Rangeland Ecology & Management 68 (2015) 470–475

Contents lists available at ScienceDirect

Rangeland Ecology & Management

journal homepage: http://www.elsevier.com/locate/rama

Managing Mixed-Grass Prairies for Songbirds Using Variable Cattle Stocking Rates☆,☆☆

M.S. Sliwinski [a,*], N. Koper [b]

[a] PhD Student, School of Natural Resources, University of Nebraska-Lincoln, Lincoln, NE 68583, USA
[b] Associate Professor, Natural Resources Institute, University of Manitoba, Winnipeg, MB, Canada R3T 2M6

ARTICLE INFO

Article history:
Received 2 February 2015
Received in revised form 14 July 2015
Accepted 20 July 2015

Key words:
Baird's sparrow
cattle grazing
chestnut-collared longspur
ecological threshold
grassland management
Sprague's pipit
stocking rates

ABSTRACT

Most remaining grasslands are used for livestock grazing; stocking rates could be managed to help stop declining songbird populations. We examined the effects of stocking rates on grassland songbirds in northern mixed-grass prairies using a beyond–Before-After-Control-Impact manipulative experiment in Canada's Grasslands National Park and adjacent community pastures. The study area consisted of nine 300-ha pastures grazed at a range of stocking rates starting in 2008. We conducted songbird surveys at six upland plots in each pasture from 2006–2010 and measured vegetation structure within each plot from 2008–2010 ($n = 54$). We evaluated the effects of stocking rates on habitat structure and songbird abundance using linear and generalized linear mixed models. Baird's sparrow *(Ammodramus bairdii)* relative abundance declined with increasing stocking rates. Chestnut-collared longspur *(Calcarius ornatus)* relative abundance increased only at higher stocking rates, indicating a possible threshold effect. Savannah sparrow *(Passerculus sandwichensis)* relative abundance decreased with stocking rates above 0.4 AUM after a year of grazing. Sprague's pipit *(Anthus spragueii)* relative abundance declined with grazing, but the effect was weak and only significant in 1 year. Western meadowlark *(Sturnella neglecta)* abundance was unaffected by grazing. Stocking rates may be used to benefit grassland songbirds and may alter avian communities after as little as 1 month of livestock grazing. Applying a range of stocking rates regionally may provide habitat for many species.

Introduction

Grassland managers often promote structural homogeneity in grasslands, such as "management to the middle" in the case of private landowners, and exclusion of livestock and fire in the case of public landowners (Fuhlendorf et al., 2012). Unfortunately, this structural homogeneity may be contributing to declining grassland bird populations (Samson and Knopf, 1994; Brennan and Kuvlesky, 2005). To conserve grassland birds with different habitat needs, managers should focus on restoring multiscale heterogeneity (Fuhlendorf and Engle, 2004).

Stocking rates are a grazing tool that may be used to manage structural heterogeneity at different scales: low stocking rates will allow habitat structure measures to increase and heterogeneity to decrease because there is more forage available than cattle can consume; moderate stocking rates allow cattle to forage selectively, which should increase within-pasture heterogeneity (Hart et al., 1993); high stocking rates result in increased removal of vegetation from a pasture, resulting in decreased habitat structure and heterogeneity (Fritcher et al., 2004). The number of years a pasture is grazed may also have important consequences for habitat structure and heterogeneity because the effects of grazing can be cumulative across years (Johnson et al., 2011). Although managers understand the effects of stocking rates on vegetation structure, the effects of stocking rates on songbirds are not well understood.

To examine the effects of different cattle stocking rates and years of grazing on habitat structure and songbird abundance, we developed a large-scale beyond–Before-After-Control-Impact (BACI; Underwood, 1994) grazing experiment in a northern mixed-grass prairie. Using this design, we were able to determine if any effects of stocking rate were nonlinear, which could indicate an ecological threshold (the point at which an ecological measure begins to change in response to management; Johnson et al., 2011). Focal species for our study included Baird's sparrow *(Ammodramus bairdii)*, chestnut-collared longspur *(Calcarius ornatus)*, Savannah sparrow *(Passerculus sandwichensis)*, Sprague's pipit *(Anthus spragueii)*, and western meadowlark *(Sturnella neglecta)*. This group includes two species at risk in Canada (chestnut-collared longspur and Sprague's pipit; COSEWIC, 2010).

