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Original Research

Impacts of Rotational Grazing and Hay Management on the Reproductive Success of Bobolink (*Dolichonyx oryzivorus*) in Eastern Ontario, Canada

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Abstract

We investigated the impact of beef cattle (*Bos taurus*) farm management, including rotationally grazed pastures and managed hayfields, on the reproductive success of bobolink (*Dolichonyx oryzivorus*) in eastern Ontario, Canada. Bobolinks nesting in fields grazed by cattle or cut for hay before 1 July had significantly lower reproductive success than those nesting in untouched fields. Bobolinks did not recolonize or re-nest in paddocks that were grazed early (before 2 June) and followed by a rest period. Bobolink abundance and productivity (based on an index), were lower in managed fields and pastures than in untouched fields and hayfields. As the number of paddocks grazed by a single herd during the nesting season increased, the proportion of paddocks containing bobolinks that reproduced successfully, decreased. We used a clay pigeon target experiment to support our hypothesis that nest loss in paddocks was due to trampling and not predation. With the exception of 1 trial with a low cattle stocking rate, cattle exposure to clay pigeon targets resulted in disturbance of >90% of targets. As with other studies from eastern North America, we conclude that the best method for improving the reproductive success of bobolinks on beef cattle farms is to provide some untouched hayfields and pasture paddocks until nesting is complete. In our study area, bobolinks reproduced successfully on most farm operations that were managed for beef cattle, without incentive programs.

Key Words: Bobolink, Beef Cattle, Eastern Ontario, Farm Management, Reproductive Success.

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INTRODUCTION

Grasslands are among the most endangered and human-altered ecosystems worldwide (Samson and Knopf 1994; Vickery *et al.* 1999). Over the past half-century, grassland bird populations have declined significantly, largely due to habitat loss and degradation (Martin and Gavin 1995; Sauer *et al.* 2014). Historically, as grasslands disappeared, human-modified agricultural land (hayfields and pastures) provided surrogate habitat for grassland birds (Bollinger *et al.*1990; Martin and Gavin 1995; Vickery *et al.* 1999). In the last quarter century, the availability of surrogate habitat for grassland birds in eastern North America has also declined due to changes in farm management. Farm abandonment has increased with subsequent afforestation (Askins 1993), agricultural practices have shifted to earlier and more frequent hay cuts (Bollinger and Gavin 1992; Tews *et al.* 2013), hayfields and pastures have been converted to row crops (e.g., corn, wheat, soybean) (McCracken *et al.* 2013), and pesticide use has increased (Freemark and Kirk 2001). Bobolink (*Dolichonyx oryzivorus*), a grassland obligate bird, breeds in pasture and hayfields and disturbances by agricultural practices (grazing cattle [*Bos taurus*] and hay cutting) often overlap with the nesting period, resulting in direct and indirect nest failure (Martin and Gavin 1995; Nocera *et al.* 2005; Perlut *et al.* 2006; Perlut and Strong 2011). Bobolink is listed as threatened federally in Canada (COSEWIC 2010) and provincially in Ontario (COSSARO 2010). Using Breeding Bird Survey data from 1998-2007, the Canadian bobolink population was estimated to be approximately 1.1 million breeding pairs, with 45% of the population in Ontario (approximately 900,000 pairs) (COSEWIC 2010).

Although many studies have investigated the effects of farm management on grassland birds (e.g., Bollinger *et al.* 1990; Temple *et al.* 1999; Norment *et al.* 2010; Perlut and Strong 2011), few researchers have investigated the breeding biology of grassland bird species in hayfields and pastures in eastern Canada. Regional climatic variations and underlying geomorphology influence primary productivity and, in turn, the use and intensity of agricultural lands for grazing and hay production; these variations result in different grazing pressures (e.g., stocking rates) and possibly different rates of nest destruction (Smart *et al.* 2010; Bleho *et al.* 2014). Therefore, impacts of farm management practices on breeding grassland birds may differ among geographical areas. For example, Perlut *et al.* (2011) concluded that, in Vermont, USA, an early first hay harvest was an alternative hay management strategy that could benefit grassland bird reproduction. The rationale was that this early harvest (before 2 June) followed by a minimum 65-day rest period would disrupt breeding grassland birds early but then allow sufficient time for them to recolonize and re-nest successfully after this date (Perlut *et al.* 2011). Although this strategy improved grassland bird reproductive rates in Vermont, the same strategy was unsuccessful in Ontario, Canada where no bobolinks re-nested on early cut fields (before 1 June) during the 65-day interim, indicating that alternative management plans cannot be applied on a broad scale (Diemer and Nocera 2016).

