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Research Paper

Rotational grazing of beef cattle to support Bobolink breeding success

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ABSTRACT. Conservation actions for the federally and provincially threatened Bobolink (*Dolichonyx oryzivorus*) in Ontario, Canada are ongoing in agricultural landscapes, including pastures. However, conditions conducive to Bobolink fledging young from breeding territories in rotationally grazed beef cattle (*Bos taurus*) pastures are not well understood. We tested two management strategies designed to provide habitat where Bobolink could fledge young in rotationally grazed pastures. We conducted (1) a refuge paddock experiment using a crossover design, comparing fledging success when paddocks were ungrazed in one year to when they were grazed in another year; and (2) a light spring grazing experiment. Additionally, we explored associations between fledging of young from territories with cattle stocking rate and date that cattle first entered paddocks. We used spot mapping and nest monitoring to determine if young fledged in 83 Bobolink territories in 2016 and 72 territories in 2017 on six farms in the Ottawa Valley, Ontario. In the refuge paddock experiment, 54% (*N* = 28) of Bobolink territories fledged young in eight ungrazed paddocks compared to 16% (*N* = 25) when these paddocks were grazed in another breeding season. In the light spring grazing experiment, 67% (*N* = 12) of territories fledged young from four paddocks that were grazed with a low stocking rate between 21 May and 03 June 2017 and not again until after 02 July. Additionally, predictions from a logistic regression model indicated that the probability of young fledging from a territory (*N* = 118) decreased from 0.53 to 0.04 when mid-season stocking rates increased from 0 to 174 cattle-days/ha. Our results illustrate that paddocks on rotationally grazed beef cattle farms that are ungrazed until the Bobolink breeding season is finished or grazed lightly for a brief duration soon after territories are established can provide areas that enable Bobolink to fledge young.

Rotation des pâturages de b!ufs pour soutenir le succès de nidification du Goglu des prés

RÉSUMÉ. Des activités de conservation visant le Goglu des prés (*Dolichonyx oryzivorus*), espèce menacée au niveaux fédéral et provincial en Ontario, Canada, ont cours dans les paysages agricoles, y compris les pâturages. Toutefois, on ne comprend pas bien les conditions qui favorisent l'envol des jeunes goglus de territoires de nidification situés dans des pâturages de b!ufs (*Bos taurus*) sous rotation. Nous avons testé deux stratégies de gestion visant à fournir de l'habitat dans lequel les goglus pouvaient mener leurs jeunes à l'envol dans des pâturages sous rotation. Nous avons effectué (1) une expérience d'enclos-refuge au moyen d'un plan d'étude croisé, comparant le succès de jeunes à l'envol lorsque des enclos ne servaient pas de pâturage une année à celui lorsque les enclos servaient de pâturage une autre année; et (2) une expérience de pâturage printanier léger. De plus, nous avons exploré les relations entre l'envol de jeunes et la densité de bétail, et la date à laquelle le bétail entrait dans l'enclos. Nous avons déterminé l'envol des jeunes à partir de la cartographie d'observations et de la surveillance de nids, dans 83 territoires de goglus en 2016 et 72 territoires en 2017, sur six fermes dans la vallée de l'Outaouais, en Ontario. Dans l'expérience d'enclos-refuge, 54 % (N = 28) des territoires de goglus ont vu les jeunes prendre leur envol dans huit enclos non utilisés comme pâturage, comparativement à 16 % (N = 25) lorsque ces enclos servaient de pâturage lors d'une autre saison de nidification. Dans l'expérience de pâturage printanier léger, 67 % (N = 12) des territoires ont permis aux jeunes de prendre leur envol dans quatre enclos ayant servi de pâturage à du bétail en faible densité entre le 21 mai et le 3 juin 2017, puis seulement après le 2 juillet. Aussi, les prédictions d'un modèle de régression logistique ont indiqué que la probabilité d'envol de jeunes d'un territoire (N = 118) diminuait de 0,53 à 0,04 lorsque la densité du bétail en mi-saison augmentait de 0 à 174 animaux-jours/ha. Nos résultats montrent que les enclos de pâturage de b!ufs sous rotation qui ne sont pas utilisés jusqu'à ce que la saison de nidification des goglus soit terminée ou qui ne sont que faiblement utilisés pour une brève période suivant l'établissement des territoires de goglus, permettent de fournir des lieux où les goglus sont capables de mener leurs jeunes à l'envol.

Key Words: *Bobolink; Dolichonyx oryzivorus; grassland birds; nesting habitat; Ontario; pasture management; rotational grazing; stocking rate*

INTRODUCTION

Long-term population declines of songbirds (i.e., order Passeriformes) that breed in grasslands in North America have led to conservation concern for some of these species (Sauer et. al 2013). Bobolink (*Dolichonyx oryzivorus*) is a species of conservation concern across multiple jurisdictions because of a 2.0% average annual population decline from 1966 to 2015 across its breeding range in North America (Sauer et al. 2017). Although designated least concern by the International Union for Conservation of Nature because of the species' large global population and breeding range (BirdLife International 2016), Bobolink is listed as threatened by the Canadian federal and Ontario provincial governments (Government of Canada 2017, OMNRF 2017). Approximately 13% of the Bobolink population

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breeds in Ontario, which is the largest percentage for any province and is surpassed only by the states of North Dakota and Minnesota (Partners in Flight 2013). Bobolink conservation in Ontario includes a provincial government plan for recovery to counter the 2.6% average annual population decline, determined based on Ontario Breeding Bird Survey data from 1968 to 2008 (COSEWIC 2010, OMNRF 2015). The provincial government plan states that the current population cannot be maintained because of habitat loss on agricultural land and instead aims to maintain the population at 65% of its estimated size in 2015 (OMNRF 2015), which may be larger than the population prior to European settlement (COSEWIC 2010). Probable causes of the Bobolink population decline include habitat loss and a decrease in habitat quality on breeding grounds (COSEWIC 2010, McCracken et al. 2013, OMNRF 2015, Ethier and Nudds 2017). Habitat quality on breeding grounds can be poor because of agricultural practices (e.g., hay harvest and livestock grazing) that result in direct and indirect destruction of nests (Bollinger et al. 1990, Perlut et al. 2006, MacDonald and Nol 2017). Additional research is needed to identify land management practices that enable Bobolink to fledge young from nests on agricultural land, where most of the Ontario population nests, providing information that could be used to increase fecundity and help to address population declines (OMNRF 2015).

