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Restoring Tallgrass Prairie and Grassland Bird Populations in Tall Fescue Pastures With Winter Grazing

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Abstract

Restoration of grasslands dominated by tall fescue (*Schedonorus phoenix* [Scop.] Holub) to native tallgrass prairie usually requires burning, herbicides, or reseeding. We tested seasonal grazing by livestock in winter, combined with cessation of fertilization, as a restoration tool for modifying the competitive dynamics among herbaceous plants to restore tallgrass prairie communities in southeastern Kansas. In 2004–2005, we compared responses of grassland plants and birds across a chronosequence of pastures that were winter-grazed from 1 yr to 5 yr. We compared winter-grazed pastures to pastures grazed year-round and to local native prairie remnants as starting and endpoints for restoration, respectively. Abundance of native warm-season grasses increased from 2% to 3% mean relative frequency in pastures grazed year-round to 18% to 30% in winter-grazed pastures, and increased with duration of winter-grazing. Native warm-season grasses accounted for 1–6% of total live aboveground biomass in pastures grazed year-round, 1–34% in winter-grazed pastures, and 31–34% in native prairie remnants. Tall fescue abundance and biomass were similar among grazing treatments, with a trend for tall fescue to be less dominant in winter-grazed pastures. Tall fescue made up 9–40% of total aboveground biomass in year-round grazed pastures and 10–25% in winter-grazed pastures. Grassland birds showed variable responses to winter-grazing. Dickcissels (*Spiza americana*) and Henslow's sparrows (*Ammodramus henslowii*) were more abundant in winter-grazed pastures, whereas eastern meadowlarks (*Sturnella magna*) and grasshopper sparrows (*A. savannarum*) had similar abundance in pastures grazed year-round and during winter. Winter-grazing of pastures dominated by tall fescue combined with suspension of nitrogen fertilization could be an effective restoration technique that allows use of prairie rangeland while improving habitat for sensitive grassland birds.

Resumen

La rehabilitación de los pastizales dominados por festuca alta (*Schedonorus phoenix* [Scop.] Holub) a pastizales nativos generalmente requiere el uso de fuego, herbicidas, o resiembras. Utilizamos el pastoreo estacional con ganado durante el invierno, combinado con el cese de fertilización como una herramienta rotacional de rehabilitación para modificar la dinámica competitiva entre plantas herbáceas y con esto rehabilitar las comunidades de pastizales de pastos altos en el sudeste de Kansas. En 2004–2005, se compararon las respuestas de las plantas en estos pastizales y las aves a través de una cronosecuencia de los potreros que se pastorearon durante el invierno de uno a cinco años. Comparamos los potreros que se pastorearon durante el invierno a los que se pastorearon todo el año, con los remanentes de la vegetación nativa del pastizal como punto inicial y final para la rehabilitación respectivamente. La abundancia de pastos nativos de crecimiento de verano aumentó de un 2–3% de la media de la frecuencia relativa en los potreros pastoreados todo el año, a 18–30% de los potreros pastoreados en el invierno, y se incrementó con la duración del pastoreo de invierno. Los pastos de crecimiento de verano representaron del 1–6% de la biomasa aérea total en potreros pastoreados todo el año, del 1–34% en los potreros pastoreados en el invierno, y de 31–34% en el remanente de la vegetación nativa. La abundancia y biomasa de festuca alta fueron similares entre los tratamientos, con una tendencia hacia festuca alta a ser menos dominante en los potreros pastoreados en el invierno. Festuca alta representó de 9–40% de la biomasa aérea total en los potreros pastoreados todo el año y de 10–25% en los potreros pastoreados durante el invierno. Las aves de los pastizales presentaron una respuesta variable al pastoreo del invierno. Dickcissels (*Spiza americana*) y Henslow's sparrows (*Ammodramus henslowii*) fueron más abundantes en los potreros pastoreados en el invierno, mientras que eastern meadowlarks (*Sturnella magna*) y grasshopper sparrows (*A. savannarum*) tuvieron un abundancia similar en los potreros pastoreados todo el año, así como el de invierno. El pastoreo de invierno de los potreros dominados por festuca alta en combinación con la suspensión de fertilización de nitrógeno podría ser una técnica eficaz de rehabilitación que permita el uso de estos pastizales a la vez que mejora el hábitat para las aves más sensibles de los pastizales.

Key Words: compositional and structural changes, ground-nesting birds, habitat quality, plant community, prairie restoration, rangeland management

INTRODUCTION

In the southern Great Plains and southeastern United States, tall fescue (*Schedonorus phoenix* [Scop.] Holub) is an exotic cool-season perennial widely used as cattle forage. Tall fescue was introduced from Europe in the 1800s and now covers >14 million ha in the United States (Buckner et al. 1979; Ball et al.

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1993; Clay and Holah 1999; Barnes 2004). Overseeding of native grasslands, year-round cattle grazing, and annual fertilization has converted native plant communities to pastures dominated by tall fescue (Mitchell et al. 1985; Barnes et al. 1995; Brummer and Moore 2000). Tall fescue is listed as invasive in 10 states, reduces plant community diversity in native grasslands because it is tolerant to drought and grazing if nutrient availability is high, and has potential for allelopathy (Barnes et al. 1995; Clay and Holah 1999; Spyreas et al. 2001; Renne et al. 2004; Swearingen 2005).

