOVA was used. Welch's ANOVA is robust to the assumption of equal variances with little loss of power as compared to a standard ANOVA (SAS 2000). Post-hoc Tukey's multiple comparison tests were conducted for pair-wise comparisons of treatment means.

RESULTS

There were more sulfur cinquefoil stems in both the ungrazed and deer and elk only grazing treatments than in the cattle, deer, and elk grazing treatments (Table 1). The number of flowers or seed heads differed significantly ($P < 0.0001$) among all grazing levels at all sampling periods. During the May sampling, which represents the seed heads produced in July of the previous year, there were approximately 75% and 99% more seed heads in the ungrazed level than in the deer, elk grazing and the cattle, deer, and elk grazing levels, respectively. During the June sampling, which represents current year production of flowers, there were 27% and 78% more flowers per stem in the ungrazed treatment than in the deer and elk grazing and the cattle, deer, and elk grazing treatments, respectively. During August, which represents the standing vegetation that will be available as wildlife forage on the winter rangeland, there were 42% and 94% more seed heads in the ungrazed plots than in the deer and elk grazing and cattle, deer, and elk grazing treatments, respectively. During both June and August, the percent of grazed stems and the height of sulfur cinquefoil plants varied significantly among grazing intensities (Table 1). Sulfur cinquefoil plants were shortest in the cattle, deer, and elk intensity where the whole plant was often grazed low to the ground. Sulfur cinquefoil plants in the deer and elk grazed treatment were usually taller, and grazed stems often had just the seed head and upper stem portion removed.

Both total vegetation biomass and sulfur cinquefoil biomass were significantly higher ($P < 0.0001$) in August in the grazing treatments that excluded cattle (Figure 1). Grass biomass was significantly ($P <$

Table 1. Evaluation of sulfur cinquefoil plants in three grazing treatments during the growing season. Different letters within each month for each plant measurement indicate significant differences between grazing treatments; Tukey's multiple comparison test ($P < 0.05$).

	May			June			August		
	Ungrazed	Deer & Elk	Cattle, Deer, & Elk	Ungrazed	Deer & Elk	Cattle, Deer, & Elk	Ungrazed	Deer & Elk	Cattle, Deer, & Elk
Mean density (stems/m^2)	44.2^a	43.8^a	13.8^b	62.5^a	45.4^a	31.3^b	58.3^a	52.1^a	24.6^b
Mean number of flowers per stem	--	--	--	19.4^a	14.1^b	4.3^c	--	--	--
Mean density of seed heads/m^2	303.0^a	76.7^b	3.8^c	--	--	--	958.8^a	557.1^b	62.1^c
Mean percent cover/	--	--	--	44.0^a	31.2^b	19.1^c	--	--	--
Mean percent of grazed stems/plot	8.4^a	84.7^b	93.1^b	0^a	9.3^b	80.6^c	0^a	9.1^b	52.5^c
Mean height (cm) of ungrazed stems	27.1^a	26.4^a	7.3^b	45.6^a	31.4^b	9.5^c	47.6^a	34.0^b	16.1^c

0.05) higher in the ungrazed treatment than in the cattle, deer, and elk grazed treatment; however, grass biomass in the deer and elk grazed treatment was not significantly ($P < 0.05$) different from the other two treatments. While total biomass and grass biomass was the lowest for the cattle, deer, and elk grazing treatment, there was a higher percentage of forbs other than sulfur cinquefoil than other treatments ($P = 0.0002$). The forb biomass was primarily "weedy" annuals such as the tarweeds.

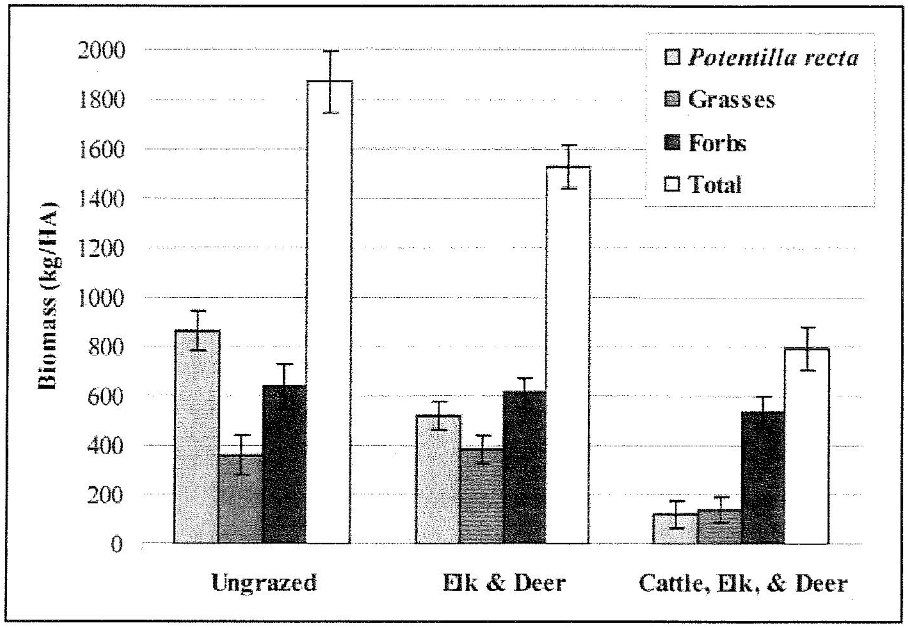

Figure 1. Mean (±S.E.M.) plant biomass in three grazing treatments in August.