Pasture management and its effects on bobolinks have not been well studied in Ontario and managers of legislated species at risk in Ontario require local information with which to inform local policy decisions (e.g., guidelines for timing of hay harvest). The majority of breeding habitat for bobolinks in Ontario occurs in pastures and hayfields (McCracken *et al.* 2013). In 2011, the total area of hay and pasture in Ontario was 1,501,982 ha and accounted for 29% of all farmland in the province. Of this total, there was approximately 841,000 ha of hay and 661,000 ha of pasture (Statistics Canada 2011 cited in McCracken *et al.* 2013). In addition, Ontario’s beef industry requires large acreage of hay and pasture and play an important role in bobolink populations in Ontario (McCracken *et al.* 2013). In Ontario, grazing management systems range from continuous grazing to intensive rotational grazing. Continuous grazing is a practice where cattle graze one area over a long period of time while rotational grazing consists of a pasture area divided into multiple paddocks (MacPhail and Kyle 2012). With rotational grazing, cattle are rotated through the paddocks, grazing 1 paddock at a time thereby allowing the remainder of the pasture to “rest” and regrow (Undersander *et al.* 1991; Teague and Dowhower 2003). When ground nests are exposed to grazing cattle, trampling causes nest failure and losses increase exponentially with the length of time cattle spend in each paddock (Paine *et al.* 1996), although the rate of nest failure may be low when cattle stocking densities are low (Bleho *et al.* 2014). We studied nest phenology, reproductive success, and densities of bobolink on paddocks and associated hayfields while simultaneously monitoring farm management. The purpose of this study was to evaluate the impact of farm management on bobolink in eastern Ontario, and to provide alternative management strategies that can benefit bobolinks.

STUDY AREA AND METHODS

Research was conducted on 4 privately owned beef cattle farms (centered on 45° 63'N, 76° 88'W) located in Renfrew County, Ontario. We studied bobolinks from the end of April through July in 2012 and 2013. Bobolinks were present at the

Table 1. Number and mean size of fields (pasture paddocks and hayfields) monitored each year on 4 privately owned beef-cattle farms in Renfrew Country, Ontario, Canada in 2012 and 2013.

Field type	Year	Number of fields monitored	Mean field/paddock size ha – size ± SD (ac – size ± SD)	Range ha (ac)
Pasture paddock	2012	62	3.88 ± 2.10	0.56 – 9.43
			(9.6 ± 5.2)	(1.4 – 23.3)
	2013	61	3.93 ± 1.98	0.57 – 9.31
			(9.7 ± 4.9)	(1.4 – 23.0)
Hayfield	2012	27	6.76 ± 3.68	1.29 – 14.16
			(16.7 ± 9.1)	(3.2 – 35.0)
	2013	31	6.39 ± 3.72	1.21– 14.16
			(15.8 ± 9.2)	(3.0 – 35.0)

beginning of our study on all farms in both years. Each beef cattle farm contained both pasture paddocks and hayfields, and farms were managed without researcher interference. In 2012, eastern Ontario experienced extreme heat and low rainfall amounts (125-175 mm from 9 May to 6 August) causing drought-like conditions, whereas in 2013, the study area experienced normal rainfall amounts (275-300 mm from 8 May to 5 August) (Agriculture and Agri-Food Canada's National Agroclimate Information Service 2012, 2013).

We monitored approximately 440 ha of pasture and hayfield on 4 farm operations (mean operation size = 110 ha). At each farm, rotational grazing was practiced on pasture divided into paddocks. Additionally, each farm contained hayfields that were managed to provide food for the beef cattle. Twenty-seven and 31 hayfields were monitored in 2012 and 2013, respectively, with 25 of the same hayfields monitored in both years. Sixty-two and 61 pasture paddocks were monitored in 2012 and 2013, respectively, and 56 of the same paddocks were monitored both years (Table 1). Hayfields were, on average, larger than paddocks (Table 1). Twenty-five beef-cattle herds were rotationally grazed and monitored over 2 years (2012 n = 12 herds; 2013 n = 13 herds). Each herd was rotated among 2–9 paddocks throughout the grazing season. With the assistance of the farmers, beef cattle herd sizes, dates cattle entered and exited paddocks, and hay cut dates were recorded. Stocking rates for each grazed paddock were calculated using the number of cattle grazing a pasture paddock for a period of time, expressed as animal units (AU) by days (grazing period) per pasture paddock size (ha) (AU x days x ha^{-1}). An animal unit is typically a 453.6 kg (1,000 pounds) cow, with or without a calf (Manitoba Forage & Grassland Association 2009). Since we were interested in the impact of grazing cattle on grassland birds and not the amount of forage required for cattle, we assumed that each cow or heifer was 1 AU (although weight could range between 385 – 475 kg). The mean stocking rate for 2012 was 248.62 ± 4.81 SE AU x days x ha^{-1} (range: 41.53 – 1456.12 AU x days x ha^{-1}) and in 2013 the mean stocking rate was 206.74 ± 3.19 SE AU x days x ha^{-1} (range: 17.07 – 1050.01 AU x days x ha^{-1}). Paddocks and hayfields that were grazed or cut on or before 1 July were classified as 'managed' and paddocks and hayfields that remained uncut or ungrazed until after 1 July were classified as 'untouched'. We used 1 July as our reference date because the management recommendation to promote grassland bird reproductive success in Ontario is to delay hay cutting until at least 1 July to allow most fledglings to sustain flight and escape safely (Frei 2009). However, 15 July was identified as the optimal date to delay hay cutting to allow bobolinks to fledge (Frei 2009).