Several land uses and cover types provide nesting habitat for Bobolink in Ontario, including hay field, pasture, and other grasslands (McCracken et al. 2013). Although the proportion of the Bobolink population that breeds in the ~525,000 ha of various pasture types in Ontario (OMAFRA 2016*b*) is unknown, the ~6700 beef (*Bos taurus*) farms in the province (OMAFRA 2016*a*) comprise a substantial amount of pasture that may provide nesting habitat. Rotational grazing has been proposed as a best management practice to benefit agricultural production and the environment compared to continuous grazing (OMAFRA 2012). Rotational grazing involves moving cattle through ≥ 3 paddocks of subdivided pasture during the grazing season, whereas, in continuous grazing, cattle have unrestricted access to a pasture for the entire grazing season (OMAFRA 2012). Although benefits to breeding grassland birds have been suggested (McGauley 2004, OMAFRA 2012), empirical evidence of the effects of rotational grazing on Bobolink breeding success is limited. Bleho et al. (2014) found that the risk of nest destruction from cattle was similar between continuous and rotational grazing for songbirds, ducks, and shorebirds in Canada. However, rotational grazing may provide management opportunities that benefit breeding grassland birds because cattle grazing is spatially and temporally controlled across paddocks.

Previous research indicates that Bobolink can fledge young from nests in rotationally grazed pastures (Perlut et al. 2006, Kerns et al. 2010, MacDonald and Nol 2017). In Vermont, the number of young fledged per female Bobolink was higher in rotationally grazed pastures compared to hay fields cut early in the breeding season, but lower than in hay fields cut late in the season (Perlut et al. 2006). Information in the literature about the effects of rotational grazing on nesting Bobolink is scarce for eastern North America. The effects of grazing on grassland birds, including their nest success, can vary regionally based on local environmental conditions, although the effects of some factors may be consistent across regions (Koper and Nudds 2011, Perlut and Strong 2011).

One likely reason for Bobolink failing to fledge young under some grazing practices is the effect of cattle stocking rate (Guthery and Bingham 1996). Cattle can negatively affect nests by removing vegetation that provides cover for nests (potentially increasing predation) and by trampling (i.e., stepping or lying down on nests; Temple et al. 1999, Renfrew et al. 2005, Perlut and Strong 2011, MacDonald and Nol 2017). The proportion of nests affected by cattle is based on a combination of stocking density (i.e., the number of cattle per unit area) and the number of days a paddock is grazed (i.e., stocking rate, calculated as: number of cattle × days grazed/area grazed; Jensen et al. 1990, Paine et al. 1996, Bleho et al. 2014, MacDonald and Nol 2017). In North Dakota, Kerns et al. (2010) found that rotational grazing by cattle was not associated with Bobolink nest survival; 1 of 91 nests was trampled under typical stocking rates for the region. In contrast, a study in eastern Ontario attributed 27% of known nest failures to trampling by rotationally grazed cattle (75 nests monitored, 30 failed; MacDonald and Nol 2017). A meta-analysis of 18 studies in Canada found that 1.5% of songbird, duck, and shorebird nests ($N = 9132$) in pastures were destroyed by cattle (Bleho et al. 2014). However, Bleho et al. (2014) included only one study from eastern Canada and found that nests were more frequently destroyed by cattle there (33% of 21 nests) compared to elsewhere in Canada, possibly because the region has high primary productivity, enabling high stocking rates. In addition to stocking rate across the breeding season, the dates when cattle graze a paddock may differentially affect fledging by Bobolink because of breeding phenology. Rotational grazing enables the control of stocking rate and dates when cattle graze particular paddocks, potentially providing opportunities for adjustments to management practices that benefit nesting Bobolink.

Empirical tests of management strategies intended to benefit Bobolink conservation and minimize impacts on grazing are needed. Leaving some paddocks ungrazed during the Bobolink breeding season has been suggested as a management strategy to increase the number of nests that fledge young in rotationally grazed pastures (Temple et al. 1999, MacDonald and Nol 2017). However, this strategy has not yet been tested explicitly to quantify the potential gains for Bobolink. Additionally, because paddocks often need to be grazed during the Bobolink breeding season to meet cattle production needs, management options that enable some grazing while minimizing impacts on Bobolink are also needed. Identifying stocking rates and dates of grazing that enable Bobolink nests to fledge young could lead to management strategies that may be more feasible for farmers, compared to leaving paddocks undisturbed throughout the Bobolink breeding season, because forage quality declines across the season (Brown and Nocera 2017).

Our goal was to test if two management strategies benefited Bobolink nesting in pastures rotationally grazed by beef cattle. We used replicated manipulative field experiments (i.e., directed by us) and quasi-experiments (i.e., occurring because of farm operations) to test these strategies (Morrison et al. 2008). In the refuge paddock experiment, we tested the effects on Bobolink nesting of integrating ungrazed paddocks into rotationally grazed pastures. We predicted that the percentage of Bobolink breeding territories that fledged young would be higher in ungrazed paddocks than in grazed paddocks; however, the efficacy of this conservation strategy depends on the magnitude of the effect. In the light spring grazing experiment, we tested if Bobolink could fledge young in paddocks that were grazed lightly, early in the breeding season. We predicted that when paddocks were grazed early in the breeding season at a low stocking rate, Bobolink nest failure from trampling would be infrequent, and young would fledge at a frequency similar to undisturbed fields. To further elucidate the ecological relationships underlying these two management strategies, we quantified associations between the fledging of young from territories with stocking rate and the date that cattle first entered paddocks. We predicted that the probability of Bobolink fledging young in a territory was (1) negatively associated with stocking rate and (2) positively associated with the date that cattle entered paddocks, under typical stocking rates for the farms in our study.

METHODS

Study species

The Bobolink breeding range stretches across southern Canada and northern USA (Renfrew et al. 2015). In contrast, the species has a relatively small nonbreeding range in the southern interior of South America, predominantly in Paraguay, eastern Bolivia, northeastern Argentina, and southwestern Brazil (COSEWIC 2010, Renfrew et al. 2015). The spring transequatorial migration begins in late March and early April (Renfrew et al. 2015). Arrival on the Ontario breeding grounds begins in early May; nesting is typically complete by mid-July (Renfrew et al. 2015). The Bobolink rarely raises more than one brood of young per year; however, individuals may attempt a second nest following an initial nest failure (Renfrew et al. 2015). The dates that cattle grazed on farms in our study overlapped with the Bobolink breeding season, as noted below.