Habitat loss and changes in habitat quality caused by introduced plants can have large impacts on animal communities, especially ground-nesting birds (Askins 1993; Horncastle et al. 2005). Tall fescue alters both vegetation composition and structure, affecting resource availability for birds that require grassland habitats for food, nesting substrate, or escape cover (Barnes et al. 1995). Tall fescue is often infected with the symbiotic fungal endophyte *Neotyphodium coenophialum* (Clavicipitaceae), which can be toxic to animals and affect plant community dynamics (Barnes et al. 1995; Conover and Messmer 1996a, 1996b; Durham and Tannenbaum 1998; Rudgers et al. 2004). Many species of grassland birds are declining, and understanding bird–tall fescue relationships is critical to rangeland wildlife management where tall fescue has been established (Sauer et al. 2007).

Restoration of grasslands dominated by tall fescue usually involves a combination of herbicide application, prescribed burning, clipping, or overseeding with native grasses (Washburn et al. 2002; Wilson and Pärtel 2003; Barnes 2004). These methods are costly, labor-intensive, and can have negative effects on some nontarget native species (Lawrence et al. 1995; Sheley and Krueger-Mangold 2003). Modifying livestock grazing management through season of grazing may restore tall fescue-dominated grasslands, but has not been investigated. Selective grazing by large herbivores can influence competitive interactions among plant species by reducing biomass of dominant species and allowing subordinate species to flourish (Collins et al. 1998; Knapp et al. 1999; Chase et al. 2002; Cummings et al. 2007).

Our experimental restoration aimed to alter competitive dynamics of prairie plants in pastures dominated by tall fescue. We tested whether seasonal grazing by cattle during the cool-season but not the warm-season growing period favored native warm-season grasses over tall fescue. Tall fescue is dependent on nitrogen addition to sustain rapid growth, and we combined winter grazing with cessation of biennial fertilization (Mitchell et al. 1985; Mazzanti et al. 1994). Our three objectives were to evaluate effects of winter-grazing by cattle and cessation of fertilization on 1) abundance and biomass of tall fescue and native warm-season grasses, 2) densities of grassland songbirds, and 3) habitat variables important for predicting densities of breeding birds. We predicted that winter-grazing would affect densities of grassland birds through reduction of tall fescue and increases in native warm-season grasses. We expected grassland birds to respond in accordance with their species-specific habitat preferences: species requiring structural diversity should increase in abundance, whereas species preferring less structural diversity would decrease.

METHODS

Study Site

We conducted our study from 2000 to 2005 at the Kansas Army Ammunition Plant (KSAAP), a 5 555-ha military installation in north central Labette County, Kansas (lat 37°18′N, long 95°10′W). Most KSAAP lands are pastures that were historically dominated by big bluestem (*Andropogon gerardii* [Vitman]), little bluestem (*Schizachyrium scoparium* [Michx.] Nash), switchgrass (*Panicum virgatum* [L.]), and indiangrass (*Sorghastrum nutans* [L.] Nash) in upland areas, with deciduous and cross timbers forest along creeks and river valleys (Johnson et al. 2009). In the 1940s, pastures with native vegetation were overseeded with tall fescue. Tall fescue pastures are currently managed with year-round or seasonal livestock grazing and biennial nitrogen fertilization. Woody plants in grazed pastures are removed by cutting once every 5 yr (C. Deurmyer, personal communication, March 2004). The study site contains silt loam surface soil with a clay or loam subsoil, slopes range from 0% to 3%, and the site is dominated by loamy or clay upland ecological sites (Owens et al. 1990; Natural Resources Conservation Service 2009). In 2004–2005, total annual precipitation was 1 071 mm and 830 mm, of which 543 mm and 562 mm fell from April through September, respectively. The 80-yr mean annual total precipitation is 1 041 mm (High Plains Regional Climate Center 2009).

Table 1. Pasture, area, animal unit months, grazing treatment, and duration of treatment for 10 experimental pastures at the Kansas Army Ammunition Plant, Kansas.

Pasture	Area (ha)	Animal unit months (per ha)[1]	Treatment	Year initiated
9	64.8	2.25	Winter	2003
18	67.6	4.50	Winter	2000
22	134.4	7.50	Winter	2000
26	121.8	3.75	Winter	2003
30	71.6	4.36	Year-round	Pre-1995[2]
1 700	42.9	7.49	Winter	2002
1 800	63.9	5.81	Year-round	Pre-1995[2]
1 900	190.6	11.24	Winter	2002
NP1.5[3]	6.9	—	Ungrazed	—
NP2.5[3]	10.9	—	Ungrazed	—

[1]Winter-grazed pastures were assumed grazed 7 mo with cow-calf pairs (1.3 animal unit equivalents [AUE]) and pastures grazed year-round were assumed grazed 7 mo with cow-calf pairs (1.3 AUE) and 5 mo with just the cow (1.0 AUE).

[2]Dates of establishment for year-round grazed pastures were unavailable but each were grazed year-round for ≥ 9 yr before treatments were evaluated.

[3]NP indicates native prairie sites used as a baseline for native species abundance.

