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Impact of grazing and conservation opportunities for nesting grassland birds in a community pasture

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Abstract
Multiple bird species-at-risk nest on the ground in hayfields and pastures, making nests susceptible to inadvertent destruction from agricultural activity (e.g., trampling by livestock). To better understand the impact of Domestic Cattle (*Bos taurus*) grazing, we assessed the distribution and breeding status of nesting grassland birds in 2019 and 2020 at the Grey Dufferin Community Pasture, a ~234 ha pasture in southern Ontario, Canada. We estimated there were 86 male Bobolink (*Dolichonyx oryzivorus*) in the community pasture in 2019 and 100 in 2020 before grazing began; observed abundance decreased by 73% in fields after grazing in 2020. Eastern Meadowlark (*Sturnella magna*) maintained territories after grazing and fledged young in 67% (n = 21) of territories. Savannah Sparrow (*Passerculus sandwichensis*) was common across the community pasture before and after grazing occurred. We detected evidence of nesting more frequently in Bobolink and Savannah Sparrow territories in ungrazed than in grazed fields. Our results support previous research indicating nesting Bobolink often disperse from moderately to heavily grazed fields, whereas Eastern Meadowlark and Savannah Sparrow largely remain and renest. Despite the inadvertent negative impacts of cattle stepping or laying on nests and consuming vegetative cover, the community pasture provides areas for successful nesting, with Eastern Meadowlark faring better than Bobolink. Flexibility in the timing and duration of grazing in rotational grazing systems may enable strategic management in target fields (e.g., maintaining enough vegetation for nesting Bobolink). Information about the distribution and abundance of birds can be used to target particular fields for conservation.

Key words: Distance sampling; nest monitoring; range management; regenerative agriculture; spot mapping; stocking rate; Vickery index

Introduction
Temperate grassland is the terrestrial biome of greatest conservation risk for wildlife worldwide because 46% of the land has been converted to other uses and only 5% are in protected areas (Hoekstra *et al.* 2005). A substantial portion of temperate grasslands in North America has been converted from native grassland to farmland (Samson and Knopf 1994; Hoekstra *et al.* 2005). In addition to providing food, fibre, and fuel for the human population and contributing to the economy, farmland also provides wildlife habitat (Kremen and Merenlender 2018). In eastern North America, where temperate grasslands were rare before European colonization, agricultural grasslands were created through the conversion of other land-cover types, such as forest, to farmland. These agricultural grasslands (i.e., hayfields and pastures) are currently the most common type of grassland in the region, providing important wildlife habitat. Thus, collaboration between conservation biologists and farmers is essential for identifying ways to support grassland species that are compatible with farm management.

Populations of birds that nest in grasslands (e.g., Bobolink [*Dolichonyx oryzivorus*]) have been declining in North America since at least the first half of the 20th century, based on observations of naturalists and ornithologists (Forbush 1907; Bent 1958). Grassland bird populations decreased by 53% in North America between 1970 and 2017, more than birds in any other biome (Rosenberg *et al.* 2019). These population declines have led to conservation concern for multiple species that nest in grasslands (i.e., hayfields, pastures, fallow or old fields, native grasslands, restored grasslands). Bobolink and Eastern Meadowlark (*Sturnella magna*), which nest on the ground exclusively in grasslands, are listed as Threatened in Canada (Government of Canada 2017); their populations declined by 73% and 88%, respectively, between 1970 and 2019 (Smith *et al.* 2020). Savannah

Sparrow (*Passerculus sandwichensis*), which is not a grassland obligate but frequently nests in grasslands, is considered a conservation priority in some regions (Environment Canada 2014). Its population declined by 38% in Canada between 1970 and 2019 (Smith *et al.* 2020).

Habitat loss and a decrease in habitat quality are likely the two most important factors contributing to population declines in grassland birds on their breeding grounds (COSEWIC 2010, 2011; McCracken *et al.* 2013; MECP 2015). Habitat loss has occurred because of the conversion of hayfields, pastures, and native grasslands to other types of landcover (Samson and Knopf 1994; Smith 2015). In hayfields and pastures, early and frequent hay harvests and intensive livestock grazing result in poor habitat quality for nesting birds by creating an ecological trap (Schlaepfer *et al.* 2002). Nests can be destroyed, and young birds can be killed directly (e.g., nests crushed by mowing [Tews *et al.* 2013] or trampled by livestock) or indirectly (e.g., exposure to predators; Bollinger *et al.* 1990; Perlut *et al.* 2006; MacDonald and Nol 2017). Stewardship practices on farms meant to benefit nesting grassland birds often involve delaying grazing or hay harvest until birds finish nesting, typically in July (COSEWIC 2010; McCracken *et al.* 2013; MECP 2015; OSCIA 2020). Unfortunately, these stewardship practices often have negative impacts on farm production. For example, the protein content of unharvested forage decreases across June and July, reducing nutritional quality for livestock (Brown and Nocera 2017).

