The Professional Animal Scientist 30 (2014):270–278

Case Study: Reducing cheatgrass (*Bromus tectorum* L.) fuel loads using fall cattle grazing

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ABSTRACT

Wildfire is a major concern in the Intermountain West. Fuels management can lower the potential for negative wildfire effects. Cheatgrass (Bromus tectorum L.), a nonnative annual grass, invasion has resulted in a buildup of highly flammable fine fuels that promote frequent wildfire. Removal of cheatgrass standing crop through targeted, prescriptive grazing should provide a reduction in fire intensity and possibly frequency on a local basis. Spring cattle-grazing prescriptions have provided critical reductions in cheatgrass standing crop and seed production. However, annual fluctuations in timing of readiness and standing crop production pose planning difficulties for both producers and land managers. With fall grazing, the uncertainties are no longer planning obstacles. We examined the effects of pasture-scale fall grazing of cheatgrass by cattle on standing crop (fuel reduction), the perennial vegetation community, and cattle performance. Fall grazing removed significant amounts of cheatgrass standing crop during 2006 to 2009: 79, 80, 79, and 58%, respectively. Cumulatively, 675 kg/ha were removed from the fuel base, significantly reducing carryover fuels. With protein supplementation, cattle increased BCS and gained BW in all 3 yr of the assessment (0.17, 0.35, and 0.29 kg/d in 2007 to 2009, respectively). Cheatgrass seed bank decreased by 6-fold in the grazed treatment and a little more than 2-fold in the ungrazed area 2007 to 2009. Perennial plants increased standing crop production at the expense of cheatgrass production. Fall grazing of cheatgrass can remove significant amounts of fine fuel with beneficial effects to grazing animals and the perennial plant community.

Key words: annual grass, downy brome, targeted grazing, fine fuel, wildfire

INTRODUCTION

Cheatgrass or downy brome (*Bromus tectorum* L.), a nonindigenous, annual, cool-season grass, is present in every region of the United States, except the coastal southeast (Young et al., 1987; Monsen, 1994; Pellant and Hall, 1994). Cheatgrass has become a significant component of sagebrush and salt desert shrub plant communities in the Great Basin. The Bureau of Land Management (BLM, 1991) has estimated that it manages 3.6 million hectares of land with cheatgrass as the ecologically dominant understory species, and cheatgrass-dominated landscapes could eventually increase to 16.2 million hectares. Meinke et al. (2009) found that almost half of the Great Basin (28.1×10^6 ha) had a moderate to high probability of cheatgrass dominance. Because of this dominance, cheatgrass was a major fuel contributor to 8 of 9 most significant wildfire seasons since 1960, all of which occurred since 2000 (NIFC, 2012). In Nevada, 600,000 ha (1.5 million acres) more have burned each decade than in the previous decade since the 1970s (Gruell and Swanson, 2012). During the 1990s, cheatgrass-dominated areas burned 4 times more frequently than native vegetation, and it was disproportionately represented in the 50 largest fires recorded in the 2000s (Balch et al., 2013). Cheatgrass

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dominance also increases fine fuel production and continuity, raising fire risk probabilities (Davies and Nafus, 2013). Davies and Nafus (2013) also specifically suggest that research is needed to develop methods to mediate and reverse fuel characteristics associated with cheatgrass invasion.

Spring livestock grazing as a control measure for cheatgrass first received attention early in the 20th century (Piemeisel, 1938). Mulch accumulations, plant density, growth, and seed production declined after both spring and simulated-spring grazing treatments (Tausch et al., 1994; Valentine and Stevens, 1994; Mosley, 1996). Lower fuel continuity, reduced flame lengths, and lower intensity and rate of spread have also been linked to spring-grazing utilization levels and grazing in general (Finnerty and Klingman, 1962; Launchbaugh et al., 2008; Diamond et al., 2009). According to Hulbert (1955) and Pellant (1990), cheatgrass must be grazed before seed set if seed production control is an objective.

