THE EFFECTS OF ROTATIONAL GRAZING AND HAY MANAGEMENT ON THE REPRODUCTIVE SUCCESS OF BOBOLINK AND EASTERN MEADOWLARK IN EASTERN ONTARIO

A Thesis Submitted to the Committee on Graduate Studies

in Partial Fulfillment of the Requirements for the Degree of Master of Science

in the Faculty of Arts and Sciences

TRENT UNIVERSITY

Peterborough, Ontario, Canada

Environmental and Life Sciences M.Sc. Graduate Program

May 2014

ABSTRACT

The effects of rotational grazing and hay management on the reproductive success of Bobolink and Eastern Meadowlark in Eastern Ontario

Nicole M. MacDonald

I investigated the impact of beef-cattle farm management on the reproductive success of Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*) within Eastern Ontario. I monitored rotational grazing management regimes and hay cut dates while assessing breeding phenology and reproductive success of Bobolinks and Eastern Meadowlarks. In pasture paddocks the major factor determining Bobolink reproductive success was the date that cattle entered a paddock to graze, with earlier entries resulting in lower reproductive success. On a landscape scale, within a series of paddocks grazed by a single herd, as the number of paddocks grazed during the nesting season increased, the number of Bobolinks that reproduced successfully decreased. Experimental quantification of trampling showed that cattle exposure to clay pigeon targets, regardless of stocking rates, resulted in the majority of targets being trampled. In hayfields associated with beef-cattle operations, grassland birds had a higher likelihood of success when cutting occurred after 4 July. The best method to improve the reproductive success of Bobolinks and Eastern Meadowlarks is to leave some hayfields and pasture paddocks undisturbed until nesting is complete.

Key words: Bobolink, Eastern Meadowlark, *Dolichonyx oryzivorus*, *Sturnella magna,* farm management, rotational grazing, paddock, cattle, stocking rate, entry date, hayfield management, reproductive success, reproductive activity index, nesting season

ACKNOWLEDGEMENTS

I especially want to thank the farmers involved with my project because without your cooperation this project would not have been possible. Thank you for not only allowing me to roam your fields, but for teaching me about farming, sharing your stories, and making me feel at home. I thoroughly enjoyed the time I was able to spend with you, your family, and all your farm animals.

A special thank you to my supervisor, Erica Nol, for your constant support, encouragement, and for sharing your passion. I could not have asked for a better supervisor and role model. I want to thank my committee members, Joe Nocera and David Beresford, for your invaluable feedback. I also want to thank Chris Risley for your guidance along the way. I want to thank Jack Kyle for sharing his grazing knowledge.

I am grateful to Ontario Soil and Crop Improvement Association (OSCIA) for initiating this research project, especially Christine Schmalz and Andrew Graham who were OSCIA's main contacts. I am also grateful to the Ontario Ministry of Natural Resources Species at Risk Research Fund, which helped to support the second field season.

I want to thank everyone who helped with fieldwork: Kristen Mancuso, Chris Street, Morgan Hawkins and Mary Heung. I want to thank fellow ENLS students for all the fun and knowledge you've shared. I especially want to thank members of the Nol lab and Kristen Diemer, for your encouragement and all bird related discussions.

Thank you to my family, especially my parents, for your constant support and encouragement. Last but certainly not least, I would like to thank Rachel for encouraging me to pursue my passion and for always being my biggest supporter and motivator (no matter how many miles away).

TABLE OF CONTENTS

LIST OF FIGURES

Chapter 2

LIST OF TABLES

CHAPTER 1: GENERAL INTRODUCTION

Grasslands are one of the most human-altered and endangered ecosystems in North America, and grassland birds, dependent upon grassland ecosystems for habitat, have experienced widespread population declines across the continent (Vickery et al. 1999, Samson and Knopf 1994, Brennan and Kuvlesky 2005). Historically, European immigrants to North America had both positive and negative effects on grassland bird communities. As Europeans settled North America, they altered or destroyed native grasslands by converting them into agricultural land (Askins 1993). Simultaneously, forests were cleared in the east for development and conversion into agricultural fields, providing surrogate habitat and thus enabling grassland bird species to expand or relocate their distributions from the western grasslands eastward (Peterjohn and Rice 1991, Martin and Gavin 1995, Askins 1999).

In the last half-century the availability of surrogate habitat for grassland birds in eastern North America began to decline due to changes in farm management. On the breeding grounds, farm abandonment has increased with subsequent afforestation (Askins 1993), agricultural practices have shifted to earlier and more frequent hay cuts (Bollinger and Gavin 1992, Tews et al. 2013), hayfields and pastures have been converted to row crops (e.g., corn, wheat, soybean) (McCracken et al. 2013), and there has been an increased use of pesticides on existing farms (Freemark and Kirk 2001). Two species that are especially sensitive to these risks are the Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*). These grassland bird species also experience risks during migration and on their wintering grounds. For example, Bobolink are treated as pests and exposed to toxic pesticides in South America (Renfrew and Saavedra 2007).

These factors during all life stages are cumulatively responsible for the decline in grassland bird populations (Brennan and Kuvlesky 2005), particularly the Bobolink and Eastern Meadowlark. The Bobolink and Eastern Meadowlark have been listed as threatened at provincial (Ontario, COSSARO) and federal (COSEWIC) levels in Canada.

The Bobolink and Eastern Meadowlark are obligate grassland species, relying throughout their range on agricultural hayfields and pastures for breeding habitat (Martin and Gavin 1995, Jaster et al. 2012). The Bobolink, a neotropical migrant, winters in central South America (Martin and Gavin 1995), while the Eastern Meadowlark migrates shorter distances, with most of the Canadian population believed to winter in south-central and southeastern United States (COSEWIC 2011). Although Eastern Meadowlarks have overwintered in southern Ontario in small numbers, most begin to arrive in Ontario in March from their non-breeding grounds (Sullivan et al. 2009, Jaster et al. 2012). Bobolinks typically begin to appear in Ontario during the first few weeks of May (Martin and Gavin 1995). Because of long migrations, Bobolinks have a short breeding period at the northern edge of their range, producing only one brood each year with most young leaving the nest by 1 July. Females will attempt to renest if failure occurs early in the breeding season (Martin and Gavin 1995, Frei 2009). Eastern Meadowlarks have a longer breeding season that can extend into August, sometimes attempting to produce two broods (Jaster et al. 2012). Unsuccessful females will attempt to renest following nest failure (Lanyon 1957, Peck and James 1987). Although Bobolink and Eastern Meadowlark breed in pastures and hayfields, often in the same field, their microhabitat preferences differ. Bobolink nest at the base of forbs while Eastern Meadowlark prefer to nest in tall grasses, which they use to construct a roof for nest concealment (Martin and Gavin 1995, Jaster et al. 2012). Because Bobolink and Eastern

Meadowlark breed in pasture and hayfields, disturbances by agricultural practices (grazing cattle and hay cutting) often overlap with the nesting period, resulting in direct and indirect nest failure (Martin and Gavin 1995, Nocera et al. 2005, Perlut et al. 2006, Perlut and Strong 2011, Jaster et al. 2012).

The Bobolink and Eastern Meadowlark are represented within the same recovery strategy in Ontario because both rely on grasslands, have similar breeding distributions in Ontario, and experience similar threats (McCracken et al. 2013). The recovery and conservation of these grassland birds within Ontario depends upon the management practices on privately owned agricultural lands. Many questions remain regarding how to best manage these lands to benefit grassland birds.

The purpose of this research project was to provide further information about the breeding ecology of the Bobolink and Eastern Meadowlark in Eastern Ontario, particularly on hayfields and rotationally grazed pastures. Renfrew County, Ontario served as a suitable research location because, due to the high density of beef-cattle farming and thus large areas of pastures and hayfields, both the Bobolink and Eastern Meadowlark are abundant in the area relative to other regions in Ontario (Cadman et al. 2007, Statistics Canada 2011, McCracken et al 2013, p. 12-13). In addition, Renfrew County beef-cattle farmers were willing to participate in the research project.

Renfrew County, the largest county in Ontario, is bordered by Algonquin Park to the west and the Ottawa River to the east. Renfrew County consists of mixed and dense forests (75%), farmland (17%), and wetlands (8%) (Harrison 2004). The most abundant agricultural operation in the county is beef-cattle farming; there are 106,563 acres of pasture for grazing and 92,339 acres of hay for harvesting (Statistics Canada 2011).

