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Livestock grazing in intermountain depressional wetlands—Effects on plant strategies, soil characteristics and biomass

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ABSTRACT

Prairie wetlands are considered valuable habitat for plants, birds, and wildlife. Livestock use of these wetlands can create conflicts with conservation issues. To achieve proper management, patterns and processes induced by grazing livestock need to be understood. In this study, we examined interactions of livestock use, soil and vegetation of depressional prairie wetlands in British Columbia, Canada. Plant community composition, biomass, and soil properties (bulk density, salinity, nitrogen and carbon content) were sampled on transects in marsh and wet meadow vegetation zones of wetlands along a grazing intensity gradient. Grime's CSR-strategies were used to calibrate strategy signatures, which indicate the importance of competition, stress and disturbance. Heavily grazed sites had higher salinity, less biomass, and proportionally less belowground biomass. Differences concerning strategies between vegetation zones were only apparent in un/lightly grazed sites, where stress was higher in marsh and competition higher in wet meadow zones. Livestock use and nitrogen were positively correlated with ruderal abundance and negatively correlated with competitors and stress-tolerators. Livestock use was identified to be most influential on plant strategies. Our results indicate that heavy livestock use significantly alters vegetation patterns and processes in prairie wetlands and may have negative impact on valuable habitat. Management decisions should consider reduced livestock access and incorporate conservation issues in grazing schemes.

1. Introduction

Prairie wetlands and their associated vegetation play important ecological and economic roles in large parts of North America (Mitsch and Gosselink, 2000). As islands within relatively dry regions, they are especially vital for providing several ecological services, such as water filtration and storage (Leibowitz, 2003) and carbon sequestration (Euliss et al., 2006). They are fundamental in offering breeding habitat and shelter to a variety of waterfowl (Batt et al., 1989; Johnson et al., 2005), other wetland associated birds (Weller and Spatcher, 1965), and amphibians (Piha et al., 2007). Besides also hosting a number of wetland plant species, they supply wildlife with water and forage, and are thus of great conservation concern (Leibowitz, 2003; Seabloom and van der Valk, 2003). The semiarid grasslands, where these wetland ecosystems can be found, are important forage pastures for livestock and agriculture industries. Many of these wetlands have thus either been converted to agricultural land (Galatowitsch, 1993), or are under high grazing pressure by livestock (van Ryswyk et al., 1992).

Grazing is known to have the potential to alter ecosystems and change their structure and function (Hobbs, 1996). The general effects of livestock use on vegetation and soil are well-studied; cattle remove aboveground biomass, reduce litter accumulation, compact and disturb the soil (Austin et al., 2007; Greenwood and Mackenzie, 2001; Schulz and Leininger, 1990; Wheeler et al., 2002), further promoting erosion through mechanical disturbance of the soil surface (Pietola et al., 2005). Additionally, several studies have observed changed nutrient conditions (Bakker et al., 2004; Golluscio et al., 2009; McNaughton et al., 1997; Reeder and Schuman, 2002) and an increase in soil salinity (Belsky et al., 1999; Lavado and Taboada, 1987; Srivastava and Jefferies, 1996) under grazing in several regions. Moreover, a number of studies have investigated the responses of wetland vegetation communities to livestock use, and have found reactions to be dependent on hydrological conditions, and the intensity and seasonal occurrence of grazing (Austin et al., 2007; Jones et al., 2011; Lucas et al., 2004; Schulz and Leininger, 1990). Consistent findings regarding changes in vegetation and community structure show a decrease in litter accumulation, and shifts in plant functional types including

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decreased abundance of tall and rhizomatous species, and an increase of species with an annual lifecycle and short canopy height. On the other hand, moderate levels of disturbance have been shown to diversify vegetation composition and structure (e.g. Grace and Jutila, 1999; Marty, 2005; Jones et al., 2011), according to the 'hump-backed model' of plant species richness (Grime, 1973), and thus diversify habitats for other species (van Wieren, 1995; Metera et al., 2010). However, studies rarely consider the interactions of soil characteristics and livestock use and their relative importance in shaping vegetation patterns in prairie wetland vegetation.

One attempt to describe responses of plant communities to different soil and site characteristics has been made with Grime's plant strategy theory (Grime, 1974, 1977, 2001). This theory makes predictions about the distribution of species according to their adaptations to stress and disturbance, as well as their competitive ability when those two factors are negligible. Herein, stress is defined as a limitation of plant growth, either due to a deficit in essential resources or the presence of a growth-limiting factor, and disturbance as the destruction or damage of living plant material. Wetland vegetation is naturally exposed to stress through excess levels of water causing anoxic conditions. Livestock use has the potential to add to the stress component, by reducing nutrient availability and increasing salinity. Grazing and trampling, however, act as a disturbance (Grime, 2001), further altering competitive interactions (Gough and Grace, 1998). Species that are either tolerant or adapted to grazing (e.g. low palatability, adapted growth form) can react with compensatory growth, compensating or even increasing productivity (McNaughton, 1983), and are thus favored (Grime, 2001). Besides affecting plant growth, heavy grazing and trampling also creates gaps and reduces litter accumulation. This changes the competition for light (Olff and Ritchie, 1998), promoting the establishment of low growing perennial forbs and ruderal, early successional species (e.g. Bullock et al., 2001; Evju et al., 2010; Milchunas et al., 1988; van der Valk, 1986).

