Plant community functional shifts in response to livestock grazing in intermountain depressional wetlands in British Columbia, Canada

W. Marc Jones [a,*], Lauchlan H. Fraser [b], P. Jefferson Curtis [a]

[a] Department of Chemistry, Earth and Environmental Sciences, University of British Columbia Okanagan, Kelowna, British Columbia, Canada V1V 1V7
[b] Department of Natural Resource Science, Thompson Rivers University, Kamloops, British Columbia, Canada V2C 5N3

ARTICLE INFO

ABSTRACT

Wetlands are ecologically and economically important ecosystems with high conservation value. Although wetland vegetation is strongly determined by abiotic factors, grazing disturbance may also be an important influence on this community. We evaluated the effects of livestock grazing on wetland vegetation in marsh and wet meadow zones in intermountain depressional wetlands in the southern interior of British Columbia, Canada. We sampled marshes and wet meadows in 36 wetlands along a grazing intensity gradient ranging from fully fenced and ungrazed wetlands to unfenced wetlands heavily grazed by livestock. The amount of bare ground was used as a surrogate measure of the intensity of livestock grazing. Vegetation community structure and composition was strongly associated with grazing intensity. Increased livestock grazing favored shorter-lived and smaller plants; conversely, the frequency of tall and rhizomatous species, which constitute the dominant plant species in these systems, declined with higher livestock use. The effects of grazing were more pronounced in the marsh than in the wet meadow. Associations between species richness and grazing differed between zones: native and exotic species richness showed a unimodal response in the marsh while in the wet meadow exotic richness increased and native richness showed no response. The relationship between exotic frequency and grazing was also inconsistent between zones, with a negative association in the marsh and a positive but weak association in the wet meadow. Grazing-related changes in vegetation along the grazing intensity gradient were substantial and may affect the habitat value of these wetlands for dependent wildlife such as breeding waterfowl.

1. Introduction

Half of the world's land area is rangeland (Havstad, 2008), and grazing by domestic livestock is a substantial and pervasive land use throughout the world (Milchunas and Lauenroth, 1993; Diaz et al., 2007). The effects of livestock grazing on rangelands and riparian areas have been well studied. Livestock selectively remove biomass, trample vegetation, disturb and compact soil, and add nutrients, and grazing can significantly alter the structure, productivity, diversity, and plant competitive interactions of grazed ecosystems (Martin and Chambers, 2001; Kauffman et al., 2004; Frank, 2005; Manier and Hobbs, 2007).

Freshwater depressional wetlands often occur within a rangeland matrix, such as in the intermountain west and prairie pothole regions of North America. Freshwater wetlands provide important ecological and economic services, such as wildlife habitat, regulation of water regimes, filtration of polluted water, and production of forage (Mitsch and Gosselink, 2000) and are critically important for breeding waterfowl and amphibians (Johnson et al., 2005; Piha et al., 2007). However, our understanding of the effects of livestock grazing on freshwater wetlands is limited, especially for the study area (Austin et al., 2007). A better understanding of how grazing affects vegetation (and thus wetland habitat) is an important step in determining tradeoffs between the ecological and economic services of wetlands and maintaining their biodiversity and productivity.

Several models have been proposed that predict vegetation community response to grazing with regard to simple functional attributes, including the generalized model (Milchunas et al., 1988; Milchunas and Lauenroth, 1993), competitor-stress tolerator-ruderal (CSR) model (Grime, 1977, 2001), and the range succession model (Dyksterhuis, 1949). These models predict that grazing will favor plant species with an annual life history, short canopy height, and (in the cases of the generalized and range succession models) a rhizomatous or stoloniferous root architecture. Empirical studies have largely validated these predictions in a variety of rangeland types (McIntyre et al., 1995; Diaz et al., 2001, 2007). Grazers preferentially forage tall, fast-growing, competitively dominant species (Fraser and Grime, 1999). Reduction of the

dominant species through grazing can reduce the competitive advantage of these species and benefit shorter-statured, slow-growing species as well as increase species richness and community diversity (Gough and Grace, 1998; Fraser and Grime, 1999). Grazing can also increase gaps in vegetation and reduce litter accumulation, and moderate grazing can thereby provide greater establishment opportunities for species with life histories, architectures, or dispersal strategies that allow them to exploit these gaps (van der Valk, 1986; Humphrey and Patterson, 2000; Bullock et al., 2001; Dorrough et al., 2004).

We examined the effects of livestock grazing on intermountain depressional wetlands to see if predictions of grazing models developed for rangelands could be extended to highly productive wetland systems that are subject to flooding stress not encountered in upland systems. We examined differences in the wetland vegetation community along a grazing intensity gradient and between wetland zones subject to different flooding regimes. We evaluated vegetation biomass and litter, species composition and richness, and frequency of functional groups.