Given the importance of Renfrew County for grassland-dependent birds, my research aims were to determine which rotational grazing management plan, cattle stocking rate, and hay harvest date would produce the highest reproductive success for Bobolink and Eastern Meadowlark in Eastern Ontario. To determine the impacts of farming management on breeding grassland birds, I monitored the reproductive success of Bobolink and Eastern Meadowlarks, and assessed the impact of different grazing regimes and hay cut dates on their success. These findings will help fill knowledge gaps in Ontario (McCracken et al. 2013, p.35). This information can then be used collectively to suggest alternative grassland management systems to accommodate the needs of both farmers and threatened grassland birds.

CHAPTER 2: THE EFFECTS OF ROTATIONAL GRAZING AND HAY MANAGEMENT ON THE REPRODUCTIVE SUCCESS OF BOBOLINK AND EASTERN MEADOWLARK IN EASTERN ONTARIO

INTRODUCTION

Native grasslands are the most human-altered ecosystem of North America (Vickery et al. 1999) and considered the most endangered (Samson and Knopf 1994). As native grasslands disappeared, human-modified agricultural lands (hayfields and pastures) increased, providing surrogate habitat for grassland-dependent wildlife, particularly obligate grassland birds (Bollinger et al. 1990; Hannah et al. 1995; Vickery et al. 1999). Hayfields and pastures now serve as the primary breeding habitat for most grassland birds. Unfortunately, exposure to frequent disturbances due to intensive agricultural operations is one factor contributing to a widespread decline of grassland bird populations across North America (Murphy 2003, Brennan and Kuvlesky 2005, Perlut et al. 2011). These declines have led the Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*), two obligate grassland species, to be listed as threatened at provincial (COSSARO 2010, 2011) and federal levels (COSEWIC 2010, 2011).

When grassland birds arrive in the spring they are attracted to undisturbed pastures and hayfields (Temple et al. 1999, Bollinger et al. 1990). Pasture grazing and hay harvesting can have both positive and negative effects on grassland birds. Management of land for agriculture provides suitable habitat by minimizing woody vegetation and preventing forest succession. However, disturbance due to grazing cattle and hay cutting results in both direct and indirect nest failure (Perlut and Strong 2011).

Rotational grazing is a method of pasture management that divides a pasture into various paddocks. Cattle are rotated throughout a pasture, grazing one paddock at a time thereby allowing the remainder of the pasture to "rest" and regrow. Therefore, rotational grazing helps prevent patch overgrazing and deterioration of pasture (Undersander et al. 2002; Teague and Dowhower 2003). Grazing management systems vary based on the farmers' discretion. Farmers can manage their pasture area using a simple grazing management plan, which consists of large paddocks grazed for long periods of time with cattle rotated through paddocks once over the grazing season. Intensive rotational grazing systems contain smaller paddocks that are grazed for short periods of time with cattle rotated frequently, resulting in each individual paddock grazed more than once during the grazing season (MacPhail and Kyle 2012).

Bobolink and Eastern Meadowlark nest densities were higher in rotationally grazed pastures in Wisconsin than in continuously grazed and ungrazed pastures (Temple et al. 1999). However, nest success was significantly lower in rotationally grazed pastures than in continuously grazed pastures (Temple et al. 1999). When nests are exposed to grazing cattle, trampling is the main cause of nest failure and losses increase exponentially with the length of time cattle spend in each paddock (Paine et al. 1996).

Although studies have evaluated the effects of grazing cattle on breeding grassland birds, the management practices and ecological factors researched were unlike those in Eastern Ontario (e.g., Koerth et al. 1983 in Texas; Temple et al. 1999 in Wisconsin). Farm management in northeastern North America is different than farm management in the Midwest. Farms in northeastern North America are much smaller in size and do not incorporate burning (Perlut and Strong 2011). Research was conducted on two rotational grazing management systems in Vermont and New York's Champlain

Valley, where farm management is most similar to that conducted in Eastern Ontario (Perlut et al. 2006, Perlut and Strong 2011). However, there are key management differences. Cattle stocking density was 1.25 cows/acre and herds were rotated through paddocks of 3.0 and 4.8 acres in size (Perlut and Strong 2011). Farms monitored in Eastern Ontario have larger herds (average stocking density of 4.42 cows/acre) grazing larger paddocks, averaging 10.3 acres in size. Given the site-specific nature of research reported to date, it is warranted to conduct a study on intermediate-sized paddocks with high stocking densities in a climate with generally lower primary productivity because of the higher latitude.

Hayfields are often associated with beef-cattle operations because the farmers use hay to feed their cattle during winter and other periods when pasture feed is unavailable. As hayfields also serve as important breeding habitat for grassland birds, hay cutting will cause nest failure if it occurs during the breeding season (Bollinger et al. 1990; Nocera et al. 2005; Frei 2009). However, if hay cutting is delayed, nest success increases significantly (Dale et al. 2007; Perlut 2007; Frei 2009). A study conducted in Quebec and Ontario at a similar latitude to that of the study areas in the current study, found that Bobolink breeding in hayfields cut after 1 July reproduced successfully because young were able to sustain flight and escape hay cutting (Frei 2009).

I studied the breeding ecology of the Bobolink and Eastern Meadowlark in Eastern Ontario on rotationally grazed pastures and associated hayfields. Studies show that grazing cattle negatively affect breeding grassland birds, but no studies have investigated the impact of grazing management practices in Eastern Ontario on the Bobolink and Eastern Meadowlark. My research aims were to determine which rotational grazing management plan, cattle stocking rate, and hay harvest date in the context of typical operations in Eastern Ontario, would produce the highest reproductive success for Bobolinks and Eastern Meadowlarks. Given the high concentration of these two species in this Ontario region, I studied the effects of local farming because any recommendations implemented to reduce the impacts of farming activities on nesting birds would have potentially large beneficial effects on these species' populations in Ontario. Additionally, the Ontario Bobolink and Eastern Meadowlark Recovery Strategies rely on province-based research for recommendations.

I hypothesized that the reproductive success of Bobolink and Eastern Meadowlark would differ between simple grazing management systems and intensive grazing management systems. I predicted that a simple grazing management plan would produce a higher reproductive success for both species than an intensive grazing management plan. Simple grazing management rotates cattle through paddocks less frequently than intensive grazing management; therefore some pasture area may remain undisturbed during the nesting season. I hypothesized that the impact on simulated nests (clay pigeon targets) due to grazing cattle would differ when exposed to high and low cattle stocking rates. I predicted that a high cattle stocking rate would have a greater impact due to trampling on simulated nests than a low cattle stocking rate; as targets are more likely to be trampled with more cattle present. Lastly, I hypothesized that the reproductive success of Bobolink would vary based on the timing of hay cuts. I predicted that hayfields cut after 1 July would allow for successful Bobolink reproduction, while hayfields cut before 1 July would not, because most young are unable to sustain flight and escape hay cutting prior to 1 July.

My objective was to use this information to suggest alternative grassland management systems that could accommodate the needs both of threatened grassland birds and farmers in eastern Ontario.

METHODS

Study sites

Research was conducted on four privately owned beef-cattle farms located in Renfrew County, Ontario (centered on 45° 63’N, 76° 88’W) from the end of April through July in 2012 and 2013. Bobolink and Eastern Meadowlark were present on all farms in both years. Each beef-cattle farm contained both pasture paddocks and hayfields and farms were managed without researcher interference. Farmers maintained hayfields for the purposes of providing additional food to their mostly grass-fed beef-cattle.

I monitored approximately 1,100 ac (445 ha) of pasture and hayfield on 4 farms. The average pasture paddock size was 10.32 ± 0.08 SE ac (4.18 ± 0.03 SE ha) and the average size of a hayfield was 15.46 ± 0.33 SE acres (6.26 ± 0.13 SE ha). Twenty-seven hayfields were monitored in 2012 and 31 hayfields were monitored in 2013, with 26 of the same hayfields monitored in both years. Sixty pasture paddocks were monitored each year. Twenty-five herds were rotationally grazed and monitored over two years (2012 n = 12; 2013 n = 13). Each herd was rotated between 2-9 paddocks throughout the grazing season. Stocking rate was measured in animal units (AU) per size of paddocks (acres) per number of days grazed (AU/acres/days). AU is typically a 1000-pound cow, with or without a calf (Manitoba Forage & Grassland Association 2009). Because I was concerned with grazing cattle’s impact on grassland birds and not the amount of forage required for cattle, I assumed that each cow or heifer was 1 AU (although weight could range between 850-1050 pounds). The average stocking rate for 2012 and 2013 was 0.52 ± 0.01 SE AU/acre/day and 0.57 ± 0.01 SE AU/acre/day, respectively.

