



Variation in Surrogate Breeding Habitat Quality Between Continuously Grazed Rangelands and Late-Cut Hayfields for a Threatened Grassland Birds

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ARTICLE INFO

Article history:

Received 25 September 2018

Received in revised form 28 December 2018

Accepted 7 January 2019

Key Words:

Bobolink
continuous grazing
grassland birds
late-cut hay
nest success
rangeland management

ABSTRACT

Rangelands and hayfields provide a large portion of remaining surrogate habitat for many species of declining grassland birds in North America. We compared late-cut hayfields and continuously grazed pastures at low to moderate cattle densities for providing suitable breeding habitat in eastern Canada for the nationally threatened Bobolink (*Dolichonyx oryzivorus*). To examine the quality of both habitats, we conducted point counts and monitored 87 nests during the 2015 and 2016 breeding seasons. Bobolink abundance and daily survival rate (DSR) of nests were modeled sequentially by habitat and sex as a function of vegetation structure, prey availability, and agricultural management. Year and habitat were the strongest predictors of abundance. When analyzed separately for pastures and hayfields, vegetation height was most important for female abundance in pastures while pasture size was most important for males. Nests in hayfields had significantly higher daily survival (DSR = 0.98 ± 0.01) than nests in pastures (DSR = 0.94 ± 0.01). Nesting success was highest in hayfields with taller vegetation, while in pastures, no microhabitat variable showed a clear relationship with DSR. Within pastures, cattle stocking densities of ≤ 1 animal units (AU) · ha⁻¹ were not related to DSR. This study provides evidence that late-cut hay is of highest quality, but that small-scale beef farms with low to moderate stocking densities are suitable targets for conservation efforts of Bobolinks in eastern North America.

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Introduction

Grassland birds have experienced consistent and steep declines across North America (Vickery et al., 2000; Sauer et al., 2014). On the breeding grounds, this decline has been attributed, in part, to the loss of natural grasslands and the intensification of surrogate agricultural breeding habitat—hay mowing during the breeding season, overgrazed rangelands, and habitat conversion to cropland (Bollinger et al., 1990; Murphy, 2003; Brennan and Kuvlesky, 2005; McCracken, 2005; Nocera et al., 2005; Perlut et al., 2006). Farm abandonment and fire suppression, which have allowed afforestation on rangelands, have also caused the decline of breeding habitat and a reduction in grassland bird diversity (Vickery et al., 2000; Chapman et al., 2004). The Bobolink (*Dolichonyx oryzivorus*), an obligate grassland bird and neotropical migrant, has been assessed as federally threatened in Canada (COSEWIC, 2010). There are many knowledge gaps on the effects of various agricultural management practices on nest productivity of Bobolinks, such as the relative quality of habitats under different management schemes

or the productivity of hay versus rangeland habitat (McCracken et al., 2013).

Studies on Bobolinks in agricultural settings have focused mainly on hayfields where Bobolinks are typically at their highest densities (Bollinger et al., 1990; Macdonald and Nol, 2017). In North America, most hayfield mowing dates coincide with the Bobolink nesting season and, hence, hayfields often serve as ecological traps and sink habitats (Bollinger et al., 1990; Herkert, 1997; Perlut et al., 2006; Diemer and Nocera, 2016). Hayfields are frequently used in combination with rangelands as hay provides forage for beef cattle during both winter and times of drought. Beef operations have been highlighted as a key component for conservation of the Bobolink and other species of grassland bird as the industry provides a large amount of remaining suitable habitat (McCracken et al., 2013). Cutting of hay and grazing can have both positive and negative impacts on grassland birds, grassland vegetation, and bird invertebrate prey (Askins, 1999; Vickery et al., 2001; Fondell and Ball, 2004; Askins et al., 2007; Zalik and Strong, 2008; Duchardt et al., 2016; Gennet et al., 2017). Farmers employ both continuous grazing, which provides livestock with unrestricted access to the pasture for most or all the grazing season, and several types of rotational grazing. In the latter method, farmers rotate livestock through sections of the pasture during the grazing season (Undersander et al., 2000).

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High nest losses for Bobolinks have been reported from rotationally grazed fields with stocking densities (AU per hectare [ha]) in the range of 2.5–248.62 AU·ha⁻¹ (Perlut et al., 2006; Perlut and Strong, 2011; Macdonald and Nol, 2017).

Less is known about the impacts of continuous grazing on Bobolink abundance and nesting productivity (McCracken et al., 2013). Unlike Temple et al. (1999), Renfrew and Ribic (2001) found no difference in Bobolink density between rotational and continuous grazing. Low to moderate continuous grazing can have neutral and positive relationships with other grassland songbirds and shorebirds (Lusk and Koper, 2013; Mandema et al., 2015). However, responses to grazing intensity differs by species and no one agricultural scheme is universally effective for promoting grassland bird productivity (Báldi et al., 2005).

Bobolink can also be impacted by grassland vegetation structure and invertebrate communities. Bobolinks tend to prefer sites with moderate vegetation height and density, a high amount of grass and forbs, low percentage of bare ground and alfalfa, and moderate litter depth (Bollinger and Gavin, 1989; Renfrew and Ribic 2002; Nocera et al., 2007). Bobolinks are typically area sensitive and edge sensitive, having positive associations with larger patch sizes varying with habitat quality (Vickery et al. 1994; Thogmartin et al., 2006; Ribic et al. 2009). Food supply is another possible limiting factor for Bobolinks and other grassland birds (McCracken, 2005). During the breeding season, the diet of adult Bobolinks consists mainly of invertebrate prey items and nestlings are fed exclusively on invertebrates consisting largely of Lepidopteran and Hymenopteran larvae and Orthopterans (Wittenberger, 1982). Prey availability can affect the incidence of polygyny (Wittenberger, 1980), parental behavior (Wittenberger, 1982), and territory size (Diemer and Nocera, 2014).

For this study, we report on the suitability of low to moderate continuous grazing for Bobolink breeding success. Our objective was to assess whether 1) vegetation structure, 2) food availability, and/or 3) agricultural management influenced Bobolink abundance and nesting productivity in continuously grazed rangelands and to compare this system with late-cut hayfields. We predicted that late-cut hayfields would have higher abundances of Bobolinks and greater productivity than pastures and that, within grazed pastures, cattle stocking would have no impact up to a threshold density above which Bobolink nesting success would decline. We expected a positive association between Bobolinks and prey item availability and/or preferred vegetation structure such as taller vegetation cover.

Methods

Study Sites

We studied breeding Bobolinks from May to July 2015 and 2016 in late-cut hayfields and continuously grazed pastures located in Carden, Ontario, Canada (44°38'58"N, 79°01'59"W). This region has been designated as an international Important Bird Area (Bird Studies Canada, 2017) and is partly composed of a globally rare alvar. Alvar environments consist of shallow soils atop limestone bedrock. Land use in this area consists mainly of rangeland for beef production and associated hayfields, nature reserves, and limestone quarries (Wildlife Preservation Canada et al., 2008). The grass community in the rangelands and hayfields is typically composed of introduced species such as timothy (*Phleum pratense*), Canada bluegrass (*Poa compressa*), brome grasses (*Bromus* spp.), and fescue varieties (*Festuca* spp.). Some of the common native grasses include poverty grass (*Danthonia spicata*) and tufted hairgrass (*Deschampsia cespitosa*). In most of our study area, landowners were partially restricted in their land use, through either easements or conservation agreements.

We monitored 10 pastures in 2015, 8 pastures in 2016, and 6 hayfields in both years. Hayfields were typically situated in areas with deeper soil on the alvar and pastures were typically in rangelands with soil too shallow for cultivation. Sites were under various ownership,

including private or nongovernmental organizations. Hayfields ranged in size from 5 to 15 ha (mean field size of 8.4 ha). Pastures ranged in size from 14 to 161 ha (mean field size of 66.4 ha) with stocking densities of 0.31 – 1.24 AU·ha⁻¹. All hayfields were used as supplemental feed for the local, mostly grass-fed beef cattle. Farmers with hayfields were not allowed to cut their hay before 15 July, by prior arrangement with the Couchiching Conservancy and the Nature Conservancy of Canada. Entry dates of cattle onto pastures ranged from 10 May to 3 June, and exit dates ranged from 30 September to 23 November. Weather conditions between study years were markedly different as 2015 was considered a wet yr (total precipitation from May to July 187.0 mm) and 2016 a drought yr (total precipitation 91.8 mm) (Environment Canada, 2016).