We predicted that habitat structure measures, including vegetation height, canopy height, visual obstruction, and litter depth, would decrease with increasing stocking rate and that habitat heterogeneity would be highest at moderate stocking rates because grazing removes

☆ Research was funded by Parks Canada, World Wildlife Fund, University of Manitoba, Natural Sciences and Engineering Research Council, Canadian Foundation for Innovation, Manitoba Research Innovations Fund, Clayton H. Riddell Endowment Fund, and the Government of Manitoba.
☆☆ At the time of research, Sliwinski was a Masters student, Natural Resources Institute, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2M6.
* Correspondence: M. Sliwinski, School of Natural Resources, University of Nebraska-Lincoln, Lincoln, NE 68583, USA.
E-mail address: maggi.sliwinski@gmail.com (M.S. Sliwinski).

http://dx.doi.org/10.1016/j.rama.2015.07.010
1550-7424/

vegetation and foraging selectivity is predicted to be highest at low and moderate grazing intensities (Hart et al., 1993). We expected abundances of Sprague's pipit and Baird's sparrow to decrease and chestnut-collared longspur to increase as stocking rates increased because of these species' habitat structure preferences. We did not expect to see a change in western meadowlark or Savannah sparrow abundance in response to stocking rate because they are generalist species (Mengel, 1970).

Methods

Study Site and Design

In 2006, a grazing experiment was implemented in the East Block of Grasslands National Park of Canada (GNP) in southwestern Saskatchewan (lat 49°01′00″N, long 106°49′00″W). GNP consists of rolling hills of native mixed-grass prairie and falls within the Missouri River drainage basin (Coupland, 1950). The uplands were dominated by grasses including *Hesperostipa comata, Elymus lanceolatus, Bouteloua gracilis, Koeleria macrantha,* and *Pascopyrum smithii* and forbs including *Artemesia frigida, Phlox hoodii,* and *Sphaeralcea coccinea; Selaginella densa* was the dominant groundcover (Coupland, 1950). The study site had never been cultivated and was ungrazed since 1992, when Parks Canada purchased the land.

We used a beyond-BACI study design, which included multiple control and treatment pastures, and baseline data collection before implementation of grazing (Underwood, 1994; Koper et al., 2008). Nine pastures (average size 296 ha, SD = 14 ha, range = 280–331 ha) were delineated in GNP encompassing equal proportions of upland habitat among pastures (Table A1). Six pastures were grazed treatments, and three pastures were ungrazed controls (for more information and map, see Koper et al., 2008). The uplands of each pasture included six 100-m radius (3.2 ha) permanent sampling plots (hereafter plots); each plot was at least 250 m from fences and other plots. There were 36 grazed plots and 18 ungrazed control plots inside GNP ($n = 54$).

In early 2008, fencing for the six grazed pastures within GNP was erected and each pasture was supplemented with two water troughs, one located in the lowland and one in the upland. These water troughs decreased grazing pressure on potentially sensitive riparian areas and encouraged more uniform grazing distribution consistent with the management of cattle on private lands (Reece et al., 2008), thus allowing us to make recommendations about grazing management both in the park and in rangelands managed for commercial purposes.

Cattle grazing typically aims for ~50% biomass removal (Abouguendia, 1990), which is estimated to require 0.63 AUM·ha^{-1} in this region (Parks Canada, 2006). GNP pastures were managed with six grazing intensities ranging from 0.23 AUM·ha^{-1} to 0.83 AUM·ha^{-1} (Table A2). Cattle were first reintroduced to GNP treatment pastures on 5 June 2008. In 2009 and 2010, cattle were placed in the treatment pastures on 15 and 26 of May, respectively. Grazing was season-long continuous and lasted approximately 4 months each year; no supplemental feed was provided to cattle.