Research is needed to better understand how the needs of nesting grassland birds can be incorporated into farm management, while minimizing negative impacts on farm production. Management of grasslands in Ontario, Canada, where Bobolink and Eastern Meadowlark are listed as Threatened provincially (MECP 2010, 2012), is important for the conservation of grassland birds. For example, ~10% of the global Bobolink population breeds in the province (Partners in Flight 2020). There are ~525 000 ha of various pasture types in Ontario (OMAFRA 2016), which can potentially provide productive nesting habitat for grassland birds under particular conditions.

Our overall goal was to improve our understanding of the impacts of the rotational grazing of Domestic Cattle (*Bos taurus*) on nesting grassland birds. Rotational grazing is promoted as a best management practice for agricultural production and typically entails moving livestock through at least three fields during the grazing season (OMAFRA 2012). The Grey Dufferin Community Pasture provided a unique opportunity to monitor the impacts of rotational grazing on multiple species of grassland birds in a large block of grassland. Improving our knowledge about the status of grassland birds in pastures and the impact of management practices (e.g., rotational grazing) may help guide future conservation efforts to provide the greatest positive impacts for grassland birds in agricultural grasslands. Our objectives were to assess: (1) Bobolink abundance before and after grazing occurred and the impact of grazing on breeding status, (2) Eastern Meadowlark distribution, abundance, and breeding success throughout the breeding season, and (3) Savannah Sparrow distribution before and after grazing occurred and the impact of grazing on breeding status.

Study Area

We monitored grassland birds in 2019 and 2020 at the Grey Dufferin Community Pasture (hereafter community pasture), in Grey County, southern Ontario, Canada (44.094°N, 80.440°W). Grey County is in the Mount Forest ecodistrict within the Mixedwood Plains ecozone (Ontario GeoHub 2012). The ~868 000 ha ecodistrict is primarily rural, consisting of 72% pasture and cropland, and 20% forest (Wester *et al.* 2018). The community pasture is privately owned and managed by a committee to provide grazing opportunities to local farmers for beef cattle. The property includes ~234 ha of pasture (predominantly open grassland with some wooded areas) which supports ~600 cattle through rotational grazing each spring and summer. It also provides a significant amount of wildlife habitat, primarily for grassland species, although the property also includes forested, wetland, and riparian areas. There are permanently fenced fields in the community pasture, some of which are further subdivided with temporary fencing to enable rotational grazing throughout the grazing season. For our study, we identified 21 fields (2.6–20.5 ha); these field boundaries largely followed permanent fencing. In 2019, 430 steers and 250 heifers were rotated through the pasture as separate groups beginning on 28 May. In 2020, 325 steers and 271 heifers were rotated through the pasture as separate groups beginning on 27 May. Each field was grazed once or twice by the end of July and was grazed for about 1–12 days each time cattle entered the field. After the first grazing occasion, each field was rested for about four to five weeks in 2019 and about six to seven weeks in 2020 before being grazed a second time.

Methods

Transect surveys

We used transects to survey the number of Bobolink before and after grazing occurred in 2019 and 2020. Additionally, we used transects to detect the presence of Savannah Sparrow in each field in 2020. We placed one transect in each of the 21 fields using a geographic information system (QGIS version 3.4; QGIS Development Team 2019) and aerial photographs. The length of each transect varied based on the number of 100 m sections that fit in each field (200–600 m). We visited each transect four times each year, except for transects in fields being grazed by cattle on the day of a survey. In both years, visits one and two occurred before grazing began (22–29 May) in 20 fields; one field was grazed before we could complete surveys. Visits three and four occurred from 20 to 25 June in both years. During visits three and four in 2019, we surveyed 17 grazed and one ungrazed field(s). During visits three and four in 2020, we surveyed nine grazed and eight ungrazed fields. The number of ungrazed fields surveyed was larger in 2020 because cattle were rotated through fields more slowly compared to 2019.

During each survey, we walked the transect at a pace of one step/sec. We recorded detections of Bobolink within 75 m of either side of the transect line. When we detected a Bobolink, we noted how we detected the individual (i.e., by song, call, or visually), the sex of the individual (if possible), and perpendicular distance from the transect line to the individual when it was first detected. Because Savannah Sparrow was abundant across the pasture, we did not record detections of individuals. Instead, we noted if we detected the species on each 100 m section of the transect. We conducted all surveys between sunrise and 0940 during appropriate weather conditions for detecting birds (i.e., not during rain or strong wind).