Data collection

Monitoring Nests – We watched for behaviour that indicated nesting while walking through the fields, during point counts, and during vegetation surveys. Nest searching occurred in fields where territorial male bobolinks were present. We located nests by monitoring bobolink breeding behaviour from the edges of fields to help us decrease the area required to search for the nest and to decrease disturbance to nesting bobolinks. Once located, nests were monitored every 2-4 d until nest outcome could be determined. Nest fates were determined by examining nests for signs of success or failure. If nests were exposed to grazing cattle or machinery for hay cutting, the nest location was revisited after exposure to determine the fate. Nests were categorized as failure due to predation if signs including partially consumed young, broken eggs, or disturbed nest cups were observed. We assumed young had left the nest (hereafter 'fledged') if signs of predation and farm practices were absent and if nestlings were close to fledgling in the previous visit. When the date of at least one nesting stage was known for a nest (e.g., egg laying, hatching, or fledging), we calculated nest initiation dates and dates young fledged. For these calculations, we assumed that one egg was laid per day, that incubation began with the penultimate egg and the incubation period was 12 d, and young fledged after 10 d (Martin 1974; Martin and Gavin 1995).

Bobolink reproductive activity indices and densities

We conducted single-observer, 5 min, 100-m radius point counts from the centre of each paddock or hayfield between sunrise and 10h00, weather permitting (no precipitation and wind speed <20 km/h), from the end of April to 15 July in 2012 and 2013. These counts augmented the results from our nest searching because we did not find all nests in all paddocks or hayfields. These point count surveys provided both a measure of relative abundance of bobolinks (i.e., number of individuals per point count station) and an index of reproductive activity, using the field (either paddock or hayfield) as the experimental unit. A minimum of 8 point counts (mean = 13 counts) were conducted in each paddock and hayfield each year. We divided the point counts into 2 categories within each paddock or hayfield: those conducted before management (i.e., before cattle entered or before hay was cut) and those conducted after. Individuals were monitored visually for the duration of the point count to limit double counting and adult reproductive behaviour was recorded. Based on behavioural observations, a seasonal reproductive index for bobolink was assigned to each paddock and hayfield (Vickery *et al.* 1992; Tucker *et al.* 2006; Althoff *et al.* 2009). Following Vickery *et al.* (1992), we attributed a reproductive index score of 0 when males were not present for >3 wks; 1 for the presence of a territorial male for >3 wks; 2 for male and female presence only (>3 wks); 3 when a confirmed pair was present and observed with nesting material; 4 for adults seen carrying food to presumed nestlings; and 5 when a known nest was successful or we observed fledglings in areas of known nest locations (Vickery *et al.* 1992).

Clay Pigeon Target Experiment – Clay pigeon targets were used as simulated nests to investigate the trampling impact of different stocking rates (AU x days x ha-1) on bobolink nests. Each target was painted dark green to minimize detectability by cattle, thus preventing targets from being intentionally avoided or trampled (Pavel 2004). Targets were also hidden from direct view due to the height of the vegetation. Targets were placed on the ground in 5 or 6 parallel lines within a paddock approximately 30 m apart at a density of 50 targets per 4.05 ha (10 ac). We placed targets in 5 paddocks prior to exposure to grazing cattle and in 2 controls (ungrazed paddocks). At each target location, Global Positioning System (GPS) coordinates were recorded and a metal tent peg was placed in the ground to later help relocate targets with a metal detector, to determine if targets were disturbed from the location by grazing cattle. Within 12 h of when cattle were rotated out of the paddock, each target was relocated and classified as intact (no damage and in same location) or disturbed (flipped over, moved, or broken). Targets that were disturbed in paddocks with cattle were assumed to represent the potential damage done to nests by grazing cattle.

Vegetation Surveys – Vegetation surveys were conducted in mid-May each year during male bobolink territory establishment. Within each 100 m-radius point count circle, a 50 x 50 cm Daubenmire frame (Daubenmire 1959) was placed at random in 4 sampling locations per site. Within each Daubenmire frame, percent cover of grass, forbs, alfalfa (*Medicago sativa*), dung, litter, and bare ground were estimated. We also estimated percent cover of live and dead vegetation in each frame. Vegetation height and litter depth (height of dead vegetation) were measured at the 4 corners of the frame and values were averaged for each paddock or hayfield. Within each frame, an additional index of visual obstruction that incorporated both vegetation height and density was obtained. We stood 4 m from a Robel pole (Robel *et al.* 1970) placed in the centre of the frame, observed from an eye-level of 1 m above the ground, and recorded the lowest visible section on the pole. We recorded this index from each cardinal direction. All 16 measurements (from 4 directions from each of 4 sampling locations in each paddock or hayfield) were averaged.

Statistical analysis

All statistical analyses were conducted using program R v. 2.15.1 and v. 3.2.2 (R Core Team 2015). We used the logistic-exposure method (Shaffer 2004) to model the effect of predictor variables on nest outcome. Predictor variables included year, field type (pasture or hayfield), date, and whether the field was managed (grazed or cut) during the nesting period.

Poisson generalized linear models (GLM) were developed to compare the reproductive activity indices (counts of 0-5) of bobolinks in managed and untouched hayfields and pastures. We used year, field type (hayfield or pasture), and field management as potential explanatory variables. We also used negative binomial GLMs to compare bobolink abundance in managed and untouched hayfields and pastures. We used Bayesian Information Criterion (BIC) to select top models for both reproductive activity index and point count abundance, as BIC will penalize the complexity of the model more heavily than Akaike's Information Criterion (AIC) and thus help to understand the primary factors affecting bobolink nest outcome, reproductive index, and abundance (Posada and Buckley 2004).