Data Collection

Monitoring Nests

Behavioural observations and haphazard walking were used to locate Bobolink and Eastern Meadowlark nests. Nests were monitored every 2-4 days until nest outcome could be determined. Both Bobolink and Eastern Meadowlark nests were deemed successful if the site was undisturbed for 7 days after the date of fledging (e.g., when the young leave the nest). Martin and Gavin (1995) indicated Bobolinks may be able to sustain flight 6 days after leaving the nest, yet Perlut et al. (2006) indicated that even after 7 days post-fledging Bobolink may not be able to fly far enough to escape haying events. Eastern Meadowlarks are only capable of short flights approximately 6 days after fledging and sustained flight around 11 days post-fledging (Jaster et al. 2012).

Grassland Bird Surveys

Five-minute, 100 m radius point counts were conducted in the center of each pasture paddock or hayfield (2012: n =60 pasture paddocks, n =27 hayfields; 2013: pasture paddock n =60; hayfield n =31) between sunrise and 10:00h, weather permitting (no precipitation and wind speed <20 km/hr), from the end of April to July 15 in 2012 and 2013. A minimum of 8 point counts (mean = 13 counts per station) was conducted at each paddock and hayfield each year. Two focal species, the Bobolink and Eastern Meadowlark, were recorded during point counts. I counted males, females, and fledglings and recorded reproductive behaviour to provide information about reproductive success. Individuals were monitored visually throughout the point count to limit double counting.

A seasonal estimate of reproduction per point count site (Vickery et al. 1992) was then assigned using a modified Vickery index (hereafter reproductive activity index) where nest outcomes and field observations were used to complement point counts (Tucker et al. 2006, Althoff et al. 2009). Sites were assigned an index of 0 if no birds were present throughout the season, 1 for a single bird present for > 3 weeks, 2 if two or more birds were present for > 3 weeks, 3 when adults were seen with nesting material, 4 for adults carrying food to presumed nestlings or fledglings, and a 5 for evidence of fledglings able to sustain flight (referred to as a reproductively successful site). Because I did not mark individual birds, I was unable to determine if any Eastern Meadowlarks were on their second attempt. For statistical analysis I used binary data where sites assigned an index of 5 were reproductively successful (1) while those ranked 0-4 were reproductively unsuccessful (0).

Vegetation Surveys

Vegetative surveys were conducted mid-May during male Bobolink territory establishment to determine which vegetation cues males used to select territory in pastures and hayfields (Martin and Gavin 1995). Within each 100m-radius point count circle, a 50 x 50 cm Daubenmire frame (Daubenmire 1959) was placed at random for a total of 4 different sampling locations per site. Within each Daubenmire frame, percent cover of grass, forbs, alfalfa (*Medicago sativa*), dung, litter, and bare ground were estimated. I also measured the percent cover of live and dead vegetation in each frame. Vegetation height and litter depth (height of dead vegetation) were measured at the four corners of the quadrat and values were averaged for each quadrat. Within each quadrat, vegetation height and density (visual obstruction) measurements were taken (from a distance of 4 meters and a height of 1 meter) from each cardinal direction to determine vertical cover using a Robel pole (Robel et al. 1970) and all 16 measurements were averaged.

Farm Management

With the assistance of all farmers, agricultural management practices were recorded. Beef-cattle herd sizes, date cattle entered and exited paddocks, and hay cut dates were all recorded. Any hayfield or paddocks untouched after 15 July were dated 16 July for analysis purposes.

Clay Pigeon Target Experiment

Clay pigeon targets were used as simulated nests to investigate the impact of different stocking rates (AU/acres/days) on the trampling of grassland bird nests. Targets were painted dark green to minimize detectability by cattle thus preventing targets from being intentionally avoided or trampled (Pavel 2004). Targets were placed on the ground in 5 or 6 parallel lines approximately 30 meters apart at 50 targets per 10 acres. Though the study species do not nest at the used target density, relative trampling loss of simulated nests does not increase with higher simulated nest densities (Koerth et al. 1983, Beintema & Müskens 1987). At each target location, GPS coordinates were recorded and a metal tent peg was placed in the ground to later help relocate targets with a metal detector to determine if targets were disturbed from the location by grazing cattle. Paddocks were grazed at different stocking rates (AU/acres/day) (n =5) and control paddocks were not exposed to grazing cattle (*n* =2). Within 12 hours of cattle being rotated out of the paddock, each target was relocated and classified as intact (no damage and in same location) or disturbed (flipped over, moved and/or broken). Targets that were disturbed were assumed to represent damage done to nests by grazing cattle.

Statistical analysis

All statistical analyses were conducted using program R (version 2.15.1). Bobolink abundance (per 100 meter radius point count) was measured each year during territory establishment in paddocks and hayfields. Bobolink abundance was also measured each year on reproductively successful paddocks and hayfields that remained untouched until 1 July. Two-way analysis of variance (ANOVA) was used to assess the main effects of field type and year on vegetation characteristics and Bobolink abundance during Bobolink territory establishment. Because there was only one significant interaction term and this effect was weak (interaction between year and field type for alfalfa cover: $F_{1,171} = 4.73$, $P = 0.03$), the significance of the interaction terms were not provided.

Multiple logistic regressions with a binary dependent variable for Bobolink reproductive success (1) or failure (0) in each paddock were performed. The number of successful Eastern Meadowlark sites was too low to confidently evaluate impacts statistically. Due to multicollinearity within vegetative predictor variables, I performed a Principal Component Analysis (PCA) and retained those PCs that accounted for >10% of the total variance (Jolliffe 2002). A combination of farm management predictor variables (date herd entered a paddock (hereafter entry date), stocking rate (AU/acres/days), number of times a paddock was grazed (hereafter number of entries)) and vegetation predictor variables (PC1, PC2, and PC3) were included in the models. Because of the large number of predictor variables I chose to use Bayesian Information Criterion (BIC) as it will penalize the complexity of the model more heavily than Akaike's Information Criterion (AIC) and thus help me understand the primary factors affecting Bobolink's reproductive success (Posada and Buckley 2004). The importance values of each variable were calculated by adding the weights of each variable included in all models up to the global model. Parameter estimates and 95% confidence intervals for each variable were calculated for each model-averaged logistic regression equation for each year. Because year was the main effect when years were analyzed together, I separated data and analyzed years separately. BIC calculations were carried out in R using package MuMIn (Barton 2012).

The impact that grazing cattle herds have on Bobolink reproductive success was assessed at the landscape level by comparing the proportion of grazed paddocks on the farm and the proportion of paddocks on the farm producing ≥ 1 Bobolink young for each year. A total of 25 herds were rotationally grazed and monitored between 2012 (n = 12) and 2013 (n = 13). Each herd was rotated between 2-9 paddocks throughout the breeding season. I separated herds into three different categories based on the proportion of pasture paddocks grazed. The lowest category contained herds that grazed 30-65% of the paddocks available on the farm (3-9 paddocks), the second category included a set of paddocks in which 80-90% were grazed (3-7 paddocks), and the last category contained herds that grazed all paddocks on the farm (2-8 paddocks). No herds grazed < 30% of the paddocks or fell between grazed category ranges. A Kruskal-Wallis non-parametric rank sum test was used to determine if there was a difference in Bobolink reproductive success among the 3 different categories of grazing intensity. The impact of trampling by cattle was assessed using a Pearson's chi-squared test to compare the number of targets damaged versus intact during exposure to grazing cattle or in the control sites.

Simple logistic regression with a binary dependent variable for Bobolink reproductive success (1) or failure (0) in each hayfield was performed to determine how the date of hay cut affected the reproductive success of Bobolink.

RESULTS

In 2012, 13 paddocks (21.7%) were not exposed to grazing cattle and 14 hayfields (51.9%) were not cut until after 1 July. In 2013, 7 pastures (11.7%) were ungrazed and 26 hayfields (83.9%) were left uncut until after 1 July.

Nest success

I found a total of 75 Bobolink nests in pasture paddocks (*n* = 33) and hayfields (*n* = 42), whereas the totals by year are 20 nests in 2012 and 55 nests in 2013 (Table 1). From the 75 Bobolink nests, 43 were successful (producing ≥ 1 fledgling), 30 failed, and 2 nest outcomes were unknown. Most nests (84%) were found in pastures or hayfields that were not exposed to agricultural practices (hay cuts or grazing cattle) during the breeding period. Predation accounted for the loss of 18 Bobolink nests. Farming activity accounted for 12 failures: cattle trampled 8 nests and 4 were mowed during hay cutting. Successful Bobolink nests in 2012 (*n* = 8) had a mean fledge date of June 16 (± 2.47 SD, June 13-20) and those in 2013 (*n* = 35) had a mean fledge date of 22 June (± 7.23 SD, 15 June- 12 July).