Spot mapping

We used spot mapping (*sensu* Wiens 1969) to collect data on grassland bird territories. We collected spot mapping data differently in each year and for each species. Bobolink, Eastern Meadowlark, and Savannah Sparrow are migratory songbirds. Males typically arrive on breeding grounds before females and establish individual breeding territories that they defend to exclude conspecific males (Jaster *et al.* 2020; Renfrew *et al.* 2020; Wheelwright and Rising 2020). It is common for >1 adult female to breed in a territory (Jaster *et al.* 2020; Renfrew *et al.* 2020; Wheelwright and Rising 2020). We used spot mapping to assess the breeding status of Bobolink in 2019 and 2020 in grazed and ungrazed fields from 20 to 28 June. We selected this time period to coincide with when most Bobolink in the study area have mature nestlings or young fledglings (Campomizzi *et al.* 2020). We used detections of Bobolink on the third and fourth transect visit to guide territory sampling and distributed sampled territories across as many fields as possible. We attempted to sample 10 territories in grazed fields and 10 territories in ungrazed fields in each year. Because many Bobolink had dispersed due to grazing by late June, there was a scarcity of territories to spot map. As a result, we sampled 19 territories in grazed fields and 18 in ungrazed fields across 2019 and 2020. We visited each territory once.

Similarly, we used spot mapping to assess the breeding status of Savannah Sparrow, in 2020 only, in grazed and ungrazed fields. We visited sampled territories once from 14 to 16 June because Savannah Sparrow arrives (Renfrew *et al.* 2020; Wheelwright and Rising 2020) and starts breeding earlier than Bobolink (Peck and James 1987). We randomly selected a sample of 10 territories in grazed fields and 10 in ungrazed fields by walking into a field and spot mapping the first individual we detected. We distributed sampled territories across as many fields as possible.

In 2020, we also used spot mapping to assess distribution, abundance, and evidence of breeding of Eastern Meadowlark throughout the breeding season. We visited each field about once per week from 21 May to 5 August to monitor Eastern Meadowlark. We were unable to begin spot mapping in April when Eastern Meadowlark arrive because of government restrictions due to the COVID-19 pandemic, which delayed the start of field work.

Once we located birds in a target territory, we observed Bobolink and Savannah Sparrow for a maximum of 30 min and Eastern Meadowlark for up to 60 min. For Bobolink and Savannah Sparrow, we ended a spot mapping visit early if we detected evidence of nesting or fledged young. For Eastern Meadowlark, we used observations of evidence of nesting to help locate nests (see below). On each visit to a territory for all three species, we recorded the coordinates of three to six locations used by the birds on a hand-held global positioning system (GPS) unit (eTrex 20 and GPSMAP 78; Garmin International Inc., Olathe, Kansas, USA). At each location, we noted the behaviour of the birds, prioritizing behaviours that indicated nesting or fledged young. For Bobolink, we considered observations of nest building, incubating eggs, faecal sac carry from a nest, food carry to a nest, and agitated alarm calling as evidence of nesting, and food carry to fledglings or dependent fledglings as evidence of fledged young. We considered all other behaviours (i.e., loafing, vocalizing, foraging, territorial behaviour, courtship) to not indicate evidence of nesting or fledged young. For Savannah Sparrow and Eastern Meadowlark, we used the same criteria except we did not record the agitated alarm calling behaviour.

Nest monitoring

In 2020, we searched for and monitored Eastern Meadowlark nests about once per week from 21

May to mid-August, during and after spot mapping. We also monitored Savannah Sparrow and Bobolink nests, located opportunistically, about once per week over the same time period.

For Eastern Meadowlark, we used behavioural cues and systematic searching to locate nests (Martin and Geupel 1993; Winter *et al.* 2003). For Savannah Sparrow and Bobolink, we located nests opportunistically from behavioural cues observed while in the community pasture (e.g., a female flushing from a nest as we walked nearby).

We did not approach nests when females were building to minimize the risk of nest abandonment. Once females were incubating eggs, we visited nests approximately once per week 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 behaviour. We considered a nest to have fledged young if we had evidence of ≥1 young leaving the nest (e.g., presence of flightless dependent fledglings, adults alarm calling or carrying food); otherwise, we considered the nest to have failed. We considered a nest predated 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. We considered a nest failed due to trampling if we found evidence of livestock movements around the nest location (i.e., flattened and grazed vegetation) and either saw a flattened nest or did not observe the adult birds tending to a nest we were unable to relocate. Because birds were unmarked and we visited nests about once per week and did not visit fields that were being actively grazed, we were occasionally unable to determine nest outcome or reason for nest failure even when we suspected failure due to trampling.

Vegetation sampling

We measured vegetation height to assess differences between grazed and ungrazed fields and Bobolink use of fields from 21 to 26 June to coincide with Bobolink spot mapping. Each year, we used QGIS to generate 90 random sampling locations in each of three field types: 30 in ungrazed fields, 30 in grazed fields where we detected Bobolink on the third or fourth transect visit, and 30 in grazed fields where we did not detect Bobolink on the third or fourth transect visit.