Point Counts and Nest Monitoring

Point count surveys were conducted every week in the center of each pasture or hayfield throughout the breeding season. Each 5-min, 150-m radius point count was conducted between sunrise and 10 a. m., weather permitting (wind speed of < 20 km/hr and no precipitation). Point counts were conducted by a single observer to avoid observation detection biases. During point counts all birds (seen and heard) were counted, sexed, and aged (adults or fledglings). Point counts were conducted from 19 May to 9 July 2015 in 2015 and 2016 with a total of 9 point counts per field per year. Double counting between survey locations was minimized by conducting surveys during the breeding season when males are protecting relatively small territories and females also remain within these territories and close to their nests (Wittenberger, 1978; Diemer and Nocera, 2014).

We located and monitored nests at all hayfield and pasture sites in both years. Universal Transverse Mercator (UTM) coordinates were recorded at each nest. No other markers were used around nests to minimize disturbance and avoid predator attraction. Nests were monitored every 2–4 d. We monitored fledged young 7 d past the date of fledging because they can be susceptible to predation, trampling, and mowing during this time (Perlut et al., 2006). We monitored fledged young by returning to the nest location and seeing fledglings or by observing whether adults were exhibiting protective behavior or feeding fledglings. A nest was considered successful when at least one offspring from the nest had successfully fledged, defined as surviving to 7 d after leaving the nest (Lusk and Koper, 2013).

Site and Nest Vegetation Surveys

Vegetation surveys (hereafter “site vegetation surveys”) were completed at the point count stations of each pasture and hayfield. In 2015 and 2016, site vegetation surveys were conducted once during mid-May while in 2016, we completed an additional site vegetation survey in mid-July, corresponding with the timing of the nest vegetation surveys. All vegetation surveys were completed within ~1 wk to avoid any biases from the growing season. Site vegetation surveys consisted of 9 systematically sampled 50 × 50 cm sampling frames per site (Daubenmire, 1959). We recorded vegetation height using Robel poles (Robel et al., 1970). For each frame, we visually approximated percent cover of forbs, grass, alfalfa, thatch, woody plants, dung, moss, bare ground, leaf litter, bare rock, and sedge. In 2016, we also took a measurement of soil moisture by inserting a soil moisture meter (scale of 0–10) 6 cm in soil in the center of the sampling frames. We used an open reel measuring tape to establish a 10-m radius circle around the center of each quadrat. Every shrub within this boundary was measured (height, width, length), and the shrub species was recorded. Nest vegetation surveys were conducted for ~1 wk once the last young had fledged from all nests monitored in our study to avoid disturbing the nesting effort. The exact same sampling method was undertaken as with the site vegetation surveys, with the nest in the middle of the frame. All vegetation measurements were taken by a single observer.

Invertebrate Sampling

To evaluate the association of prey availability on Bobolink abundance and productivity, we trapped invertebrates using pitfall pan traps and sweep netting. Surveys were conducted on days with no precipitation, low wind speed, and a temperature $>15^{\circ}\text{C}$. Traps and sweeps were completed twice during the breeding season in both sampling years, once in mid-May and once in late June. Invertebrate sampling methods consisted of 6 traps or 6 sweeps sampled systematically within the point count radius. Pitfall pan traps were composed of shallow yellow plastic bowls, filled with soapy water, and dug into the ground until the soil was even with the rim of the trap. Each trap was left for 48 h. Sweep netting was done using standard 38-cm diameter nets (BioQuip Products, Rancho Dominguez, CA). Each sweep session consisted of 8 back-and-forth sweeps through vegetation. Specimens were collected and stored in vials with 75% ethanol. Lepidopteran, Hymenopteran, and Coleopteran larvae were all grouped as caterpillars. We sorted only Orthopterans, adult Lepidopterans, and caterpillars as these Orders were more likely to be used as Bobolink prey (Wittenberger, 1982). We took body length measurements of each specimen for length-mass relationship equations created by Ganihar (1997) and Rogers et al. (1977) to calculate the biomass estimates of each order and major life stages (larvae and adults).

Statistical Analysis

Abundance

To analyze our point count data, we used package Unmarked function `pcount` (Fiske et al., 2015) in R 3.1.1 (R Core Team, 2014). This program analyzes abundance data while accounting for imperfect detection using N-mixture models (Royle, 2004). We used data from the 9 repeated point counts for both pasture and hayfield sites. As the range of values for certain variables (ex. vegetation height) did not overlap between the two habitats and we were interested in habitat-specific effects on Bobolink abundance, we used a sequential modeling approach. We initially modeled abundance and detection probability using year and habitat as covariates for abundance, as well as Julian date as a covariate for detection probability. We then divided the two habitats to obtain some specificity for habitat relations in hayfields and pastures separately. We tested a set of 14 models for hayfield sites and 17 models for pasture sites. Models were determined a priori on the basis of the literature, with the inclusion of variables in individual models that made biological sense and which could be interpreted easily by managers of Bobolinks. Estimated abundance was modeled as a function of site vegetation variables from the first survey, including vegetation height (cm), percent forb cover, percent grass cover, percent thatch cover, percent alfalfa cover, percent shrub cover, caterpillar biomass (mg), adult Lepidopteran biomass (mg), Orthopteran biomass (mg), cattle stocking density ($\text{AU}\cdot\text{ha}^{-1}$), and site size (ha). Year and site were used as grouping variables.

The abundance and detection probability of each sex was modeled separately as we predicted different detection probabilities between males and females due to behavioral and plumage differences during the breeding season and the potential for variability in habitat selection strategies. The carrying capacity (K) for models was set to the maximum number of individuals found within each habitat per sex. We used Akaike's information criterion corrected for small sample size (AIC_c). We considered models with $\Delta\text{AIC}_c < 2$ to have substantial support. Covariates were considered biologically significant when included in a model with $\Delta\text{AIC}_c < 2$ and which had a 95% confidence interval of their beta coefficient that did not overlap zero. To establish collinearity between potential model variables, we used Pearson's correlation coefficient and exempted one of two variables if $|r| > 0.7$. We used the `AICcmodavg` package (Mazerolle, 2016) to obtain model-averaged estimates and 95% confidence intervals for abundance and detection probability where applicable.

Reproductive Success

The effect of habitat variables on the reproductive success of Bobolinks was determined by calculating the daily survival rates (DSR) of Bobolink nests with known fates (Rotella et al., 2004). We modeled DSR using the package RMARK nest success model (Collier et al., 2016), which is an extension of Program MARK (Dinsmore and Dinsmore, 2007) in R 3.1.1 (R Core Team, 2014). We initially modeled DSR using year, habitat, and site. We then tested a candidate set of 16 models for hayfield nests and 17 models for pasture nests. Nest vegetation height (cm), percent cover of forbs, percent cover of grass, percent cover of thatch, caterpillar biomass (mg), Lepidoptera biomass (mg), Orthopteran biomass (mg), cattle stocking density ($\text{AU}\cdot\text{ha}^{-1}$), site size, nest age, and year as an interaction term were used as covariates for DSR. Site and year were used as grouping variables. We tested for collinearity between these variables using Pearson's correlation coefficient (r). We used Akaike's information criterion adjusted for small sample size (AIC_c) to determine the most parsimonious model. We considered models with $\Delta\text{AIC}_c < 2$ to have substantial support. Covariates were considered significant when included in a model with $\Delta\text{AIC}_c < 2$ and a 95% confidence interval that did not overlap zero.

Results

Bobolink Abundance

During the 2015 and 2016 breeding seasons, we completed 297 point counts. Hayfields consistently had higher average abundances of Bobolinks per point count than pastures, with greater discrepancy between the two habitats in 2016 than in 2015 (number of Bobolinks per count \pm SD: hayfields 2015 = 8.52 ± 2.43 ; pastures 2015 = 5.17 ± 1.73 [$t(14) = 2.14, P = 0.006$]; hayfields 2016 = 10.56 ± 2.82 ; pastures 2016 = 3.36 ± 1.64 [$t(12) = 2.18, P < 0.001$]). Hayfield sites had significantly taller vegetation cover than pasture sites ($F_{1,15} = 17.06, P < 0.001$). Vegetation height was also significantly shorter in both habitats in 2015 compared with 2016 ($F_{1,198} = 42.33, P < 0.0001$). The only other site vegetation variable that markedly differed between habitat was percent alfalfa cover, which was higher in hayfields in both years ($F_{1,15} = 40.89, P < 0.0001$) (Table 1).