Study area

We studied Bobolink on six private farms that were rotationally grazed by beef cattle in the Ottawa Valley (< 20 km from the town of Cobden [45°37’36”, −76°52’53”]), Renfrew County, eastern Ontario, Canada. Although farm operations limit options for experimental design, they provided the best available in situ conditions for our study. Farms included pastures, hay fields, hedgerows, woodlands, and wetlands. All farms were in the Ottawa Valley Clay Plains physiographic region (Chapman and Putnam 2007). Long-term average rainfall during the months of the Bobolink breeding season, i.e., May, June, and July, was 264 mm (30-year average from 1981 to 2010 for the nearest weather station with recent data [Ottawa CDA]; ECCC 2018*a*). Over the same months, rainfall was 184 mm in 2016 and 499 mm in 2017 (ECCC 2018*b*). Beef cattle farming forms a substantial portion of the agricultural industry in the county, accounting for 321 farms (OMAFRA 2016*a*). Approximately 26% of farmland in the county is pasture (OMAFRA 2016*a*). The average number of beef cattle per operation in Ontario was 57 in 2017, excluding feed operations (AAFC 2018). The six farms in our study had between 26 and 100 cattle or cow-calf pairs on 15 to 59 ha of pasture. Farmers moved cattle from nongrazing areas on farms used during the winter to pastures between 10 and 29 May in 2016 and 14 May and 09 June in 2017. Vegetation in pastures was primarily cool-season grasses such as orchard grass (*Dactylis glomerata*), smooth brome (*Bromus inermis*), and timothy (*Phleum pratense*), and secondarily forbs such as alfalfa (*Medicago sativa*) and clover (*Trifolium* spp.). Pasture on each farm was subdivided into 5 to 17 paddocks that cattle rotated through for grazing. We calculated stocking rate (as in Guthery and Bingham 1996) for each paddock from the start of the grazing season in May through 15 July as: number of cattle × days grazed/area grazed. We did not calculate animal unit months or days because we were interested in the effects of cattle on nesting rather than metrics for cattle production (Beef Cattle Research Council, grazing management: http://www.beefresearch.ca/research-topic.cfm/grazing-management-48). Thus, we counted cow-calf pairs as 1.5 cattle for calculations of stocking rate because we assumed that grazing, footsteps, and lying down by a calf would equal about half the impact of a cow. Additionally, we included all area available to cattle for each rotation because sometimes cattle had access to more than one paddock, typically to access water. In 2016, the median stocking rate in paddocks was 107 cattle-days/ha (range: 0 to 400); in 2017, the median was 111 cattle-days/ha (range: 0 to 721).

Monitoring Bobolink in paddocks

We attempted to monitor all Bobolink nesting in all paddocks on the six farms through spot mapping and nest monitoring. We monitored 83 Bobolink breeding territories in 2016 and 72 territories in 2017.

We used a modified spot mapping method (see Wiens 1969) to delineate and monitor Bobolink territories. From mid-May to mid-July, we visited each paddock approximately twice per week to search for Bobolink. We spot-mapped each individual or pair approximately once per week, following the bird(s) for up to 30 min to record three to six global positioning system (GPS) locations and bird behavior at each location to document breeding activity. Repeated visits to paddocks enabled us to delineate territories based on clusters of GPS locations and the number of individuals we detected on each visit. We classified behavioral observations using a modified Vickery index of breeding success (Vickery et al. 1992), providing evidence of nests (i.e., adults carrying nest materials or food) and fledging (i.e., adults delivering food to multiple locations after evidence of a nest was observed, flightless dependent fledglings, or adults carrying food for ≥ 11 days) in each Bobolink territory. We considered adults carrying food to one location for ≥ 11 days as evidence of fledging because Bobolink young remain in the nest for 10 to 11 days (Renfrew et al. 2015).

We also searched for Bobolink nests using behavioral cues and systematic searching (Martin and Geupel 1993, Winter et al. 2003). We did not approach nests when females were building, to minimize disturbance when the chance of nest abandonment can be high (Renfrew et al. 2015). Once females were incubating eggs, we visited nests approximately once every three days, on the expected fledge date, and on subsequent days until a nest was no longer active. On each visit, we recorded the number of eggs, number of young, age of young, condition of the nest, and adult behavior. We considered a nest to have fledged if we had evidence of one or more young leaving the nest (including presence of flightless dependent fledglings or adults alarm-calling or carrying food); otherwise, we considered the nest to have failed. We considered a nest failed due to trampling if we found evidence of cattle movements around the nest location (i.e., flattened or grazed vegetation) and either (1) saw a flattened nest or (2) did

Table 1. Percentage of Bobolink territories that fledged young in each paddock under treatment (ungrazed) and control (grazed) conditions for the refuge paddock experiment on rotationally grazed beef cattle farms in 2016 and 2017 in Renfrew County, Ontario, Canada. Evidence of young fledging in territories was based on spot mapping and nest monitoring. Some territories had > 1 nest. Stocking rate calculations counted each cow-calf pair as 1.5 cattle. In some cases, stocking rate calculations incorporated the area of other paddocks simultaneously available to cattle to provide access to water.

		Ungrazed			Grazed						
Paddock	Area (ha)	Year	Fledged (%)	Territories monitored (*N*)	Year	Fledged (%)	Territories monitored (*N*)	Cattle (*N*)	Time grazed (d)	Stocking rate (cattle-days/ha)†	Date first grazed
KF1	7.4	2016	17	6	2017	43	7	45–58.5	17	70	29 May
CQ1	3.1	2016	100	2	2017	0	3	48	11	119	13 June
BD1	3.1	2016	75	4	2017	0	4	64	6	122	13 June
HL2	2.7	2017	100	1	2016	0	1	26	13	125	28 May
BD2	1.8	2017	100	1	2016	0	1	12–19	15	134	07 June
CH1	3.4	2016	20	5	2017	33	3	27	31	138	04 June
CH2	3.1	2017	75	4	2016	0	3	25.5	18	149	14 June
HL1	2.8	2016	60	5	2017	0	3	26	18	167	09 June

†Stocking rate was calculated as: number of cattle × days grazed/area grazed.

not observe the adult birds tending to a nest or young for a nest we were unable to relocate. We considered a nest depredated if we found a nest empty after the nest contained eggs or nestlings on the previous visit and we did not observe evidence of fledged young or trampling. For each nest with sufficient information, we estimated the first-egg date, hatch date, and fledge date based on our observations and previously documented time periods (i.e., one egg laid per day, 12 days of incubation, 11 days from hatch to fledge; Renfrew et al. 2015). If cattle were present in a paddock, we watched bird behavior from outside the paddock to look for evidence of nesting and fledging. Although imperfect, this technique was the best option available, and Bobolink detection probability is high, based on the literature (Rotella et al. 1999, Lueders et al. 2006, Shustack et al. 2010). When possible (i.e., if cattle were occupied in another area of the paddock), we also entered to check nests.