Analyses

We conducted all analyses in program R (version 4.0.3; R Core Team 2020) and considered resulting P values < 0.05 statistically significant. Except for distance sampling, we used fairly simple statistical tests to address our objectives because sample sizes were small and not conducive to complex modelling (e.g., models with hierarchical structure).

We used distance sampling (Buckland *et al.* 1993a) to estimate the number of male Bobolink across the 205 ha of open pasture in each year (excluding forested areas where Bobolink territories would not occur). We used data from the first and second transect visit, which occurred before grazing began. Distance sampling provides estimates of abundance, density, and detection probability based on the distance from the survey location to the detected individual. Estimating detection probability addresses the imperfect detection of birds on surveys (e.g., some individuals go undetected because, for example, a male may not vocalize during the survey; MacKenzie *et al.* 2002). We used the "Distance" package in R for the distance sampling analysis (Miller 2019). We ran four models for each year: uniform key function with cosine adjustments, half-normal key function with cosine adjustments, half-normal key function with Hermite polynomial adjustments, and hazard-rate key function with polynomial adjustments, following recommendations by Thomas *et al.* (2010). Key functions provide a baseline shape of the relationship between detection probability and distance from survey location. We truncated the distance to 55 m (excluding males detected 56–75 m) to improve model performance while retaining sufficient detections (i.e., 64 in 2019, 68 in 2020). Because our sample size was small, we did not include covariates in models. We compared relative model performance using AICc (Akaike 1974; Burnham and Anderson 2002) and considered models with ΔAICc <7 to have some support compared to the best-supported model (Burnham *et al.* 2011). We calculated ΔAICc using the *aictabCustom* function in the R package "AICcmodavg" (Mazerolle 2019). We used the *gof_ds* function to apply the Cramer-von Mises test to evaluate goodness-of-fit and considered P values < 0.05 as evidence of poor model fit. We used transect length and the area of open pasture in the distance sampling analysis to enable estimates of male Bobolink abundance for the area of open pasture. We include estimates of male Bobolink density for future use by other researchers.

For comparison with results from the distance sampling analysis, we summed the maximum number of males detected ≤75 m on either side of the transect line in each field across the first and second transect visit in 20 fields because Campomizzi *et al.* (2020) found the maximum number of males detected was a reasonable estimate of the number of Bobolink territories in a surveyed area.

We did not detect enough males on the third and fourth transect visit to estimate abundance with distance sampling (Buckland *et al.* 1993b) because most

Bobolink had dispersed after grazing. Thus, for comparison with the first and second transect visit in 2019, we summed the maximum number of males detected ≤75 m on either side of the transect line in each field across the third and fourth transect visit in grazed and ungrazed fields because there was only one ungrazed field. In 2020, we used a before-after-control-impact design (Morrison *et al.* 2008) with males detected ≤75 m on either side of the transect line because about half of fields had been grazed when we made the third and fourth transect visit. For the 17 fields with comparable data in 2020, we summed the maximum number of males detected in each field across the first and second transect visit to provide data before the grazing impact occurred separately for fields that remained ungrazed and those that were grazed by the third and fourth visit. We also summed the maximum number of males detected in each field across the third and fourth transect visit to provide data after the grazing impact occurred separately for fields that were ungrazed and grazed at that time. We used two Wilcox paired-sample tests (Zar 1999), the first to assess if the maximum number of male Bobolink detected differed between visits one and two compared to visits three and four for fields that remained ungrazed (controls) and the second test for those that had been grazed (impact) by transect visit three and four. Although this approach did not model the imperfect detection of birds on surveys, it provided direct comparisons and an index of abundance based on a fixed distance from the transect line (Johnson 2008; Hutto 2016).

Repeat visits to spot map Eastern Meadowlark territories enabled us to determine the number of territories across the pasture based on GPS location clusters and the number of individuals detected on each visit. We combined observations of evidence of nesting and fledging from spot mapping with nest monitoring data to provide an estimate of the number of territories that had nests and fledged young. For Bobolink and Savannah Sparrow, we used Fisher's exact tests to assess if the proportion of territories with evidence of nesting from spot mapping was different between territories in grazed and ungrazed fields for each species (Zar 1999). We did not assess the relationship between the spatial distribution of breeding territories and field and landscape variables.