Depressional wetlands in the intermountain west are situated in a matrix of semiarid grasslands, similar to those in the Prairie Pothole Region of North America. But unlike the prairies east of the Rocky Mountains, this region did not support large herds of herbivores before human settlement and the introduction of cattle and horses (Mack and Thompson, 1982). Cattle ranching is now a widespread land use practice and of great commercial importance (van Ryswyk et al., 1992) making wetlands prone to alterations in their form and function. For this reason, it is essential to understand the processes, especially those altered by livestock use, to develop sustainable management practices for these valuable ecosystems.

This study examined the effects of livestock use on soil properties and plant strategies in depressional wetlands of southern interior British Columbia in the summer of 2010. We hypothesized that (i) soil salinity would increase, but soil carbon content, along with biomass and the proportion of belowground biomass, would decrease with increasing livestock use. We further expected (ii) stress-tolerant species to be more abundant in the more frequently inundated parts of the wetlands, and competitors to dominate drier and less disturbed areas. Additionally, we hypothesized that (iii) higher levels of salinity and decreased levels of nitrogen would increase the importance of stress tolerance, whereas high degrees of disturbance would primarily alter the vegetation community to more ruderal species, and decrease the importance of competition.

2. Methods

2.1. Study area

The study was conducted on the Thompson plateau in south central British Columbia, Canada (Fig. 1). This region is characterized by a continental semiarid climate, with mean annual precipitation of approximately 380 mm, and mean July temperature exceeding 20 °C at altitudes of the study sites (Wikeem and Wikeem, 2004).

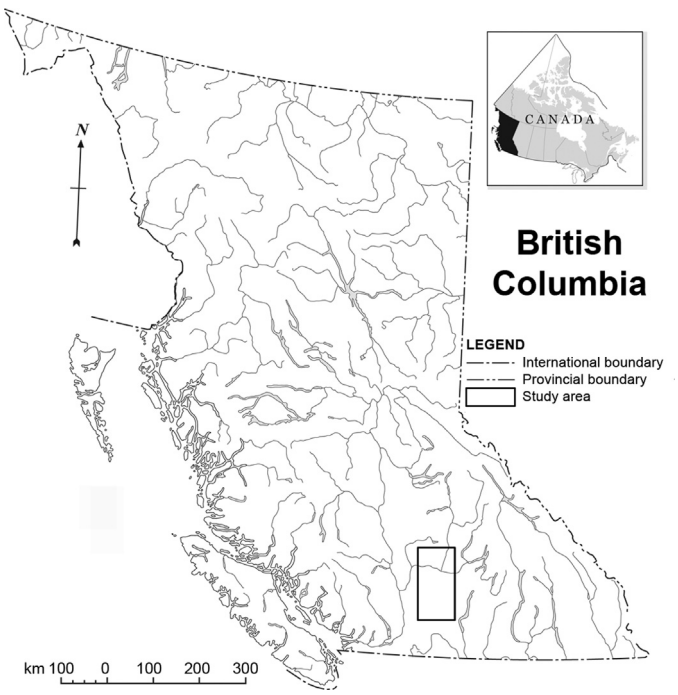

Fig. 1. Map of the study area.
Source: http://atlas.gc.ca.

Depressional wetlands in this area are similar in structure to those of the Prairie Pothole Region of North America (Kantrud, 1989), and are characterized by vegetation zones that form according to flooding height and duration (Jones et al., 2011). The marsh zone is defined by the open water and the height of the seasonal inundation, and is dominated by perennial graminoids such as *Scirpus acutus* and *Puccinellia nuttaliana*. The wet meadow zone does not experience regular flooding, and draws the line to the upland vegetation. It is dominated by *Juncus balticus*, *Hordeum jubatum* and *Poa pratensis*.

Eleven depressional wetlands at two locations representing a grazing intensity gradient were chosen for the study. Five were located at Hamilton Commonage southwest of Nicola Lake, and six were located in Lac du Bois Grasslands Provincial Park north of Kamloops. Three wetlands were fully fenced off, and two had partial fencing. The latter two and the remaining six wetlands were part of one or more pastures with stocking rates ranging from 0.8 to 2 cattle/ha. Wetland size ranged from 0.3 to 65 ha, and flooding was permanent to seasonal.

2.2. Field sampling

We laid out three to six transects at each wetland, equally spaced around its edge. This resulted in a total of 46 transects that were 60–650 m apart. The number of transects per wetland depended on its accessibility and on the presence of partial fencing in which case we increased the sampling effort. Transects were oriented perpendicular to the hydrologic gradient, from the inundated marsh to the edge of the lower prairie vegetation. Each transect was classified as either 'un-/lightly grazed' or 'heavily grazed' prior to field sampling, mainly based on indications of use, like trampling and signs of grazing, as well as local factors, such as abundance and accessibility of wetlands, and stocking rates. However, stocking rates