From our top-ranked model, detection probabilities over the breeding season differed between male and female Bobolinks (Fig. 1). Male detection probability decreased significantly as the season progressed (estimate \pm SE = $-0.02 \pm 0.003, P < 0.001$). By contrast, female detection probability increased as the season progressed (estimate \pm SE = $0.02 \pm 0.004, P = 0.002$). Detection probability also varied by habitat, as both sexes were detected more often in hayfields than pastures (mean detection probability, females, hayfields: 0.43 [estimate \pm SE = $0.02 \pm 0.004, P < 0.001$], pastures: 0.21 [estimate \pm SE = $0.02 \pm 0.005, P < 0.001$]; males, hayfields: 0.59 [estimate \pm SE = $-0.01 \pm 0.003, P < 0.001$] pastures: 0.41 [estimate \pm SE = $-0.01 \pm 0.004, P < 0.001$]).

In the first step of our hierarchical modeling, our best-fitting models for estimating abundance included habitat, year, and the interaction between habitat and year, for both male (habitat * year model: $K = 6, \text{AIC}$

Table 1

Vegetation characteristics measured during Bobolink territory establishment in 6 hayfields and 10 pastures during the 2015 and 2016 breeding season. Values were averaged across sites

Yr	Habitat	Vegetation height \pm SD (cm)	Vegetation cover \pm SD (%)			
			Forb	Grass	Alfalfa	Thatch
2015	Hayfields	28.5 ± 3.6	26.5 ± 20.8	26.5 ± 5.9	8.2 ± 5.6	34.7 ± 21.4
2016	Hayfields	24.4 ± 2.0	19.6 ± 10.3	36.2 ± 5.0	11.0 ± 4.5	28.7 ± 10.8
2015	Pastures	23.9 ± 6.0	28.6 ± 17.6	31.5 ± 15.6	1.4 ± 4.3	38.3 ± 15.3
2016	Pastures	16.5 ± 3.5	27.6 ± 11.9	28.3 ± 9.5	0.9 ± 2.5	36.2 ± 12.4

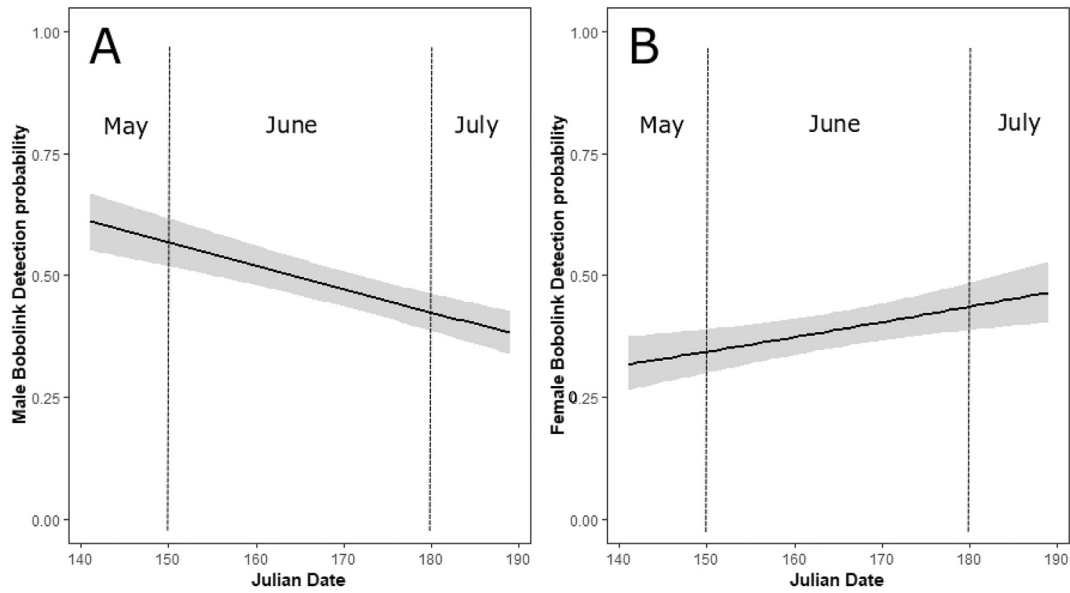


Figure 1. Relationship between (A) male and (B) female Bobolink detection probability and Julian date for 6 hayfields and 10 pastures combined.

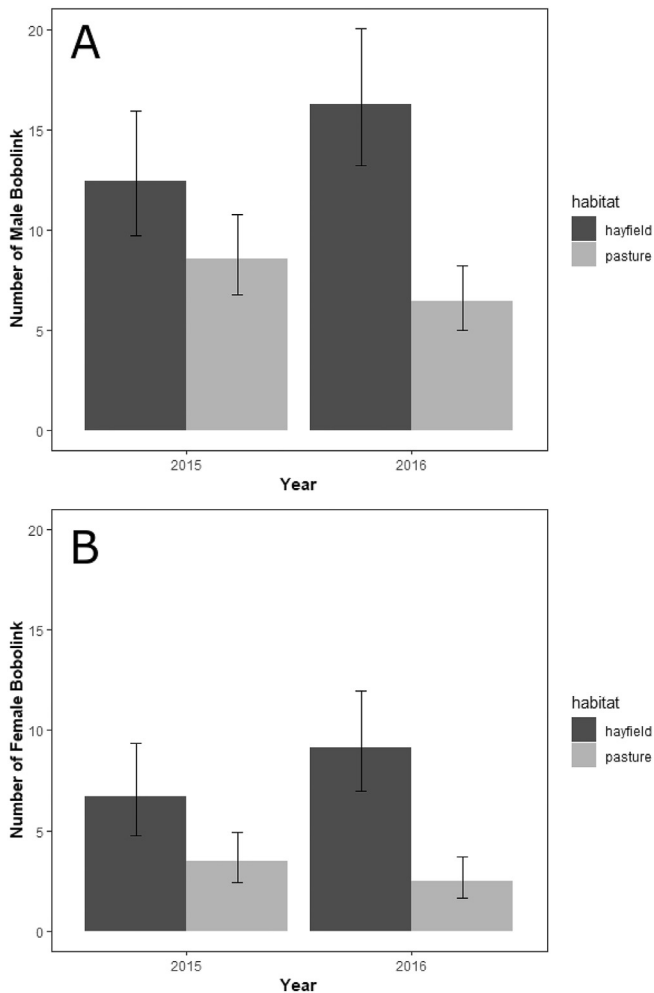


Figure 2. Relationship between the estimated abundance of (A) male and (B) female Bobolinks and the interaction between yr (2015/wet yr and 2016/dry yr) and habitat type (late-cut hayfield and continuously grazed pasture) from the top-ranked model.

= 1263.42, $\Delta AIC = 0.00$, $w_i = 0.71$) and female (habitat model: $K = 4$, $AIC = 972.50$, $\Delta AIC = 0.00$, $w_i = 0.55$; habitat * year model: $K = 6$, $AIC = 972.90$, $\Delta AIC = 0.41$, $w_i = 0.45$) models. Habitat, year, and null models were not competitive for both sexes. However, female abundance varied significantly only by habitat ($\beta = -0.90$, $SE = 0.24$, 95% $CI = -1.37 - -0.43$), with greater abundances in hayfields than in pastures. For males, there was significant variation by habitat ($\beta = -0.38$, $SE = 0.17$, 95% $CI = -0.70 - -0.05$) with a greater abundance in hayfields than pastures and the top model also included a significant interaction between habitat and year ($\beta = -0.56$, $SE = 0.23$, 95% $CI = -1.01 - -0.10$; Fig. 2). For the second step of our modeling, where we conducted separate analyses for pastures and hayfields, only mean vegetation height entered the top-ranked models for male and female Bobolink abundance in hayfields (Table 2), and this association was significant for both sexes (Table 3): As vegetation height increased, the abundance of both sexes decreased (Fig. 3). We also determined whether vegetation height was correlated with the previous year's cut date (only available between 2016 height and 2015 cut dates) and soil moisture (only available for 2016), but there were no significant relationships ($P > 0.05$). In pastures, however, female abundance was best explained by a positive relationship with vegetation height (see Fig. 3). For male Bobolinks in pastures, there was no clear best-fitting model and many habitat variables were included in models with $\Delta AIC < 2$ (see Table 3). However, pasture size was the only variable with a significant beta coefficient and had a positive relationship with estimated male abundance (see Fig. 3).

Nest Survival

We monitored a total of 87 Bobolink nests with 29 nests in late-cut hayfields and 58 in continuously grazed pastures. In 2015, the average date at which Bobolinks fledged was 26 June and the latest was 10 July, while in 2016, the average fledging date (7 d post leaving the nest) was 30 June and the latest was 15 July. The largest source of nest failure was predation, accounting for 37.9% of mortality in hayfields and 55.2% in pastures with most nest loss due to predation occurring in 2016 for both habitats. In pastures, three nests (5.2%) were trampled by cattle.