We measured vegetation height and visual obstruction (i.e., a combination of vegetation height and density) in each paddock periodically throughout the season to quantify effects of grazing on vegetation. To measure vegetation, we visited each paddock on up to four dates across the breeding season, resulting in 149 visits to 48 paddocks in 2016 and 172 visits to 47 paddocks in 2017. In the center of each paddock, we recorded measurements at six locations, each spaced 5 m apart, along a 25-m transect. At each location, we measured maximum vegetation height (to the nearest cm) and visual obstruction using the Robel method (Robel et al. 1970). From a 3-m distance and 1-m height, we recorded the decimeter of the Robel pole nearest the ground that was visible (i.e., not obstructed by vegetation).

Refuge paddock experiment

We conducted the refuge paddock experiment on a subset of monitored paddocks. We used a crossover design (Morrison et al. 2008) in which each treatment paddock (N = 8) remained ungrazed during the Bobolink breeding season (i.e., May through 15 July) in one of the two years of the study. We used this date range based on information available in the literature (Renfrew et al. 2015) and discussions with researchers in the region. After 15 July, farmers managed treatment paddocks as needed (e.g., grazed, mowed). In the year when a paddock was not selected for treatment, it served as its own control (i.e., grazed normally during the breeding season). The eight paddocks used for the refuge experiment were spread across five farms; one farmer was unable to accommodate this experiment. We identified paddocks for the refuge experiment based on (1) landscape characteristics associated with Bobolink occurrence and fledging young (from the literature, see below), (2) observed Bobolink locations in the spring, and (3) production needs of farmers. We identified candidate paddocks that were mostly surrounded by pasture rather than woodland (Bollinger and Gavin 2004, Ribic et al. 2009, Perkins et al. 2013) and minimized paddock edge to area ratio (Keyel et al. 2013). We documented Bobolink distribution in pastures (see spot mapping methods above) when Bobolink arrived in the spring. We also met with farmers to discuss possible locations for the refuge experiment paddocks and incorporated grazing needs into determining the size and location of areas to be left ungrazed, which we assumed did not introduce bias. Paddocks used for the refuge experiment were 1.8 to 7.4 ha (target size was approximately 2.0 to 5.0 ha; Table 1), providing enough area for multiple Bobolink breeding territories (mean territory size 0.5 to 2.0 ha; Renfrew et al. 2015).

We randomly selected the year of treatment (i.e., when paddocks were left ungrazed) for six of the paddocks included in the experiment by flipping a coin; farmers determined the year of treatment for two of the paddocks based on when they could accommodate an ungrazed paddock in their operations. Five of the eight refuge experiment paddocks were ungrazed in 2016 and three were ungrazed in 2017. In the year that these eight paddocks were grazed, stocking rates ranged from 70 to 167 cattle-days/ha (Table 1).

Light spring grazing experiment

We conducted the light spring grazing experiment on a subset of monitored paddocks not used for the refuge experiment. We identified paddocks (N = 4) for light spring grazing in 2017 based on the presence of breeding Bobolink in 2016 and the ability of

Table 2. Bobolink territories and nests that fledged young in each paddock used for the light spring grazing experiment on rotationally grazed beef cattle farms in 2017 in Renfrew County, Ontario, Canada. Grazing occurred for four to eight days between 21 May and 03 June. A fledged territory had evidence of young fledging from ≥ 1 nest. The number of nests includes those found through nest monitoring and others inferred through adult behavior during spot mapping. Stocking rate calculations counted each cow-calf pair as 1.5 cattle. Stocking rate calculations incorporated the area of other paddocks simultaneously available to cattle to provide access to water.

					Territories		Nests			
Paddock	Area (ha)	Cattle (*N*)	Time grazed (d)	Stocking rate (cattle-days/ha)†	*N*	Fledged	*N*	Fledged	Trampled	Depredated
CQ05	2.7	21	6	31	1	1	3	1	1‡	1
CH02	2.8	22.5–27	8	34	4	3	5	5	0	0
CQ06	2.9	21	7	35	4	2	8	3	2	3
BD16	5.3	64	4	40	3	2	2	2	0	0

†Stocking rate was calculated as: number of cattle × days grazed/area grazed.
‡Nest was trampled during subsequent grazing occasion in July.

farmers to have cattle graze paddocks early in the breeding season. Paddocks were grazed for four to eight days between 21 May and 03 June and then not again until after 02 July. Grazing after 02 July occurred at the farmers' discretion based on production needs. Cattle entered paddocks in May after Bobolink arrived and established territories, reducing the chance of breeding birds avoiding paddocks because of lightly grazed vegetation or the presence of cattle. Our target stocking rate (i.e., 50 cattle-days/ha) to minimize trampling of nests by cattle was based on field observations in 2016 that indicated some Bobolink nests remained active in three paddocks with stocking rates of 58 to 130 cattle-days/ha. Field implementation by farmers in 2017 resulted in stocking rates of 31 to 40 cattle-days/ha (Table 2). Paddocks used for light spring grazing were 2.7 to 5.3 ha (Table 2).

Analyses

To test the effect of the refuge experiment, we used a Wilcoxon paired-sample test (Zar 1999). For each paddock, we determined the percentage of territories with evidence of fledging when the paddock was grazed and when it was ungrazed, using nest monitoring and spot mapping methods described above. Combining nest monitoring and spot mapping data provided the best information on evidence of fledging for each Bobolink territory (one to seven territories per paddock used for the refuge experiment) and data applicable to a paired statistical test. By determining the percentage of territories with evidence of fledging, we avoided bias associated with not correcting for the number of days a nest is observed (i.e., exposure days; Mayfield 1961, Dinsmore et al. 2002). Spot mapping data likely underestimates the percentage of territories that fledge young because some young fledglings die before detection (Naef-Daenzer and Grüebler 2016). We assumed that any biases were similar when paddocks were grazed compared to when they were ungrazed. Evidence of fledging based on the Vickery index (Vickery et al. 1992, Christoferson and Morrison 2001) has been used in previous studies to examine relationships with various environmental metrics (Butcher et al. 2010, Klassen et al. 2012, Robinson et al. 2018). Data for the test were paired, comparing the percentage of territories with evidence of fledging for each paddock when ungrazed in one year to grazed conditions in the other year of the experiment. We used the function wilcox.test in R (version 3.4.1, https://cran.r-project.org/) to run the statistical test. We considered $P < 0.05$ statistically significant and interpreted the biological importance of the direction and magnitude of the effect (Johnson 1999, Guthery et al. 2001).

For the light spring grazing experiment, we collated data from nest monitoring and spot mapping to determine the number of territories and territories with evidence of fledging, nests, fledged nests, trampled nests, and depredated nests for each paddock. We used estimates of first-egg dates for each nest to assess the number of nests initiated before and during vs. after light spring grazing.