The impact that grazing cattle herds had on bobolink reproductive success was also assessed at the landscape (farm) level by comparing the proportion of paddocks on the farm that were grazed to the proportion of paddocks on the farm producing at least 1 bobolink young. We separated herds into 3 different categories based on the proportion of pasture paddocks grazed prior to 1 July and to make sample sizes of farms approximately equal. The lowest category contained herds that grazed 30-65% of the paddocks available on the farm (3-9 paddocks available per farm), the second category contained herds that grazed 80-90% of the paddocks available on the farm (3-7 paddocks), and the last category contained herds that grazed all paddocks on the farm (2-8 paddocks). No herds grazed <30% of the paddocks or fell between the ranges of the above categories. A Kruskal-Wallis non-parametric rank sum test was used to determine if there was a difference in bobolink reproductive success (proportion of paddocks that produced at least 1 young) among the 3 different categories of grazing intensity. To analyze results of the clay target experiment, we compared the number of targets damaged versus intact in exposed and control fields using a chi-square test.

We analyzed the effects of field type and year on vegetation characteristics using two-way analysis of variance (ANOVA). As there was only 1 significant interaction term (interaction between year and field type for the dependent variable, alfalfa cover: $F_{1,171} = 4.73$, $P = 0.03$), the significance of the remainder of the interaction terms is not provided.

RESULTS

Nest success

We found a total of 33 nests in pasture paddocks and 42 nests in hayfields. Most monitored nests (84%) were found in paddocks or hayfields that were not exposed to hay cutting or grazing cattle during nesting. Of the 75 nests, 43 (57.3%) were successful (producing ≥1 fledgling), 30 (40%) failed, and 2 (2.7%) nest outcomes were unknown. Predation accounted for 60% of nest failures (18 nests). Farming activity accounted for 12 (40%) known failures: 8 nests (27% of nest failures) were trampled by cattle, and 4 were mowed during hay cutting (13% of nest failures). Across all 75 monitored nests, 2.8 fledglings per nest were raised (± 0.03 SE, range: 0 to 7). Average nest productivity was 2.1 ± 0.08 SE and 3.3 ± 0.06 SE fledglings per nest in pasture paddocks and hayfields respectively. Across all sites and years, the mean nest initiation date (including possible re-nests) was 28 May (± 7.9 SD, range 19 May – 23 June) and the mean date that young fledged was 23 June (± 7.5 SD, range 15 June – 17 July). Of successful nests, 90.5% contained young that fledged by 26 June, 92.9% by 8 July, and 100% on 13 July (Figure 1).

Nest exposure models

The best-supported models (ΔBIC of < 2.0) for explaining variation in nest success included management and year (Table 2). In both study years, bobolinks nesting in managed fields (grazed or cut by 1 July), experienced much lower daily survival rates (DSR) than those nesting in fields left untouched until after 1 July (2012: DSR (95% CI) untouched fields: 0.995 (0.987-0.998), managed fields: 0.950 (0.770-0.991); 2013: untouched fields: 0.984 (0.916 - 0.997), managed fields: 0.864 (0.318-0.989)). Field type (hay or pasture) was not included in the best-supported models (Table 2).

Field Management

Bobolink abundance during territory establishment was significantly higher in hayfields than in pastures and was higher in 2012 than in 2013 (Table 3). The mean reproductive activity index achieved in untouched fields was 4.0 ± 0.4 SD and 4.3 ± 0.3 SD in 2012 and 2013, respectively, indices that indicate evidence of nestlings on the field. Reproductive activity indices for managed fields were 1.4 ± 0.2 SD in 2012 and 1.6 ± 0.3 SD in 2013, indices that indicate evidence that at least one pair was present for >3 wks. Bobolink reproductive activity index was negatively associated with managed fields and pasture (Table 4).

The top model (weight = 0.82) for explaining abundance across the 93 fields included the variables year, field type, date, and whether or not the field was managed (Table 4).

Table 2. Parameter estimates and weight of Bayesian Information Criterion (BIC) model selection of logistic exposure models (top models: ΔBIC< 2) describing bobolink nest success on 4 beef cattle farms in Renfrew County, Ontario, Canada, 2012-2013. The top model BIC = 169.9.

Model	*df*	LogLik	ΔBIC	Weight
5.25 – 2.31(managed) – 1.10(year)	3	-76.64	0	0.50
4.428 – 1.83(managed)	2	-79.85	0.99	0.30
5.52 – 0.56(field) – 2.14(managed) – 1.19(year)	4	-75.73	3.62	0.08
6.42 – 0.02(date) – 2.23(managed) – 1.18(year)	4	-76.22	4.61	0.05
4.56 – 0.31(field) – 1.74(managed)	3	-79.54	5.8	0.03