Spring grazing has shown some success in reducing cheatgrass fuel accumulations and continuity, but 3 challenges affect the ability to successfully implement spring or early summer grazing management of cheatgrass in much of the Intermountain West. First, cheatgrass grazing readiness varies from year to year. The fast growth and annual life form of cheatgrass makes biomass production highly dependent on the amount, periodicity, and timing of precipitation (Stewart and Young, 1939). Some years, cheatgrass germinates and establishes in the fall, but in other years it may not germinate and establish until late spring. Readiness for spring grazing is a moving target, dependent upon precipitation and temperature characteristics, particularly those near the beginning of the growing season (Fulcher and Mathews, 1965). As cheatgrass matures and sets seed, it loses palatability and diet preference because the seed heads have characteristics that increase the potential for mechanical injury to livestock (Hulbert, 1955). In generally dry years, the grazing window between readiness and seed set is a matter of a few days; in other years the window may be months. On an annual basis, producers do not know when they will be able to initiate grazing or how long they will be able to graze until just before grazing should commence. This moving target complicates the planning and permitting process on both private and public lands. In fact, it is a logistical impossibility to have enough grazing animals ready to graze an unknown quantity of forage for an unknown amount of time.

Second, in some years, cheatgrass has grazeable quantities in late winter, whereas in others there is not enough production for grazing turnout until late spring or not at all. Annual standing crop on the same area varies up to 10-fold (Hull and Pechanec, 1947). This variability is untenable for most livestock operations because of the necessity to maintain stable herd numbers and the inability to plan on a consistent forage base (Young et al., 1987). Producers have difficulty determining how many animals will be required to reduce fuels to desired levels. In highly productive years, producers may find it difficult or impossible to acquire enough nonbreeding stock to reduce cheatgrass fuels at all.

Third, perennial grasses, forbs, and woody shrubs in the plant community may be at risk from overuse during the critical spring grazing period. Daubenmire (1940) noted that to suppress cheatgrass seed production, grazing pressure had to be heavy enough to eliminate almost all seed, or scattered plants can rapidly repopulate the area. There are fewer ecological concerns when grazing cheatgrass stands with relatively low diversity indices than for areas with perennial grass populations large enough to warrant consideration about how they will respond (increase or decrease) to grazing management (Mosley and Roselle, 2006). When perennial grass populations require more intensive management consideration, spring grazing for the control of cheatgrass (or any undesired species) must be monitored carefully to ensure that perennial grass species are not overused (Miller et al., 1986).

Fall or winter grazing of cheatgrass as a fuel-reduction strategy is not a new idea (DeFlon, 1986; Tipton, 1994). However, Young et al. (1987) concluded there was a lack of literature on the subject of fall or winter cheatgrass nutritional quality. Murray et al. (1978) described cheatgrass nutrition declining rapidly as cheatgrass matures. The colloquial moniker, cheatgrass, is indicative of conventional ideas about the nutritional quality of the species. Cook and Harris (1952) measured cheatgrass CP levels during fall and winter at 3.5%. Ganskopp and Bohnert (2001), during a year of abundant soil moisture, found that cheatgrass CP levels were deficient by the end of July and stayed deficient through November, and they described deficient as being below 7.5%, the adequate maintenance threshold for many domestic herbivores (NRC, 2000, 2007a,b). Supplementation is generally necessary during fall cheatgrass grazing to ensure nutritional needs of domestic grazers are met.

To improve understanding of the feasibility of fall grazing as a cheatgrass fuel-reduction tool, along with associated effects on perennial plant community characteristics and cattle performance, we conducted an experiment with 3 specific objectives: 1) to determine the effects of pasture-scale, fall grazing of cheatgrass as a fuels-reduction practice; 2) to determine potential plant-community effects; and 3) to determine the associated effects on cattle BCS and weight.

MATERIALS AND METHODS

Study Area

The project was located on the Nevada Agriculture Experiment Station Gund Ranch approximately 65 km north of Austin, Nevada, near the geographic center of Nevada (39°53′0″N; 116°35′11.9″W). The ranch is specifically located in Grass Valley, and the allotment runs north to south, extending west to east from the playa margin to the top of the Simpson Park Mountains, with a predominantly west aspect. Total study area consisted of 607 ha (1,500 acres), and grazing treatments were applied to 285 ha (705 acres), whereas the remainder was left ungrazed. The study site was selected for cheatgrass continuity and its valley bench location adjacent to an upland, high-value, native perennial grass site that burned in 1999. The entire area has the potential for entering a cheatgrass fire cycle (Pickford, 1932). The predominant ecological site was a Loamy 20 to 25 cm (8–10 in) precipitation zone (NRCS, 2003). Elevation is approximately 1,700 m with slope ≤5%. Records show a 35-yr annual precipitation average of 270 mm (10.7 in; WRCC, 2010).