We graphed vegetation data for each paddock (separately for 2016 and 2017) to compare vegetation height and visual obstruction across the season for paddocks exposed to light spring grazing, normal grazing (i.e., based on farmer needs without restrictions), and no grazing. We plotted data for paddocks as ungrazed until a paddock was grazed in each year, unless the paddock was part of the light spring grazing experiment. We graphed median vegetation height and visual obstruction from the six measurements taken on each visit to each paddock. We graphed dates as ordinal dates (i.e., day of year from 1 to 365).

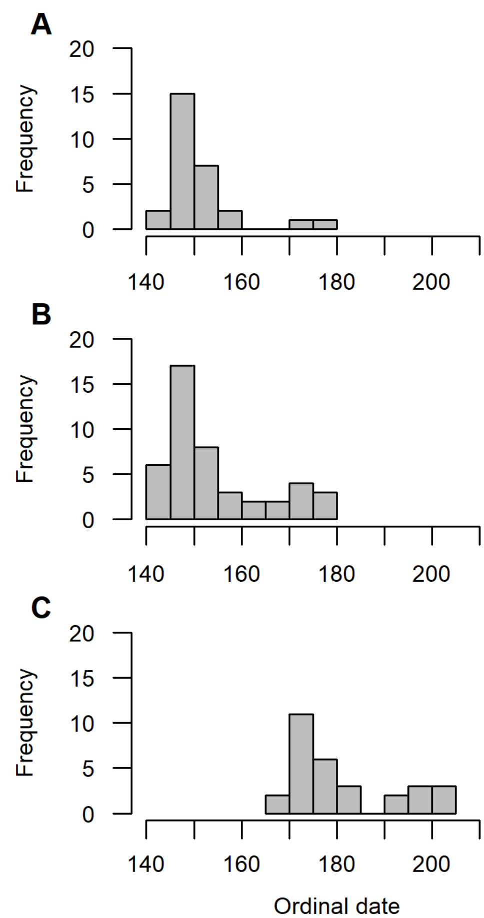
We used logistic regression (Harrell 2001) to quantify relationships between evidence of fledging in each territory (yes or no) with stocking rate and the date that cattle first entered paddocks (i.e., standardized to the date that cattle first entered paddocks used by Bobolink [day 1 = 17 May]). As stated above, combining nest monitoring and spot mapping data provided the best information on evidence of fledging for each Bobolink territory; additionally, we assumed no bias in evidence of fledging across values of predictor variables. We assessed stocking rate across the Bobolink breeding season and split into three time periods relevant to Bobolink breeding phenology: (1) early-season stocking rate (beginning of grazing season through 26 May, which includes Bobolink arrival through territory establishment and first-egg dates of early nesting attempts), (2) mid-season stocking rate (27 May through 24 June, from earliest first date of incubation through median date when apparent first nesting attempts fledged), and (3) late-season stocking rate (25 June through 15 July). We included all 118 territories that occurred in paddocks grazed during the Bobolink breeding season over the two years of study. We excluded territories ($N = 37$) in ungrazed paddocks used for the refuge experiment or not grazed for other reasons because they lacked date first grazed; this exclusion enabled relative model comparisons using the Akaike Information Criterion (AIC; Akaike 1974, Burnham and Anderson 2002) with one dataset. We ran eight logistic regression models. We ran five models based on our hypothesized relationships between probability of fledging in a territory and predictor variables: (1) stocking rate (across the breeding season), (2) early-season stocking rate, (3) mid-season stocking rate, (4) late-season stocking rate, and (5) date first grazed. We included three additional models: (1) year (because the probability of a territory fledging might vary between years and rainfall was 2.7 times higher in 2017 than 2016), (2) farm (because fledging, edaphic features, and landscapes may vary among farms), and (3) an intercept-only model (assuming a constant probability of a territory fledging young). Stocking rate and date that cattle first entered paddocks were negatively correlated, based on a Spearman rank correlation test ($\rho = -0.52$, $S = 414{,}990$, $P \leq 0.001$); on average, stocking rate decreased as date that cattle first entered paddocks increased. We did not run a model containing both stocking rate and date that cattle first entered paddocks to avoid problems associated with including correlated predictor variables in a single logistic regression model (Graham 2003, Zuur et al. 2010). We evaluated relative support for models based on AIC and considered models with Δ AIC < 7 to have some support (Burnham et al. 2011). We further assessed the best-supported model because there was minimal model uncertainty and we were interested in potential management implications (Guthery 2008, Symonds and Moussalli 2011, Fieberg and Johnson 2015). To evaluate the capability of the best-supported model to predict fledging from territories, we used a receiver operating characteristic (ROC) and calculated area under the ROC curve (AUC; Boyce et al. 2002, Sing et al. 2005). We made predictions of statistical relationships based on the best-supported model because the model had some explanatory power for ecological relationships, i.e., AUC ~0.7 (0.5 = no predictive power, 1.0 = perfect predictive power) and the model was supported better than the intercept-only model. We used the function glm to run logistic regression models in R.

RESULTS

We first detected Bobolink on farms in the study area on 10 May in 2016 and 09 May in 2017. The number of Bobolink territories per farm ranged from 10 to 17 in 2016 and 9 to 17 in 2017, based on spot mapping. The earliest estimated first-egg date was 23 May in both years (Fig. 1A,B). Some Bobolink initiated nests later in the season; the latest first-egg date was 25 June in 2016 and 28 June in 2017, likely following earlier failed nesting attempts. The earliest date when young fledged from nests was 19 June in 2016 and 18 June in 2017 (Fig. 1C). The latest nests fledged on 27 June in 2016 and 22 July in 2017. Although we observed nesting activity in July 2016, none of those nests fledged young.

In 2016, 37% ($N = 83$) of Bobolink territories across all paddocks had evidence of fledging young compared to 40% ($N = 72$) in 2017. Of the nests we monitored, 48% ($N = 31$) fledged young in 2016 and 48% ($N = 65$) fledged in 2017. Thirteen percent of nests were trampled by cattle in 2016, compared to 28% in 2017. Of the trampled nests, 77% ($N = 22$) were in paddocks that had a mid-season stocking rate ≥ 50 cattle-days/ha.

Fig. 1. Histograms showing the frequency of first-egg dates for Bobolink nests in 2016 (A) and 2017 (B) and fledge dates for 2017 (C) on six rotationally grazed beef cattle farms in Renfrew County, Ontario, Canada. We had insufficient data on ageing of nestlings to estimate fledge dates for nests in 2016. We graphed dates as ordinal dates (i.e., day of year from 1 to 365); ordinal day 140 = 20 May.