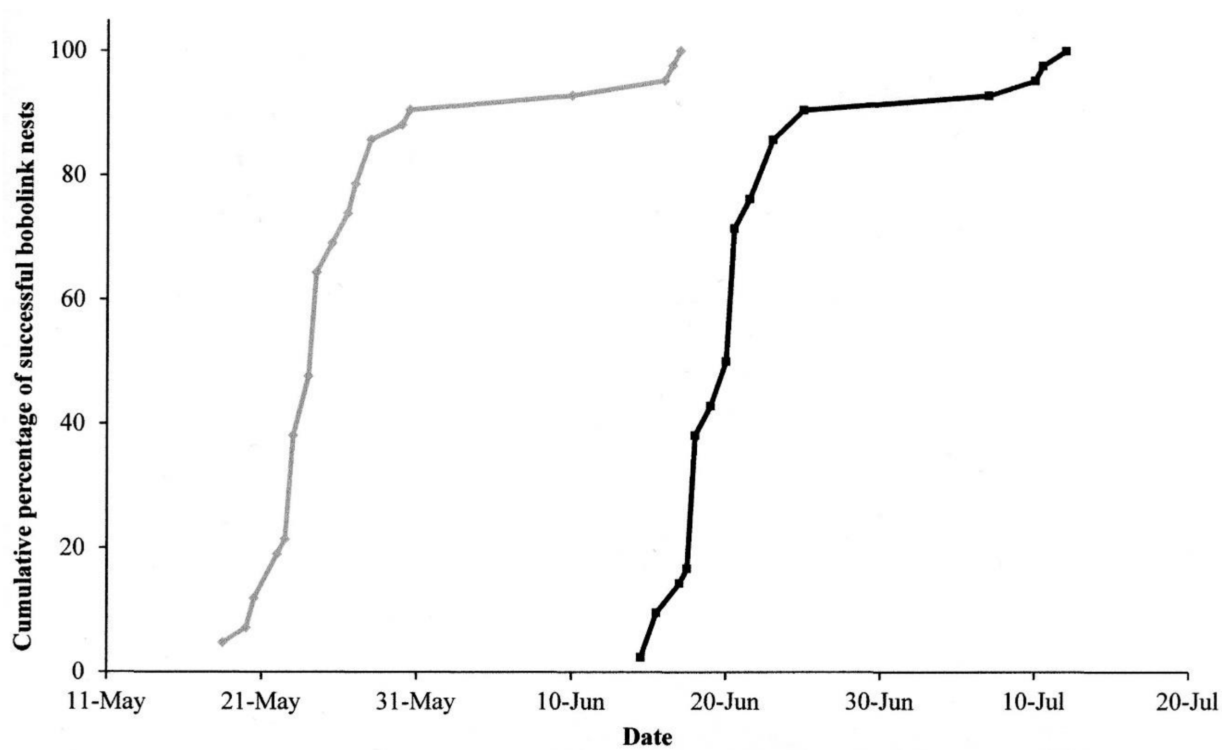

Figure 1. Cumulative percentages of nest initiation dates (grey) and the fledgling date (black) for nests monitored on four privately owned beef cattle farms in Renfrew County in 2012 and 2013.

Table 3. Vegetation characteristics (mean ± SE) during bobolink territory establishment for hayfields and pasture sites in Renfrew County in 2012 and 2013. Bolded values indicate significant difference (*P*< 0.05) between years and/or field types.

Characteristic	Hayfields 2012	Hayfields 2013	Paddocks 2012	Paddocks 2013	Year ($F_{1,171}$)	Field Type ($F_{1,171}$)
Grass cover (%)	31.68 ± 1.22	31.12 ± 0.59	45.37 ± 0.29	41.35 ± 0.29	0.21	**< 0.001**
Forb cover (%)	27.31 ± 1.05	25.85 ± 0.51	33.85 ± 0.29	26.44 ± 0.24	0.17	**0.02**
Alfalfa cover (%)	18.41 ± 0.71	8.95 ± 0.49	2.81 ± 0.14	1.02 ± 0.05	**0.02**	**< 0.001***
Dung cover (%)	0.29 ± 0.01	0.36 ± 0.04	1.39 ± 0.07	1.46 ± 0.05	0.92	**0.03**
Bare ground cover (%)	9.38 ± 0.36	11.19 ± 0.24	5.66 ± 0.13	9.25 ± 0.20	**0.03**	0.08
Litter cover (%)	12.93 ± 0.50	22.54 ± 0.45	11.21 ± 0.17	20.13 ± 0.23	**< 0.001**	0.29
Live vegetation cover (%)	96.83 ± 3.72	65.78 ± 0.44	94.73 ± 0.12	69.56 ± 0.25	**< 0.001**	0.62
Dead vegetation cover (%)	3.22 ± 0.12	34.22 ± 0.44	4.98 ± 0.11	30.17 ± 0.25	**< 0.001**	0.50
Vegetation height and density (cm)	22.48 ± 0.86	13.20 ± 0.20	16.65 ± 0.19	10.99 ± 0.10	**< 0.001**	**0.008**
Height (cm)	38.25 ± 1.47	24.95 ± 0.23	31.6 ± 0.24	21.51 ± 0.15	**< 0.001**	**0.007**
Litter depth (cm)	1.14 ± 0.04	1.80 ± 0.05	1.34 ± 0.02	1.70 ± 0.02	**0.009**	0.80
Bobolink abundance per point count**	6.77 ± 0.20	4.16 ± 0.11	2.27 ± 0.06	1.17 ± 0.04	**0.004**	**< 0.001**

*Significant interaction effect. ** Both sexes, $F_{1,154}$.

There were fewer bobolinks in 2013, in pastures, and in managed fields. As the season progressed there were significantly more bobolinks, possibly reflecting the presence of non-resident transients disturbed from adjacent farms.