Female Bobolinks generally constructed nests in areas of high forb (% cover $\pm SE = 36.57\% \pm 24.25\%$), grass ($36.05\% \pm 21.54\%$), and thatch

Table 2
Model selection results of estimated Bobolink abundance ranked by Akaike's information criterion corrected for small sample size (AIC_c) for 6 hayfields and 10 pasture sites^a

Model	K	ΔAIC_c^a	w_i
Hayfield females			
Vegetation height	4	0.00	0.46
Grass	4	3.15	0.09
Lepidoptera	4	3.55	0.08
Alfalfa	4	3.80	0.07
Caterpillars	4	3.81	0.07
Vegetation height + Forb + Alfalfa + Grass	7	3.88	0.07
Orthoptera	4	3.95	0.06
Forb	4	4.25	0.05
Hayfield males			
Vegetation height	4	0.00	0.34
Field size	4	1.78	0.14
Grass	4	2.41	0.10
Forb	4	3.03	0.08
Lepidoptera	4	3.05	0.08
Caterpillars	4	3.12	0.07
Orthoptera	4	3.17	0.07
Alfalfa	4	3.45	0.06
Pasture females			
Vegetation height	4	0.00	0.29
Orthoptera	4	2.15	0.10
Field size	4	2.25	0.09
Stocking density	4	2.77	0.07
Vegetation height + Forb + Grass + Thatch	7	2.84	0.07
Caterpillars	4	2.85	0.07
Site	13	3.28	0.06
Thatch	4	3.37	0.05
Lepidoptera	4	3.75	0.04
Forb	4	3.77	0.04
Grass	4	3.79	0.04
Stocking density · Vegetation height	6	3.99	0.04
Pasture males			
Vegetation height	4	0.00	0.14
Orthoptera	4	0.40	0.11
Grass	4	0.51	0.10
Caterpillars	4	0.57	0.10
Field size	4	0.64	0.10
Vegetation height + Forb + Grass + Thatch	7	1.06	0.08
Thatch	4	1.38	0.07
Site	13	1.46	0.07
Stocking density	4	1.66	0.06
Lepidoptera	4	1.67	0.06
Forb	4	1.68	0.06

K indicates number of parameters; w_i Akaike's weight. Only models that make up 95% of w_i are shown.

^a The AIC_c value for the top-ranked model was 547.65 for hayfield females, 597.25 for hayfield males, 555.82 for pasture females, and 936.35 for pasture males.

(22.47% ± 15.40%) cover with low alfalfa cover (0.95% ± 3.41%). The height of vegetation surrounding nests varied significantly by year and habitat. Nests in hayfields had significantly taller vegetation cover than nests in pastures ($F_{1,14} = 101.66, P < 0.001$) and nests, regardless of habitat, had shorter vegetation cover in 2016 than in 2015 ($F_{1,69} = 41.17, P < 0.001$). There was significantly more thatch cover around nests in pasture than hayfields ($F_{1,14} = 6.48, P < 0.05$) and higher thatch cover in 2016 ($F_{1,69} = 7.52, P < 0.05$) than in 2015. By contrast, forb cover was significantly lower in 2016 ($F_{1,69} = 5.03, P < 0.05$). Some vegetation characteristics of nests, including forb and grass cover, differed significantly from those of the average available habitat at sites. Average vegetation height was greater in hayfields than pastures, but the height of vegetation at nests did not differ from the height available at sites ($F_{1,12} = 56.37, P < 0.0001$). Bobolinks in both habitats chose nest sites with a higher soil moisture content than the average soil moisture available ($F_{1,163} = 70.05, P < 0.0001$), and hayfield nest sites had higher soil moisture content than pasture nest sites ($F_{1,163} = 21.19, P < 0.0001$; Fig. 4).

When we modeled daily survival rates of nests, habitat type was the best explanatory variable for nest survival with no other competitive

Table 3
Model averaged beta coefficients (β) from the top-ranked models ($\Delta AIC_c < 2$) of abundance modeling for estimated Bobolink abundance. Separated by habitat and sex for 6 hayfields and 10 pasture sites

Grouping	Parameter	β	SE	95% CI ¹
Hayfield females				
	Intercept	4.10	0.82	2.49-5.71*
	Vegetation height	-0.06	0.03	-0.13-0.00*
Hayfield males				
	Intercept	3.90	0.71	2.50-5.29*
	Vegetation height	-0.05	0.03	-0.10-0.00*
Pasture females				
	Intercept	0.64	0.43	-0.20-1.48
	Vegetation height	0.04	0.02	0.00-0.07*
Pasture males				
	Intercept	2.00	0.31	1.40-2.60*
	Orthoptera	-0.10	0.09	-0.28-0.08
	Vegetation height	0.02	0.01	-0.01-0.05
	Size	0.00	0.00	0.00-0.01*
	Caterpillars	-0.10	0.10	-0.31-0.10
	Forb	0.00	0.01	-0.02-0.02
	Stocking density	-0.02	0.08	-0.18-0.15
	Grass	-0.01	0.01	-0.03-0.01
	Thatch	0.00	0.01	-0.01-0.02
	Lepidoptera	0.01	0.08	-0.15-0.17

¹ An asterisk indicates that the 95% confidence interval does not overlap zero.

models ($K = 2, AIC_c = 174.60, \Delta AIC_c = 0.00, w_i = 0.83, \text{deviance} = 270.59$). Nests in hayfields had significantly higher DSR than those in pastures ($\beta = -1.07, 95\% \text{ CI: } -1.78 - -0.36$). Daily survival rate was 0.978 ± 0.008 for nests in hayfields and 0.939 ± 0.010 for nests in pastures. Therefore, with an incubation and nestling period of ~24 d, the probability of survival of a nest would be 0.59 for hayfield nests and 0.23 for pasture nests. When we examined finer-scale habitat characteristics of each habitat type, the best-fitting models indicated that hayfield and pasture nest DSRs were influenced by different variables (Table 4). Nest survival in hayfields was best explained by vegetation height surrounding the nest ($w_i = 0.32$); DSR in hayfields had a positive relationship with average vegetation height surrounding the nest ($\beta = 0.08, SE = 0.04, 95\% \text{ CI: } 0.00-0.15$; Fig. 5). Nest survival in pastures was best explained by the interaction between caterpillar biomass and year ($w_i = 0.51$; see Table 4). The model with the interaction between Lepidoptera biomass and year was also competitive ($\Delta AIC_c = 1.80$). Caterpillar biomass had a negative relationship with DSR but was not significant ($\beta = -0.49, SE = 0.32, 95\% \text{ CI: } -1.01-0.03$). Year was a strong predictor of DSR with 2016 having lower nest survival than 2015 ($\beta = -1.41, SE = 0.50, 95\% \text{ CI: } -2.39 - -0.43$). The interaction between year and caterpillar biomass in the best-fitting model was also significant ($\beta = -3.76, SE = 1.48, 95\% \text{ CI: } -6.66 - -0.86$).

Discussion

Our evaluation of low-stocking density continuous grazing demonstrated that these pastures provide Bobolink breeding habitat but that late-cut hayfields have greater abundance and nest survival and, hence, offer better habitat for sustaining Bobolink populations.

Bobolink Abundance and Detection Probability

Models of factors affecting abundance contained a significant interaction between year and habitat, with about 4× more Bobolinks in hayfields than pastures in 2016 as compared with 2015. This variation in relative abundance may relate to the variation in precipitation between the 2 yr of study. An influence of climate, especially variation in annual precipitation, on Bobolink, Grasshopper Sparrow (*Ammodramus savannarum*), and grassland bird communities has been observed in other studies (Thogmartin et al., 2006; Ahlering and Merkord, 2016).