We classified species into groups based on readily observable functional traits such as life history, architecture, height, growth form, and origin. Study wetlands are currently subject to pervasive grazing pressure but have a short evolutionary history of grazing (Daubenmire, 1970; Mack and Thompson, 1982) and are therefore likely to show a strong functional response to grazing (Milchunas and Lauenroth, 1993; Diaz et al., 2007). We expected annuals, short and rhizomatous species, and forbs to increase with increasing grazing intensity, perennials, medium, tall, and non-rhizomatous species to decrease with increasing grazing intensity, and the response of graminoids to be neutral.

Following Kantrud et al. (1989), we classified wetland vegetation into two zones: marsh (typically inundated for much of the growing season and characterized by dense stands of tall emergent vegetation) and wet meadow (temporarily flooded during the growing season and dominated by smaller graminoids). Given the abundance of emergent vegetation, competition for light may be more intense in the marsh, and we expected the effects of grazing to be more pronounced there, which would be consistent with predictions of the CSR and generalized models. The marsh zone is subject to greater flooding stress but is less hydrologically variable (Kantrud and Stewart, 1977) and less species rich (Keddy, 2000) than the wet meadow.

2. Methods

2.1. Study Sites

We sampled 36 depressional wetlands from the southern interior of British Columbia, Canada, near the city of Kamloops. Twenty-five wetlands were sampled in June and July of 2006 and the remaining eleven were sampled in July and early August of 2007. We selected sites from wetlands that are part of a long-term (20 years) waterfowl breeding pair survey conducted by Ducks Unlimited Canada and the Canadian Wildlife Service. Sample wetlands were either semipermanently or permanently flooded (except for two sites that were seasonally flooded) and ranged from oligo- to mesosaline. Sites encompassed a grazing disturbance gradient from fully fenced and ungrazed to unfenced and heavily grazed by livestock (pasture-level stocking densities at grazed sites ranged from 0.4 to 2 cattle/ha). Fenced sites included one fully fenced and three partially fenced wetlands that have been managed as cattle exclosures for approximately 15 years. Common wet meadow species include *Carex praegracilis* (field sedge), *Hordeum jubatum* (foxtail barley), and *Juncus balticus* (Baltic rush); typical marsh species include *Bolboschoenus maritimus* (seacoast

bulrush), *Schoenoplectus acutus* and *Schoenoplectus tabernaemontani* (hard- and soft-stemmed bulrush), and *Puccinellia nuttalliana* (Nuttall's alkaligrass).

2.2. Wetland vegetation

We sampled vegetation along six transects systematically placed around the wetland equidistant from one another. We placed transects parallel to the hydrological gradient and ran from the aquatic-emergent vegetation boundary in the marsh zone to the wetland-terrestrial vegetation boundary in the wet meadow zone. Transect lengths varied depending on the width of these zones, from approximately 10 m to 100 m. We delimited wetland zones based on the dominant vegetation of each wetland using species-hydrology associations summarized in Kantrud et al. (1989). We measured plant species frequency of occurrence in 60 0.5-m^2 quadrats placed equidistant along transects (30 in each zone). Species nomenclature followed Douglas et al. (1998–2002).

We separately sampled aboveground biomass and litter from the middle of the wet meadow and marsh zones at each vegetation transect (six samples per zone per site) using 0.25-m^2 quadrats. We clipped aboveground biomass to a height of 1 cm. Biomass and litter samples were oven-dried at 65 °C for at least 72 h to a constant dry mass.

2.3. Plant traits

We evaluated nine non-mutually exclusive functionally defined groups. These were based on species' life history (annual or biennial, perennial), root architecture (rhizomatous, non-rhizomatous), canopy height (short, medium, tall), and growth form (forb, graminoid). We also evaluated species of exotic origin. The rhizomatous category included species with rhizomes and stolons as well as creeping species that develop nodal roots. Breaks for the height category were <40 cm (short), between 40 and 80 cm (medium), and >80 cm (tall) (Diaz et al., 2001; Pykälä, 2004). All species classifications were based on Douglas et al. (1998-2002). To measure functional group similarity, we calculated the proportion of species shared between each pair of groups using the Jaccard coefficient of community.

2.4. Grazing intensity

We measured bare ground and soil bulk density at each wetland. For each wetland zone, bare ground was calculated as the mean number of vegetation quadrat corners that intersected bare ground ($n = 30$/zone), while soil bulk density was calculated for each wetland ($n = 6$/site). Where quadrats were inundated, a rod projected vertically from the quadrat corner to the substrate was used. The site-level measure of bare ground was highly correlated with soil bulk density ($r = 0.83$), and we used bare ground as our indicator of grazing intensity within each wetland zone (Greenwood and McKenzie, 2001; Hendricks et al., 2005; Manier and Hobbs, 2007). Although bare ground is used as a surrogate measure of grazing intensity, it can also be indicative of mechanical disturbance through hoof shear and trailing (M. Jones, personal observation). To improve the interpretability of this measure, it was rescaled so that it ranged from 0 to 100.

2.5. Statistical analysis

We used a Wilcoxon rank sum test to compare whether bare ground was different between the marsh and wet meadow zones and whether aboveground biomass was different between the zones at wetlands with no measurable grazing pressure (bare ground = 0). We used linear regressions to model the relationships