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Original Research

Eighty Years of Grazing by Cattle Modifies Sagebrush and Bunchgrass Structure☆

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ABSTRACT

Grazing by cattle is ubiquitous across the sagebrush steppe; however, little is known about its effects on sagebrush and native bunchgrass structure. Understanding the effects of long-term grazing on sagebrush and bunchgrass structure is important because sagebrush is a keystone species and bunchgrasses are the dominant herbaceous functional group in these communities. To investigate the effects of long-term grazing on sagebrush and bunchgrass structure, we compared nine grazing exclosures with nine adjacent rangelands that were grazed by cattle in southeast Oregon. Grazing was moderate utilization (30 − 45%) with altering season of use and infrequent rest. Long-term grazing by cattle altered some structural aspects of bunchgrasses and sagebrush. Ungrazed bunchgrasses had larger dead centers in their crowns, as well as greater dead fuel depths below and above the crown level compared with grazed bunchgrasses. This accumulation of dry fuel near the meristematic tissue may increase the probability of fire-induced mortality during a wildfire. Bunchgrasses in the ungrazed treatment had more reproductive stems than those in the long-term grazed treatment. This suggests that seed production of bunchgrasses may be greater in ungrazed areas. Sagebrush height and longest canopy diameter were 15% and 20% greater in the ungrazed compared with the grazed treatment, respectively. However, the bottom of the sagebrush canopy was closer to the ground in the grazed compared with the ungrazed treatment, which may provide better hiding cover for ground-nesting avian species. Sagebrush basal stem diameter, number of stems, amount of dead material in the canopy, canopy gap size, and number of canopy gaps did not differ between ungrazed and grazed treatments. Moderate grazing does not appear to alter the competitive relationship between a generally unpalatable shrub and palatable bunchgrasses. Long-term, moderate grazing appears to have minimal effects to the structure of bunchgrasses and sagebrush, other than reducing the risk of bunchgrass mortality during a fire event.

Introduction

Grazing by livestock in sagebrush steppe communities of the Great Basin can be controversial. This is largely because these communities historically experienced limited grazing pressure from large ungulates (Mack and Thompson, 1982) and because of resource damage from widespread overuse by sheep, cattle, and horses following initial European settlement (Mack, 1981; Young and Allen, 1997; Chambers et al., 2007). Examples of glaring mismanagement, particularly in riparian areas (Beschta et al., 2014; Batchelor et al., 2015), have led many to assume that all grazing negatively affects sagebrush steppe ecosystems. However, ungrazed rangelands and moderate grazed rangelands have repeatedly been demonstrated to be similar in production, native species composition and abundance, and exotic annual grass abundance (Sneva et al., 1980; Courtois et al., 2004; Davies et al., 2009; Davies et al., 2014). Moderate grazing is utilization levels of 30%−45% of available forage (Holechek et al., 1999) with season of use altering between growing season and dormant season use. In contrast, overgrazing (greater utilization and often repeated growing season use) of sagebrush (*Artemisia* L.) steppe communities reduces native perennial grasses and promotes exotic annual grass invasion (Laycock, 1967; Mack, 1981; Young and Allen, 1997; Reisner et al., 2013).

Moderate grazing, however, does alter some plant community characteristics. Grazed areas generally have less herbaceous cover than ungrazed areas (Szaro and Pase, 1983; Davies et al., 2010; Kerns et al., 2011; Bates and Davies, 2014). There may also be some shifts in competition that favor plants not grazed compared with grazed plants because of the loss of photosynthetic tissues (Caldwell et al., 1987; Briske and Richards, 1995). Grazed plant communities can have greater fine fuel moisture content than ungrazed plant communities (Davies et al., 2015, 2016, 2017). Ungrazed rangelands also have an accumulation of fuels, particularly standing-dead fine fuels (Davies et al., 2010,

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2017). Ungrazed rangelands, because of an accumulation of dry fine fuels, are at a greater risk of fire propagation (Davies et al., 2017) and more likely to experience a more intense and severe fire than moderate grazed rangelands (Davies et al., 2009, 2016).

However, little is known about the effects of cattle grazing on many structural characteristics of sagebrush communities. Grazing by sheep has been demonstrated to reduce sagebrush cover, especially with fall grazing (Laycock, 1967; Bork et al., 1998), which likely translates to smaller sagebrush canopies. Sheep consume more browse than cattle and therefore results from sheep studies should not be extrapolated to cattle. Shrub cover was similar in cattle grazed compared with ungrazed sagebrush steppe (Davies et al., 2010), but response of sagebrush was not evaluated on an individual plant basis. However, grazing of riparian areas by cattle during the summer can alter the structure of other shrubs such as willows (*Salix* sp.) (Schultz and Leininger, 1990). Livestock grazing alterations to woody vegetation structure can also influence fire intensity and frequency in forested ecosystems (Zimmerman and Neuenschwander, 1984).