Table 1
Parameter estimates (β), standard errors, *P* values, and 90% confidence intervals for the Baird's sparrow relative log (abundance) in Grasslands National Park, 2006–2010. Model: Baird's sparrow = Year + Stocking Rate + Year · Stocking Rate.

Parameter	β	SE	*P*	LCL, 90%	UCL, 90%
Intercept	2.68	0.05	<0.001	2.60	2.76
AUM	-0.03	0.09	0.749	-0.19	0.13
After 1 mo	0.16	0.10	0.100	-0.001	0.33
After 1 yr	-0.25	0.10	0.014	-0.42	-0.08
After 2 yr	0.11	0.09	0.194	-0.03	0.26
AUM·After 1 mo	-0.01	0.20	0.963	-0.33	0.31
AUM·After 1 yr	**-0.41**	**0.21**	**0.052**	**-0.75**	**-0.06**
AUM·After 2 yr	**-0.34**	**0.18**	**0.060**	**-0.63**	**-0.04**

Bolded text indicates a significant interaction; AUM, stocking rate (AUM·ha^{-1}).

Field Methods

In May and July 2008–2010, we measured habitat structure variables that tend to influence the abundance of grassland birds (Fisher and Davis, 2010). We took habitat measurements within a 1.0 × 0.5 m sampling quadrat made of polyvinyl chloride pipe that was placed on the ground at 50 m and 100 m from the center of each plot in the four cardinal directions (8 samples per plot). Habitat structure variables that we measured within each sampling quadrat included visual obstruction reading (estimate of vegetation biomass; see later), tallest vegetation height (i.e., grass, forb, or shrub; dead or alive), canopy height (height at which a 20 × 50 cm Styrofoam board rested when placed on top of the vegetation in the middle of the quadrat), and litter depth measured in the center of the quadrat. We measured visual obstruction as the height at which vegetation obscured 50% of a pole marked with 5-cm increments, when visualized from a height of 1 m and at 4 m distance (modified from Robel et al., 1970).

We visited each plot at least three times per year between mid-May and 30 June in 2006–2010 to quantify bird abundance. To assess the immediate impact of cattle reintroduction on songbirds in 2008, we completed two visits before and two visits after cattle reintroduction. We used 5-minute, 100-m radius point counts (modified following Hutto et al., 1986). All birds seen or heard during the 5 minutes were recorded, along with sex of individuals when possible. All point counts were conducted between sunrise and 1000 hours and each plot was surveyed by at least two observers in all years to lessen observer bias. No surveys were conducted on days with excessive wind (>15 km·h^{-1}) or rain.

Statistical Analysis

Because pasture was the treatment unit for livestock management, our habitat structure and songbird abundance analyses were conducted at the pasture scale. We calculated means and standard deviations of habitat structure measures within each pasture and year using data collected during the May sampling period. Standard deviations were used as an index of habitat heterogeneity (Fuhlendorf and Engle, 2004). Due to an error in measuring litter depth in May 2009, litter depth data were analyzed in May 2008, July 2009, and July 2010. We summed counts of male songbirds of each focal species within each pasture, visit, and year. We used unadjusted counts to measure relative abundance for several reasons, although we acknowledge that detectability of birds during point-count surveys is always imperfect. In northern mixed-grass prairies, dependent double-observer sampling has demonstrated that perceptibility of Baird's sparrow, chestnut-collared longspur, Sprague's pipit, and western meadowlark is high (Leston et al., 2015). In addition, assumptions of distance sampling are difficult to meet in the field (Efford and Dawson, 2009), and not meeting these assumptions can increase rather than decrease estimate bias (Johnson, 2008).

To assess the effects of stocking rate and number of years grazed on habitat and songbirds, we analyzed data from pregrazed years, grazed years, treatment pastures, and control pastures using a BACI design. This design accounts for preexisting trends in the data (e.g., due to topo-edaphic features of the study site) by using interactions to examine differences in pretreatment and post-treatment data and controls (Underwood, 1994). For example, a treatment effect alone (e.g., significant effect of stocking rate before grazing was implemented) could indicate that our pastures had a pattern before treatment. Only a significant interaction between the main effects of treatment and time indicates a true effect of treatment.