Common vegetation species included cheatgrass, crested wheatgrass (*Agropyron cristatum* Nutt.), needle-and-thread grass (*Stipa comata* Trin. & Rupr.), Sandberg bluegrass (*Poa secunda* Presl.), Indian ricegrass [*Oryzopsis hymenoides* (Roem. & Schult.) Ricker], redstem filaree [*Erodium cicutarium* (L.) L'Hér. ex Aiton], Russian thistle (*Salsola iberica* Sennen), bur buttercup (*Ranunculus testiculatus* Crantz), blue mustard [*Chorispora tenella* (Pall.) DC.], tansy mustard [*Descurainia pinnata* (Walter) Britton], and other mustards (*Descurainia* spp.). The site also supported rubber rabbitbrush [*Chrysothamnus nauseosus* (Pall.) Britton], fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.], basin big sagebrush (*Artemisia tridentata* ssp. *tridentata* Nutt.), squirreltail [*Elymus elymoides* (Raf.) Swezey], and scarlet globemallow [*Sphaeralcea coccinea* (Nutt.) Rydb.].

Study Design

In this *case study*, all data were collected along three 627-m-long parallel transects (replicates) spaced 150 m apart, in both grazing and nongrazing treatment areas. A major difficulty in designing this and other studies like it was maintaining a balance between treatment plot size and replication. A small-scale paddock study using small replicated grazing plots would not allow the expression of animal behavior similar to that found in most grazing allotments and associated pastures. Questions about the efficacy of using protein supplement to concentrate cattle on cheatgrass-dominated areas also could not be answered in small replicated plots; confinement would have been due to fencing rather than the presence of the nutrient supplement. However, replicating a study of this geographic magnitude was beyond the fiscal and logistical possibilities at the time. Specific comparisons of one site versus a paired site often provide more valuable information than averaging effects over several geographically dispersed but unrealistically small replicated sites. We recognize that pseudo-replication may technically exist in the design; however, parallel transects 627 m in length and spaced 150 m apart provided more area and sample points than the same study if conducted on small, 1-ha grazing paddocks in a replicated design. Understanding these trade-offs, we chose to use the term *case study* when characterizing the design.

Plant-Community Analysis

The specific grazing prescription was to lower cheatgrass fuel loads below 100 kg/ha. For the overall plant-community analysis, the project was arranged in a 2 × 2 × 8 factorial-repeated-measures ANOVA. Grazing treatments included 2 levels, a grazed area and a nongrazed area (control), 2 years of observation (2007–2008), and eight 8-plant species or life forms of interest, including cheatgrass, Indian ricegrass, needle-and-thread grass, Sandberg bluegrass, crested wheatgrass, and 3 annual forbs (mustards, redstem filaree, and Russian thistle). Response variables for each species included basal cover, density, standing crop, and seed-bank potential.

To assess the nutritional content of the grazing forage, a standard wet chemistry analysis was performed by Stukenholtz Laboratory Inc. (Twin Falls, ID) during 2006 to 2009 for cheatgrass and during 2007 to 2009 for the combined perennial grasses (crested wheatgrass, needle-and-thread grass, and Sandberg bluegrass). A one-way ANOVA was used to analyze CP and TDN content among years (2007, 2008, and 2009) for cheatgrass only, and a 2-way ANOVA analyzed content between cheatgrass and perennial grasses among years (2007, 2008, and 2009).

Livestock Analysis

Prior to cattle grazing in September of 2007 to 2009, a subsample of approximately 25% of the cattle were weighed and given a BCS (1 = emaciated to 9 = obese; Richards et al., 1986), with measurements repeated at the end of the grazing period. Only bulls aged ≥5 years with a BCS 4 score or better and dry cows (calves were weaned before initiation of the study) with the same age and BCS criteria in their late first or early second trimester of gestation were included. Based on the recommended requirements for cows during their second trimester of gestation (CP 6.2%, TDN 46%; NRC, 2000), the initial 2006 nutritional assay indicated cheatgrass was deficient in both CP and TDN (3.4 and 49.6%, respectively). Given this, a 14% all-natural CP liquid supplement (brand name: Anipro, XF Enterprises Inc., Greely, CO) was fed free choice, formulated to regulate consumption at 0.45 kg/d per animal. The supplement was fed in tubs [1.5-m (5-ft) diameter] spaced at 200-m intervals across the landscape and moved periodically to encourage even utilization of the pasture. Protein supplementation was offered each year of the study. Before-and-after grazing weights and BCS were analyzed (2007–2009) using a paired *t*-test. All grazing activities were in compliance with University of Nevada–Reno Institutional Animal Care and Use Committee standard operating procedures.