Hay management

Mean hay cut dates for fields cut before 15 July was 25 June ± 2.0 days SE in 2012 and 2 July ± 2.4 days SE in 2013. Thirty-one (53.4%) hayfields produced ≥1 bobolink young.

Pasture management

In both survey years, 17 paddocks were grazed prior to 2 June and left to rest until after 1 July. Bobolinks did not recolonize or re-nest on the early grazed paddocks and thus did not reproduce successfully in these paddocks.

More paddocks produced at least 1 bobolink young when the proportion of paddocks grazed by a single herd was low (Figure 2, 2012: χ^2 = 6.55, df = 2, *P* = 0.038; 2013: χ^2 = 6.76, df = 2, *P* = 0.034). In 2012, only farms where the proportion of paddocks grazed was between 30-65% raised any bobolink young. In 2013, 2 farms with 100% of the paddocks grazed before 1 July produced bobolink because some bobolink young were capable of flight prior to cattle entering those paddocks (Figure 2).

Clay pigeon target experiment

During 2 control trials in paddocks not exposed to cattle, 128 targets were deployed for 8 d. All targets were relocated: 123 (96.1%) targets were intact and 5 (3.9%) were disturbed. We suspect these 5 targets were disturbed by groundhogs (*Marmota monax*), as groundhogs and burrows were observed in both paddocks. During 5 experimental trials in pasture paddocks exposed to grazing cattle (stocking rate ranging from 9.98 to 171.31 AU x days x ha-1), 264 targets were deployed for 7-18 days. Of these targets, 251 targets were relocated: 46 (18.3%) were intact, and 205 (81.7%) were disturbed and the disturbed targets were distributed throughout the grazed paddocks. Targets exposed to grazing cattle were significantly more likely to be disturbed than targets in control sites (χ^2 = 208.27, df = 1, *P*<0.001) (Figure 3).

Bobolink and vegetation surveys

Alfalfa cover was significantly greater in hayfields than in paddocks and significantly greater in 2012 than in 2013. Vegetation height and vegetation height/density measurements were significantly higher in hayfields than in paddocks, and higher in 2012 than 2013. In 2012, live vegetation cover was significantly higher than in 2013. Bare

Table 4. Parameter estimates and weight of Bayesian Information Criterion (BIC) model selection of logistic exposure models (top models: ΔBIC< 2) describing bobolink reproductive activity index and abundance on 4 beef cattle farms in Renfrew County, Ontario, Canada, 2012-2013. The top model for reproductive activity index and abundance BIC = 719.4 and 4479.0 respectively.

Response variable	Model	df	LogLik	ΔBIC	Weight
Reproductive activity index	$1.48 - 0.43(\text{managed}) - 0.16(\text{field}_{\text{pasture}}) - 0.63(\text{managed} * \text{field}_{\text{pasture}})$	4	-349.31	0.00	0.61
	$1.54 - 0.43(\text{managed}) - 0.16(\text{field}_{\text{pasture}})$	3	-352.66	1.50	0.29
	$-219.4 - 0.43(\text{managed}) - 0.16(\text{field}_{\text{pasture}}) - 0.63(\text{managed} * \text{field}_{\text{pasture}}) + 0.11(\text{year}_{2013})$	5	-348.73	4.03	0.08
Point count abundance	$1051 - 0.52(\text{year}_{2013}) - 0.64(\text{field}_{\text{pasture}}) + 0.01(\text{date}) - 1.60(\text{managed})$	6	-2218.54	0.00	0.82
	$1033 - 0.51(\text{year}_{2013}) - 0.64(\text{field}_{\text{pasture}}) - 1.60(\text{managed})$	5	-2223.54	3.0	0.18

Reproductive activity index: P managed < 0.01, P managed * field < 0.01

Point count abundance: P year < 0.0001, P field < 0.0001, P date < 0.002, P managed < 0.0001

ground and litter cover were significantly lower in 2012 than 2013. Grass and forb cover was significantly greater in paddocks than hayfields (Table 3).

DISCUSSION

In eastern Ontario, farm management was the strongest factor influencing the reproductive outcome for bobolink, though on most farms in this region, many paddocks and hayfields did allow for bobolinks to reproduce successfully. The productivity of bobolink at a regional scale was quite good with an average of >2 young raised across the 75 nests that we monitored. In many hayfields associated with the beef cattle operations, the timing of hay cutting was late enough to ensure bobolink production.

By contrast, when individual fields were grazed by cattle or cut for hay, bobolink reproductive success and abundance was reduced substantially. Nests that were exposed to farm management failed and bobolinks vacated fields that were exposed to grazing cattle or machinery for haying. In Vermont, hayfields cut prior to 2 June then rested, experienced increased reproductive success by allowing birds to re-nest (Perlut *et al.* 2011). However, when applied in Ontario (cut before 1 June), this method did not result in successful re-nesting (Diemer and Nocera 2016). Similarly, bobolink did not recolonize and re-nest in paddocks that were grazed early then rested in our study.