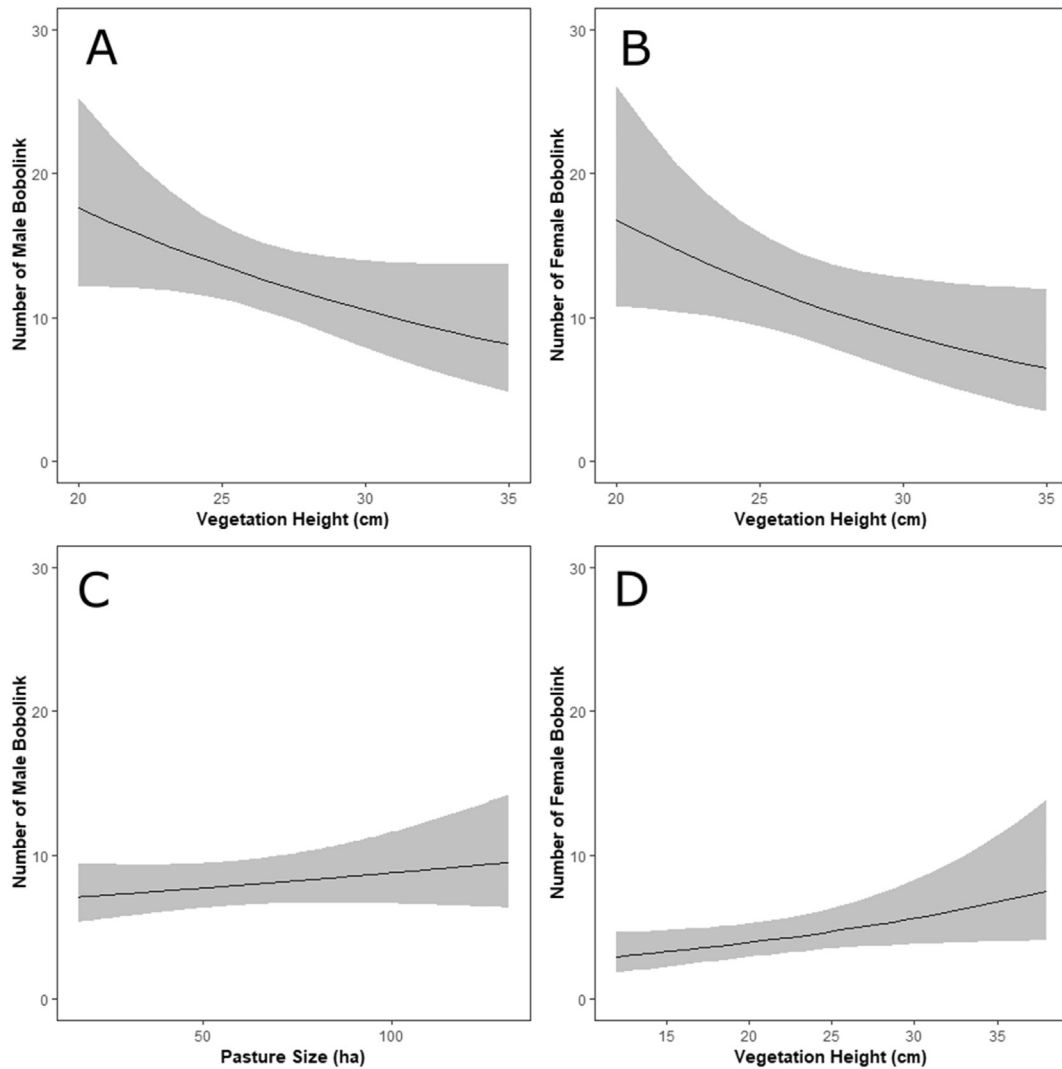


Figure 3. Results from top-ranked abundance models for the relationship between (A) male abundance and vegetation height (cm) in hayfields, (B) female abundance and vegetation height (cm) in hayfields, (C) male abundance and pasture size (ha) in continuously grazed pastures, and (D) female abundance and vegetation height (cm) in continuously grazed pastures. Shaded areas represent the 95% confidence interval.

Bobolinks may be relying more heavily on hayfields, which have greater vegetation height than pastures, during dry years (e.g., 2016) and expanding into pastures during wet years (e.g., 2015), but further study of the interannual movements of individuals is warranted. Pastures were recorded to have significantly taller vegetation in 2016 compared with 2015, vegetation height being positively related to female abundance, which indicates that pastures may be of greater value in areas of higher precipitation or mesic habitat sustaining taller vegetation. However, pastures had significantly later nest initiation dates which suggest that Bobolinks nonetheless preferred hayfields over pastures during the wet year. Our study indicates that linking goals for local abundance of Bobolinks between continuously grazed pastures and late-cut hayfields in the landscape may be of value, with the potential for a variety of land uses representing suitable habitat based on local climatic conditions.

Variation in abundance in hayfields was associated with decreasing vegetation height, which was an unusual result, as Bobolink abundance has typically been recorded to have positive associations with higher and denser vegetation (Nocera et al., 2007; Ranellucci, 2010). However, similar to our results in late-cut hayfields, a negative relationship between vegetation vertical density and Bobolink abundance has been

recorded (Delisle and Savidge, 1997). The relationship between vegetation height and Bobolink abundance could be unimodal, with moderate heights preferred, presumably balancing the need for cover from potential predators and the ability by adults and fledglings to move easily through the vegetation. Litter depth or another variable that was not measured, such as the previous years' productivity, may be better predictors of Bobolink abundance in hayfields (Delisle and Savidge, 1997; Renfrew and Ribic, 2001). Our model results for pastures, with males preferring larger pastures, aligns with other studies highlighting the area sensitivity of Bobolinks (Winter et al., 2006; Shustack et al., 2010). Female Bobolinks in pastures appeared to be sensitive to vegetation structure (Wittenberger, 1980; Bollinger and Gavin, 1989; Patterson and Best, 1996; Nocera et al., 2007). The difference that we recorded between males and females may be attributed to their breeding behavior. Males establish territories and therefore may be more sensitive to patch size (Diemer and Nocera, 2014). Females select nesting sites and construct nests (Wittenberger, 1978) and appear to be more sensitive to vegetation structure. In terms of cattle management, we found no relationship between cattle stocking density and Bobolink abundance within the range of cattle densities in our study area ($0.31 - 1.24 \text{ AU} \cdot \text{ha}^{-1}$).

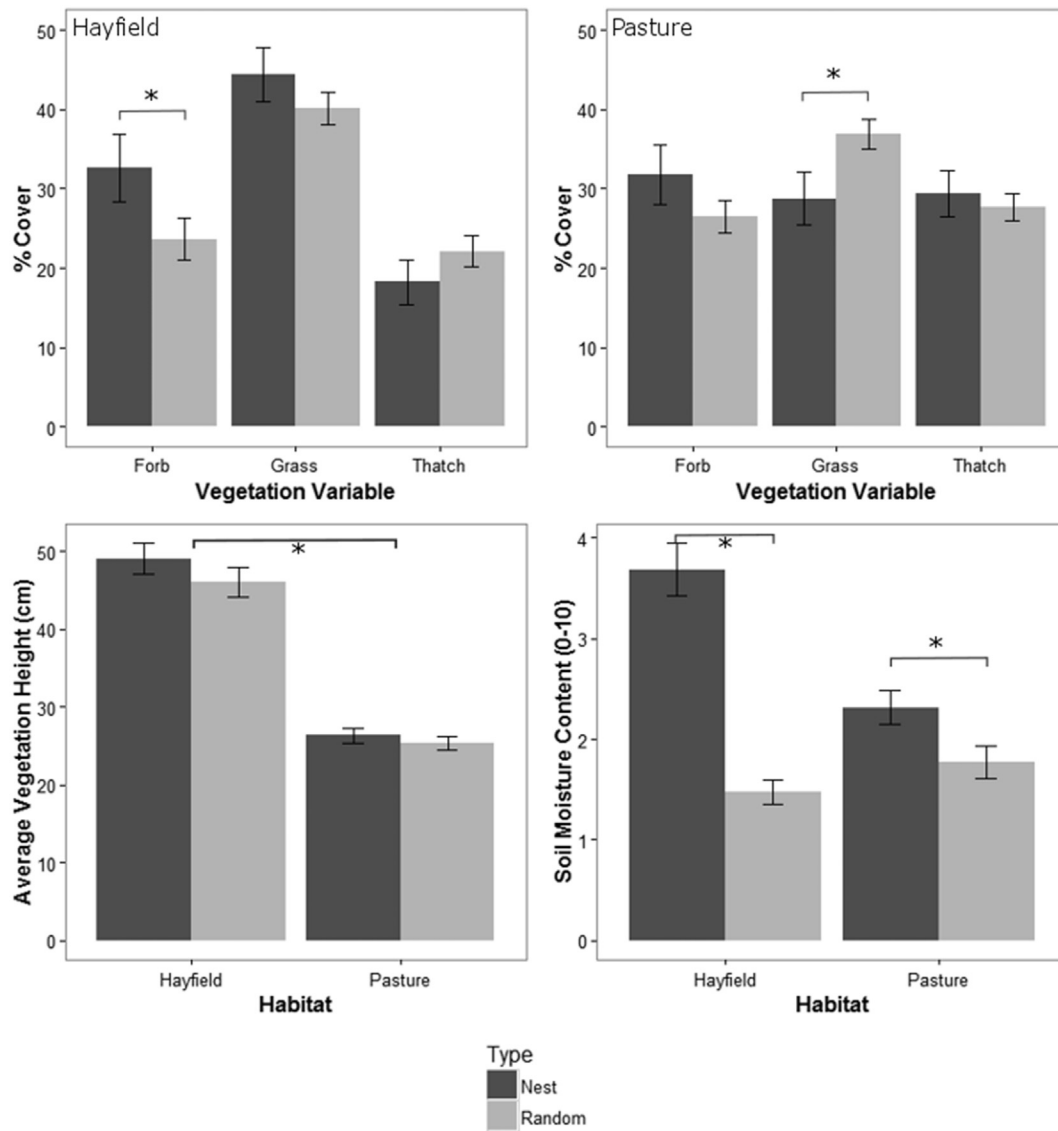


Figure 4. Comparison of 87 Bobolink nest site characteristics and available nesting site characteristics from 6 hayfields and 8 pastures. An asterisk represents a significant ($P \leq 0.05$) difference between groups.