Vegetation Sampling Methods

After sample adequacy calculations, the required number of samples per

Table 1. Pre- and postgrazing cheatgrass standing crop (kg/ha) and percentage (%) utilization in the grazed treatment area, 2006 to 2009

Year	Pregraze	Postgraze	% Removed
2006	495	106	79
2007	221	44	80
2008	74	16	79
2009	98	56	58

transect (8 samples) were divided by the length of the transects to yield sample intervals of 84 m (274 ft) for density, standing crop (a combination of standing litter and current year production) and seed-bank emergence potential, and 42 m (137 ft) for vegetation cover (15 samples). Transects were marked using GPS points and discrete stake markers to aid in relocation.

Measurements of cover, density, and pregraze standing crop were collected after plants had reached peak production. Cover was measured in July of 2007 and 2008 using a 10-point point frame (Heady and Radar, 1958). Density was measured for cheatgrass and perennial grasses before each fall grazing period by counting plants using a 1-m^2 circular quadrat. One quarter of the quadrat was used to estimate cheatgrass density.

Pregraze-standing-crop sampling was conducted in August 2006 to 2009 after cheatgrass plants had dropped seed. Cheatgrass and perennial grass standing crop was determined by clipping plant material from a 1-m^2 circular quadrat. Clippings were separated by species, transported to the University of Nevada–Reno, oven dried at 60°C for 48 h, weighed, and calculated as kilograms per hectare dry weight (Bonham, 1989). Postgraze sampling was completed in late October to mid-November 2006 to 2009. Perennial grasses exhibited no green-up at the time of sampling with the exception of crested wheatgrass in 2007, when it exhibited scattered and very small indications of green-up, which were not included in the sample. After weighing, pregraze standing crop from all clipped samples were pooled by transects in each grazing treatment by year. Samples were delivered to Stukenholtz Laboratory Inc. (Twin Falls, ID) for standard wet-chemistry nutritional analysis. Results are reported on a DM basis.

A soil seed-bank assay was conducted on samples collected in September 2007, 2008, and 2009 (Ball and Miller, 1989). Soil samples 7.6 cm × 12.7 cm × 5.1 cm deep were obtained each year along transects before application of the grazing treatment and after seed dehiscence. Samples included the carryover seed bank as well as current-year seed production. Seedling emergence was used to determine seed-bank potential and composition. Soil from each plot was mixed with steam-sterilized sand (250 cm^3) and placed into 25 × 25 cm greenhouse flats. Flats were placed in the greenhouse at 18 ± 5°C under natural sunlight and watered as needed. Emergence was monitored weekly by counting and carefully removing emerged seedlings. After 30 d, soils in each flat were thoroughly mixed and then monitored for an additional 30 d.

All statistical analyses were conducted with JMP version 7.0.2 (SAS Institute Inc., Cary, NC). Percent cover values were arcsine transformed for analysis but reported as percentages. Means comparisons were analyzed using Tukey's honestly significant difference, and all analyses were evaluated at $P < 0.05$.

RESULTS AND DISCUSSION

Cattle grazed for 278, 295, 191, and 456 animal unit months during 2006, 2007, 2008, and 2009, respectively. These animal unit months consisted of 185 cows and bulls grazing for 45 d in 2006, 240 animals for 37 d in 2007, 230 animals for 25 d during 2008, and 280 animals grazing for 49 d in 2009. Treatment dates were Oct. 31 to Dec. 14, Sep. 28 to Nov. 3, Sep. 9 to Oct. 4, and Sep. 9 to Oct. 26, during 2006, 2007, 2008, and 2009, respectively.

Fall grazing removed 58 to 80% of cheatgrass standing crop each year (Table 1). Grazing met the target of 45 kg (100 lb)/acre, and cheatgrass fuels were reduced to less than 90 kg (200 lb)/acre, an amount defined as a fuel level with the potential to generate extreme fire behavior and equivalent to a fire line intensity of 100 BTU/ft per second (Launchbaugh et al., 2008). Above this level, direct attack of fires is not recommended. Although not quantitatively determined, periodic moving of the supplement tubs did increase animal distribution and utilization across the pasture.