For each Eastern Meadowlark nest with sufficient data, we estimated first-egg date (n = 12) and fledge date (n = 7) based on our observations and the literature (one egg laid/day, average clutch size of five eggs, 14 days of incubation, 11 days from hatch to fledge; Jaster *et al.* 2020). For each Savannah Sparrow nest with sufficient data, we estimated first-egg date (n = 21) and fledge date (n = 6) based on our observations and the literature (one egg laid/day, average clutch size of four eggs, 12 days of incubation, 10 days from hatch to fledge; Wheelwright *et al.* 2020). For each Bobolink nest with sufficient data, we estimated first-egg date (n = 3) based on our observations and the literature (one egg laid/day, average clutch size of five eggs, 12 days of incubation, 11 days from hatch to fledge; Renfrew *et al.* 2020). We did not monitor any Bobolink nests that were confirmed to have fledged young. Results herein are observed nest success uncorrected for exposure days (Mayfield 1961; Dinsmore *et al.* 2002).

We report median vegetation height to assess differences among ungrazed fields, grazed fields with Bobolink, and grazed fields without Bobolink. We used a t-test for each year to test if mean vegetation height was different between grazed fields with Bobolink and grazed fields without Bobolink (Zar 1999).

Results

Observed abundance and occurrence

The sum of the maximum number of male Bobolink we detected in each field was 68 in 2019 and 58 in 2020 across the first and second transect visit before grazing occurred in 20 fields. These 20 fields contained 69, 100 m transect sections. In both years, Bobolink was unevenly distributed across the pasture. During the third and fourth transect visit, the maximum number of male Bobolink we detected was lower in grazed fields than in ungrazed fields. On the third and fourth visits in 2019, we detected two males on three 100 m transect sections in an ungrazed field and 10 males on 56 transect sections in 16 grazed fields. In 2020, the number of males detected decreased by 73% (26 to seven males on 32 transect sections) in fields that were grazed by transect visit three and four (P = 0.013). In contrast, the number of males detected in fields that remained ungrazed was similar across visits one and two compared to visits three and four (19 to 24 males on 24 transect sections; P = 0.281).

In 2020, we detected Savannah Sparrow on 83% of transect sections during visit one and 76% during visit two (n = 71 100-m transect sections). On the third transect visit, we detected Savannah Sparrow on 100% of transect sections in ungrazed fields (n = 30 transect sections) and 91% in grazed fields (n = 34 transect sections). On the fourth transect visit, we detected Savannah Sparrow on 100% of transect sections in ungrazed fields (n = 25 transect sections) and 92% in grazed fields (n = 37 transect sections).

Estimated Bobolink abundance

In 2019, the only acceptable distance sampling model (goodness-of-fit test P = 0.119) had a hazard-rate key function and polynomial adjustment (scale coefficient 4.231, SE 0.125; shape coefficient 3.754, SE 3.747); other models had SEs that were orders of magnitude higher than coefficients. Based on the only acceptable model, detection probability was 1.0 and the estimated number of male Bobolink across the 205 ha of open pasture was 86 (95% CI 67–112; Figure 1). Estimated density of male Bobolink in 2019 was 0.42/ ha, based on this model.

In 2020, both distance sampling models with a half-normal key function were simplified to remove adjustments based on the internal model selection process of the distance sampling function, resulting in only one half-normal model being used. Multiple models had some support because the three models used had ΔAICc < 7 (Table 1). However, results were fairly consistent among the three models; detection probability was 0.92–1.0 and estimated abundance of male Bobolink in the 205 ha of open pasture was 92–100 (Table 1). The best-supported model had a uniform key function, a cosine adjustment coefficient of 0.088 (SE 0.169), and 95% CI for male abundance was 67–148 (Figure 1). Estimated density of male Bobolink was 0.45–0.49/ha in 2020, based on the three models receiving some support.

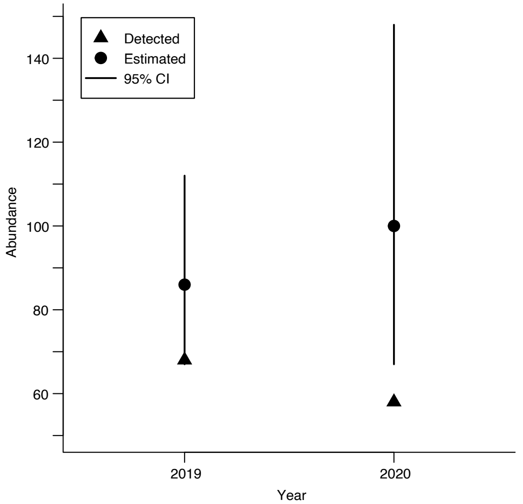

FIGURE 1. The number of male Bobolink (*Dolichonyx oryzivorus*) detected and estimated in 2019 and 2020 in the Grey Dufferin Community Pasture, southern Ontario, Canada. The number detected was based on the maximum number of males detected in each of 20 fields across two visits to transect surveys each year. The estimated abundance was based on the best-supported distance sampling model from analysis of transect survey data, specified for the 205 ha of open pasture each year.