At the landscape level, when a herd was rotated among a series of paddocks on a farm, the negative impact of cattle herds on bobolink reproductive success increased as a function of the number of paddocks grazed. Successful reproduction was primarily documented in paddocks where

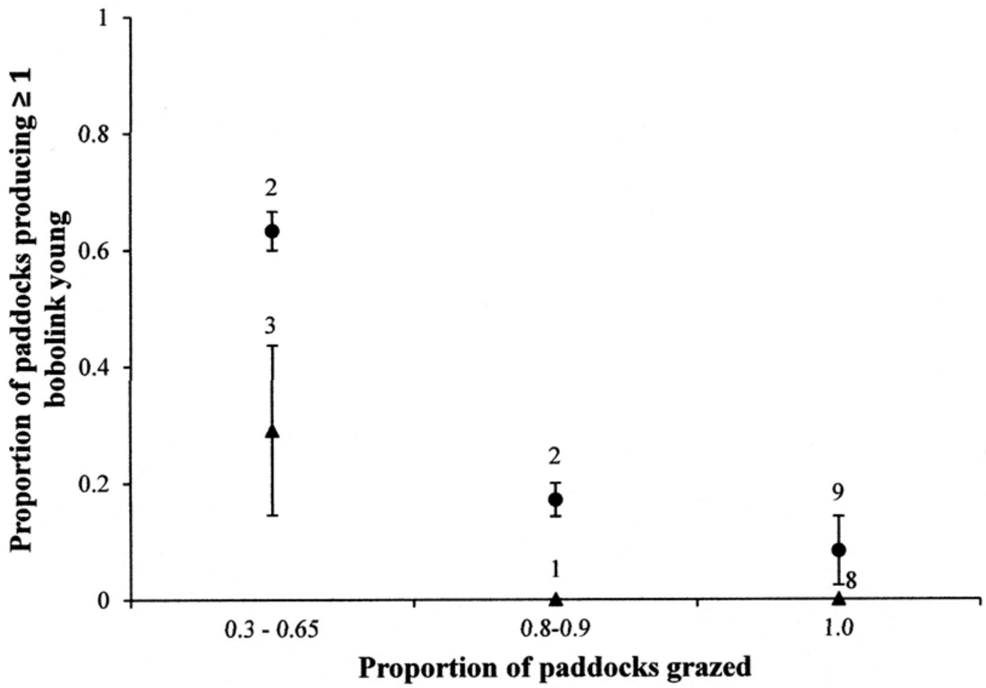

Figure 2. The mean proportion of paddocks producing at least 1 bobolink young for each category of proportion of paddocks grazed by each herd (2-9 paddocks) before 1 July for 2012 (n =12, triangles) and 2013 (n =13, circles). The number of herds within each category is located above error bars.

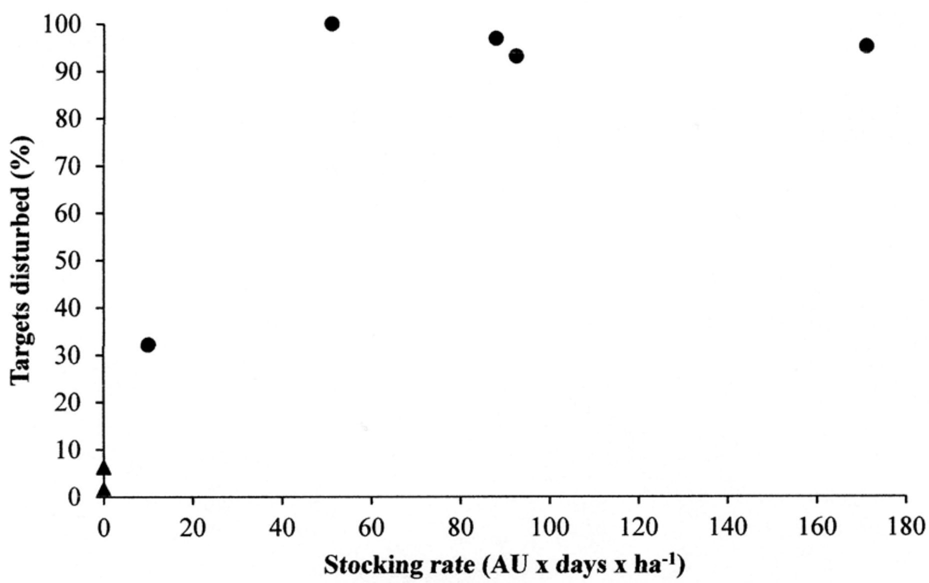

Figure 3. Percent of clay pigeon targets disturbed during 5 trials exposed to varying stocking rates (AU x days x ha^{-1}) (circles, n =5) and 2 control trials with no exposure to cattle (triangles, n =2).

cattle had not entered before young fledged; we had almost complete nest failure in the presence of cattle. In comparison, Bleho *et al.* (2014) found rates of nest destruction by cattle were generally low in Canada, however, most of the data included in that study came from western Canada where stocking rates are typically lower. Studies conducted in the eastern United States, relatively close by and in ecologically similar landscapes, found 57% and 65% of bobolink nests failed due to disturbance by cattle (Perlut and Strong 2011 in Champlain Valley, Vermont, and Temple *et al.* 1999 in Wisconsin, respectively).