A total of 15 Eastern Meadowlark nests were found in pasture paddocks (*n* = 8) and hayfields (*n* = 7). The majority of nests (*n* = 11, 73%) were in untouched paddocks and hayfields. Seven nests were successful and 8 failed. Of the nests that failed, 3 were depredated, 4 failed due to farm activity (cattle trampled 2, 2 were mowed during hay cutting), and 1 nest was abandoned. All successful Eastern Meadowlark nests (*n* = 8) were found in 2013 and contained a mean fledging date of 16 June (± 8.39 SD, June 6-29).

Vegetation and Bobolink Surveys

Vegetation characteristics measured during Bobolink territory establishment (mid-May) were compared for hayfields and paddocks and between years (Table 2). Alfalfa cover was significantly greater in hayfields than in paddocks and significantly greater in 2012 than in 2013. Vegetation height and vegetation height/density measurements were significantly higher in hayfields than in paddocks and higher in 2012 than 2013. In 2012, live vegetation cover was significantly higher than in 2013. Bare ground and litter cover were significantly lower in 2012 than 2013. Grass and forb cover was significantly greater in paddocks than hayfields (Table 2).

Bobolink abundance during territory establishment was significantly higher in hayfields than in pastures and in 2012 than in 2013 (Table 2). Bobolink abundance on reproductively successful sites left untouched until after 1 July was significantly different amongst field types ($F_{1,46} = 5.57$, $P = 0.02$) and years ($F_{1,46} = 16.36$, $P < 0.001$), with greater abundance in hayfields than in pastures and in 2012 than in 2013 (Table 3).

Pasture management

The first 3 PCs of the vegetation predictor variables were retained as they explained 42%, 27% and 12% of the variance respectively and 81% cumulatively (Table 4). PC1 separates paddocks that include high cover of live vegetation and deep litter depth (positive values) from paddocks that include tall vegetation (negative values). PC2 contrasts paddocks with high grass cover (positive value) from paddocks with high forb cover (negative value). Paddocks dominated by high forb cover (positive values) were separated from paddocks with deep litter depths in PC3 (Table 4).

The 3 PCs and farm management predictor variables (entry date, number of entries, and stocking rate) were included in the multiple logistic regression models to predict the reproductive success of Bobolinks from each year. There was no clear top model in either year. Models with a ΔBIC of < 2.0 from the top model were considered well supported (Burnham and Anderson 2003) and used for model averaging (Table 5). In 2012, the reproductive outcome of Bobolink was best described by the model-averaged logistic regression equation (Figure 1):

$$g(x) = -25.16 + 0.130\ (\text{entry date}) - 0.021(\text{PC2}) + 0.025(\text{PC3})$$

In 2013, the Bobolink reproductive outcome is best described by the model-averaged logistic regression equation (Figure 2):

$$g(x)= -14.43 + 0.085\ (\text{entry date}) - 2.326\ (\text{stocking rate})$$

Entry date occurred in all top models with a ΔBIC of < 2.0 (Table 5) and had the highest importance value in both 2012 and 2013 (Table 6). Entry date is the only variable whose parameter estimates do not overlap zero, indicating a significant effect of this variable on the probability of Bobolink reproductive success. Vegetation characteristics (PC2 and PC3) occurred in the averaged model for 2012 while stocking rate occurred in the averaged model for 2013 (Table 5). Vegetation and stocking rate had parameter estimates that included zero, indicating weak effects of these variables on Bobolink reproductive success (Table 7).

Herds that grazed a lower proportion of paddocks during the breeding season resulted in a higher proportion of paddocks producing ≥ 1 Bobolink young. In 2012, the mean proportion of paddocks producing ≥ 1 Bobolink young for each grazing category was 0.29 ± 0.15 SE for 30-65% of paddocks, 0 ± 0 SE for 80-90% of paddocks, and 0 ± 0 SE for 100% paddocks. For 2013, the mean proportion of paddocks producing ≥ 1 Bobolink young was 0.63 ± 0.03 SE for 30-65% of paddocks, 0.17 ± 0.03 SE for 80-90% of paddocks, and 0.08 ± 0.06 SE for 100% of paddocks (Figure 3). A Kruskal-Wallis non-parametric rank sum test indicated there was a significant difference in proportion of paddocks producing ≥ 1 Bobolink young between grazing categories in 2012 and 2013 (Kruskal-Wallis $\chi^2 = 6.55$, df = 2, p = 0.038; Kruskal-Wallis $\chi^2 = 6.76$, df = 2, p = 0.034 respectively).

Clay Pigeon Target Experiment

A total of 128 targets were deployed for 8 days during 2 control trials (not exposed to grazing cattle). All 128 targets were relocated, wherein 123 (96.1%) targets remained intact while 5 (3.9%) were disturbed. During 5 trials, 264 targets were exposed to grazing cattle (stocking rate ranging from 0.08-0.966 AU/acres/days). Of these targets, 251 targets were relocated. Of the 251 targets, 205 (81.7%) were disturbed and 46 (18.3%) remained intact. Targets exposed to grazing cattle were more likely to be disturbed than targets in control sites (Pearson's Chi-squared test, $\chi^2 = 208.27$, df = 1, p <

0.001). Targets exposed to a stocking density > 0.08 AU/acres/days resulted in ≥ 93% of targets disturbed (Figure 4).

Hay management

Twenty-seven hayfields were monitored in 2012 and 31 hayfields were monitored in 2013. Reproductive activity indices were assigned for Bobolink (Figure 5) and Eastern Meadowlark (Figure 6) for each hayfield site at the end of each season. Average hay cut dates for fields cut before 15 July were 25 June ± 2.0 days SE and 2 July ± 2.4 days SE for 2012 and 2013 respectively. Thirty-one (53.4%) hayfields produced ≥ 1 Bobolink young while 27 (46.6%) hayfields failed to produce any Bobolink young. Four (6.9%) hayfields produced at least 1 Eastern Meadowlark young and 54 (93.1%) produced none.

In 2012, reproductive outcome of Bobolinks in hayfields with cut dates beginning on 12 June 2012 was best described by the logistic regression equation:

$$g(x) = -35.65 + 0.20 \text{ (hay cut date)}$$

whereas in 2013 the equation was:

$$g(x) = -35.50 + 0.19 \text{ (hay cut date)}$$

The odds ratios were 1.22 (95% CI: 1.09-1.47) and 1.21 (95% CI: 1.07-1.47) in 2012 and 2013 respectively. Thus, in both years, with each additional day without hay cutting the probability of Bobolink producing at least 1 young increased by more than 20% (Figure 7 & 8).

DISCUSSION AND MANAGEMENT IMPLICATIONS

Farm management was the strongest factor influencing the reproductive outcome of Bobolink and Eastern Meadowlark, particularly the date cattle entered a paddock to graze and the date hay was cut. Although only a small proportion of monitored nests were exposed to farming activities and all nests that were exposed failed.

Bobolink occurred in significantly higher densities in hayfields than in paddocks, possibly because of preferred habitat characteristics. Bobolinks occur in greater abundance in larger grassland areas (Herkert et al. 1993), in tall and dense vegetation (Nocera et al. 2007), and prefer nesting in vegetation 33-41 cm in height (Joyner 1978 in Ontario). On average, monitored hayfield sites were 5 acres larger than paddocks and vegetation height and density was higher in hayfields than paddocks both years. In 2012, Eastern Ontario experienced extreme heat and low rainfall amounts (151.4 mm) causing drought-like conditions ("Drought in Central, Eastern Canada," 2012, Statistics Canada 2012). Because of the drought conditions, hayfields and pastures had a low amount of regrowth after cutting and grazing events. With lack of regrowth, pastures and hayfields were left with less biomass at the end of the grazing and haying season than in non-drought years, which led to significantly shorter vegetation, reduced live vegetation cover, and higher amounts of bare ground and litter cover in mid-May of 2013. The vegetation differences in drought and non-drought conditions and accompanying declines in densities of grassland birds after a drought year suggest that if Eastern Ontario experienced multiple consecutive drought years, agricultural land may not be suitable Bobolink habitat.

Pasture Management

The primary factor influencing the reproductive outcome of Bobolink on pastures is grazing cattle. At the scale of a paddock, the date cattle enter that paddock is the main factor influencing Bobolink reproductive success. When the paddock entry date is later in the nesting season or after the nesting season, Bobolink experience higher reproductive success. At the herd level, when a herd was rotated across a series of fields within a farm using a rotational grazing system, the negative impact of cattle herds on Bobolink reproductive success increased as a function of the number of paddocks grazed. Successful reproduction was only documented in paddocks that cattle had not entered before fledglings were capable of sustaining flight.