An initial concern was that cattle would lose BW and BCS while grazing on what was traditionally considered to be a low-CP, high-structural-carbohydrate-content forage. Although no differences were detected ($P < 0.05$), cattle gained BW and BCS between pre- and postgraze weigh ins for all 3 yr (Table 2). In 2007, animals gained 7 kg/animal during the 37-d grazing period, providing an ADG of 0.17 kg/d, and mean BCS increased from 5.5 ± 0.07 to 5.8 ± 0.07. In 2008 cattle gained 20 kg/animal during the 25-d grazing period for an average of 0.35 kg/d, and mean BCS increased from 5.6 ± 0.05 to 6.0 ± 0.05. Animals gained 14 kg/animal during a 49-d grazing period (0.29 kg/d daily gain) in 2009, with an increase in BCS from 4.8 ± 0.38 to 5.0 ± 0.38.

In this study, cattle supplemented with protein gained weight grazing senesced cheatgrass in the fall. Klemmedson and Smith (1964) demonstrated a decline in average daily gain for unsupplemented cattle grazing in the fall on cheatgrass ranges of southern Idaho. This leads us to believe that cheatgrass nutritional-quality dynamics need further evaluation under field conditions. Conventional thought

Table 2. Mean pre- and postgrazing cattle weights (kg), BCS, SE (±), net gain, and number of animals included for 2007, 2008, and 2009

Item	2007	2008	2009
Pregraze wt.	534 ± 7	541 ± 7	549 ± 54
Postgraze wt.	541 ± 8	561 ± 7	563 ± 50
Net gain	7	20	14
Pregraze BCS	5.5 ± 0.07	5.6 ± 0.05	4.8 ± 0.38
Postgraze BCS	5.8 ± 0.07	6.0 ± 0.05	5.0 ± 0.38
Net gain	0.3	0.4	0.2
No. of animals	41	57	49

was that dry, senesced cheatgrass had limited nutritional quality and did have low CP in 2006, initiating our offering of supplement. Nutritional quality varied considerably by year but was overall much higher than we expected. Both CP ($P = 0.002$) and TDN ($P = 0.015$) were less in 2006 than in 2007 or 2008. The CP values were 3.4% ± 0.5 in 2006, 7.0% ± 0.3 in 2007, and 7.8% ± 0.6 in 2008. Total digestible nutrients followed the same pattern, 45.9% ± 2.1 in 2006, 60.8% ± 1.5 in 2007, and 56.8% ± 2.9 in 2008. No differences were detected among years or species for CP or TDN (cheatgrass, crested wheatgrass, needle-and-thread, and Sandberg bluegrass).

Ganskopp and Bohnert (2001) found that cheatgrass nutritional quality was characterized by significant annual variation. This study corroborates their findings. In years when early spring moisture is limiting, cool-season grasses (including cheatgrass) produce forage with a higher nutritional plane than in a more abundant moisture year. The marked difference in nutritional content for both CP and TDN between 2006 and the drought years of 2007 and 2008 was an example of this physiological expression.

Because of 3-way and 2-way species treatment interactions for density, percent cover, standing crop, and seed-bank potential, a separate repeated-measures 2-way ANOVA was performed for each species category comparing grazing treatments (grazed and ungrazed) and years (2007 and 2008). An additional year, 2009, was included for cheatgrass, crested wheatgrass, and perennial grass standing crop, and cheatgrass seed-bank potential.

There were no differences ($P \geq 0.05$) in cheatgrass cover or density in 2007, but by 2008 both cover and density were greater in the ungrazed treatment than grazed areas (Tables 3 and 4). A long-term grazing exclosure study in Nevada by Courtois et al. (2004) found that when cheatgrass was present on a site, there was always greater cheatgrass cover and density inside the ungrazed exclosure. Cheatgrass density decreased in 2008 in both grazing treatments, a probable artifact of droughty growing conditions.

There were differences in cover between years and grazing treatments for perennial grasses and annual forbs (Table 3), and there were a few differences in plant density (Table 4). The values were so small that they likely have no biological significance after only 2 yr. Long-term application of fall grazing is needed to determine the response of perennial grasses to this grazing treatment in cheatgrass-invaded areas. It is notable that in the first growing season after the original 2006 grazing treatment, there was a small spike in the density of annual forbs (primarily Russian thistle) in the grazed treatment that began to disappear in the 2008 assessment (Table 4). It has been observed for decades that Russian thistle tends to dominate areas in early successional recovery where resource competition is low, such as reclaimed mined lands. This dominance decreases as competition from other growth forms increases (Narten et al., 1983) and should give little cause for concern.