Refuge paddock experiment

In the eight paddocks used for the refuge experiment, we monitored 28 Bobolink territories when paddocks were ungrazed compared to 25 territories when paddocks were grazed. In the year when paddocks were ungrazed, 54% ($N = 28$) of Bobolink territories had evidence of fledging; when these same paddocks were grazed in the other year, 16% ($N = 25$) of territories had evidence of fledging ($V = 33$, $P = 0.041$; Table 1).

Light spring grazing experiment

We monitored 12 Bobolink territories and had evidence of 18 nests in the four paddocks used for the light spring grazing experiment. Young fledged from all four paddocks (Table 2). Sixty-seven percent of territories ($N = 12$) had evidence of ≥ 1 nest fledging, and 61% of nests ($N = 18$) had evidence of fledging young (Table 2). Three nests were likely trampled by cattle, two during light spring grazing and one during a subsequent grazing occasion in July. Bobolink began laying eggs in nine nests before or during light spring grazing, compared to nine nests after grazing occurred.

Vegetation

As the breeding season progressed, the median vegetation height was greater in some ungrazed paddocks than in grazed paddocks, but there was overlap in median height between ungrazed and grazed paddocks (Fig. 2A,B). In 2016, median vegetation height in ungrazed paddocks was 0.21 m in May and 0.56 m in June, whereas median vegetation height in grazed paddocks was 0.16 m in May and 0.34 m in June. Median vegetation height in paddocks used for the light spring grazing experiment in 2017 was in the height range where ungrazed and grazed paddocks overlapped (Fig. 2B). In 2017, median vegetation height in May and June was 0.37 and 0.80 m in ungrazed paddocks, 0.20 and 0.47 m in grazed paddocks, and 0.33 and 0.66 m in paddocks used for light spring grazing, respectively. Median visual obstruction was higher in some ungrazed paddocks compared to grazed paddocks across the breeding season, but there was overlap (Fig. 3A,B). Median visual obstruction in paddocks used for the light spring grazing experiment was in the range of overlap between ungrazed and grazed paddocks across the breeding season (Fig. 3B).

Effect of cattle on fledging

Thirty-seven percent of Bobolink territories (N = 118) in paddocks that were grazed had evidence of fledged young. The best-supported logistic regression model for predicting probability of young fledging from territories in grazed paddocks contained mid-season stocking rate (Table 3). Other models, including models that contained stocking rate across the entire breeding season, date that cattle first grazed paddocks, year, and farm were not competitive. The model that contained mid-season stocking rate was supported better than the intercept-only model and had moderate predictive ability to classify correctly a territory as having fledged young based on mid-season stocking rate (AUC = 0.69). Predictions from the best-supported model indicated that the mean probability of young fledging from a territory decreased across the increasing range of mid-season stocking rates from a 0.53 probability of fledging (95% CI: 0.41, 0.65) when stocking rate was 0 cattle-days/ha to a 0.04 probability of fledging (CI: 0.00, 0.18) when stocking rate was 174 cattle-days/ha (Fig. 4). The proportion of territories (N = 37) that fledged young from all paddocks that were ungrazed (and thus not included in the logistic regression analysis) was 0.43, which was within the 95% confidence interval predicted for probability of fledging young when mid-season stocking rate was low (Fig. 4). Additionally, territories rarely fledged young when mid-season stocking rates were high; for example, 6% (N = 17) of territories fledged young from paddocks with a mid-season stocking rate > 100 cattle-days/ha.

DISCUSSION

Our experiments in pastures rotationally grazed by beef cattle identified two grazing strategies that benefitted nesting Bobolink. More than one-half of Bobolink territories fledged young in paddocks that were left ungrazed during the Bobolink breeding season for the refuge experiment or were grazed lightly during late May to early June and then not grazed again until July for the light spring grazing experiment. Additionally, our study demonstrated that the probability of young fledging in a territory was negatively associated with mid-season stocking rate (i.e., when most nests were active). To our knowledge, these are the first tests of grazing strategies to support nesting Bobolink in rotationally grazed pastures. Additional research is needed to improve our understanding of the impact of cattle on nesting Bobolink in pastures and to test additional land management practices intended to benefit Bobolink.

Paddocks left ungrazed for the refuge experiment provided nesting areas where Bobolink frequently fledged young. We found evidence of fledging in 54% of territories when the refuge experiment paddocks were ungrazed, which is roughly

Fig. 2. Median vegetation height in paddocks on six rotationally grazed beef cattle farms in Renfrew County, Ontario, Canada. We visited each paddock on up to four dates across the breeding season, resulting in 149 visits to 48 paddocks in 2016 (A) and 172 visits to 47 paddocks in 2017 (B). We graphed dates as ordinal dates (i.e., day of year from 1 to 365); ordinal day 130 = 10 May. We plotted data for paddocks as ungrazed until a paddock was grazed in each year, unless the paddock was part of the light spring grazing experiment.

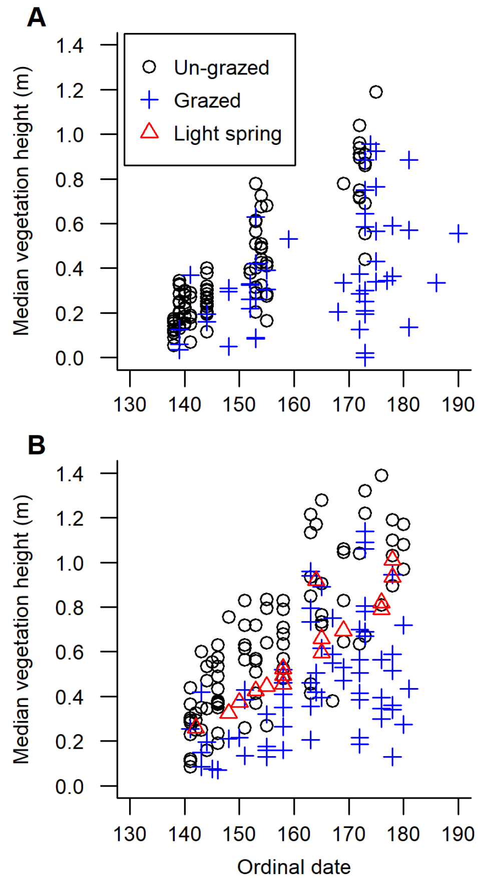


Table 3. Evaluation of logistic regression models for predicting the probability of young fledging from Bobolink territories in rotationally grazed paddocks on six beef cattle farms in Renfrew County, Ontario, Canada. *N* = 118 territories.