Cattle influence the structure of vegetation they consume, but vegetation's long-term structural response to grazing is generally unknown. Even less is known about the influence of cattle on the structure of vegetation they generally do not consume. Of particular interest in sagebrush steppe communities would be the structural response of sagebrush and large perennial bunchgrasses to long-term, moderate grazing. Sagebrush is a keystone species that provides vital habitat to sagebrush obligate wildlife species (Connelly et al., 2000; Prevéy et al., 2010). Alterations to sagebrush structure may influence wildlife that use sagebrush for hiding and nesting cover. For example, greater sage-grouse *(Centrocercus urophasianus)* mostly nest under sagebrush, and sagebrush structure often determines preference (Sveum et al., 1998). Though cattle generally consume very little, if any, sagebrush (Krysl et al., 1984), they may physically damage sagebrush as they graze herbaceous vegetation between and underneath sagebrush canopies. Large perennial bunchgrasses are vital because they are the most important plant functional group to preventing exotic annual grass invasion (Chambers et al., 2007; Davies, 2008) and, subsequently, the development of an exotic annual grass − fire cycle (D'Antonio and Vitousek, 1992). Alteration to bunchgrass structure through grazing, such as reducing fuel accumulations on their crowns, may influence their sensitivity to disturbances (Davies et al., 2009). Perennial bunchgrasses also provide important hiding cover for wildlife (Sveum et al., 1998; Connelly et al., 2000). Considering that cattle grazing is extensive across the sagebrush steppe (Davies et al., 2014), it is critical to understand the influence of long-term grazing by cattle on sagebrush and perennial bunchgrass structure.

The purpose of this study was to evaluate the effects of long-term (80 yr) grazing compared with no grazing by cattle on sagebrush and perennial bunchgrass structure. We hypothesized that grazing by cattle would alter sagebrush and native bunchgrass structure. Specificity, we expected that sagebrush canopies would be smaller with long-term grazing by cattle because of physical damage. In addition, we hypothesized that grazing by cattle would reduce dead fuels in the center of bunchgrasses.

Methods

Study Area

The study was conducted in southeastern Oregon approximately 50 − 60 km west of Burns, Oregon, at the Northern Great Basin Experimental Range (NGBER) (lat 43°29′N, long 119°43′W). Climate at the NGBER is typical of the northern Great Basin with cool, wet winters and hot, dry summers. The headquarters of the NGBER received on average 300 mm of precipitation annually during the past 50 yr (1956 − 2005). Elevation at the study sites ranges from approximately 1 300 to 1 500 m above sea level, and the topography is flat (slopes 0° − 3°) to 15° with aspects from south to north. Soils at the study sites are Aridisols, Mollisols, and Andisols with varying soil depths (Lentz and Simonson, 1986). Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* [Beetle and A. Young] S. L. Welsh) and mountain big sagebrush (*A. t.* spp. *vaseyana* [Rydb.] Beetle) were the dominant shrubs with dominant bunchgrass species varying by study site. Thurber's needlegrass (*Achnatherum thurberianum* [Piper] Barkworth), Idaho fescue (*Festuca idahoensis* Elmer), prairie junegrass (*Koeleria macrantha* [Ledeb.] J. A. Schultes), bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve), needle and thread (*Hesperostipa comata* [Trin. and Rupr.] Barkworth), and bottlebrush squirreltail (*Elymus elymoides* [Raf.] Swezey) were common large perennial bunchgrasses at the study sites. Plant communities were dominated by native perennial vegetation (sagebrush and bunchgrasses) with very limited abundance of exotic annual grasses (< 4% cover). Plant community composition and plant functional group densities were similar between exclosures and grazed areas (Bates et al., unpublished data). The plant communities at the study sites are common in the northern Great Basin (Daubenmire, 1970; Davies et al., 2006; Davies and Bates, 2010). These plant communities are not believed to have recently evolved with high numbers of large ungulates (Mack and Thompson, 1982), but they have evolved with periodic fire (Wright and Bailey, 1982; Miller and Rose, 1999; Mensing et al., 2006; Miller and Heyerdahl, 2008).

Experimental Design

We used a randomized complete block design with two treatments. Treatments were long-term, moderate grazing (grazed), and long-term grazing exclusion (ungrazed) and were applied to nine different sites with varying vegetation, soils, and topography. The ungrazed treatments were 2-ha livestock exclosures established in 1936. The grazed treatments were concurrently established adjacent to the livestock exclosures and were similar in site characteristics (soil, topography, etc.) and vegetation composition. Thus, the experiment consisted of nine grazed and nine ungrazed areas. We considered moderate grazing to be utilization between 30% and 45% (Holechek et al., 1999) and season of use altering between growing season and dormant season use (deferred rotation). In 1937, density was similar among treatments for large perennial bunchgrasses, Sandberg bluegrass, perennial forbs, annual forbs, and annual grass ($P > 0.05$). Grazed treatments were grazed by cattle through 2015. Grazing pressure by cattle was moderate, 30 − 45% use of the available forage. From 1938 to 1949 cattle use was rotation grazing with stocking rates determined from range surveys conducted in 1938 and 1944. From 1949 to 2015, the grazing program was a deferred-rotational system with an occasional year of complete rest. Stocking rates ranged between 0.15 and 0.36 animal unit months (AUMs) per ha with an average of 0.22 AUMs per ha. In 2016, no grazing occurred before sampling. Grazed treatments were in nine fenced rangeland pastures ranging in size from 65 to 810 ha. Wildlife were not excluded from the grazed or ungrazed treatments.

Measurements

Bunchgrass and sagebrush structure was measured in late June through July 2016. Fifty native perennial bunchgrasses, excluding Sandberg bluegrass (*Poa secunda* J. Presl), were randomly selected in each treatment replication. Sandberg bluegrass was excluded from measurements because it is smaller in stature, develops phenologically earlier (James et al., 2008), and differs in its response to disturbances compared with larger native bunchgrasses (McLean and Tisdale, 1972; Yensen et al., 1992). Total crown diameter (live and dead), dead crown center diameter, crown height, and depth of fuel in dead center above and below crown level were measured on each selected bunchgrass. Crown height was measured as the distance between the surrounding soil surface and the crown. Depth of fuel below the crown level was measured by excavating a small hole in the center of