We used linear and generalized linear mixed models to test for significant ($\alpha = 0.10$) interactions between years grazed and stocking rate (Table A2) in R Statistical software version 9.3 (R Core Team, 2012). We included pasture as a random effect in each model. Years grazed was modeled as a categorical variable: pregrazed years (2006–May 2008) were combined as year "0," June 2008 was "after 1 month," 2009 was "after 1 year," and 2010 was "after 2 years" of grazing. Stocking rate was modeled as a continuous variable. We overlaid average future stocking rates on the pretreatment data to allow the use of interactions between years grazed and stocking rate. We first tested for a significant interaction between a quadratic effect of stocking rate and years grazed, which would indicate a polynomial effect of grazing (model structure: response variable = Years Grazed + Stocking Rate + Stocking Rate^2 + Years Grazed · Stocking Rate + Years Grazed · Stocking Rate^2). If the quadratic interaction term was not significant, we removed it to reduce problems with collinearity (Quinn and Keough, 2002) and examined the interaction term in the linear model (model structure: response variable = Years Grazed + Stocking Rate + Years Grazed · Stocking Rate).

Distributions of the residuals were examined using diagnostic graphs and the deviance/*df* ratio; we concluded that distributions of the error terms were best described as normal for habitat structure and Poisson with a log link for count data. We checked for collinearity between main effects of interest; none were collinear at $r > 0.10$.

Results

None of the models assessing habitat structure variables (both means and heterogeneity) had a significant interaction term in either the quadratic or linear models, indicating that our sampling methods did not allow us to detect an effect of stocking rate on habitat structure. However, differences among pastures are visible in aerial images after 2 years of grazing (Fig. S1).

Relative abundance of Baird's sparrow was not affected within the first month of grazing (interaction term between "after 1 month" and stocking rate was not significant, $P = 0.963$) but declined after the first and second years of grazing ($P = 0.052$, $P = 0.060$; Table 1, Fig. 1A). Pastures with the highest stocking rates had three and four fewer Baird's sparrows per pasture after 1 and 2 years of grazing, respectively.

Relative abundance of Savannah sparrow was unaffected after the first month of grazing ($P = 0.261$) but declined after the first year ($P = 0.021$) and second year above approximately 0.4 AUM·ha^{-1} ($P = 0.063$) by one and two birds per pasture, respectively (Table 2, Fig. 1B). Sprague's pipit relative abundance was unaffected after the first month of grazing ($P = 0.234$), declined weakly with grazing after the first year ($P = 0.092$), but was unaffected after 2 years of grazing ($P = 0.550$; Table 3; Fig. 1C). Western meadowlark relative abundance exhibited no effect of grazing after 1 month ($P = 0.826$), 1 year ($P = 0.843$), or 2 years of grazing ($P = 0.472$).

Chestnut-collared longspur relative abundance increased with stocking rate within the first month of grazing ($P = 0.037$) and continued this trend after an additional year of grazing ($P = 0.003$; Table 4). After the second year of grazing, the quadratic stocking rate by years grazed interaction was not significant, but the linear interaction was significant ($P < 0.001$). The increase in longspur abundance was most pronounced at stocking rates > 0.6 AUM·ha^{-1} (Fig. 1D). Relative to ungrazed pastures, longspur abundance increased at 0.83 AUM·ha^{-1} by five birds per pasture in the first month of grazing, seven birds per pasture after 1 year of grazing, and 10 birds per pasture after 2 years of grazing. In contrast, there was little change in the number of birds per pasture from the ungrazed pastures to the moderately grazed pastures (see Fig. 1D).