We anticipated that perennial plants may benefit from reduced cheatgrass competition (Klemmedson and Smith, 1964; Hilbert et al., 1981). The benefit expressed itself in standing-crop production. There was a clear trend of increasing perennial-grass standing crop and a relative decline in cheatgrass standing crop within the grazed treatment (Table 5). It could be construed that cheatgrass decline might be an artifact of lower precipitation in

Table 3. Percentage (%) plant cover and SE (±) by category and grazing treatment (grazed and ungrazed) for 2007 and 2008

Category	Treatment	2007	2008
Cheatgrass	Grazed	20.8 ± 2.2^{a,c}	15.0 ± 3.1^{b,c}
	Ungrazed	19.9 ± 0.7^{a,c}	22.2 ± 0.6^{a,d}
Crested wheatgrass	Grazed	0.9 ± 0.5^{a,c}	1.7 ± 0.9^{a,c}
	Ungrazed	1.6 ± 0.9^{a,c}	1.3 ± 0.4^{a,c}
Needle-and-thread grass	Grazed	0.3 ± 0.2^{a,c}	0.3 ± 0.2^{a,c}
	Ungrazed	0.4 ± 0.4^{a,c}	0.9 ± 0.6^{a,c}
Sandberg bluegrass	Grazed	3.5 ± 0.9^{a,c}	3.9 ± 0.7^{a,c}
	Ungrazed	2.9 ± 0.8^{a,c}	1.8 ± 1.1^{a,d}
Annual forbs	Grazed	3.9 ± 0.6^{a,c}	2.5 ± 0.9^{a,c}
	Ungrazed	1.5 ± 0.2^{a,d}	0.7 ± 0.7^{a,d}

^{a,b}Row means within a category with different superscripts differ at $P \leq 0.05$.

^{c,d}Column means within a category with different superscripts differ at $P \leq 0.05$.

Table 4. Plant density (plants/m²) and SE (±) by category and grazing treatment (grazed and ungrazed) for 2007 and 2008

Category	Treatment	2007	2008
Cheatgrass	Grazed	921 ± 102[a,c]	333 ± 43[b,c]
	Ungrazed	1,032 ± 120[a,c]	535 ± 81[b,d]
Crested wheatgrass	Grazed	0.7 ± 0.2[a,c]	0.9 ± 0.2[a,c]
	Ungrazed	0.7 ± 0.3[a,c]	1.6 ± 0.5[b,d]
Needle-and-thread grass	Grazed	1.1 ± 0.5[a,c]	0.4 ± 0.2[a,c]
	Ungrazed	0 ± 0[a,d]	0 ± 0[a,d]
Sandberg bluegrass	Grazed	9.4 ± 1.9[a,c]	8.7 ± 1.8[a,c]
	Ungrazed	4.5 ± 1.3[a,d]	8.2 ± 2.0[a,c]
Annual forbs	Grazed	36 ± 11[a,c]	10 ± 2.3[b,c]
	Ungrazed	4.8 ± 1.3[a,d]	2.1 ± 0.5[b,d]

[a,b]Row means within a category with different superscripts differ at $P \leq 0.05$.
[c,d]Column means within a category with different superscripts differ at $P \leq 0.05$.

2008; however, perennial-grass standing crop increased in 2008 over 2007, despite drier growing conditions. The 2009 values of perennial-grass standing crop show a clear difference between grazed and ungrazed (560 and 214 kg/ha, respectively), indicating that the competitive advantage may be shifting from cheatgrass to perennial grasses, primarily crested wheatgrass. By 2009, perennial-grass standing crop in the grazed area was the major source of forage rather than cheatgrass.

Cheatgrass standing crop varies and may be difficult to predict from year to year because it is highly dependent on the amount and temporal distribution of moisture. However, this difference in production may be no greater than that of perennial grasses as long as there is adequate spring moisture (Young and Allen, 1997). Standing crop is especially reduced when cheatgrass germinates in spring rather than fall (Anderson, 1990). All years of our study had below-average precipitation and received no fall moisture to initiate cheatgrass growth.

Considering the combined use of all perennial-grass species for 2007 and 2008 (62 and 59% utilization, respectively) and cheatgrass use, cattle preferred cheatgrass, utilizing 80 and 79%, respectively, for the same time period. We hypothesize that was due to low diet preference for crested wheatgrass. Others have also described a preference for cheatgrass in the fall or winter (DeFlon, 1986; Tipton, 1994; Bishop et al., 2001).