Model	K†	Δ AIC‡	AIC weight	−2 log-likelihood
Mid-season stocking rate	2	0	0.99	−70.26
Stocking rate	2	11.12	0	−75.82
Late-season stocking rate	2	11.58	0	−76.04
Intercept only	1	13.36	0	−77.94
Date first grazed	2	15.22	0	−77.87
Year	2	15.32	0	−77.92
Early-season stocking rate	2	15.35	0	−77.93
Farm	6	17.29	0	−74.90

†Number of parameters in the model.
‡Difference in Akaike Information Criterion values compared to the best-supported model. AIC = 144.51 for the best-supported model.

Fig. 3. Median visual obstruction (a combination of vegetation height and density) in paddocks on six rotationally grazed beef cattle farms in Renfrew County, Ontario, Canada. We visited each paddock on up to four dates across the breeding season, resulting in 149 visits to 48 paddocks in 2016 (A) and 172 visits to 47 paddocks in 2017 (B). Visual obstruction was measured as the decimeter of the Robel pole nearest the ground that was visible (i.e., not obstructed by vegetation) from a 3-m distance and 1-m height. We graphed dates as ordinal dates (i.e., day of year from 1 to 365); ordinal day 130 = 10 May. Data points were jittered minimally on the x- and y-axes to make them easily visible. We plotted data for paddocks as ungrazed until a paddock was grazed in each year, unless the paddock was part of the light spring grazing experiment.

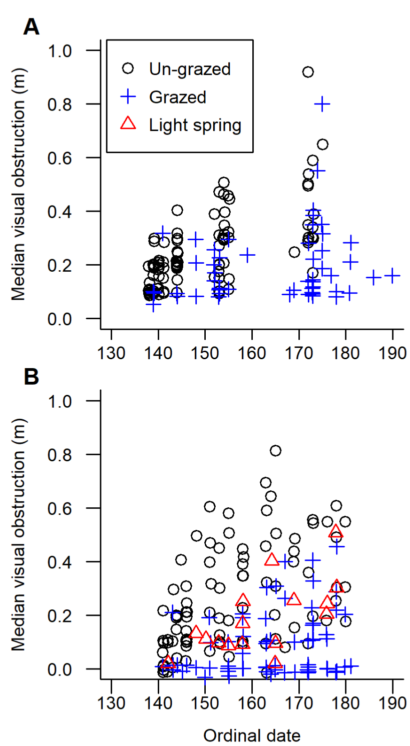
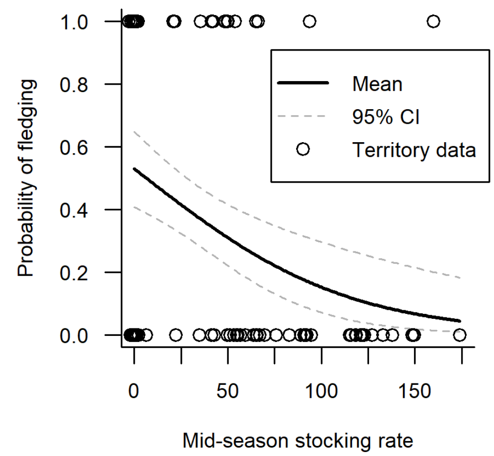


Fig. 4. Predicted mean and 95% confidence interval for probability of Bobolink fledging young from a territory in a grazed paddock based on the best-supported logistic regression model. The model contained an intercept and mid-season stocking rate (calculated as: number of cattle × days grazed/ area grazed) while most nests were active (i.e., 27 May through 24 June). For plotted territory data, 0 = no evidence of fledging and 1 = evidence of fledging for each territory (*N* = 118), based on spot mapping and nest monitoring data.



comparable to the percentage of fledging from nests previously reported in fields undisturbed by agricultural activity. For example, previous research in the study area in 2012 and 2013 found that 56% (*N* = 25) of nests fledged in ungrazed paddocks and 76% (*N* = 38) fledged in uncut hay fields (MacDonald 2014). A study in Vermont found that 64% of nests in uncut hay fields fledged young (Perlut et al. 2006). Additionally, we found that more than three times as many territories fledged young when paddocks were ungrazed compared to when the same paddocks were grazed in a different year in the refuge experiment. Our results indicate that Bobolink nest mortality associated with grazing (i.e., primarily trampling and secondarily reduced vegetation cover at nests) can be additive rather than compensatory with other reasons for nest failure (primarily nest predation; Burnham and Anderson 1984). If nest mortality caused by cattle was compensatory with other reasons for nest failure, then on average we would expect a similar frequency of nest mortality in paddocks with and without grazing. Such a scenario could occur if frequency of nest predation were higher than normal. Typically, approximately one-half of songbird nests fail to fledge young for various reasons, primarily nest predation (Nice 1957, Ricklefs 1969, Martin 1993).

Similar to paddocks that were ungrazed for the refuge experiment, 67% of Bobolink territories fledged young in paddocks that were grazed lightly in the spring (i.e., late May to early June) and then not grazed again until July in the light spring grazing experiment. The proportion of territories that fledged young was similar to previous results for undisturbed agricultural fields, as noted above. The proportion of territories that fledged young in these paddocks was higher than the 43% of territories that fledged young from all ungrazed paddocks in our study, suggesting that the light spring grazing in our experiment (i.e., with stocking rates between 31 and 40 cattle-days/ha) introduced little or no additivenest mortality from trampling or removal of vegetation by cattle. Effects on vegetation by cattle in light spring grazing paddocks resulted in vegetation height and visual obstruction similar to the lower range of ungrazed paddocks and upper range of grazed paddocks. Interestingly, previous research in the study area in 2012 and 2013 found that Bobolink did not build nests in June or fledge young in 17 paddocks that were grazed before 02 June and then not again until after 01 July (MacDonald and Nol 2017). We suspect that the timing of grazing and low stocking rates in our light spring grazing experiment account for the different response of Bobolink to grazing compared to MacDonald and Nol's (2017) study. Initiating grazing in late May, after territories are established, may reduce the likelihood of abandonment because individuals are invested in territories and early nesting attempts. Additionally, a low stocking rate may retain enough vegetation for birds to continue nesting and renest if a nest is trampled, which is more likely following an early nest failure compared to a failure later in the season.

We were unable to find previous manipulative experiments in the literature that tested rotational grazing strategies to benefit nesting Bobolink. However, previous mensurative experiments reported fledging success in pastures. In rotationally grazed pastures, Perlut et al. (2006) found that the observed percentage of Bobolink nests fledging was 34% (21% for model-based estimates), which was similar to the 37% of territories with evidence of fledging across all grazed paddocks in our study. For a suite of ground-nesting songbird species, Temple et al. (1999) estimated that the frequency of young fledging from nests was lower in rotationally grazed pasture (~10 to 15% of nests) compared to ungrazed and continuously grazed pasture because of trampling and desertion of nests after grazing. Nest desertion following grazing of vegetation around nests, as observed by Temple et al. (1999), suggests that light grazing that retains vegetation cover around nests may enable birds to continue nesting, as we noted above for our light spring grazing experiment.