Discussion

The effects of stocking rates on grassland birds are not well understood, even though most of their habitat is used for livestock grazing (NABCI, 2013). Cumulatively, our results suggest a large effect of interannual variability on the habitat structure variables that we measured. Climate factors, such as interannual variability in precipitation (Environment Canada, 2011), or within-pasture variability due to topo-edaphic factors may have prevented detection of changes in habitat structure. Additionally, our habitat data were collected starting in

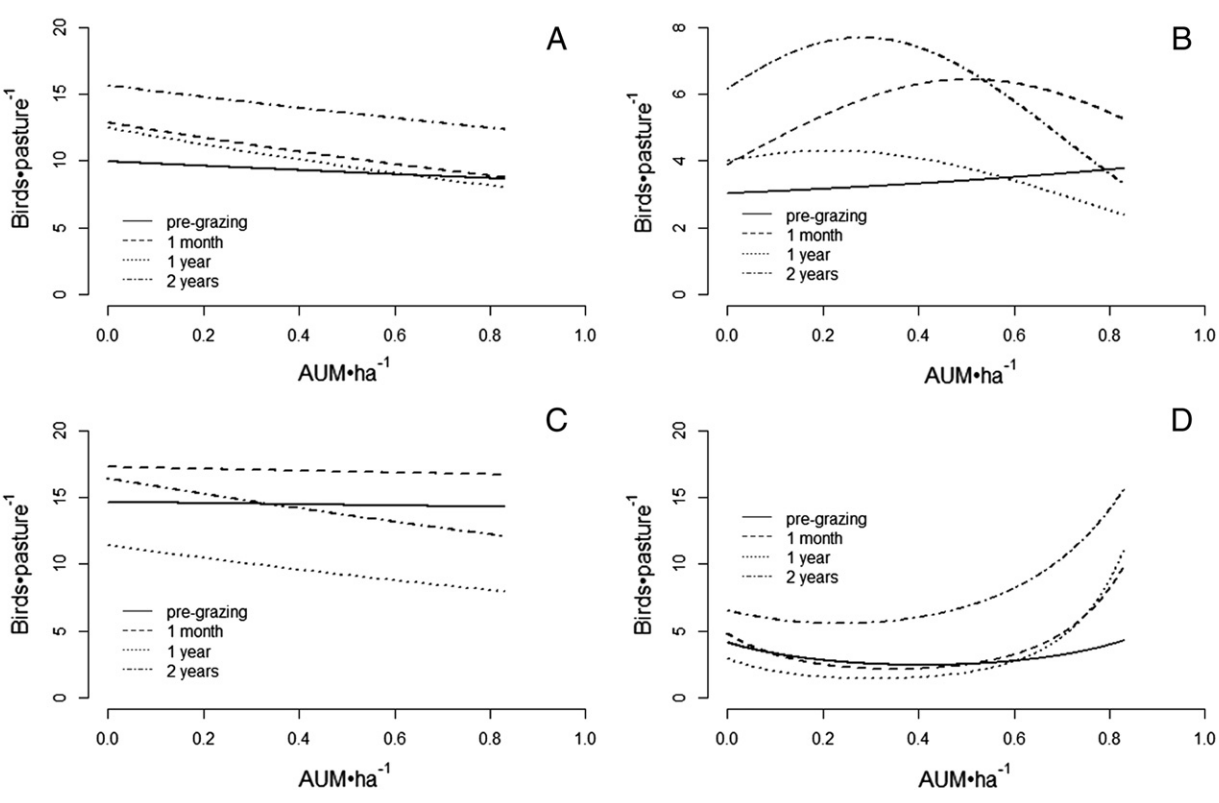

Figure 1. Predicted effects of grazing intensity at the pasture scale on (A) Baird's sparrow, (B) Savannah sparrow, (C) Sprague's pipit, and (D) chestnut-collared longspur relative abundance in Grasslands National Park of Canada, 2006–2010.

Table 2
Parameter estimates (β), standard errors, *p* values, and 90% confidence intervals for the Savannah sparrow relative log(abundance) in Grasslands National Park, 2006–2010. Model: Savannah sparrow = Year + Stocking Rate + Stocking Rate^2 + Year · Stocking Rate + Year · Stocking Rate^2.