Spot mapping

We detected evidence of nesting more frequently in Bobolink territories in ungrazed fields (50%, n = 18 territories) than in grazed fields (16%, n = 19 territories; P = 0.038; Figure 2). Similarly, we detected evidence of nesting more frequently in Savannah Sparrow territories in ungrazed fields (60%, n = 10 territories) than in grazed fields (0%, n = 10 territories; P = 0.011; Figure 2b). We did not detect evidence of fledging from one visit to each sampled Bobolink and Savannah Sparrow territory for spot mapping.

We estimated 21 Eastern Meadowlark territories across the community pasture. Weekly visits to fields indicated that the number and distribution of Eastern Meadowlark territories was fairly consistent throughout the breeding season. Eastern Meadowlark continued to use and nest in fields that had been grazed, even after nests failed to fledge young. We confirmed the presence of two nesting females in six of the territories and suspected a second female in another three territories; however, these were unconfirmed. We found evidence of nesting in all Eastern Meadowlark territories and evidence of fledged young in 67% (n = 21) of territories, based on spot mapping and nest monitoring.

Nest monitoring

We monitored 16 Eastern Meadowlark nests, 26 Savannah Sparrow nests, and three Bobolink nests across the community pasture in 2020 (Table 2). First-egg dates ranged from 5 May to 13 July (n = 12) for Eastern Meadowlark, 22 May to 14 July (n = 21) for Savannah Sparrow, and 30 May to 10 June (n = 3) for Bobolink. Our infrequent visits to nests resulted in few nests with estimated fledge dates. Fledge dates ranged from 3 June to 30 July (n = 7) for Eastern

TABLE 1. Model results for distance sampling from transect surveys for male Bobolink (*Dolichonyx oryzivorus*) in the Grey Dufferin Community Pasture, southern Ontario, Canada in 2020.

Key function	Adjustment	*K**	ΔAICc†	*P*‡	Detection§	Abundance‖
Uniform	Cosine	2	0.00	0.95	0.92	100
Half-normal	None	2	0.22	0.89	0.97	95
Hazard-rate	None	3	2.23	0.78	1.00	92

*Number of parameters in model.
†AICc for best-supported model = 548.91.
‡Cramer-von Mises goodness-of-fit test.
§Estimated average probability of detection for male Bobolink on transect surveys.
‖Estimated abundance of male Bobolink in the 205 ha of open pasture.

Meadowlark and 14 June to 3 July (n = 6) for Savannah Sparrow. We observed evidence of nesting activity for all three species throughout the pasture before any grazing occurred; however, we located few Bobolink and Savannah Sparrow nests relative to the number of individuals in the pasture because we were not actively searching for their nests.

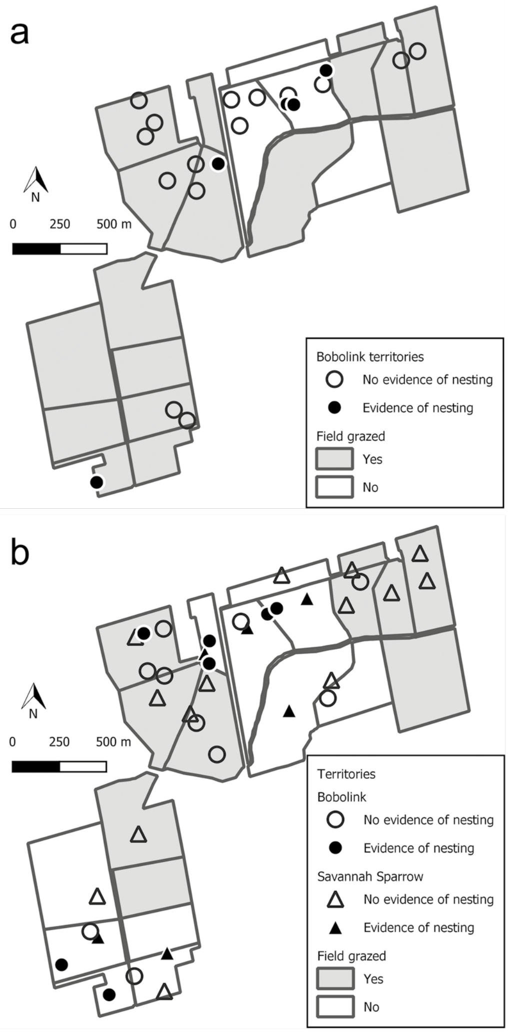

FIGURE 2. Approximate locations of Bobolink (*Dolichonyx oryzivorus*) territories selected for sampling of breeding status at the Grey Dufferin Community Pasture, southern Ontario, Canada in a. 2019 and b. 2020, also showing locations of Savannah Sparrow (*Passerculus sandwichensis*) territories selected for sampling. We visited each sampled territory once and used behavioural observations to assess if there was evidence of nesting. Symbols show locations of sampled territories, not territory size; sampled territories were distributed across fields as much as possible, but not all fields had territories when sampling occurred. We indicate whether a field had been grazed as of when we sampled each territory: a: 21–28 June or by 28 June for fields where we did not sample territories; b: 14–16 June for Savannah Sparrow and 20–25 June for Bobolink or by 25 June for fields where we did not sample territories.