Restoration Treatment and Experimental Design

Winter grazing of cattle occurred between October and April, and coincided with the growing period of tall fescue in southeastern Kansas. Cattle were then removed from pastures between May and September, the growing period of native warm-season grasses. Winter-grazing started in 2000, 2002, and 2003 in 10 pastures, and we evaluated community responses in a subset of six pastures during May to August of 2004–2005. Our protocol created a chronosequence of pastures that had been winter-grazed from 1 yr to 5 yr (Table 1). Pastures were chosen as replicates within each time step of the chronosequence based on similarity of livestock density ($\bar{x} = 2.18$ ha · animal unit^{-1}, SD = 0.47 ha · animal unit^{-1}; Table 1), but in some cases, there were only two winter-grazed pastures available to represent a particular time step. We included two replicates for each of the three winter grazing treatments. All pastures had been previously grazed year-round. There were a limited number of experimental pastures to choose from, and we were unable to standardize livestock densities among all pastures. Grazing intensity may influence plant and bird community responses, and we included livestock density as a predictor variable in our analyses.

In addition to six experimental winter-grazed pastures, we sampled four sites that represented start and endpoints for restoration efforts (total $n = 10$). Two pastures were grazed year-round and fertilized in spring in alternate years, a management practice common for tall fescue pastures in southeastern Kansas. Year-round grazing was a baseline for assessing changes in plant and bird communities. Remnant patches of native prairie persist at KSAAP as small, ungrazed hay meadows. Prairie remnants are managed with annual or biennial spring burning and by hay cutting in late July. In 2005, we sampled two small native prairie sites (7–10 ha) as an expected endpoint for restoration of native grassland. Patches were smaller than our experimental pastures, but were the largest tracts of native prairie not converted to tall fescue.

Due to differences in patch size area sensitivity of grassland birds, we did not survey bird densities in native prairie remnants (Johnson and Igl 2001; Winter et al. 2006). These sites were not burned or cut for hay in 2004–2005.

Vegetation Sampling

We determined the number of transects necessary to quantify plant community composition with preliminary sampling. We sampled three 50-m transects in a 4-yr winter-grazed pasture with high apparent plant diversity and created a species accumulation curve using the program EstimateS (Colwell 2004). We sampled additional transects one at a time until the curve reached an asymptote at nine transects. All pastures had nine transects established in a stratified random design. We placed transects > 50 m from the pasture edge to minimize boundary effects on plant communities. Transect endpoints were marked with metal T-posts and a hand-held global positioning system unit.

We sampled plant communities along transects in late May to early June, and again in late July to mid-August to account for differences in plant phenology. We used a modified step-point method to quantify community composition in all pastures, and plants were examined at fixed 1-m intervals on each transect (Owensby 1973). We used a nested sampling technique in which the closest live grass and forb to each sampling point were identified to species and recorded (Hickman et al. 2004).

We quantified aboveground biomass in early August using nine 0.25×0.25 m quadrats per pasture. Quadrats were randomly placed 1 m to either side of each vegetation transect and 5 m from the starting point, and all aboveground biomass within the quadrat was clipped to ground level. Length of grazing period was 12 mo in year-round pastures and 7 mo in winter-grazed pastures. To account for potential differences in biomass consumed by cattle over the additional 5 mo of grazing, we constructed nine circular 0.5-m^2 cattle exclosures in 2005 in pastures grazed year-round, and collected biomass samples within these exclosures. We separated and removed dead plant litter and sorted live plants to three functional categories: tall fescue, native grasses, and forbs. Plant samples were air dried in a drying oven for 48 h at 60°C, and weighed.

To examine the potential effects of the fungal endophyte *N. coenophialum* on the tall fescue response to winter-grazing, we assessed infection rates for grazed pastures. We collected seeds from > 50 different tall fescue plants from each pasture from 16 June 2004 to 20 June 2004. We systematically walked through each pasture and collected seeds from the nearest tall fescue stem at 10-m intervals, avoiding ditches, fence rows, and cattle tanks. A subset of randomly selected seeds was tested for the presence of the fungal endophyte at the Plant Disease Diagnostic Laboratory, Department of Plant Pathology, Kansas State University. We report infection rates as the proportion of seeds per pasture that tested positive for the fungus.

Bird Sampling

Within each pasture, we established two 250-m bird transects, each of which incorporated one vegetation transect. Transects were chosen to minimize edge effects on bird surveys, and starting points were > 200 m from habitat edges. We conducted bird surveys within the 4-h period after sunrise from 16 May to 15 July in 2004–2005. We did not conduct surveys during mornings with rain, fog, or wind in excess of 16 $km \cdot h^{-1}$. One observer slowly walked transects and recorded all birds encountered. The radial distance from the observer to the approximate location of each bird was measured to the nearest meter with a laser range finder, along with the angle of detection from the transect line. We conducted four biweekly surveys at each transect in 2004–2005. We systematically varied start times of surveys to control for temporal variation in bird detections.

To evaluate differences in vegetation structure among treatments that might influence bird densities, we quantified visual obstruction of vegetation along each bird transect using a 1-m pole marked with 10-dm intervals (Robel et al. 1970). Visual obstruction can be measured quickly and efficiently, and is one of the most important variables predicting the presence and abundance of grassland birds (Zimmerman 1988; Fondell and Ball 2004; Powell 2006). Visual obstruction values were recorded at 10-m intervals along the 250-m transects in early August.