DISCUSSION

Despite reports suggesting sulfur cinquefoil is minimally grazed, our results indicate substantial grazing on sulfur cinquefoil occurs in northeastern Oregon. We have observed similar signs of herbivory on sulfur cinquefoil infested grasslands in numerous other areas of northeastern Oregon. Results may not be the same elsewhere or under a different grazing regime or in different plant communities. In our study, early summer cattle grazing of sulfur cinquefoil resulted in smaller plants with few flowers and subsequent seed heads produced. Sulfur cinquefoil plants were grazed, specifically by removing seed heads, by deer and elk primarily in the fall and winter.

Not surprising, the ungrazed treatment had the highest total biomass. What is surprising is that apparently no grass biomass response to grazing exclusion occurred (Figure 1). The net affect of single or repeated grazing on the cumulative growth of palatable plants can be zero, negative, or positive and therefore a delayed growth response with grazing cessation may occur (Noy-Meir 1993). Forbs other than sulfur cinquefoil in all treatments were species generally considered unpalatable (tarweeds) or of low palatability (yarrow, lupine) and, therefore, the large differences in August biomass noted among grazed treatments for grass did not occur for forbs. Competition theory states that the consumption of one species reduces the fitness of that species relative to neighbors of lower palatability, resulting in a replacement of the palatable species by the unpalatable species (Augustine and McNaughton 1998). Our results do not clearly establish the mechanisms by which sulfur cinquefoil has established and spread on the rangeland we studied. The observed consumption of both vegetative parts and seeds of sulfur cinquefoil would suggest that it may be controlled by consumption and not become invasive. However, evidence that sulfur cinquefoil has spread quickly and is the most abundant species on our study sites suggests that it is of secondary palatability and only consumed once some threshold of utilization of species of primary palatability is reached. If species of primary palatability are more detrimentally affected by herbivory than is sulfur cinquefoil, it may gain dominance both on the site and in diets of herbivores. Compared to other available forage, sulfur cinquefoil, especially the seed heads, potentially offers relatively high nutritive value to native herbivores on winter range. Seed heads browsed above the snow may act as a nutrient-dense supplement to otherwise unavailable or poor quality winter range forage. Even small improvements in winter diet quality are important to ungulates (Albon and Langvatn 1992). However, what may be important to ungulates in the short term (winter nutrition) may be detrimental in the long term - subsequent decline of a diverse forage base as a result of the invasibility of sulfur cinquefoil.

We plan to continue the monitoring of our grazing exclosures on the Wenaha wildlife management area. In the continued absence of grazing, we hypothesize that: (l) sulfur cinquefoil will continue to increase in cover and density or (2) grass species, which are more palatable than sulfur cinquefoil, will eventually respond to release from the physiological stress of defoliation and will out-compete sulfur cinquefoil, resulting in lower sulfur cinquefoil densities. Meanwhile, wildlife area managers are increasingly concerned with both expanding and new sulfur cinquefoil populations. As research shows, seeds are shed within 3 m of parent plants (Radosevich et al. 2005; Dwire et al. 2006), and the rapid spread of sulfur cinquefoil across the Wenaha wildlife management area suggests another mechanism of seed dispersion exists. Sulfur cinquefoil plants grazed by deer and elk and subsequent deposition of the seeds by endozoochory may explain the establishment of satellite infestations across the wildlife management area and beyond.

Management Implications

- Early summer cattle grazing may have a large impact on sulfur cinquefoil populations, reducing abundance, stem density, and flower and seed head production. However, if cattle that are rotated among grazing areas are not removed from sulfur cinquefoil infested areas prior to seed head production, there is risk of cattle introducing sulfur cinquefoil into previously uninfested areas.

- Deer and elk forage primarily on seed heads and may facilitate long-distance seed dispersal through fall and winter grazing.

ACKNOWLEDGMENTS

The authors wish to thank Oregon Department of Fish and Wildlife for cooperation and Leslie Naylor, Lynda Cobb, Marti Aitken, Rob Taylor, and Stuart Markow for field assistance. We also appreciate manuscript review comments provided by Roger Sheley and Rob Taylor.

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