Nest Site Selection and Nest Survival

Cattle were directly responsible for 5% of nest losses, and this rate was low compared with results from several studies conducted on rotational grazing where trampling accounted for 57–100% of nest mortalities (Perlut et al., 2006; Perlut and Strong, 2011; Macdonald and Nol, 2017). However, Kerns et al. (2010) studied rotational grazing at stocking rates of $0.20–0.28 \text{ AU} \cdot \text{ha}^{-1}$ and had comparable trampling rates to our study. Similarly, Lusk and Koper (2013) recorded nest survival of five grassland species in Saskatchewan at $0.25–0.55 \text{ AU} \cdot \text{ha}^{-1}$ and had only one nest failure due to trampling in continuously grazed pastures. Nests in hayfields experienced higher DSR, but in both habitats, Bobolinks still produced moderate to high numbers of successful nests compared with other estimates of success for this species (hayfield DSR = 0.978 and pasture DSR = 0.939). For example, Bobolink nest DSR in fallow fields or undisturbed pastures/hayfields was recorded at 0.969 (Norment et al., 2010) and 0.967 in late or no-cut hayfields in Quebec and Ontario (Frei, 2009).

Nest survival in hayfields had a positive relationship with vegetation height surrounding the nest. An increase in vegetation cover around the nest probably provides better protection from visual predators and

adverse weather (Wittenberger, 1980; Winter et al., 2004). Nest survival in pastures was significantly lower in 2016, being best explained by the interaction between year and caterpillar biomass, although caterpillar biomass as a single variable was not significant. Contrary to our predictions, nest survival was negatively related to caterpillar biomass, although not significantly. This is counterintuitive as increases in food availability, such as caterpillars, have been shown to be positively associated with the nest success of Bobolink and other grassland species (Nocera et al., 2007; Diemer and Nocera, 2014). This is most likely a spurious result, possibly due to the limitations of the biomass equations, which are limited to invertebrate orders and the lack of nests sampled at higher caterpillar biomasses (see Fig. 5). Latent variables are most likely responsible for the quality of pasture sites, and further study examining nest success in continuously grazed pastures is necessitated. Year appears to be the only strong explanatory variable for pasture nests, and varying DSR by year may also be linked to abundance trends. Bobolink abundance increased in hayfields and decreased in pastures in 2016 when nest survival was lowest in pastures. This suggests that territory or nest establishment may have been based on environmental cues influencing future nest survival such as climate, surrounding landscape variables, or potential nest predators. Temporal changes in soil

Table 4

Model selection results for daily nest survival of Bobolink ranked by Akaike's information criterion corrected for small sample size (AIC_c) for 29 nest in 6 hayfields and 58 nests in 10 pasture sites^a

Model	K	ΔAIC_c	w_i	Deviance
Hayfield				
Vegetation height	2	0.00	0.32	72.63
Null	1	2.20	0.11	76.85
Thatch	2	2.56	0.09	75.19
Forb + Thatch + Grass + Vegetation Height	5	2.91	0.07	69.44
Vegetation height · yr	4	3.52	0.06	72.09
Caterpillar	2	3.70	0.05	76.33
Field size	2	3.80	0.05	76.43
Forb	2	3.82	0.05	76.45
Nest age	2	3.86	0.05	76.49
Orthoptera	2	4.06	0.04	76.70
Grass	2	4.14	0.04	76.77
Lepidoptera	2	4.20	0.04	76.84
Pasture				
Caterpillar · yr	4	0.00	0.51	181.77
Lepidoptera · yr	4	1.79	0.21	183.56
Caterpillar	2	3.78	0.08	189.59
Lepidoptera	2	5.47	0.03	191.29
Thatch	2	5.75	0.03	191.57
Null	1	5.90	0.03	193.74
Forb	2	6.48	0.02	192.31
Vegetation height	2	6.71	0.02	192.53
Caterpillar + Orthoptera + Lepidoptera	4	7.49	0.01	189.26
Nest age	2	7.51	0.01	193.33

K indicates number of parameters, w_i = Akaike's weight.

Only models that make up 95% of the w_i are shown.

^a The AIC value for the top-ranked model was 76.66 for hayfields and 189.84 for pastures.

moisture may also have an influence on breeding site selection and inter-annual movements as indicated by lower Bobolink abundances in pastures compared with hayfields in 2016 and nesting locations in microhabitats with moister soil than available. However, our results of nest site selection should be interpreted with caution, particularly vegetation height and soil moisture, as our second vegetation surveys were not standardized by individual nest time but rather taken at the end of the breeding season for all nests. Studies that seek to further understand Bobolink nest site selection or the link between vegetation structure and nest successful should standardize all vegetation survey methods to account for the timing of nesting (McConnell et al., 2017).

Implications

Our findings suggest that late-cut hayfields are of higher quality compared with continuously grazed rangelands and support both higher densities and greater nest survival than pastures. Because the main source of nest failure in pastures was predation, having a mosaic of short and long grass in pastures could reduce predation risk of visual predators while maintaining food supplies for breeding Bobolinks (Whittingham and Evans, 2004). Patch-burn and grazing to maintain heterogeneous open grasslands is beneficial for other grassland birds (Davis et al., 2016) and may be a useful strategy to implement for Bobolinks, pending further research. Knowledge on common nest predators in this region may also be useful because identifying specific nest predators has only been conducted in Wisconsin (Renfrew and Ribic, 2003; Ribic et al., 2012) and North Dakota (Pietz and Granfors, 2000). Further studies on Bobolink nests should evaluate higher stocking densities for negative impacts, as artificial nest studies surpassing our cattle densities suggest a much stronger effect at $\geq 2 \text{ AU} \cdot \text{ha}^{-1}$ when employing continuous grazing (Paine et al., 1996; Sabatier et al., 2015). Although rangelands are of lower quality than late-cut hayfields, proper management and habitat improvements, such as maintaining larger fields with taller grasses and moderate soil moisture, could improve breeding conditions (Pulliam and Danielson, 1991; Murphy, 2001). Working with private landowners and agricultural communities to realize a balance