Statistical Analysis

All statistical tests were performed using SAS System Version 9 (SAS 2002). To evaluate differences in plant community composition, we calculated relative frequencies of species occurrence for each grazing treatment (Hickman et al. 2004). We used the maximum observed frequency from the two sampling periods within a season as the frequency of each species per transect. We tested for differences in species abundance and plant biomass among year-round grazed pastures, winter-grazed pastures, and (for plants only) native prairie sites using a mixed model where treatment was a fixed effect, and transect nested within pasture and treatment, and pasture nested within treatment were random effects. Values were square-root transformed where necessary to satisfy assumptions of normality and homogeneity of variance. We used Tukey's adjustment for multiple comparisons, and a general Satterthwaite approximation for the denominator degrees of freedom (Littell et al. 2006). We were interested in the variation in species responses explained by duration of winter-grazing. We treated duration of winter grazing as a continuous predictor variable and used linear regression to model abundance and biomass. A limited number of replicate sites resulted in a correlation between winter-grazing and number of animals per acre, with higher livestock densities in pastures that had been winter-grazed the longest ($r = -0.56$, $P < 0.001$; Table 1). However, multicollinearity was not a confounding factor in our study ($\hat{c} < 1.5$), and duration of winter-grazing and stocking density were both included as factors in our multiple linear regression.

To estimate densities of breeding birds, we used Program Distance Version 5.0 (Distance 5.0 2005). Distance-sampling methods have received some criticism as an estimation technique (Johnson 2008), but have improved on unadjusted counts by controlling for variation in detection probability (Burnham 1981; Thompson 2002). Number of encounters for each bird species per transect were sparse. To increase precision of density estimates, we limited our analysis to encounters of singing males, pooled observations from repeated surveys, and estimated densities by multiplying transect length by the number of visits. Observations at the greatest distance from each transect were excluded from analysis to increase accuracy of our density estimates (Buckland et al. 2001). We fit detection curves for each species by transect and averaged across transects to obtain a mean density estimate per treatment ($n = 4$). Model fit was based on Kolmogorov–Smirnov and Cramer–von Mises goodness-of-fit tests. We selected among different candidate models using minimum and differences in values of Akaike's Information Criterion corrected for sample size.

For transects where detections were too sparse to model density in Program Distance, we used a different approach. We estimated the average effective strip width (ESW) for other transects within the same treatment, and calculated density of singing males ($\hat{D}$) by:

$$\hat{D} = \frac{d}{L \times 2(\mathrm{ESW})}$$

where d is the number of singing males detected, and L is the effort (length × number of visits) per transect. This approximation assumes a uniform detection function within the sampled area. Finally, we used linear regression to test whether densities of grassland birds could be explained by our gradient of grazing treatments ($n =$ two replicate pastures per treatment). Species detected too infrequently to model density for any treatment were evaluated using contingency analysis of detections.

To investigate bird–vegetation relationships in tall fescue-dominated pastures, we modeled density of each bird species versus plant community composition, grazing status (grazed or rested during the summer), and visual obstruction measurements as predictor variables. Because many habitat variables were collinear, we performed a principal components analysis to reduce six correlated habitat variables to two orthogonal axes. We then used the two principal components and grazing status as predictor variables in a linear regression. An α level of ≤ 0.05 was used to determine statistical significance, and all tests were two-tailed.

RESULTS

Plant Communities

All grazed pastures contained tall fescue plants infected with the fungal endophyte *N. coenophalium*. Fungal infection rates ranged from 42.0% to 100% seeds per pasture, and the average infection rate was 80.8% (± 6.9%, SE, $n = 8$). The highest and lowest rates of infection were detected in pastures winter-grazed for 2–3 and 1–2 yr, respectively.

Plant community composition was affected by winter-grazing treatments. The relative abundance of tall dropseed (*Sporobolus compositus* Merr.) increased with duration of winter-grazing in both 2004 (winter-grazing: $\beta = 1.78$, $t = 4.39$, $P < 0.0001$; livestock density: $\beta = 2.95$, $t = 1.91$, $P = 0.06$) and 2005 (winter-grazing: $\beta = 1.34$, $t = 3.32$, $P = 0.002$; livestock density: $\beta = 4.63$, $t = 3.01$, $P = 0.004$; Fig. 1), and was greater in native prairie sites and pastures that were winter-grazed for 3–5 yr than year-round grazed pastures ($F_{8,9} = 6.17$, $P = 0.007$). Abundance of four other native warm-season grasses did not increase significantly across a chronosequence of winter-grazed pastures (Fig. 1). Big bluestem ($F_{8,9} = 7.07$, $P = 0.004$), little bluestem ($F_{8,9} = 15.78$, $P < 0.001$), and switchgrass ($F_{8,9} = 4.67$, $P = 0.02$) were more abundant in native prairie sites than grazed pastures. Indiangrass abundance was higher in native prairie sites and pastures that were winter-grazed for 3 yr than all other pastures ($F_{8,9} = 7.26$, $P = 0.003$). Overall abundance of native warm-season grasses increased with duration of winter-grazing and livestock density in 2004 (winter-grazing: $\beta = 1.83$, $t = 2.28$, $P = 0.03$; livestock density: $\beta = 9.49$, $t = 3.11$, $P = 0.003$, $R^2 = 0.25$) and with livestock density only in 2005 ($\beta = 12.65$, $t = 3.09$, $P = 0.003$, $R^2 = 0.22$), with a trend for positive effect of duration of winter-grazing as well ($\beta = 2.04$, $t = 1.89$, $P = 0.06$). We detected no significant decrease in tall fescue abundance with duration of winter-grazing and no difference between year-round and winter-grazed pastures ($F_{7,8} = 0.32$, $P = 0.93$; Fig. 1).