Although the herd sizes varied in the clay pigeon target experiment, all herds had a similar overall impact on trampling simulated nests. The clay pigeon target experiment demonstrated that cattle stocking densities greater than 0.08 AU/acres/days had a detrimental impact due to trampling, as nearly all targets were disturbed after cattle entered. Decreasing stocking density will only be beneficial to nesting grassland birds when the herd is already very small (less than 0. 08 AU/acres/days). Even so, some targets were disturbed at low stocking rates. Average stocking rates on the farms in this region of Ontario were 7 times higher than this amount.

Pasture Management Implications

I suggest that the best method to increase the reproductive success of Bobolink on pasture paddocks in Eastern Ontario is to allow a proportion of paddocks to remain ungrazed until the nesting season is complete. Paddocks left undisturbed during nesting can be reintroduced to the grazing management regime once Bobolink nesting is complete. The more paddocks that remain ungrazed until 1 July (minimally), the higher Bobolink reproductive success will be as most Bobolink fledglings are able to sustain flight and escape trampling.

Paddocks selected to remain ungrazed and serve as a "reproductive refuge" should be suitable habitat for Bobolink and Eastern Meadowlark to ensure successful conservation efforts. If farmers have multiple paddocks adjacent to each other, paddocks most centrally located, surrounded by other paddocks and/or hayfields would be an appropriate selection. Small paddocks adjacent to forests should not be selected as Bobolinks are considered edge sensitive, with increasing occurrence and density as distance from forest edges increases, and avoid nesting close to forests (Fletcher and Koford 2003, Bollinger and Gavin 2004). Paddocks that were not grazed over winter or early spring and contain moderately tall grass (> 20 cm) during the nesting season (in mid-May) would provide suitable nesting habitat for Bobolink and Eastern Meadowlark as both species prefer nesting in tall grasses (Joyner 1978, Schroeder and Sousa 1982, this study). However, this management plan would stipulate that some paddocks sit idle until 1 July (minimally) when the nutrient quality of forage for cattle has decreased (NCR 1996), indicating a potential monetary sacrifice by farmers. Fortunately, some existing rotationally grazed management systems (rotating 1 herd) practiced in Eastern Ontario consist of some paddocks (and sometimes up to 60% of paddocks) remaining ungrazed until after 1 July, but not necessarily because of grassland bird conservation concerns.

The number of paddocks that could serve as a "reproductive refuge" for nesting grassland birds would have to be considered on a farm-by-farm basis. Farms consisting of large pasture areas and practicing a simple grazing management plan typically lead to some proportion of paddocks remaining ungrazed until after Bobolink nesting concludes. In my study, 8 of 25 farms left some paddocks ungrazed. Farmers using intensive management can only aid in Bobolink reproduction by leaving at least one paddock ungrazed until after nesting is complete. My recommendations are similar to those proposed in Wisconsin where Temple et al. (1999) suggested that a third of paddocks remain ungrazed between 15 May and 1 July to ensure that Bobolink young have sufficient time to fledge.

Hay Management

My results supported the hypothesis that hayfields cut after 1 July would have a higher likelihood of reproductive success for Bobolink. All hayfields cut prior to 1 July (except 2 fields in 2012) reached a reproductive index of 4, signifying that adults were feeding nestlings or fledglings. As a result, hay cutting would result in nearly 100% mortality for the altricial nestlings and flightless fledglings (Bollinger et al. 1990). Bobolink mean fledging date occurred on 16 June (± 2.47 SD) and 22 June (± 7.23 SD) in 2012 and 2013 respectively in Renfrew County. These dates are similar to dates from another study in Ontario and Quebec (mean fledgling June 24) and in New York (mean fledging 22 June) (Frei 2009, Norment et al. 2010). Bobolink require approximately 7 days post-fledge to be able to sustain flight which indicates hayfields cut after 1 July were typically assigned a reproductive index of 5 (reproductive success) for Bobolink, signifying that these fields contained fledglings that can sustain flight and escape hay cutting.

Eastern Meadowlarks experienced reproductive success in hayfields cut on or after 4 July, though nest success occurred before this date (mean fledge date 16 June ± 8.39 SD, June 6-29) and is similar to studies in New York with mean fledging date of 11 June (range 30 May – 3 July). Eastern Meadowlarks nesting into August (re-nesting or attempting a second brood) were not investigated; yet, Eastern Meadowlarks' second nests are significantly less successful than their initial nests (Kershner et al. 2004). A study in Wisconsin found only 17% of monitored females double-brooded (Lanyon 1957) and the number could be less at this study location as there would be a shorter breeding season in more northern latitudes. This suggests that Eastern Meadowlarks' reproductive output may be overestimated (Kershner et al. 2004).

Hay Management Implications

I recommend that hay cutting in Renfrew County be delayed until at least 1 July to ensure that many Bobolink and Eastern Meadowlark nestlings reach the fledgling stage and thus have the ability to sustain flight and escape fatal hay cutting. Monitored hay sites experienced Bobolink and Eastern Meadowlark reproductive success when hay cutting occurred after 1 July and 4 July respectively. Similarly, in New York, Bobolink and Eastern Meadowlark were fledged by the second week of July (Norment et al. 1999). Approximately 52% and 84% of hayfields monitored in Eastern Ontario during 2012 and 2013 respectively were cut after 1 July without considering grassland bird conservation or financial incentives. These later hay cut dates are due to farms having large hay acreage yet limited available harvesting assistance. In 2013 more hayfields were cut after 1 July due to rainy weather conditions that were absent in 2012. Additionally, beef-cattle have lower crude protein requirements than dairy cattle which indicates later hay cut dates have fewer negative financial effects on beef-cattle farmers than they would on dairy farmers (NCR 1996). With later hay cutting dates, beef-cattle farms in this region are providing critical habitat for Bobolink and Eastern Meadowlark production. Delaying hay cutting until July may not be feasible for many farmers because delayed cutting diminishes the nutrient quality of hay used for cattle feed in Ontario (Diemer 2013) and Nova Scotia (Nocera et al. 2005).

Beef-cattle require hay to contain approximately 10% of crude protein, while dairy-cattle require crude protein levels greater than 14% (NCR 1996). In southern Ontario, crude protein levels are approximately 14% in the first week of June and fall below 10% around 28 June (Diemer 2013). Therefore, Ontario hay used for beef-cattle feed can be cut later in the season than hay used for dairy-cattle. Similar farm management occurs in Vermont and New York's Champlain Valley; farms in the Champlain Valley that are managed for dairy cows begin hay cutting before 11 June while those managed for beef-cattle begin cutting hay between 21 June and 10 July (Perlut et al. 2011). This suggests that beef-cattle farms are more likely to contain hayfields with reproductively successful Bobolinks and Eastern Meadowlarks than dairy-cattle farms.

The same habitat that attracts Bobolinks and Eastern Meadowlarks may act as a trap if those habitats experience early hay cutting dates and grazing cattle, which are two major detriments to the reproductive success of Bobolink and Eastern Meadowlark. Thus it is critical that long-term conservation management plans for these threatened grassland birds consider acceptable modifications to agricultural practices. Although both suggested strategies of leaving proportions of pasture paddocks ungrazed and delaying hayfield cuts are ways to improve the reproductive success of the Bobolink and Eastern Meadowlark, a comparison between the feasibility of each method is required. For example, Bobolinks were found in higher densities in hayfields than paddocks (Tables 2 and 3) so delaying hay cutting could provide a larger conservation gain than to leave a paddock ungrazed. This option, however, could come at a greater cost to the farmer. An economic assessment of potential financial losses to the farmer for incorporating alternative management strategies, coupled with the conservation gain of these species is required. Determining the financial loss for delaying hay cuts until 1 July, 7 July and 15 July should be compared with quality of hay. The potential financial loss of leaving a paddock ungrazed (loss of pasture nutrient quality and potential reduction in weight gain of cattle) also needs to be assessed. Finding a balance between farmer economic loss and grassland bird reproductive success is critical for both grassland bird conservation and successful farm incentive programs.