Predation was the most common reason for nest failure (n = 14; Table 2) that we were able to identify across all monitored nests; we are uncertain of the predator species, but occasionally detected potential mammalian and avian nest predators in the community pasture. We suspect grazing caused a substantial amount of nest failure, but infrequent visits to check nests (~once per week) and our inability to check nests in fields where cattle were actively grazing resulted in some nests with unknown outcome (n = 11; Table 2) or unknown reason for failure (n = 3; Table 2).

Vegetation

In 2019, median vegetation height in the only ungrazed field was 0.70 m. Vegetation in 2019 was 32% taller in grazed fields where we detected Bobolink (0.58 m) compared to grazed fields without Bobolink detections (0.44 m; t_{50} = 2.95, P = 0.005). In 2020, median vegetation height in ungrazed fields was 0.72 m. Vegetation in 2020 was 16% taller in grazed fields where we detected Bobolink (0.52 m) compared to grazed fields without Bobolink detections (0.45 m; t_{57} = 2.36, P = 0.022).

Discussion

The community pasture provides nesting habitat for ground-nesting grassland birds. Despite the negative impacts of grazing on nests and the response to grazing varying by species, our results show that some birds are nesting successfully under the current management strategy. Additionally, rotational grazing creates opportunities to increase nest success at the community pasture by adjusting management in target fields with a higher abundance of nesting birds.

Our results provide empirical evidence of the impact of cattle grazing on multiple species of nesting grassland birds and the conditions under which nesting can occur in rotationally grazed pasture. Few Bobolink remained in fields after the first grazing occasion and they remained in fields where vegetation was taller compared to other grazed fields. In contrast, the number of Eastern Meadowlark territories did not change due to grazing. Most territories remained throughout the breeding season and pairs attempted to re-nest after suspected failure due to grazing. However, after grazing, some Eastern Meadowlark territory boundaries shifted, and some territories were apparently temporarily absent. We did not monitor Savannah Sparrow closely enough to assess their response to grazing; however, they continued to occur in most fields after grazing occurred.

TABLE 2. Summary of grassland bird nests monitored and reasons for nest failure at the Grey Dufferin Community Pasture, southern Ontario, Canada in 2020.

Species	No. (%) of nests				No. of failed nests			
	Monitored	Fledged	Failed	Outcome unknown	Predated	Trampled	Abandoned	Unknown
Savannah Sparrow (*Passerculus sandwichensis*)	26	6 (23)	11 (42)	9 (35)	8	1	2	0
Eastern Meadowlark (*Sturnella magna*)	16	7 (44)	8 (50)	1 (6)	5	0	0	3
Bobolink (*Dolichonyx oryzivorus*)	3	0 (0)	2 (67)	1 (33)	1	0	1	0

Our observations are consistent with previous research showing that nesting Eastern Meadowlark are better able to tolerate vegetation changes due to grazing than Bobolink and typically do not disperse from fields that are grazed at a light or moderate intensity. There is evidence that Eastern Meadowlark nested in pastures that were lightly to moderately grazed in Missouri, suggesting they remained after grazing occurred (Skinner 1975). In contrast, Campomizzi *et al.* (2019) reported that nesting Bobolink typically dispersed after their nests were trampled by cattle in fields that were moderately to heavily grazed in rotationally grazed pastures in eastern Ontario. Although some female Bobolink renested after grazing occurred in rotationally grazed pastures in a study in Vermont, most did not renest (Perlut *et al.* 2006). The response of nesting Bobolink to grazing undoubtedly depends on the grazing intensity and vegetation conditions, as supported by our results showing vegetation was taller in grazed fields where we detected Bobolink than in fields without Bobolink detections after grazing occurred. Although nesting Eastern Meadowlark can tolerate some grazing, there is evidence that they disperse from breeding territories following mowing of restored grassland in the Great Plains (Granfors *et al.* 1996). Of the three species we studied, Savannah Sparrow appears the most tolerant of grazing; they renested shortly after grazing occurred in rotationally grazed pasture and even after haying in a study in Vermont (Perlut *et al.* 2006). Understanding how nesting grassland birds respond to grazing is important for conservation efforts because the response varies by species, depends on when grazing occurs during the nesting season, and depends on how much vegetation remains after a field is grazed.