In 2007 the cheatgrass seed-bank potential was initially greater in the grazed treatment (10,698 plants/m²) than the ungrazed (8,917 plants/m²) but declined over time so that by 2009 the grazed area had 1,828 plants/m² and the ungrazed area had 3,354 plants/m² (Table 6). A portion of the overall decline may be directly related to low seed-production levels in 2007 and 2008, very dry years. However, fewer germinable seeds in the grazed compared with nongrazed area were consistent across both 2008 and 2009, which strongly suggests a grazing effect. Seed-bank dormancy in cheatgrass is complex, but it is has been demonstrated that cheatgrass seeds do not establish well on bare soil or areas with extremely low litter accumulations (Evans and Young, 1975a,b).

A reduction in cheatgrass seed-bank potential was documented after only one grazing treatment, with additional reductions after 2 more fall grazing treatments. Cheatgrass density did not decrease until after the second grazing treatment, leading us to conclude that at least 2 grazing treatments are necessary to initiate a significant decrease in

Table 5. Standing crop (kg/ha) and SE (±) by category and grazing treatment (grazed and ungrazed) for 2007, 2008, and 2009

Category	Treatment	2007	2008	2009
Cheatgrass	Grazed	221 ± 32[a,d]	74 ± 14[b,d]	98 ± 3[c,d]
	Ungrazed	294 ± 37[a,e]	135 ± 28[b,e]	299 ± 19[a,e]
Crested wheatgrass	Grazed	62 ± 15[a,d]	158 ± 40[b,d]	531 ± 18[c,d]
	Ungrazed	25 ± 11[a,e]	236 ± 53[b,d]	209 ± 16[b,e]
Needle-and-thread grass	Grazed	14 ± 8[a,c]	15 ± 9[a,c]	
	Ungrazed	0 ± 0[a,c]	0 ± 0[a,c]	
Sandberg bluegrass	Grazed	16 ± 3[a,c]	19 ± 3[a,c]	
	Ungrazed	9 ± 4[a,d]	23 ± 5[a,d]	
Total perennial grass	Grazed	92 ± 5[a,d]	193 ± 11[b,d]	560 ± 46[c,d]
	Ungrazed	34 ± 3[a,e]	259 ± 17[b,e]	214 ± 66[b,e]

[a–c]Row means within a category with different superscripts differ at $P \leq 0.05$.
[d,e]Column means within a category with different superscripts differ at $P \leq 0.05$.

Table 6. Seed-bank potential (plants/m²) and SE (±) by category and grazing treatment (grazed and ungrazed) for 2007, 2008, and 2009

Category	Treatment	2007	2008	2009
Cheatgrass	Grazed	10,698 ± 1044^{a,c}	2,057 ± 313^{b,c}	1,828 ± 192^{b,c}
	Ungrazed	8,917 ± 1200^{a,d}	3,750 ± 820^{b,d}	3,354 ± 356^{b,d}
Crested wheatgrass	Grazed	80 ± 32^{a,c}	173 ± 52^{a,c}	
	Ungrazed	80 ± 49^{a,c}	93 ± 39^{a,c}	
Needle-and-thread grass	Grazed	0 ± 0^{a,c}	37 ± 15^{a,c}	
	Ungrazed	83 ± 58^{a,c}	0 ± 0^{a,c}	
Sandberg bluegrass	Grazed	900 ± 302^{a,c}	688 ± 247^{a,c}	
	Ungrazed	2,527 ± 646^{a,d}	2,020 ± 691^{a,d}	
Annual forbs	Grazed	1495 ± 238^{a,c}	719 ± 123^{b,c}	
	Ungrazed	978 ± 284^{a,c}	385 ± 129^{b,c}	

^{a,b}Row means within a category with different superscripts differ at $P \leq 0.05$.

^{c,d}Column means within a category with different superscripts differ at $P \leq 0.05$.