Parameter	β	SE	*P*	LCL, 90%	UCL, 90%
Intercept	1.18	0.18	<0.001	0.90	1.48
AUM1	1.24	0.84	0.142	-0.15	2.63
AUM2	-0.04	0.84	0.964	-1.43	1.35
After 1 mo	0.54	0.13	0.001	0.33	0.75
After 1 yr	0.01	0.12	0.944	-0.19	0.21
After 2 yr	0.47	0.11	<0.001	0.29	0.64
AUM1 · After 1 mo	0.52	1.54	0.436	-2.01	3.05
AUM2 · After 1 mo	-1.61	1.43	0.261	-3.97	0.74
AUM1 · After 1 yr	**-3.52**	**1.52**	**0.021**	**-6.02**	**-1.02**
AUM2 · After 1 yr	-1.24	1.45	0.389	-3.62	1.13
AUM1 · After 2 yr	**-3.81**	**1.32**	**0.004**	**-5.98**	**-1.64**
AUM2 · After 2 yr	**-2.28**	**1.23**	**0.063**	**-4.31**	**-0.26**

Bolded text indicates a significant interaction; AUM1, linear effect of stocking rate (AUM · ha^{-1}); AUM2, quadratic effect of stocking rate.

Table 4
Parameter estimates (β), standard errors, *P* values, and 90% confidence intervals for the chestnut-collared longspur relative log (abundance) in Grasslands National Park, 2006–2010. Model: chestnut-collared longspur = Year + Stocking Rate + Stocking Rate^2 + Year · Stocking Rate + Year · Stocking Rate^2.

Parameter	β	SE	*P*	LCL, 90%	UCL, 90%
Intercept	1.17	0.16	<0.001	0.91	1.43
AUM1	0.36	1.79	0.839	-2.59	3.31
AUM2	2.88	1.85	0.119	-0.16	5.92
After 1 mo	0.27	0.14	0.052	0.04	0.50
After 1 yr	-0.05	0.13	0.686	-0.27	0.16
After 2 yr	0.85	0.09	<0.001	0.69	1.00
AUM1 · After 1 mo	**2.96**	**1.36**	**0.030**	**0.72**	**5.19**
AUM2 · After 1 mo	**3.80**	**1.82**	**0.037**	**0.80**	**6.80**
AUM1 · After 1 yr	**5.82**	**1.32**	**<0.001**	**3.65**	**7.98**
AUM2 · After 1 yr	**5.08**	**1.73**	**0.003**	**2.23**	**7.92**
AUM1 · After 2 yr	**3.98**	**1.04**	**<0.001**	**2.26**	**5.70**
AUM2 · After 2 yr	0.44	1.23	0.723	-1.56	2.46

Bolded text indicates a significant interaction; AUM1, linear effect of stocking rate (AUM · ha^{-1}); AUM2, quadratic effect of stocking rate.

2008, rather than in 2006 when the bird data were collected, which may have prevented detection of changes in habitat structure due to grazing. Other research conducted at our study site demonstrated that vegetation biomass decreased with grazing intensity at the 50 m × 20 m plot scale after a single year of livestock grazing (Bylo et al., 2014), and aerial images demonstrated visible effects of livestock grazing in our experimental pastures in September 2009, after only 2 years of grazing. Thus vegetation characteristics other than those we measured here were influenced by grazing.

Previous studies suggested that Baird's sparrow was relatively insensitive to low and moderate levels of grazing (Davis et al., 1999; Koper and Schmiegelow, 2006). In contrast, the linear effect of stocking rate that we detected suggests that any livestock grazing could negatively affect abundance of Baird's sparrows; conversely, any reduction in stocking rate is likely to have some benefits to this species.