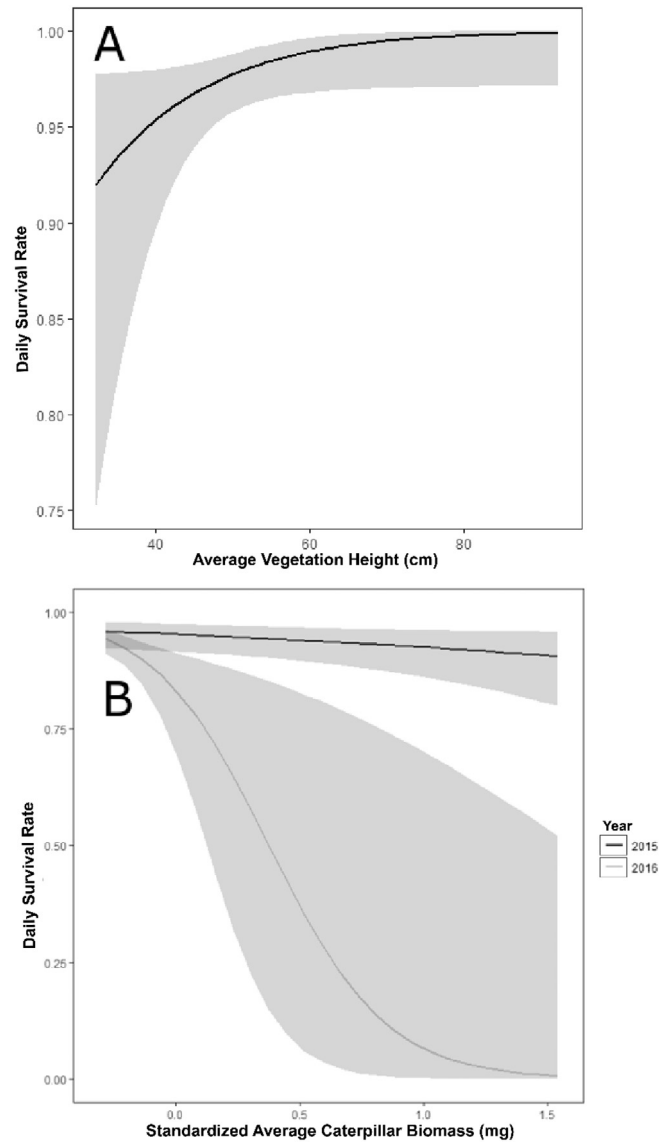


Figure 5. Relationship between (A) daily survival rate of Bobolink nests and average vegetation height (cm) surrounding the nest from the top-ranked model ($w_i = 0.32$) using 29 nests from 6 hayfield sites and (B) daily survival rate of Bobolink nests and the interaction between standardized caterpillar biomass and year from the top-ranked model ($w_i = 0.51$) using 58 nests from 10 pasture sites. Shaded areas represent the 95% confidence interval.

between species conservation and agroecosystem development is essential (Langpap and Kerkvliet, 2012). Protecting and improving breeding grounds through financial incentives and other forms of conservation easements for private landowners are crucial and have great potential in increasing growth rates for grassland bird populations (Drum et al., 2015; Horton et al., 2017).

Acknowledgments

We appreciate the support of the Couchiching Conservancy, the Nature Conservancy of Canada, Lafarge Aggregates, and all private ranchers who granted us access to conduct research on their properties. We thank all technicians for their hard work. Funding was provided by the Province of Ontario [Species at Risk Research Fund for Ontario, RF-24-15-TU2], Bird Studies Canada, the Schad Foundation, the McLean Foundation and Trent University. This study was conducted under the Animal Care Protocol #23981, Trent University Animal Care Committee, Peterborough, Ontario.