We are uncertain if Eastern Meadowlark in the community pasture are producing enough young to maintain a stable population, which has conservation implications. Although we observed evidence of fledged young in 67% of territories, we did not collect information about fecundity to understand population dynamics. In contrast to our results that show if young fledged in each territory, breeding success is often presented as a percent of nests that fledge ≥1 young or nest survival (both of which also have limitations; Mayfield 1961; Jones *et al.* 2005). For example, a large study that included active agricultural fields reported 18% of 170 Eastern Meadowlark nests fledged young in pasture compared to 38% of 280 nests in other landcover types, including hayfield and fallow fields (Roseberry and Klimstra 1970). Additionally, Eastern Meadowlark females commonly attempt to raise two broods of young per breeding season (Jaster *et al.* 2020). A study on land enrolled in the Conservation Reserve Program in Missouri estimated that Eastern Meadowlark would need to fledge 1.03–1.57 female offspring/adult female/year to sustain the population, given various assumptions including two broods attempted/female/year (McCoy *et al.* 1999). Although we did not monitor Eastern Meadowlark nesting closely enough to document all nesting attempts in the community pasture in 2020, we observed multiple nesting attempts by the same female in several territories. We documented only one instance of a female fledging two broods; however, the first successful brood was only a partial brood because some of the young were trampled by cattle. More detailed information about the number of young fledged/breeding female and multiple broods is needed to better understand how well Eastern Meadowlark is reproducing in the community pasture in particular and in pastures that are rotationally grazed by beef cattle in general.

Our evidence of more frequent nesting in ungrazed than grazed fields supports previous research on Bobolink and Savannah Sparrow. It is fairly common for cattle to cause nest failure in Bobolink and Savannah Sparrow in rotationally grazed fields in eastern North America (Perlut *et al.* 2006; MacDonald and Nol 2017; Campomizzi *et al.* 2019; Fromberger *et al.* 2020). Although we did not monitor nests frequently enough to assess reasons for nest failure as well as previous studies, we suspect grazing was the second most common reason for nest failure after predation. Additionally, we did not study the impact of reduced vegetation cover from grazing on the risk of nest predation because it was beyond the scope of our study. Lastly, we did not assess other factors that may have influenced nesting success, such as weather. Our results from nest monitoring at the community pasture should be interpreted with caution because sample sizes were small, visits to nests were too infrequent to determine nest fate in some cases, and we reported observed nest success, which can be biased because it is uncorrected for exposure days (Mayfield 1961; Dinsmore *et al.* 2002).

Conservation implications

In addition to their intended purpose of providing forage for livestock, pastures rotationally grazed by beef cattle can provide successful nesting habitat for ground-nesting grassland birds, under particular conditions. Rotational grazing enables targetting particular fields for conservation (e.g., those with higher abundance of nesting grassland birds) if there is some flexibility in the timing and duration of grazing. Fields with a higher abundance of nesting grassland birds can be placed last in the order of grazing rotation to delay grazing as long as possible, potentially giving birds time to fledge young. Additionally, because we found that vegetation was taller in fields where Bobolink remained after grazing compared to fields without detections, modifying the timing and intensity of grazing during the nesting season could benefit Bobolink. For example, grazing fields lightly in spring, leaving enough vegetation for Bobolink to remain and renest if nests are trampled, could be an effective strategy (Campomizzi *et al.* 2019). Ensuring enough vegetation remains for nesting Bobolink after light spring grazing occurs is challenging because of a lack of data about vegetation height and density. Rest period is also an important consideration to ensure birds have enough time to renest before subsequent grazing occurs. A rest period of six weeks or more should provide ample time for renesting, based on anecdotal observations and Bobolink nesting phenology, although information on the response of grassland birds to rest period is limited. Light spring grazing and typical rotational grazing have some compatibility with nesting Eastern Meadowlark. However, as with Bobolink, some nests are trampled by cattle and a sufficient rest period (e.g., six weeks) is needed to provide enough time for birds to fledge young from renesting attempts before a second grazing occurs. The conservation implications of our research will vary across geographic regions and depend on particular circumstances, including annual fluctuations in weather and vegetation growth.

Author Contributions

Conceptualization: Z.M.L. and A.J.C.; Data Curation: A.J.C. and Z.M.L.; Formal Analysis: A.J.C.; Funding Acquisition: Z.M.L. and A.J.C.; Investigation: Z.M.L. and A.J.C.; Methodology: A.J.C. and Z.M.L.; Project Administration: Z.M.L. and A.J.C.; Resources: Z.M.L. and A.J.C.; Supervision: Z.M.L. and A.J.C.; Validation: A.J.C. and Z.M.L.; Visualization: A.J.C. and Z.M.L.; Writing – Original Draft: A.J.C.; Writing – Review & Editing: A.J.C. and Z.M.L.

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