Native warm-season grasses were affected by pasture management and made up 1–6% of the total live aboveground biomass in pastures grazed year-round, 1–34% in winter-grazed pastures, and 31–34% in native prairie sites. Overall, native warm-season grass biomass was similar between year-round grazed and winter-grazed pastures in 2004 ($F_{3,4} = 1.55$, $P = 0.33$). In 2005 native warm-season grass biomass was similar among native prairie sites and pastures that had been winter-grazed for 3–5 yr, but significantly less in pastures grazed year-round ($F_{4,5} = 12.08$, $P < 0.01$). Native warm-season grasses showed significant increases in biomass along a chronosequence of winter-grazed pastures in 2005 ($F_{2,51} = 7.33$, $P < 0.01$) but not in 2004 ($F_{2,51} = 2.02$, $P = 0.14$; Fig. 2).

Tall fescue accounted for 9–40% of total live aboveground biomass in pastures grazed year-round, 10–25% in winter-grazed pastures, and 2–4% in native prairie sites. Tall fescue biomass was similar between year-round and winter-grazed pastures in 2004 ($F_{3,4} = 0.13$, $P = 0.94$) and 2005 ($F_{3,4} = 3.80$, $P = 0.12$). We did not detect a significant decrease in tall fescue biomass along a gradient of winter-grazed pastures in 2004 ($F_{2,51} = 0.27$, $P = 0.77$) or 2005 ($F_{2,51} = 0.27$, $P = 0.77$; Fig. 2).

Grassland Bird Communities

The most frequently encountered songbirds were dickcissels (*Spiza americana*), eastern meadowlarks (*Sturnella magna*), and grasshopper sparrows (*Ammodramus savannarum*; Table 2). Dickcissel densities were higher in winter-grazed than year-