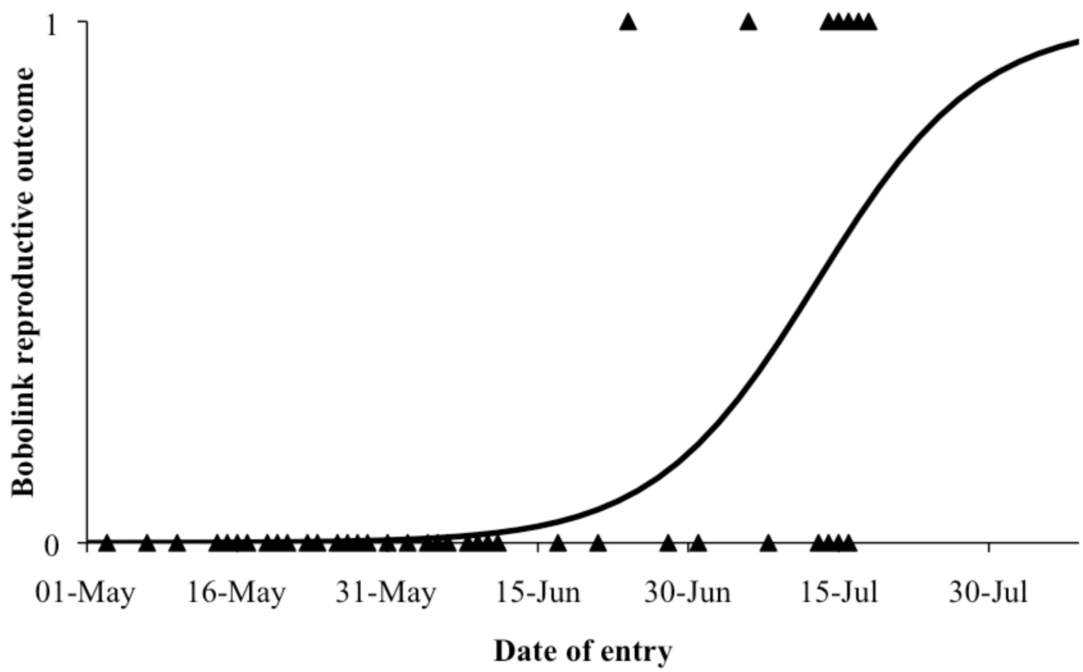

Figure 1. Models with a ΔBIC of <2.0 from the top model were considered well supported and used for model averaging. In 2012, the reproductive outcome of Bobolink was best described by the model-averaged logistic regression equation

$g(x) = -25.16 + 0.130(\text{entry date}) – 0.021(PC2) + 0.025(PC3)$, represented by the curve. Dates of entries from 2012 are plotted on the graph. Entry date = date cattle entered a paddock and averaged PCs represent different vegetation variables.

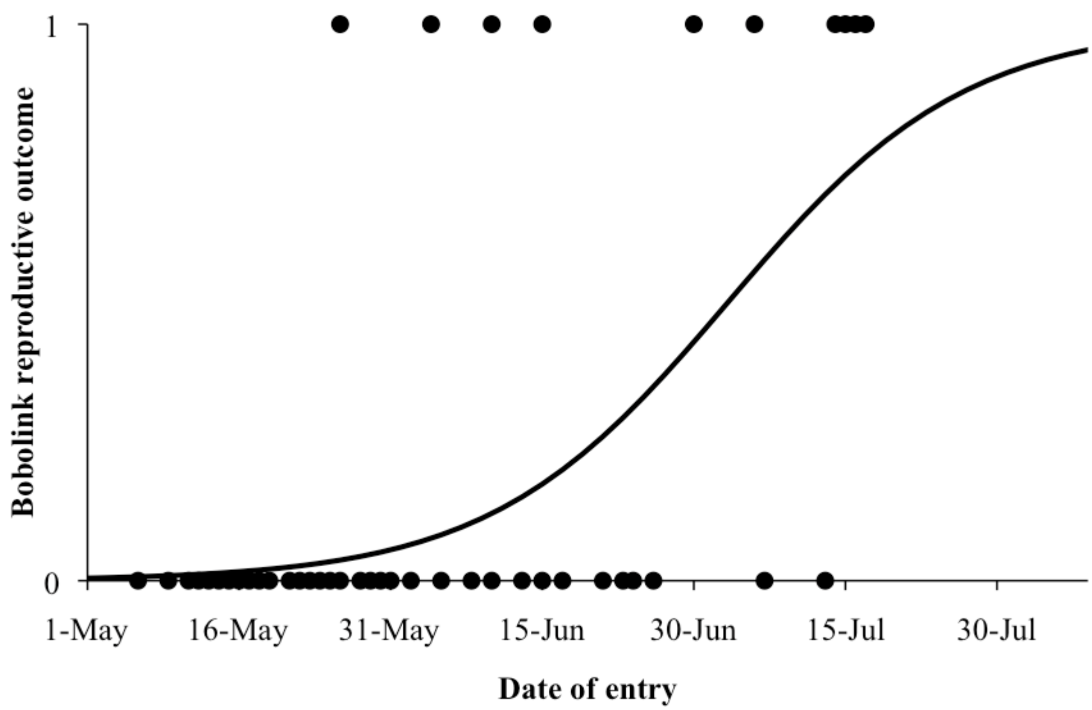

Figure 2. Models with a ΔBIC of <2.0 from the top model were considered well supported and used for model averaging. In 2013, the reproductive outcome of Bobolink was best described by the model-averaged logistic regression equation $g(x) = -14.43 + 0.085(\text{entry date}) - 2.326(\text{stocking rate})$, represented by the curve. Dates of entries from 2013 are plotted on the graph. Entry date = date cattle entered a paddock and stocking rate is measures by AU/acres/days.

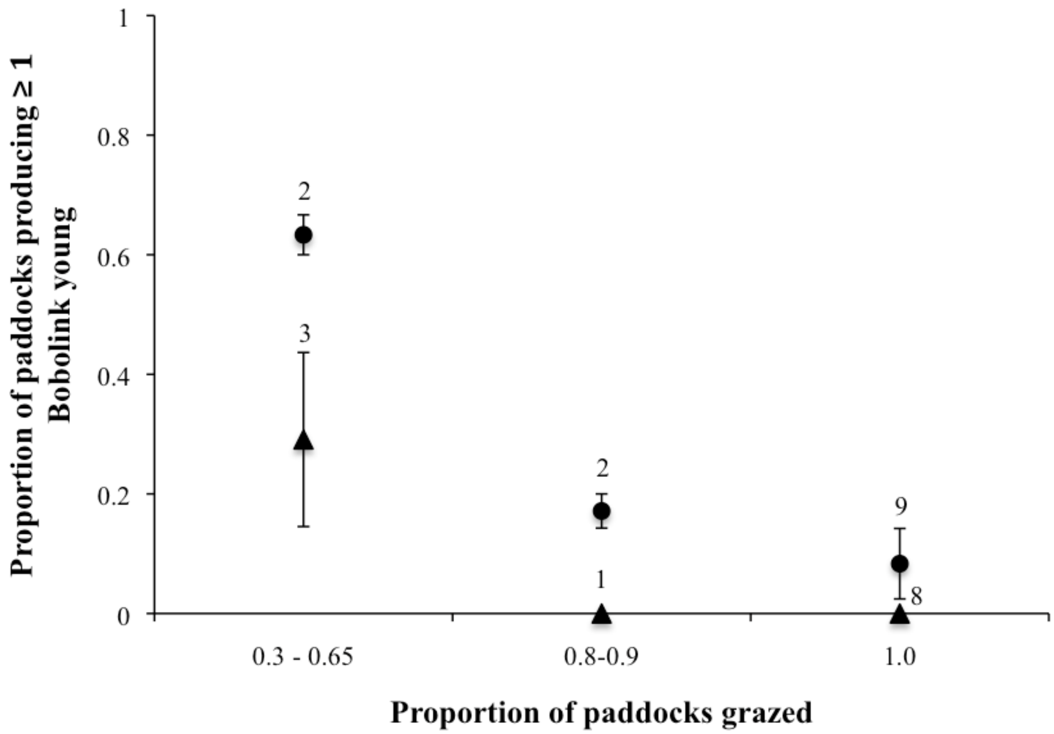

Figure 3. The mean proportion of paddocks producing at least 1 Bobolink young for each category of proportion of paddocks grazed by each herd (2-9 paddocks) for before 1 July for 2012 (*n* =12, triangles) and 2013 (*n* =13, circles). The number of herds for each category is located above error bars.

