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Grazing and solar irradiance drive patterns of change in two grassland plant communities in southern British Columbia

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A B S T R A C T

We compared the recovery of two plant communities over 14 years following a switch from spring to fall grazing (G), and in ungrazed exclosures (UG), at six sites in Lac du Bois Grasslands Provincial Park, British Columbia. Both communities showed similar large increases in cover of their respective dominant grasses – rough fescue (*Festuca campestris*), and bluebunch wheatgrass (*Pseudoroegneria spicata*) – in both G and UG treatments. As expected, the more productive rough fescue community had higher amounts of soil polysaccharides, and total soil C and N. Repeated measures ANOVA indicated significant declines in species richness and Shannon diversity over time, especially in the ungrazed rough fescue community. Non-metric multidimensional scaling of species cover data showed continued divergence between communities, largely due to an increase in abundance of the two dominant grasses. Community differences were mainly determined by aspect and its impact on soil temperature and water content. We concluded that, from a management perspective, switching to light fall grazing was as effective as removing grazing to assist in recovery from previous overgrazing, and that the relationship of grazing combined with the fine-scale pattern of variable solar irradiance was responsible for the closely interspersed mosaic of the two grassland communities.

1. Introduction

Temperate grasslands occupy a large part of central North America including the short-grass and mixed-grass prairie regions (Whittaker, 1975). Lesser extents occur in semi-arid areas of the Canadian province of British Columbia (BC) and the adjacent north-western United States (McNab et al., 2005). The temperate grasslands in these north-western areas, regionally known as Palouse Prairie, are characterized by cool season bunchgrass-type grasses (Tisdale, 1982; Chapman and Bolen, 2015), primarily bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) Á Löve), rough fescue (*Festuca campestris* Rydberg) and Idaho fescue (*Festuca idahoensis* Elmer). Even though they are limited in area, these bunchgrass dominated grasslands provide important spring and fall forage for the livestock industry and are important sources of plant and wildlife diversity including a high proportion of species at risk (Wikeem and Wikeem, 2004).

Poorly regulated grazing between the mid-1880s to 1930s led to overgrazing of BC's bunchgrass grasslands by cattle, sheep, and horses (Campbell and Bawtree, 1998), and many areas remained overgrazed until a more closely managed grazing rotation system was established in 1976 (McLean, 1982; Province of British Columbia, 2015). One development in grazing management that has shown improvement in range condition, defined as an increase in native bunchgrass cover, involves a switch in the timing of grazing from spring, when plants are actively growing, to fall, when native bunchgrasses are mostly dormant. When applied consistently over the long term, changes in the season of grazing can also have a pronounced effect on the species composition of bunchgrass communities; however, there are few published accounts of the seasonal grazing effect in Palouse grasslands. In a study of sheep grazing in Idaho, Bork et al. (1998) reported that fall grazed plots had perennial grass cover similar to that inside exclosures, while spring grazed plots had reduced perennial grass cover; moreover,

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the switch to fall grazing led to a recovery of species composition comparable to that with complete removal of grazing. Similar results were noted in a long-term (20 yr) season-of- grazing (cattle) trial for bunchgrass communities in interior BC (Thompson and Quinton, Unpublished Data, 1997). Despite these reported improvements, there remains a lack of quantitative evidence regarding species- and community-level responses to changes in grazing management, and how these changes are influenced by abiotic conditions, such as irradiance, slope, and aspect.

Coarse-scale changes in grassland plant communities are associated with differences in soil properties and water availability along elevation or geomorphic gradients (Tisdale, 1947; van Ryswyk et al., 1966; Bennie et al., 2006). A recent study by Lee et al. (2014) carried out in southern interior BC showed that aspect plays an important role in the transition from the lower elevation, bluebunch wheatgrass dominated community on warmer/drier south-facing aspects, to the higher elevation, rough fescue dominated community on cooler/wetter north aspects. The demarcation between bluebunch wheatgrass and rough fescue communities often occurs abruptly (<1 m) on intermediate aspects (i.e., easterly and westerly), suggesting a strong species response to aspect differences during the growing season. Moreover, these fine-scale distributions of plant species resulting from differing abiotic conditions may be further influenced by differing use by cattle. For example, the preference by cattle for rough fescue may have permitted the gradual, fine-scale expansion of bluebunch wheatgrass into grazed areas that were formerly dominated by rough fescue and warrants further investigation. Understanding how vegetation responds to the interaction of grazing and abiotic conditions is of great importance for sustainable management of these semi-arid grasslands.