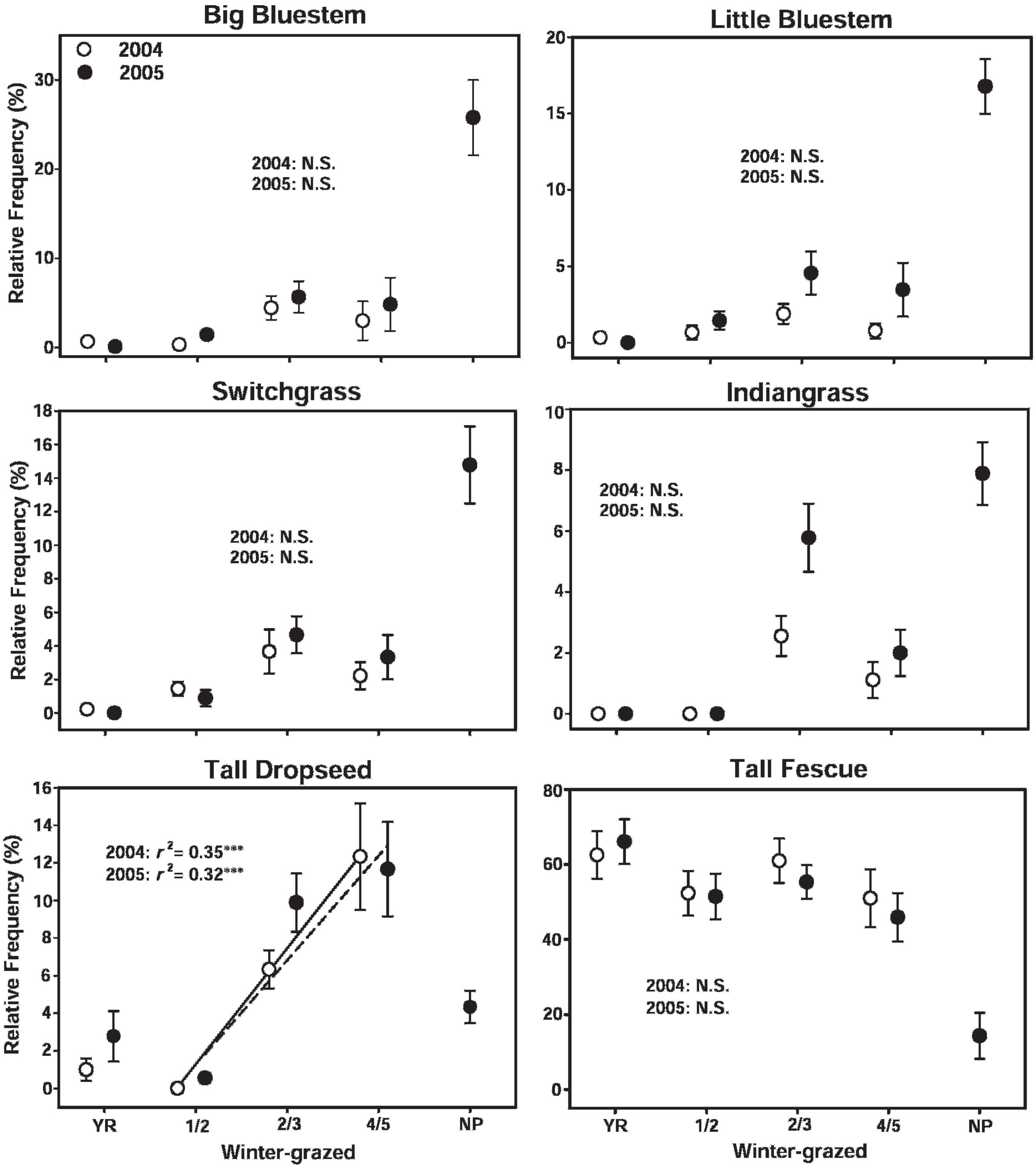

Figure 1. Mean (± SE; $n = 18$) relative frequency per 50-m transect of native warm-season grasses and tall fescue in year-round grazed pastures (YR), pastures winter-grazed from 1 to 5 yr (1/2 to 4/5), and ungrazed native prairie (NP) on the Kansas Army Ammunition Plant, Kansas. Statistical significance for treatment as a predictor variable is indicated with asterisks: $^{**}P \leq 0.05$, $^{***}P \leq 0.01$. R^2 values are from regression models that include duration of winter-grazing (1–5 yr) and stocking density as predictor variables; however, the regression lines shown represent the bivariate relationship between plant response and winter-grazing treatment only. Native prairie and pastures grazed year-round were not included in regressions but are presented for comparison. N.S. indicates nonsignificant results.

round grazed pastures in both 2004 ($F_{1,14} = 13.34$, $P = 0.003$) and 2005 ($F_{1,14} = 20.96$, $P < 0.001$). Eastern meadowlark and grasshopper sparrow densities did not differ between year-round and winter-grazed pastures in 2004 (eastern meadowlark: $F_{1,6} = 2.60$, $P = 0.16$; grasshopper sparrow: $F_{1,6} = 2.48$, $P = 0.17$) or 2005 (eastern meadowlark: $F_{1,6} = 1.78$, $P = 0.23$; grasshopper sparrow: $F_{1,6} = 0.12$, $P = 0.74$). We did not detect a trend in density associated with duration of winter-grazing for any species (Table 2). Brown-headed cowbirds (*Molothrus ater*) were detected more often in year-round than winter-grazed pastures in both 2004 (year-round = 18%, winter-grazed = 6%, $\chi^2 = 9.0$, df = 1, $P = 0.003$) and 2005 (year-round = 15%, winter-grazed = 3%, $\chi^2 = 13.0$, df = 1, $P = 0.0003$). In 2004 we observed singing Henslow's sparrows on pastures that had been winter-grazed for 4 yr but only early in the breeding season. These individuals were apparently

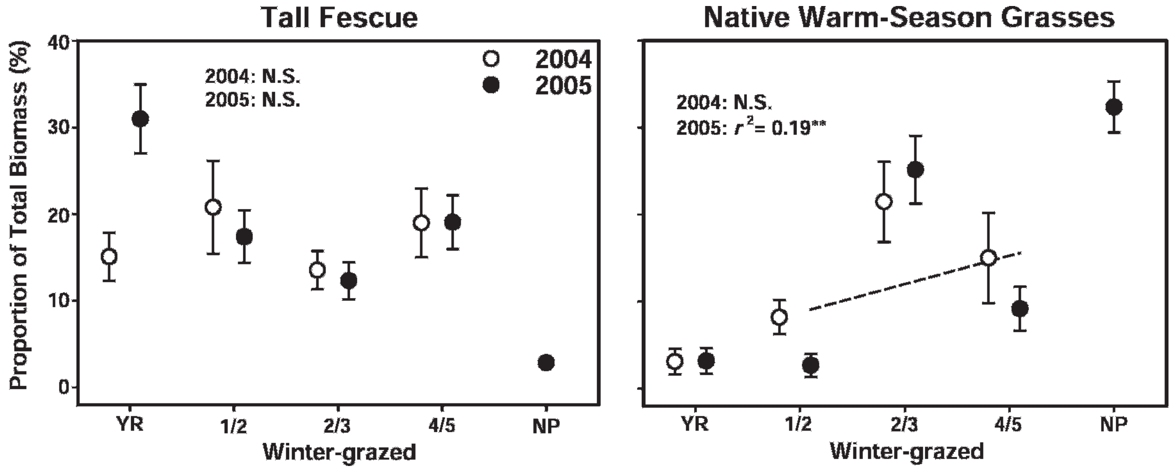

Figure 2. Mean biomass (± SE; $n = 18$) of tall fescue and native, warm-season grasses in year-round grazed pastures (YR), pastures winter-grazed from 1 to 5 yr (1/2 to 4/5), and ungrazed native prairie (NP) on the Kansas Army Ammunition Plant, Kansas. Statistical significance for treatment as a predictor variable is indicated with asterisks: $^{**}P < 0.05$, $^{***}P < 0.01$. R^2 values are from regression models that include duration of winter-grazing (1–5 yr) and stocking density as predictor variables; however, the regression lines shown represent the bivariate relationship between plant response and winter-grazing treatment only. Native prairie sites and pastures grazed year-round were not included in regressions but are presented for comparison. N.S. indicates nonsignificant results.

transient males that did not establish breeding territories. In 2005 we observed several Henslow's sparrows and common yellowthroats (*Geothlypis trichas*) displaying territorial behavior in the same pastures, then winter-grazed for 5 yr. The only other plots where we detected these species were hay meadows.