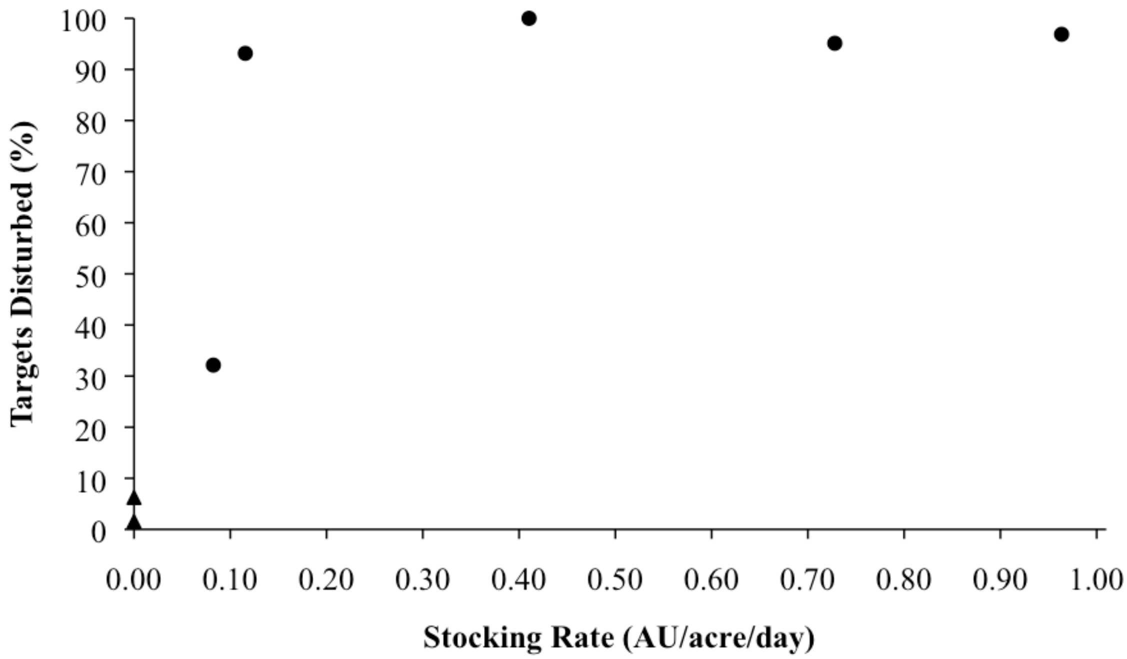

Figure 4. Percent of clay pigeon targets disturbed during 5 trials exposed to varying stocking rates (AU/acre/day) (circles, *n* =5) and 2 control trials with no exposure to cattle (triangles, *n* =2).

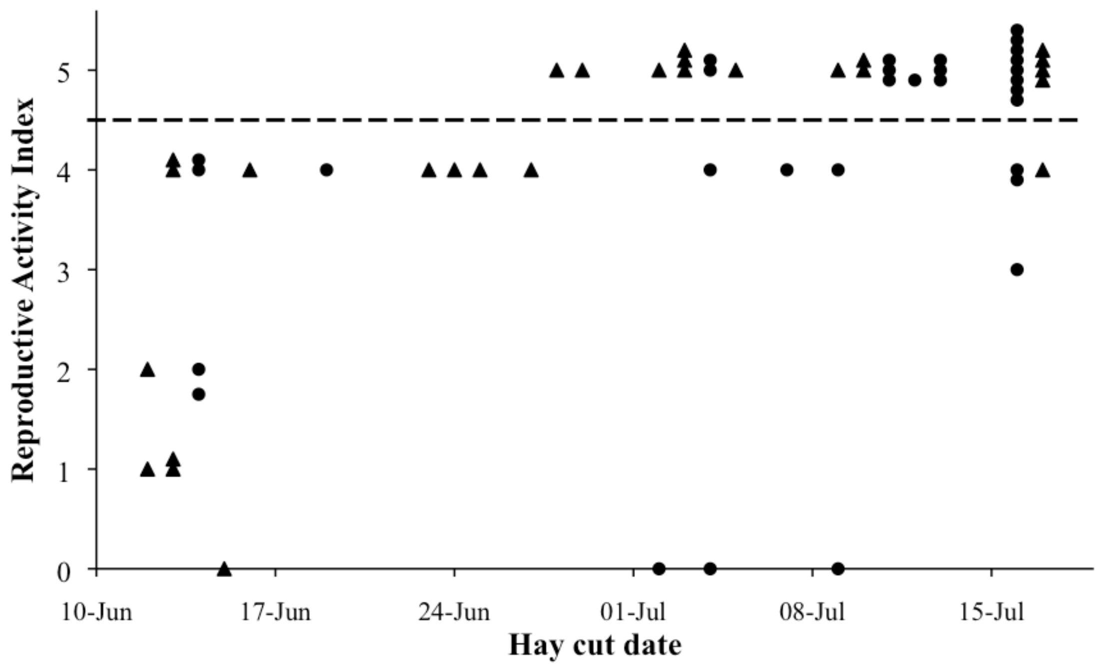

Figure 5. Bobolink reproductive activity index (jittered) at each hayfield site prior to hay cut in 2012 (triangle; *n* =27) and 2013 (circle; *n* =31). Hayfields cut after 15 July were dated 16 July. Sites above the dashed line produced at least 1 young. A reproductive index of 0 is assigned if no birds are present, 1 for a male Bobolink present for four or more weeks, 2 if a male and female Bobolink are present, 3 when adults are seen carrying nesting material, 4 for adults carrying food to nestlings, and a 5 for evidence of fledglings able to sustain flight (referred to as a reproductively successful site).

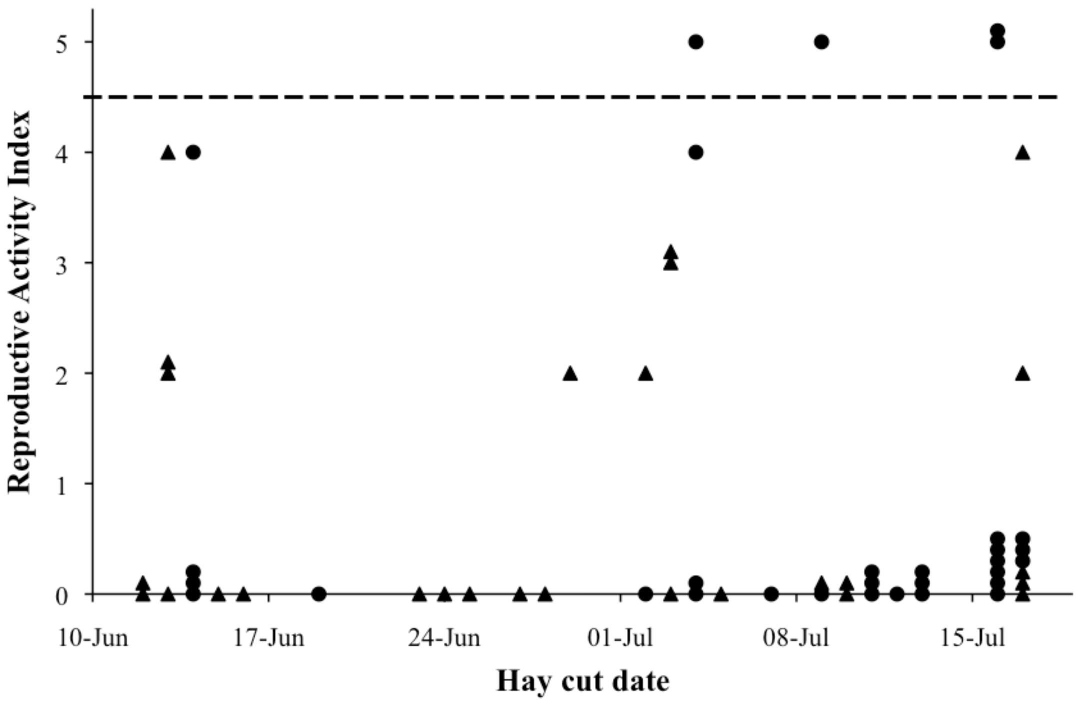

Figure 6. Eastern Meadowlark reproductive activity index (jittered) at each hayfield point count station prior to hay cut in 2012 (triangle; *n* =27) and 2013 (circle; *n* =31). Hayfields cut after 15 July were dated 16 July. Sites above the dashed line produced at least 1 young. A reproductive index of 0 is assigned if no birds are present, 1 for a single Eastern Meadowlark present for four or more weeks, 2 if two or more Eastern Meadowlarks are present, 3 when adults are seen carrying nesting material, 4 for adults carrying food to nestlings, and a 5 for evidence of fledglings able to sustain flight (referred to as a reproductively successful site).