The objectives of this study were to: (1) compare the recovery of plant species composition and cover in bluebunch wheatgrass and rough fescue communities following a switch from spring to fall grazing or rest (i.e., exclusion from cattle grazing) over a period of 14 years, and (2) determine which abiotic factors account for differences in the species composition and recovery of the bluebunch wheatgrass and rough fescue communities. First, we hypothesized that in both communities recovery of grass cover following a switch from spring to fall grazing would be comparable to removal of grazing. Second, we hypothesized that during recovery the rough fescue community may be more susceptible to a decline in species richness than the bluebunch wheatgrass community, and that this decline may be less noticeable under fall grazing than with exclusion of grazing. At our study site the two plant communities were in close proximity and we wished to determine how abiotic conditions such as topographic position, microclimate, and soil properties influenced the patterns of recovery.

2. Methods

2.1. Study sites

The study was carried out within the Lac du Bois Grasslands Provincial Park located approximately 10 km north of Kamloops, BC (50° 45′ N and 120° 25′ W). Lac du Bois Park comprises 15,000 ha with 55% of its area in grasslands (BC Parks, 2000), including both Bunchgrass very dry-hot (BGxh) and Bunchgrass very dry-warm (BGxw) subzones of the Bunchgrass Biogeoclimatic (BEC) zone, and the very dry-hot subzone (IDFxh) of the Interior Douglas-fir zone (Wikeem et al., 1993). The study was located within the middle grassland zone as differentiated by Tisdale (1947) and recently reviewed by Lee et al. (2014). The middle grasslands occur on rolling terrain between 620 and 800 m a.s.l., and comprise two main plant communities dominated by bluebunch wheatgrass and rough fescue (hereafter referred to as the BB and FE communities, respectively).

The study area has a semi-arid climate regime, which is warmer and drier at lower elevations, and becomes increasingly cooler and wetter at higher elevations. The 30-year mean annual precipitation obtained from Climate BC version 5.04 (http://cfcg.forestry.ubc.ca/projects/climate-data/climatebcwna/) is 33 cm, with 32% occurring between May and July (Environment Canada, 2013); mean annual air temperature for the study area is 6.8 °C, with an average July temperature of 20 °C. Newman et al. (2011) reported on the occurrence of a warming and drying trend for the study area in recent decades. The soils in the Lac du Bois grasslands have developed from morainal deposits associated with basic volcanic and limestone bedrock (Young et al., 1992). The study site is located on moderately alkaline, silt loam to silty clay loam McQueen Orthic Dark Brown Chernozem.

Between 1979 and 2000, the study area pasture was subjected to a heavy stocking rate (50–70% forage use) in the spring of alternate years (known as rest-rotation grazing); however, our particular study site location was in a remote corner of the pasture and received lesser use (estimated at 16–35% use). Quantitative date on forage use is currently unavailable for this area. In 2000, the season of grazing was switched from spring to fall, and six exclosures (three in BB and three in FE communities) were built (each approx. 30 m × 15 m) to compare changes resulting from the altered season of grazing (outside exclosures) to those occurring with removal of grazing (inside exclosures). The site continued to be grazed in the fall (16–35% use) over the 14 year period of our study.

2.2. Sampling and laboratory analyses

At each of the six exclosures, a pair of 25 m permanent transects was established – one transect along the center line inside the exclosure, and one approximately 2 m from the exclosure fence in the adjacent grazed area; collectively, these define the ungrazed (UG) and grazed (G) treatments of our study. Plant species composition and cover were determined using 50 Daubenmire frames (Daubenmire, 1959) positioned at 0.5 m intervals along the south side of all 12 permanent transects. Vegetation sampling occurred during the mid to late growth stages (i.e., June–July) in 2000, 2008, and 2014, yielding coverage data for a total of 48 vascular plant species and 36 transect-time units for analysis.

Soil temperature and volumetric water content (VWC) were monitored at 7.5 cm depth along the UG transects, continuously from September 2013 to October 2014. Soil temperature data were recorded using four HOBO Pendant 8 K temperature data loggers (Model #UA-001-08, Onset Computer Corporation, Bourne, MA) at 8.3 m intervals (beginning at meter zero). Soil VWC was measured using four Decagon EC-5 (#40593) soil moisture sensors and recorded using Em5b (#40705) data loggers (Decagon Devices, Inc., Pullman, WA) adjacent to the soil temperature sensors. Monitoring of soil temperature and VWC along the G transects was limited to June–October 2014, to minimize damage to sensors during grazing; in this case, only a single sensor for soil temperature and VWC was installed on each transect.

Composite soil samples, each consisting of four individual samples collected at 0–7.5 cm depth at pseudo-random locations along the UG and G transects, were collected in June 2014. Soil samples were air-dried and passed through a 2 mm sieve prior to analysis. An automated elemental analyzer (LECO CNS-2000, Leco Corp., St. Joseph, MI) was used to determine total soil C (Nelson and Sommers, 1982) and total soil N (McGill and Figueiredo, 1993) by dry combustion. Soil particle size distribution (i.e., percentages of sand, silt, and clay) was determined by the hydrometer method (Gee and Or, 2002). Soil pH was determined on a 1:2 (vol/vol) soil to