References

- Ahlering, M.A., Merkord, C.L., 2016. Cattle grazing and grassland birds in the northern tallgrass prairie. *Journal of Wildlife Management* 80, 643–654.
- Askins, R.A., 1999. History of grassland birds in eastern North America. *Studies in Avian Biology* 19, 60–71.
- Askins, R.A., Chávez-Ramírez, F., Dale, B.C., Haas, C.A., Herkert, J.R., Knopf, F.L., Vickery, P.D., 2007. Conservation of grassland birds in North America: understanding ecological processes in different regions. *Ornithological Monographs* 64, 1–46.
- Báldi, A., Batáry, P., Erdos, S., 2005. Effects of grazing intensity on bird assemblages and populations of Hungarian grasslands. *Agriculture, Ecosystems and Environment* 108, 251–263.
- Bird Studies Canada, 2017. Important bird areas Canada: Carden Alvar Site summary. Available at: <https://www.ibacanada.org>. Accessed date: 17 October 2011.
- Bollinger, E., Gavin, T., 1989. The effects of site quality on breeding-site fidelity in Bobolinks. *The Auk* 106, 584–594.
- Bollinger, E.K., Bollinger, P.B., Gavin, T.A., 1990. Effects of hay-cropping on Eastern populations of the Bobolink. *Wildlife Society Bulletin* 18, 142–150.
- Brennan, L.A., Kuvlesky, W.P., 2005. North American grassland birds: an unfolding conservation crisis? *Journal of Wildlife Management* 69, 1–13.
- Chapman, R.N., Engle, D.M., Masters, R.E., Leslie, D.M., 2004. Tree invasion constrains the influence of herbaceous structure in grassland bird habitats. *Ecoscience* 11, 55–63.
- Collier, B., Rotella, J., Pavlacky, D., Paul, A., Eberhart, L., 2016. Package "RMark".
- COSEWIC, 2010. COSEWIC assessment and status report on the Bobolink *Dolichonyx oryzivorus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.
- Daubenmire, R.A., 1959. A canopy-coverage method of vegetational analysis. *Northwest Science* 33, 43–64.
- Davis, C.A., Churchwell, R.T., Fuhlendorf, S.D., Engle, D.M., Hovick, T.J., 2016. Effect of pyric herbivory on source–sink dynamics in grassland birds. *Journal of Applied Ecology* 53, 1004–1012.
- Delisle, J.M., Savidge, J.A., 1997. Avian use and vegetation characteristics of conservation reserve program fields. *Journal of Wildlife Management* 61, 318–325.
- Diemer, K.M., Nocera, J.J., 2016. Bobolink reproductive response to three hayfield management regimens in southern Ontario. *Journal for Nature Conservation* 29, 123–131.
- Diemer, K.M., Nocera, J.J., 2014. Associations of bobolink territory size with habitat quality. *Annales Zoologici Fennici* 51, 515–525.
- Dinsmore, S.J., Dinsmore, J.J., 2007. Modeling avian nest survival in program MARK. *Studies in Avian Biology* 34, 73–83.
- Drum, R.G., Ribic, C.A., Koch, K., Lonsdorf, E., Grant, E., Ahlering, M., Barnhill, L., Dailey, T., Lor, S., Mueller, C., Pavlacky, D.C., Rideout, C., Sample, D., 2015. Strategic grassland bird conservation throughout the annual cycle: linking policy alternatives, landowner decisions, and biological population outcomes. *PLoS ONE* 10, e0142525.
- Duchardt, C.J., Miller, J.R., Debinski, D.M., Engle, D.M., 2016. Adapting the fire-grazing interaction to small pastures in a fragmented landscape for grassland bird conservation. *Rangeland Ecology & Management* 69, 300–309.
- Environment Canada, 2016. Historical climate data. Available at Orillia Brain Station http://climate.weather.gc.ca/historical_data Accessed
- Fiske, A.I., Chandler, R., Miller, D., Royle, A., Kery, M., Hostetler, J., Royle, M.A., 2015. Package "unmarked".
- Fondell, T.F., Ball, I.J., 2004. Density and success of bird nests relative to grazing on western Montana grasslands. *Biological Conservation* 117, 203–213.
- Frei, B., 2009. Ecology and management of Bobolinks in hayfields of Quebec and Ontario. [MS thesis] McGill University, Montreal, QC, Canada, pp. 1–72.
- Ganihar, S.R., 1997. Biomass estimates of terrestrial arthropods based on body length. *Journal of Biosciences* 22, 219–224.
- Gennet, S., Spotswood, E., Hammond, M., Bartolome, J.W., 2017. Livestock grazing supports native plants and songbirds in a California annual grassland. *PLoS ONE* 12, e0176367.
- Herkert, J.R., 1997. Bobolink *Dolichonyx oryzivorus* population decline in agricultural landscapes in the midwestern USA. *Biological Conservation* 80, 107–112.
- Horton, K., Knight, H., Galvin, K.A., Goldstein, J.H., Herrington, J., 2017. An evaluation of landowners' conservation easements on their livelihoods and well-being. *Biological Conservation* 209, 62–67.
- Kerns, C.K., Ryan, M.R., Murphy, R.K., Thompson, F.R., Rubin, C.S., 2010. Factors affecting songbird nest survival in northern mixed-Grass prairie. *Journal of Wildlife Management* 74, 257–264.
- Langpap, C., Kerkvliet, J., 2012. Endangered species conservation on private land: assessing the effectiveness of habitat conservation plans. *Journal of Environmental Economics and Management* 64, 1–15.
- Lusk, J.S., Koper, N., 2013. Grazing and songbird nest survival in southwestern Saskatchewan. *Rangeland Ecology & Management* 66, 401–409.
- Macdonald, N.M., Nol, E., 2017. Impacts of rotational grazing and hay management on the reproductive success of Bobolink (*Dolichonyx oryzivorus*) in eastern Ontario. *Canadian Wildlife Biology and Management* 6, 53–65.
- Mandema, F.S., Tinbergen, J.M., Ens, B.J., Koffijberg, K., Dijkema, K.S., Bakker, J.P., 2015. Moderate livestock grazing of salt and brackish marshes benefits breeding birds along the mainland coast of the Wadden Sea. *The Wilson Journal of Ornithology* 127, 467–476.
- Mazerolle, M.J., 2017. AICcmmodavg: model Selection and multimodel inference based on (Q)AIC(c). Available at: <https://cran.r-project.org/package=AICcmmodavg> Accessed
- McConnell, M.D., Monroe, A.P., Burger, L.W., Martin, J.A., 2017. Timing of nest vegetation measurement may obscure adaptive significance of nest-site characteristics: a simulation study. *Ecology and Evolution* 7 (4), 1259–1270.
- McCracken, J.D., 2005. Where the Bobolinks roam: the plight of North America's grassland birds. *Biodiversity* 6, 20–29.
- McCracken, J.D., Reid, R.A., Renfrew, R.B., Frei, B., Jalava, A.C., Couturier, A.R., 2013. Recovery strategy for the Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*) in Ontario. Ontario Recovery Strategy Series.
- Murphy, M.T., 2001. Source-sink dynamics of a declining eastern kingbird population and the value of sink habitats. *Conservation Biology* 15, 737–748.
- Murphy, M.T., 2003. Avian population trends within the evolving agricultural landscape of Eastern and Central United States. *The Auk* 120, 20–34.
- Nocera, J.J., Forbes, G., Milton, G.R., 2007. Habitat relationships of three grassland breeding bird species: broadscale comparisons and hayfield management implications. *Avian Conservation and Ecology* 2, 1–19.
- Nocera, J.J., Parsons, G.J., Milton, G.R., Fredeen, A.H., 2005. Compatibility of delayed cutting regime with bird breeding and hay nutritional quality. *Agriculture, Ecosystems & Environment* 107, 245–253.
- Norment, C.J., Runge, M.C., Morgan, M.R., 2010. Breeding biology of grassland birds in western New York: conservation and management implications. *Avian Conservation and Ecology* 5, 1–14.
- Paine, L., Undersander, D.J., Sample, D.W., Bartelt, G.A., Schatteman, T.A., 1996. Cattle trampling of simulated ground nests in rotationally grazed pastures. *Journal of Range Management* 49, 294–300.
- Patterson, M.P., Best, L.B., 1996. Bird abundance and nesting success in Iowa CRP fields: the importance of vegetation structure and composition. *American Midland Naturalist* 135, 153–167.
- Perlut, N.G., Strong, A.M., 2011. Grassland birds and rotational-grazing in the northeast: breeding ecology, survival and management opportunities. *Journal of Wildlife Management* 75, 715–720.
- Perlut, N.G., Strong, A.M., Donovan, T.M., Buckley, N.J., 2006. Grassland songbirds in a dynamic management landscape: behavioral responses and management strategies. *Ecological Applications* 16, 2235–2247.
- Pietz, P.J., Granfors, D.A., 2000. Identifying predators and fates of grassland passerine nests using miniature video cameras. *Journal of Wildlife Management* 64, 71–87.
- Pulliam, H.R., Danielson, B.J., 1991. Sources, sinks, and habitat selection: a landscape perspective on population dynamics. *American Naturalist* 137, 50–66.
- R Core Team, 2014. [computer program] R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Ranellucci, C.L., 2010. Effects of twice-over rotation grazing on the abundances of grassland birds in the mixed-grass prairie region of southwestern Manitoba. [thesis] University of Manitoba, Winnipeg, MB, Canada, pp. 1–105.
- Renfrew, R.B., Ribic, C.A., 2003. Grassland passerine nest predators near pasture edges identified on videotape. *Auk* 120, 371–383.
- Renfrew, R.B., Ribic, C.A., 2002. Influence of topography on density of grassland passerines in pastures. *American Midland Naturalist* 147, 315–325.
- Renfrew, R.B., Ribic, C.A., 2001. Grassland birds associated with agricultural riparian practices in southwestern Wisconsin. *Journal of Range Management* 54, 546–552.
- Ribic, C.A., Guzy, M.J., Anderson, T.J., Sample, D.W., Nack, J.L., 2012. Bird productivity and nest predation in agricultural grasslands. *Video Surveillance of Nesting Birds* 119–134.
- Ribic, C.A., Koford, R.R., Herkert, J.R., Johnson, D.H., Niemuth, N.D., Naugle, D.E., Bakker, K.K., Sample, D.W., Renfrew, R.B., 2009. Area sensitivity in North American grassland birds: patterns and processes. *Auk* 126, 233–244.
- Robel, R.J., Briggs, J.N., Dayton, A.D., Hulbert, L.C., 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. *Journal of Range Management* 23, 295–297.
- Rogers, L.E., Buschbom, R.L., Watson, C.R., 1977. Length-weight relationships of shrub-steppe invertebrates. *Entomological Society of America* 70, 51–53.
- Rotella, J.J., Dinsmore, S.J., Shaffer, T.L., 2004. Modeling nest–survival data: a comparison of recently developed methods that can be implemented in MARK and SAS. *Animal Biodiversity and Conservation* 27, 187–205.
- Royle, J.A., 2004. N-Mixture models for estimating population size from spatially replicated counts. *Biometrics* 60, 108–115.
- Sabatier, R., Durant, D., Ferchichi, S., Haranne, K., Léger, F., Tichit, M., 2015. Effect of cattle trampling on ground nesting birds on pastures: an experiment with artificial nests. *European Journal of Ecology* 1, 5–11.
- Sauer, J.R., Hines, J.E., Fallon, J.E., Pardiack, K.L., Ziolkowski, J.D.J., Link, W.A., 2014. The North American Breeding Bird Survey, Results and Analysis 1966–2013. Version 01.30.2015USGS. Patuxent Wildlife Research Center, Laurel, MD, USA.
- Shustack, D.P., Strong, A.M., Donovan, T.M., 2010. Habitat use patterns of Bobolinks and Savannah Sparrows in the Northeastern United States. *Avian Conservation and Ecology* 5, 11.
- Temple, S.A., Fevold, B., Paine, L.K., Undersander, D.J., Sample, D.W., 1999. Nesting birds and grazing cattle: accommodating both on Midwestern pastures. *Journal of Wildlife Management* 75, 715–720.
- Thogmartin, W.E., Knutson, M.G., Sauer, J.R., 2006. Predicting regional abundance of rare grassland birds with a hierarchical spatial count model. *Condor* 108, 25–46.
- Undersander, D.J., Temple, S., Bartlett, J., Sample, D., Paine, L., 2000. Grassland birds: fostering habitats using rotational grazing. Board of Regents of the University of Wisconsin System, Madison, WI, USA, pp. 1–12.
- Vickery, J.A., Tallowin, J.R., Feber, R.E., Asterak, E.J., Atkinson, P.W., Fuller, R.J., Brown, V.K., 2001. The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources. *Journal of Applied Ecology* 38, 647–664.
- Vickery, P.D., Herkert, J.R., Knopf, F.L., Ruth, J., Keller, C.E., 2000. Grassland birds: an overview of threats and recommended management strategies. US Forest Service, Rocky Mountain Research Station, Ogden, UT, USA, pp. 74–77.

- Vickery, P.D., Hunter, M.L., Melvin, S.M., 1994. Effects of Habitat Area on the Distribution of Grassland Birds in Maine. *Conservation Biology* 8, 1087–1097.
- Whittingham, M.J., Evans, K.L., 2004. The effects of habitat structure on predation risk of birds in agricultural landscapes. *Ibis* 146, 210–220.
- Wildlife Preservation Canada, The Couchiching Conservancy, The Nature Conservancy of Canada, 2008. *Towards an integrated Carden conservation strategy. Part 1: Healthy Ecosystems & Species at Risk.* The Couchiching Conservancy, The Nature Conservancy of Canada, Orillia, Ontario, Canada, pp. 1–42.
- Winter, M., Johnson, D.H., Shaffer, J.A., Svedarsky, W.D., 2004. Nesting biology of three grassland passerines in the northern tallgrass prairie. *Wilson Bulletin* 116, 211–223.
- Winter, M., Johnson, H.D., Shaffer, J.A., Donovan, T.M., Svedarsky, W.D., 2006. Patch size and landscape effects on density and nesting success of grassland birds. *Journal of Wildlife Management* 70, 158–172.
- Wittenberger, J.F., 1982. Factors affecting how male and female Bobolinks apportion parental investments. *Condor* 84, 22–39.
- Wittenberger, J.F., 1980. Vegetation structure, food supply, and polygyny in Bobolinks (*Dolichonyx oryzivorus*). *Ecology* 61, 140–150.
- Wittenberger, J.F., 1978. Breeding biology of an isolated Bobolink population in Oregon. *Condor* 80, 355–371.
- Zalik, N.J., Strong, A.M., 2008. Effects of hay-cropping on invertebrate biomass and the breeding ecology of Savannah sparrows (*Passerculus sandwichensis*). *The Auk* 125, 700–710.