Previous research showed that the chestnut-collared longspur prefers shorter and sparser vegetation found in early successional habitat (Davis et al., 1999; Fritcher et al., 2004). Our study showed an increase in longspur relative abundance even in the first month of cattle grazing; it is possible that the chestnut-collared longspur was affected directly by the livestock or to indicators of their presence (e.g., dung pats; Davis, 2005). The high stocking rate threshold (0.6 AUM · ha^{-1}) we found is above the moderate stocking rate recommended by most grazing literature (e.g., Abouguendia, 1990; Holechek et al., 1999) and suggests that some grasslands should be managed with higher stocking rates to benefit chestnut-collared longspur and other species with similar habitat preferences (such as McCown's longspur [*Rhynchophanes mccownii*] and horned lark [*Eremophila alpestris*]).

Table 3
Parameter estimates (β), standard errors, *P* values, and 90% confidence intervals for the Sprague's pipit relative log(abundance) in Grasslands National Park, 2006–2010. Model: Sprague's pipit = Year + Stocking Rate + Year · Stocking Rate.

Parameter	β	SE	*P*	LCL, 90%	UCL, 90%
Intercept	2.30	0.06	<0.001	2.20	2.40
AUM	-0.17	0.11	0.139	-0.35	-0.02
After 1 mo	0.26	0.12	0.029	0.06	0.46
After 1 yr	0.23	0.10	0.029	0.06	0.39
After 2 yr	0.45	0.09	<0.001	0.30	0.61
AUM · After 1 mo	-0.29	0.25	0.234	-0.70	0.11
AUM · After 1 yr	**-0.36**	**0.22**	**0.092**	**-0.72**	**-0.01**
AUM · After 2 yr	-0.12	0.19	0.550	-0.43	0.20

Bolded text indicates a significant interaction; AUM, stocking rate (AUM · ha^{-1}).

In contrast to our prediction, Savannah sparrow abundance did decline with higher stocking rates. This result suggests that Savannah sparrows tolerate low and moderate levels of grazing, at least after 2 years of grazing, and perhaps prefer lightly grazed areas in this ecoregion. One study showed that Savannah sparrow density was highest at intermediate measures of litter depth (Winter et al., 2005), which might be created with moderate stocking rates. Unlike the chestnut-collared longspur, Savannah sparrows did not respond to grazing within the first month.

We expected Sprague's pipit abundance to decline with increasing stocking rates (Davis et al., 1999), but our results were equivocal. Other studies have shown that Sprague's pipits are insensitive to grazing (e.g., Kantrud and Kologiski, 1983; Koper and Schmiegelow, 2006). Davis et al. (1999) concluded that low levels of grazing are tolerable to Sprague's pipit. Although Sprague's pipit is classified as a species at risk in Canada, other factors, such as habitat fragmentation and resulting edge effects (Koper et al., 2009; Sliwinski and Koper, 2012) or overall range condition (Davis et al., 2014), may be more important to Sprague's pipits than livestock grazing.

As we predicted, western meadowlark abundance did not change with stocking rate. This species uses a broad range of habitat types (Chapman et al., 2004); our results suggest that all stocking rates that we applied provided suitable habitat for this species in this ecoregion.

Implications

The fact that most rangelands are grazed moderately (Bradley and Wallis, 1996; Holechek et al., 1999; Toombs et al., 2010) may explain the declining population trends of both Baird's sparrow and chestnut-collared longspur (Sauer et al., 2013), species with opposite habitat preferences in mixed-grass prairies. Our research shows that some species would benefit most from periodic livestock exclusion, while others prefer higher-than-moderate stocking rates. We suggest managing stocking rates to increase landscape heterogeneity, a goal that has been widely promoted for bird conservation in recent years (e.g., Fuhlendorf et al., 2012). This may be achieved by using low stocking rates or rest on some pastures and heavy stocking rates on others. Additionally, if pastures are to be managed with high stocking rates, they should be rotated to avoid degradation from continuous heavy grazing over many years (Brennan and Kuvlesky, 2005). It is important to note here that the specific stocking rates used will depend on the region and precipitation in a given year, but our results suggest that stocking rates both above and below moderate rates may benefit species at risk in grassland ecosystems.