The principal component analysis reduced six habitat variables to two principal components (PC1 and PC2) that explained 78.2% and 81.4% of the variation in plant community data in 2004 and 2005, respectively (Table 3). Factor loadings indicated that PC1 described abundance of tall fescue, whereas PC2 described abundance of native grass and visual obstruction. Bird–vegetation relationships varied among species. The presence of cattle during the breeding season explained 62% of variation in dickcissel density in 2004. In 2005 the presence of cattle and tall fescue abundance (PC1) explained 75% of the variation in dickcissel density (Table 4). In 2004 abundance of native warm-season grasses and visual obstruction (PC2) explained 47% of the variation in grasshopper sparrow density (Table 4). We did not identify any variables that explained eastern meadowlark density.

DISCUSSION

Plant Community Responses

Winter cattle-grazing combined with cessation of fertilization favored native warm-season grasses. Although we did not detect significant decreases in tall fescue, we did observe a trend for tall fescue to become less abundant and have lower biomass in winter-grazed compared to pastures managed with traditional year-round grazing. Biomass of tall fescue was highly variable, and detection of differences was difficult with the replication in our experimental design ($n = 2$).

Native warm-season grasses remained a small component of plant communities even after 5 yr of winter-grazing (generally $< 10\%$). Native warm-season grasses are long-lived perennials

Table 2. Number of singing males per hectare (± SE, $n = 2$) for three species of grassland songbirds in winter-grazed and year-round grazed tall fescue-dominated pastures at the Kansas Army Ammunition Plant, Kansas, 2004–2005.

Species	Grazing treatment				t^1	$P \leq$
	Year-round	Winter 1/2	Winter 2/3	Winter 4/5		
Dickcissel						
2004	0.22 (± 0.07)	1.51 (± 0.23)	1.12 (± 0.12)	1.28 (± 0.22)	−1.21	0.26
2005	0.34 (± 0.12)	1.25 (± 0.10)	1.32 (± 0.12)	1.24 (± 0.08)	−0.11	0.91
Eastern meadowlark						
2004	0.86 (± 0.15)	0.51 (± 0.13)	0.75 (± 0.08)	0.29 (± 0.05)	−1.31	0.22
2005	0.31 (± 0.02)	0.15 (± 0.05)	0.31 (± 0.05)	0.11 (± 0.04)	−0.69	0.51
Grasshopper sparrow						
2004	0.32 (± 0.22)	0.05 (± 0.03)	0.14 (± 0.06)	0.00	−1.01	0.34
2005	0.20 (± 0.14)	0.07 (± 0.05)	0.36 (± 0.06)	0.00	−0.81	0.44

[1]Statistical values are from a linear regression in which bird density was regressed on duration of time in winter grazing only and the *t*-statistic represents a test of the hypothesis that the slope = 0.

Table 3. Principal components (PC) analysis of plant community composition at the Kansas Army Ammunition Plant, Kansas. Important factor loadings for each principal component are indicated in boldface.

Eigenvectors	PC1	PC2
2004		
Tall fescue (%)	**0.95**	−0.14
Native (%)	−0.11	**0.48**
Forbs (%)	−0.27	**−0.67**
Litter (%)	0.05	0.20
Bare ground (%)	−0.06	−0.27
Visual obstruction	−0.05	**0.43**
% variation explained	**59.48**	**18.73**
2005		
Tall fescue (%)	**0.99**	0.08
Native (%)	−0.11	**0.91**
Forbs (%)	−0.08	**−0.31**
Litter (%)	0.02	0.03
Bare ground (%)	0.02	−0.08
Visual obstruction	−0.02	**0.26**
% variation explained	**45.11**	**36.31**

that require several years before reaching full stature, especially if overseeding or transplanting are not part of restoration efforts (Kulmatiski and Beard 2006). Native grasses that occurred at our study site were absent or present only at low densities in year-round grazed pastures. Increases in abundance of native grasses after just 5 yr suggests winter-grazing can benefit native warm-season species in mesic prairie, despite the potential lag time required for recruitment. Additionally, we observed an increase in the biomass of native warm-season grasses; values were similar to tall fescue after only 2 yr of winter-grazing (Fig. 2). Low abundance but high biomass suggests that changes in management can allow native warm-season grasses to be successful competitors in winter-grazed pastures dominated by tall fescue.

Cessation of fertilization and winter-grazing for 5 yr did not increase most native warm-season grasses to abundances observed in native prairie, nor did it eliminate tall fescue from the community. Pretreatment data were not available, and some baseline differences in tall fescue and native warm-season grass abundance or biomass may have existed. Variation in past fertilization may have influenced the effects of winter-grazing on plant population responses because grassland plants are more susceptible to population control by herbivores when resources are less abundant (Hawkes and Sullivan 2001; Chase et al. 2002). Number of cattle differed among pastures, and our results suggest that livestock density was an important determinant for the abundance of some species. Further, endophyte infection can increase resistance to herbivory and infection levels in tall fescue were high (> 80%; Malinowski and Belesky 2000). Nevertheless, we observed a slight trend for decreases in tall fescue in winter-grazed compared to year-round grazed pastures. Winter-grazing may reduce tall fescue, but additional years of winter-grazing may not be able to reduce tall fescue below threshold values. However, used in conjunction with other restoration methods, winter-grazing and discontinued fertilization could aid tallgrass prairie restoration.

Table 4. Bird–vegetation relationships in year-round and winter-grazed pastures at the Kansas Army Ammunition Plant, Kansas. See Table 3 for factor loadings from principal component analysis. *P*-values ≤0.5 are in boldface.