cheatgrass density. Hulbert (1955) also concluded cheatgrass should be grazed 2 consecutive years to produce the best control. Finnerty and Klingman (1962) also described cheatgrass populations dropping rapidly after seed-head removal by grazing for 2 consecutive years. It is important to note that cheatgrass seed-bank potential declined in our study without removing inflorescence via a spring grazing treatment. Cattle may have consumed some of the seed bank contained in the standing cheatgrass litter, but it is absolutely unclear how much was consumed. We hypothesize that the reduction in seed-bank potential occurred primarily as a result of standing-crop removal and fewer seed-establishment sites. Although the level of reduction was impressive, it may be of little consequence because the 2009 grazed-treatment seed-bank potential of 1,754 plants/m² is far above the threshold level of 43 plants/m² reported by Young et al. (1987) that can easily out compete crested wheatgrass seedlings and displace native bunchgrass seedlings. An important and unknown question is as follows: Does sustained fall grazing remove enough standing crop to create more bare ground and fewer safe sites (Harper et al., 1965) for germination and establishment, thus functionally reducing the effectiveness of what is still a large seed bank? A seed-bank-potential study must be extended in time to definitively determine whether the decline will continue. The addition of a spring grazing treatment that would consume inflorescence should further decrease the seed-bank potential and would also offer great opportunities for new research.

This case study demonstrated that our fall-grazing prescription met the management target (100 kg/ha) and reduced cheatgrass fuel loads (standing crop) without placing grazing animal or plant community at risk. Both flame length and rate of spread can be reduced through prescriptive spring grazing of cheatgrass (Diamond et al., 2009). The same should be true for fall-grazing applications. Removal of significant amounts of standing crop reduces the amount of fuel carryover to the next fire season. Knapp (1995) demonstrated that burned area in the Intermountain West increased when weather fostered the growth of annual grasses over perennial species during previous growing seasons, effectively increasing the amount of fuel carryover.

Prescription fall grazing eliminates many of the planning challenges associated with spring-grazing prescriptions outlined earlier in this opus. Targeted grazing can also shift the competitive balance between cheatgrass and perennial grasses within a short time period and is likely to maintain the shift as long as an appropriate grazing treatment is applied on a regular basis. Given that the cheatgrass seed bank still remained relatively high after fall grazing, permanent cessation of the fall grazing treatment may lead to a return of cheatgrass dominance and unacceptable fuel loads. It is also possible that the perennial community may develop to a point where cheatgrass standing crop is moderated without repeated applications of grazing prescriptions. Because our case study had limitations, longer-term and replicated experiments are needed to determine whether either response can be predicted.

Trowbridge et al. (2013), while comparing cheatgrass dominance in the Junggar Basin of China and the Great Basin, indicated that lower grazing intensities in the United States, along with fire and climate, may be one of the significant drivers of cheatgrass dominance. Whatever the initial cheatgrass introduction and proliferation mechanisms were, it is appropriate to ask whether current mandated conservative grazing practices played a significant role in creating much of the cheatgrass dominance observed today. Deferred and rest-rotation grazing systems were created to benefit the perennial grass component of many rangeland systems. Application of these grazing systems may have been counterproductive where cheatgrass was already entrenched and had the potential to become the ecologically dominant species when spring rest from grazing allowed it to complete its annual life cycle and maximize biomass and seed production. In other words, these grazing systems were unintentionally misused in plant communities they were never designed for. Grazing was not the catalyst for expansive cheatgrass dominance but rather misapplied grazing management. We must also ask whether large federally mandated reductions in grazing (animal unit months) over the last 40 yr have also been a driver of cheatgrass dominance in areas with existing cheatgrass infestations. Grazing practices that foster the buildup of cheatgrass standing crop and litter that facilitates seed-bank expansion and seed establishment should be critically reevaluated. Additionally, other invasive species with less desirable characteristics than cheatgrass could be poised to fill niches created by a reduction in cheatgrass dominance. Grazing prescriptions must be carefully evaluated to reduce opportunities for undesirable invasive species to gain traction in plant communities of the Intermountain West. Properly managed livestock grazing can decrease the size and severity of wildfires (Diamond et al., 2009; Davies et al., 2010) and decrease the risk of postfire invasion by nonnative annual grasses (Davies et al., 2009). As science creates more knowledge, land managers and grazing permittees will require regulatory flexibility to implement strategic or targeted grazing as a fuels-management treatment.

IMPLICATIONS

These results indicate that prescribed fall grazing can reduce cheatgrass fuel loads in the Great Basin. By predetermining the nutritional quality of cheatgrass, a prescription can be crafted so that detrimental effects to livestock health and the plant community can be minimized or avoided. Although the economic inputs and outcomes of the prescription were beyond the scope of this study, fuel reductions through prescribed grazing of cheatgrass will likely lower fire-related costs and risks associated with human life, property, and resource degradation. Prescribed fall grazing may have particular utility as a fire-break tool for areas with highly regarded resource values such as critical wildlife habitat areas and wildland–urban interfaces.

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