The following is the supplementary data related to this article.

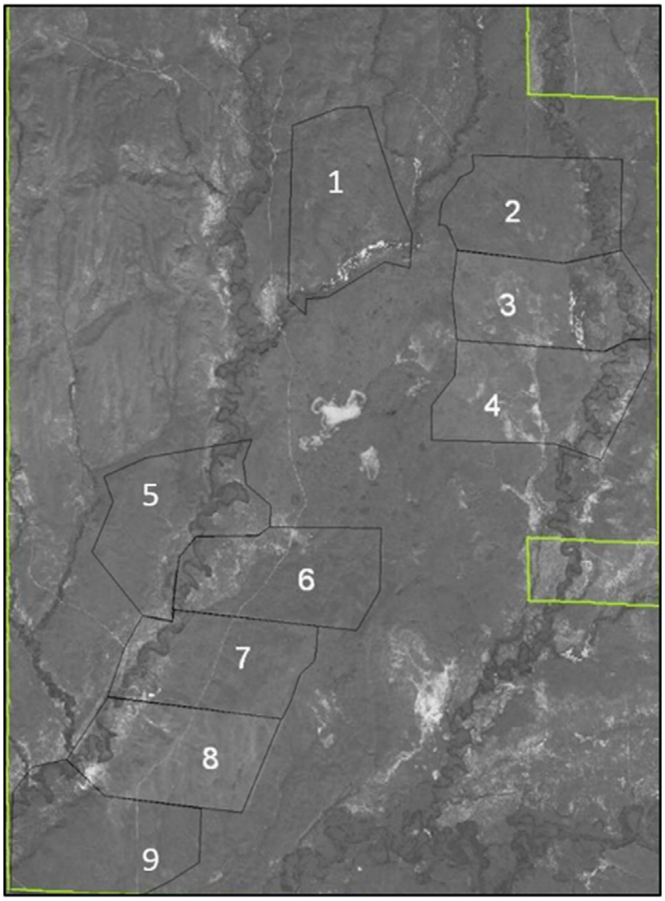

Figure S1. Satellite image of the experimental study site in Grasslands National Park, Canada, September 18, 2009. Pasture numbers correspond to the stocking rates provided in Table A2. The effects of grazing are visually apparent in the heavily grazed pastures (3, 4, and 8). (Image ©2009 CNES, Licensed by BlackBridge Geomatics Corp., www.blackbridge.com/geomatics.)

Acknowledgements

We thank the editors and anonymous reviewers who have improved the content of this article substantially. We would like to thank Parks Canada for access to Grasslands National Park and for facilitating research activities; field assistants who assisted in the research, especially Tonya Lwiwski and Adrienne Tastad; and Drew Tyre and Trevor Hefley for their statistical assistance.

Appendix A

Table A1
Proportions of habitat types comprising Pastures 1-9, East Block of Grasslands National Park, Saskatchewan, Canada, 2008 (data from Parks Canada, 2008).

	% Shrub community	% Upland grasslands	% Valley grasslands	% Sloped grasslands	% Disturbed
Pasture 1	9	74	17	0	0
Pasture 2	10	67	14	8	2
Pasture 3	11	45	33	11	0
Pasture 4	13	60	17	9	0
Pasture 5	11	70	19	0	0
Pasture 6	9	64	27	0	0
Pasture 7	10	72	18	0	0
Pasture 8	9	71	20	0	0
Pasture 9	7	59	24	9	0

Table A2
Stocking rates used in Grasslands National Park, Saskatchewan, Canada, 2008–2010.

Pasture	2008	2009	2010
	$AUM \cdot ha^{-1}$	$AUM \cdot ha^{-1}$	$AUM \cdot ha^{-1}$
1	0.00	0.00	0.00
2	0.23	0.25	0.24
3	0.66	0.71	0.70
4	0.74	0.82	0.77
5	0.00	0.00	0.00
6	0.36	0.39	0.38
7	0.54	0.57	0.55
8	0.81	0.83	0.83
9	0.00	0.00	0.00

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