Although the herd sizes varied in the clay pigeon target experiment, herds with stocking rates of 51.22 AU x days x ha^{-1} and greater, trampled most simulated nests. Decreasing stocking rate will only be beneficial to nesting grassland birds when the herd is already very small and these low rates were operationally rare in our study area. Even so, some targets were disturbed at lower stocking rates. While experiments with clay pigeon targets can be criticized because cattle are curious animals that might be attracted to novel objects and subsequently trample them (Pavel 2004), our clay pigeons were well camouflaged as they were painted green and hidden by tall grass. Additionally, even in fields with the highest stocking densities, some clay pigeons were left undisturbed. The fields in this study were on average 4.2 ha (± 2.3 SD) and generally within a few days after the entry of cattle, nearly all the vegetative cover in the field had been trampled and at least partially grazed. Thus, our clay pigeon experiment provides additional support that trampling is a major cause of nest loss in eastern Ontario beef management operations.

The mean date that bobolink fledged was 23 June (± 7.5 SD) over both years of the study. This date was similar to dates of fledging from another study conducted in Ontario and Quebec (mean fledgling 24 June, Frei 2009) and from upstate New York (mean fledging 22 June, Norment *et al.* 2010). Bobolink require approximately 7 d post-fledging to be able to sustain flight, suggesting the mean date bobolinks were capable of flight was 30 June (Martin and Gavin 1995). Much of the success of bobolink in our region occurred because of the paddocks and hayfields that were untouched until after 30 June.

Many rotationally grazed paddocks were not effective in promoting bobolink conservation as only 22% and 12% were ungrazed prior to 1 July in 2012 and 2013, respectively. However, all farm operations that we studied raised bobolink on their associated hayfields. This is because approximately 52% and 84% of hayfields monitored in 2012 and 2013, respectively, were left untouched until after 1 July without farmers considering grassland bird conservation or receiving financial incentives. These later hay cutting and grazing dates are primarily due to farms having large hayfields and pasture acreage and farmers simply could not graze or cut all paddocks and hayfields before 1 July under current management plans. Additionally, in 2013, more hayfields were cut after 1 July than in 2012, due to rainy conditions in late June which are unsuitable conditions to cut hay.

Beef cattle have lower crude protein requirements than dairy cattle (10% for beef cattle, 14% for dairy cattle, National Research Council 1996), which could lead to fewer negative financial effects on beef cattle farmers when hay cutting is delayed. In southern Ontario, crude protein levels are approximately 14% in the first week of June and fall below 10% around 28 June (Diemer and Nocera 2016). Therefore, Ontario hay used to feed beef cattle can be cut later in the season than hay used to feed dairy cattle. Similar farm management occurs in Vermont and New York's Champlain Valley; farms in the Champlain Valley that are managed for dairy cows begin hay cutting before 11 June while those managed for beef cattle begin cutting hay between 21 June and 10 July (Perlut *et al.* 2011). Thus, in general, beef cattle farms are more likely to contain hayfields with successfully breeding bobolinks than dairy cattle farms.

Hayfields contained significantly higher densities of bobolink than paddocks and hayfields had higher and denser vegetation than in paddocks, which appeared to attract more bobolinks at territory settlement. Similar preference was reported in Nova Scotia, where vegetation that was higher and denser was positively associated with increased occupancy rates and abundance of bobolinks (Nocera *et al.* 2007). While delaying hay cutting will provide an even larger conservation gain than delaying grazing in a paddock, leaving a hayfield uncut may be a financial burden on beef farmers. Delaying hay cutting either intentionally, or, as we observed in most hayfields, as part of normal farm operations, can reduce the quality of hay for beef farmers (Diemer and Nocera 2016). Delaying until 8 July resulted in only slight improvements to bobolink fledgling success. While Ontario has more recently put in place an exemption to the provincial *Endangered Species Act 2007* so that farmers can continue their agricultural operations (Government of Ontario 2015), farmers in our study in eastern Ontario were successful net exporters of bobolink without purposefully altering their management practices for bobolink.

MANAGEMENT IMPLICATIONS

Early grazed paddocks followed by a rest period do not serve as an alternative pasture management strategy in eastern Ontario. Paddocks left untouched during nesting can be reintroduced into the grazing management regime once nesting is complete. The more paddocks occupied by bobolinks, that remain ungrazed until 1 July (minimally), the greater the number of bobolinks produced on a farm. Hay cutting would also need to be delayed until 1 July (minimally) to ensure that bobolink nestlings fledge and gain the ability to sustain flight.

Hayfields that were uncut until 1 July were successful in producing bobolinks. Conservation efforts and financial incentives may be better suited for hayfields that are managed for bobolinks as they can provide a greater conservation gain. However, under current beef cattle farm practices in the study region, bobolinks are being produced successfully. Conservation efforts may be better suited to regions where hayfields are cut earlier and fail to produce bobolinks under current management.

Fields set aside as bobolink refuges to remain untouched until 1 July, will promote the conservation of this Ontario species at risk. Selecting fields to remain untouched early in the breeding season (mid-May) when bobolinks have set up territories is the best method to increase bobolink production. Determining guidelines for selecting fields can be difficult, particularly when there are conflicting findings about edge (Fletcher and Koford 2003; Bollinger and Gavin 2004) and size requirements (Renfrew and Ribic 2002; Helzer and Jelinski 1999); however, farm-specific recommendations would ensure that the most suitable bobolink refuge is selected. Associated farmer-education workshops that help farmers to quickly identify bobolinks in their fields would be necessary for farmers who are selecting fields to serve as bobolink refuges on their farms.

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