Species	Variable	β	*P*≤
Dickcissel			
2004	PC1	−0.008	0.08
	PC2	−0.009	0.34
	Grazed[1]	−1.281	**0.05**
2005	**PC1**	−0.009	**0.05**
	PC2	0.000	0.91
	Grazed	−0.935	**0.05**
Eastern meadowlark			
2004	PC1	0.000	0.91
	PC2	0.001	0.86
	Grazed	0.363	0.15
2005	PC1	0.002	0.14
	PC2	0.000	0.69
	Grazed	0.149	0.15
Grasshopper sparrow			
2004	PC1	0.000	0.97
	PC2	−0.008	**0.05**
	Grazed	0.108	0.41
2005	PC1	0.003	0.31
	PC2	0.001	0.80
	Grazed	0.889	0.63

[1]The variable grazed indicates the presence of cattle during the bird breeding season.

Grazing management that influences plant community composition will be particularly useful for restoration if it facilitates changes in communities dominated by persistent non-native species like tall fescue (D'Antonio and Meyerson 2002; Kulmatiski and Beard 2006). Continued monitoring will be necessary to determine if tall fescue can be eradicated or managed as a subdominant species by our methods, or if additional measures must be implemented to restore native plant communities. Two possibilities would be to manipulate grazing intensity during winter or to use carbon amendments to reduce soil nitrogen, potentially reducing the competitive ability of tall fescue and creating soil conditions more suitable for native prairie (Reever-Morghan and Seastedt 1999; Averett et al. 2004). Winter grazing is a promising restoration technique, but turnover in community dynamics of long-lived perennial grasses is slow and complete restoration of native plant communities may require periods longer than our 5-yr study.

Bird Community Responses

Species-specific responses to grazing management are consistent with previous studies of habitat requirements of grassland birds (Walk and Warner 2000; Applegate et al. 2002; Fontaine et al. 2004; Van Dyke et al. 2004; Lueders et al. 2006; Powell 2006). Densities of dickcissel were negatively associated with the presence of cattle, and may have been higher in winter-grazed pastures because there was less disturbance during the breeding season. Additionally, dickcissel densities were positively correlated with a decrease in the tall fescue component of the plant community. Our results are consistent with previous studies reporting that dickcissels prefer to nest in undisturbed prairie and have higher abundances in sites dominated by warm-season rather than cool-season grasses (Temple et al. 1999; Walk and Warner 2000; Dechant et al. 2003). Dickcissels are positively associated with a high forb component for nesting (Dechant et al. 2003), but we observed highest densities in winter-grazed pastures, which had fewer forbs than year-round grazed pastures (Johnson 2006). Forbs tend to increase in plant communities grazed by cattle, where herbivores preferentially remove grasses (Towne et al. 2005). Since both treatments include some level of grazing, availability of forbs for nesting may not have been a limiting factor for dickcissels.

Grasshopper sparrows were negatively associated with native warm-season grass abundance and visual obstruction, and positively associated with forb abundance. Percent composition of native, warm-season grass was positively related to visual obstruction in our study. Similarly, Scott et al. (2002) showed that grasshopper sparrows were negatively associated with vegetation density in tall fescue–dominated grasslands. Structural differences between tall fescue–dominated and native warm-season grass–dominated pastures could potentially indicate effects of dominant vegetation type on settlement decisions for grasshopper sparrows. However, grasshopper sparrow densities were similar among winter-grazed and year-round grazed pastures, suggesting the winter-grazing treatment does not remove suitable habitat for this species.

Eastern meadowlarks were a generalist species and had similar densities in winter-grazed and year-round grazed pastures. Elsewhere, eastern meadowlark habitat preferences can vary widely but they tend to respond favorably to moderate grazing, especially in the southern Great Plains (Hull 2003; Powell 2006).

Henslow's sparrows and common yellowthroats were both detected infrequently and were present only in winter-grazed pastures and native prairie. Our records of Henslow's sparrows in winter-grazed pastures were surprising, considering other studies have shown grazing is a negative influence (Herkert 2003; Powell 2006). Henslow's sparrows may have settled in winter-grazed pastures because disturbance by cattle was reduced during the breeding season or because of differences in vegetation structure between year-round grazed and winter-grazed pastures.

Our results indicate that winter-grazing of tall fescue–dominated pastures can benefit grassland bird populations in the Great Plains. Higher population density is not necessarily a good indicator of habitat quality, and tall fescue pastures could be an ecological trap if conditions during settlement are not linked to higher reproductive success. Tall fescue grows earlier than native warm-season grasses but may develop into poor quality habitat if it does not provide adequate cover during the nesting season (Lloyd and Martin 2005). Habitat-specific demographic rates and their effects on population growth should be evaluated in order to better understand the benefits of winter-grazing to grassland birds (Smallwood 2001; Schrott et al. 2005; With et al. 2008).

IMPLICATIONS

Better approaches to restoration may be achieved through increased understanding of plant and animal responses to restoration techniques, as well as the development of land-management practices that support both wildlife and private landowners (Samson and Knopf 1994; Larison et al. 2001; Murphy 2003). Winter-grazing combined with cessation of fertilization should be considered for tallgrass prairie restoration, especially in instances where tall fescue is highly abundant and land can be in production during restoration. Winter-grazing could be most beneficial during initial stages of restoration and, if used in conjunction with burning or spraying, could aid in an integrated approach to the eradication or management of tall fescue.

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