The probability of Bobolink fledging in a territory decreased with increasing mid-season stocking rate. The probability of young fledging in a territory was 0.53 (95% CI: 0.41, 0.65) from paddocks with a mid-season stocking rate of 0 cattle-days/ha, which was comparable to the 43% of territories that fledged young from all ungrazed paddocks and to previous studies of fields undisturbed by agricultural activity, as noted above. However, our results predicted that the probability of fledging in a territory decreased to as low as 0.04 when mid-season stocking rate was high (maximum = 174 cattle-days/ha). Additionally, 77% of nests that were trampled in our study occurred in paddocks that had a mid-season stocking rate ≥ 50 cattle-days/ha. In addition to the effect of trampling on nests, adult Bobolink dispersed from paddocks that were heavily grazed, except in rare cases when a nest was not trampled. Perlut et al. (2006) found that 65% of Bobolink nest failures in rotationally grazed pasture in Vermont were caused by cattle. The authors described grazing management in their study as 1 to 1.5 cattle per 0.4 ha, with animals rotating among paddocks every 7 to 14 days (Perlut et al. 2006). In contrast, Bleho et al. (2014) found that cattle accounted for 2.8% of nest failures for duck, shorebird, and songbird nests from 18 studies in rotationally and continuously grazed areas across Canada (although mostly in western Canada). They found that nest destruction by cattle was associated with stocking rate, but nest survival was not (Bleho et al. 2014). However, Bleho et al. (2014) reported a high percentage of nest failure because of cattle for one small study on ducks in eastern Canada, noting that high stocking rates in the St. Lawrence Lowlands, where our study area is located, may make nests particularly susceptible to mortality from cattle grazing. In eastern North America, available empirical evidence suggests that stocking rates can be high enough to result in additive nest mortality, based on our results and previous studies (Perlut et al. 2006, MacDonald and Nol 2017).

Although Bobolink fledged young from 54% of territories in paddocks used for the refuge experiment and 67% of territories in the light spring grazing experiment, the potential impact of these management practices across broader spatial scales on the Bobolink population is unknown. For example, ungrazed paddocks used for the refuge experiment ranged from 1.8 to 7.4 ha and contained one to six Bobolink territories. These paddocks comprised a small to moderate percentage of the area (4 to 21%) of pasture on each farm. Interestingly, the ungrazed paddocks used for the refuge experiment contained 8 to 43% of the Bobolink territories in pastures on each farm in our study, underscoring the importance of strategic selection of paddocks for Bobolink conservation actions. Although implementing these management practices widely on cattle farms might contribute to Bobolink conservation, the potential impact may be limited if the majority of grazed pasture does not provide conditions suitable for Bobolink to fledge young and becomes an ecological trap (Schlaepfer et al. 2002). For example, in 2017 on one of the farms in our study, Bobolink fledged young from the ungrazed and light spring grazing paddocks only; no nests survived in the other paddocks on this farm. Future tests of light spring grazing regimes would be beneficial because our sample size was small (i.e., 12 territories in four paddocks) and occurred in one year only. Additionally, it would be interesting for future experiments to explore the effects of light grazing at various stocking rates and dates during the breeding season on nesting Bobolink and forage production. Identifying stocking rates that are compatible with Bobolink fledging young would facilitate conservation guidelines that enable some use of paddocks for agricultural production and thus reduce the amount of forage foregone compared to leaving a paddock ungrazed throughout the Bobolink breeding season. The efficacy of grazing management practices to support Bobolink conservation and the related economic impacts of deferred grazing (Adams et al. 2010) and incentive payments (Ferraro and Kiss 2002, Polasky et al. 2014) should be examined.

CONCLUSION

Our results demonstrate that paddocks rotationally grazed by beef cattle can provide nesting habitat for Bobolink, enabling young to fledge where conditions are favorable. Favorable conditions include keeping paddocks ungrazed until 15 July or grazing paddocks lightly after territories are established. When initiating conservation practices, land managers should first identify paddocks used for nesting by Bobolink. Potential paddocks could be inferred from information in the literature about where the species nests (Renfrew et al. 2015), but field observations to confirm Bobolink presence are likely to provide more useful information. Managers should target paddocks with multiple Bobolink territories to provide nesting habitat efficiently for as many Bobolink as possible. In our study area in the Ottawa Valley, we found that keeping paddocks ungrazed until 15 July eliminated potential nest mortality from grazing for nearly the entire Bobolink breeding season; few nests were active after 15 July. The ungrazed 1.8- to 7.4-ha paddocks in our refuge experiment provided nesting habitat for one to six territories per paddock, about one-half of which fledged young. Additionally, light grazing of paddocks (stocking rate of 31 to 40 cattle-days/ha [e.g., 15 cattle for 5 days in a 2-ha paddock]) during the last week of May might enable cattle use that minimizes effects on nesting Bobolink. The applicability of these two management practices across years and conditions in pastures is uncertain, particularly for light spring grazing. We hypothesize that the effects of light spring grazing on Bobolink primarily depend on: (1) ensuring that grazing begins after territories are established, and (2) the response of the vegetation to grazing, which may vary depending on soil characteristics, vegetation species composition, and precipitation (Pakeman 2004, Heitschmidt et al. 2005, Briske et al. 2008).

Identifying the environmental conditions conducive to Bobolink fledging young is challenging in complex agricultural landscapes. Considering that approximately one-half of Bobolink nests fail to fledge young in undisturbed fields, the moderate predictive capability of mid-season stocking rate is promising for identifying grazing practices that are likely compatible with Bobolink nesting. The mechanistic relationship between fledging in Bobolink territories and cattle stocking rate is not particularly well understood. However, our results indicate that young can fledge from territories in lightly grazed paddocks in rotationally grazed pastures. Future research could: (1) replicate our approach in other parts of the Bobolink breeding range and consider effects on other grassland birds, (2) test light grazing at different times of the breeding season, and (3) adapt our approach for other grazing systems. Additional research into the relative importance of stocking rate compared to other factors associated with nest failure will likely lead to beneficial management guidelines. Although we focused on nesting, beneficial management for Bobolink on breeding grounds should include additional life stages (e.g., the needs of flightless young after they leave the nest; Renfrew et al. 2015).

Responses to this article can be read online at:
http://www.ace-eco.org/issues/responses.php/1420

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