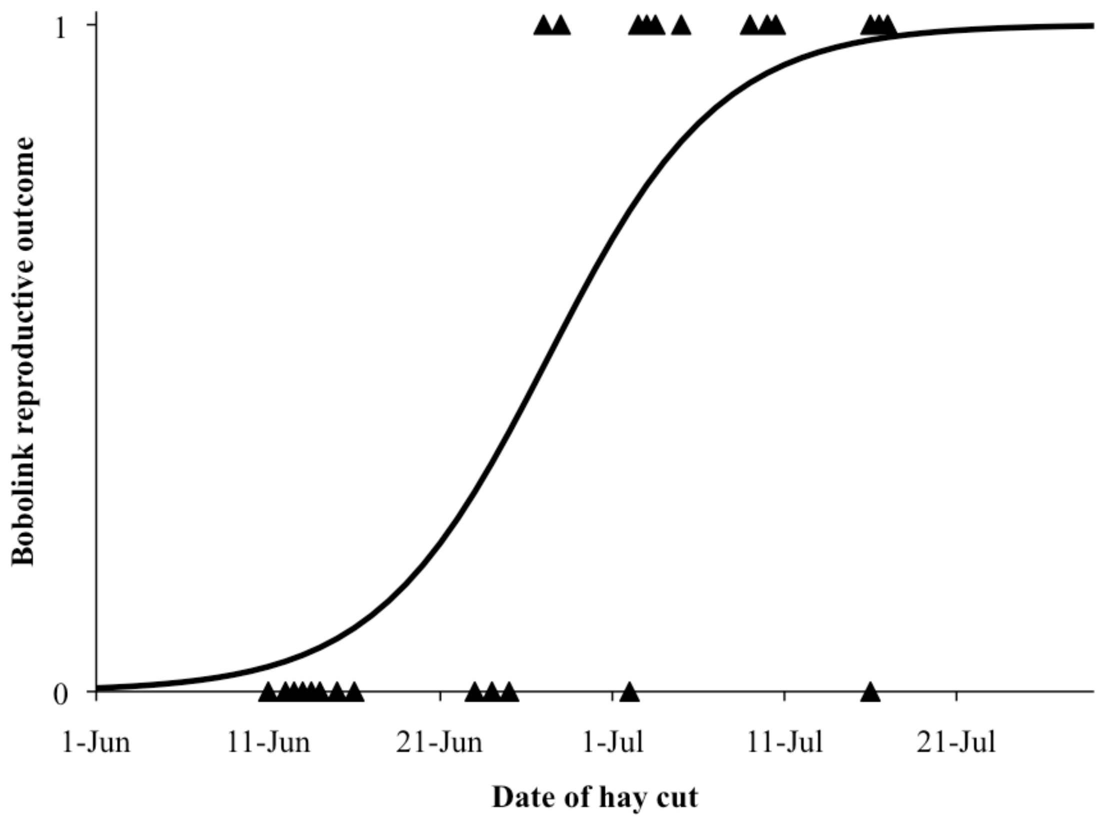

Figure 7. Bobolink reproductive outcome (0 = unsuccessful, 1 = successful; jittered) on each hayfield site prior to hay cut in 2012. Hayfields cut after 15 July were dated 16 July. The reproductive outcome of Bobolink with cut dates beginning on 12 June 2012 is described by the logistic regression equation: $g(x) = -35.65 + 0.20$ (hay cut date).

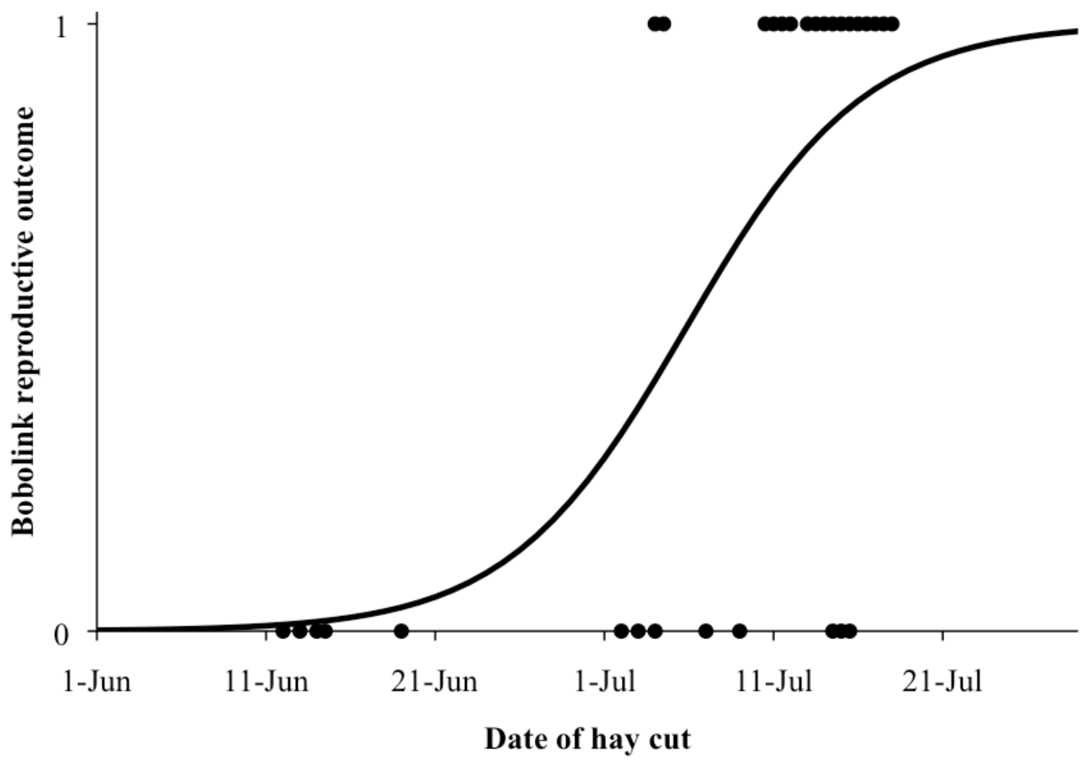

Figure 8. Bobolink reproductive outcome (0 = unsuccessful, 1 = successful; jittered) at each hayfield site just prior to hay cut in 2013. Hayfields cut after 15 July were dated 16 July. The reproductive outcome of Bobolink in hayfields with cut dates starting 14 June 2013 is described by the logistic regression equation: $g(x) = -35.50 + 0.19$ (hay cut date).

Table 1. Bobolink and Eastern Meadowlark nest outcomes (percent of total for agricultural category) found on four privately owned beef-cattle farms in Renfrew County in 2012 and 2013.

Species	Outcome	Ungrazed paddocks	Grazed paddocks	Uncut hayfield	Cut hayfield
Bobolink (*n* = 75)	Number of nests	25	8	38	4
	Successful	14 (56)	0	29 (76.3)	0
	Failed				
	Predation	9 (36)	0	9 (23.7)	0
	Farm activity	0	8 (100)	0	4 (100)
	Unknown	2 (8)	0	0	0
Eastern Meadowlark (*n* = 15)	Number of nests	6	2	5	2
	Successful	3 (50)	0	4 (80)	0
	Failed				
	Predation	3 (50)	0	0	0
	Farm activity	0	2 (100)	0	2 (100)
	Abandoned	0	0	1 (20)	0

Table 2. Mean vegetation characteristics (± standard error) measured during Bobolink territory establishment for hayfields and pasture sites on four privately owned beef-cattle farms in Renfrew County in 2012 and 2013. Bolded values indicate significant difference (Two-way ANOVA, $P < 0.05$) among year and/or field type.

Characteristic	Hayfields		Paddocks		Year	Field Type
	2012	2013	2012	2013	($F_{1,171}$)	($F_{1,171}$)
Grass cover (%)	31.68 ± 1.22	31.12 ± 0.59	45.37 ± 0.29	41.35 ± 0.29	0.21	**< 0.001**
Forb cover (%)	27.31 ± 1.05	25.85 ± 0.51	33.85 ± 0.29	26.44 ± 0.24	0.17	**0.02**
Alfalfa cover (%)	18.41 ± 0.71	8.95 ± 0.49	2.81 ± 0.14	1.02 ± 0.05	**0.02**	**< 0.001***
Dung cover (%)	0.29 ± 0.01	0.36 ± 0.04	1.39 ± 0.07	1.46 ± 0.05	0.92	**0.03**
Bare ground cover (%)	9.38 ± 0.36	11.19 ± 0.24	5.66 ± 0.13	9.25 ± 0.20	**0.03**	0.08
Litter cover (%)	12.93 ± 0.50	22.54 ± 0.45	11.21 ± 0.17	20.13 ± 0.23	**< 0.001**	0.29
Live vegetation cover (%)	96.83 ± 3.72	65.78 ± 0.44	94.73 ± 0.12	69.56 ± 0.25	**< 0.001**	0.62
Dead vegetation cover (%)	3.22 ± 0.12	34.22 ± 0.44	4.98 ± 0.11	30.17 ± 0.25	**< 0.001**	0.50
Vegetation height and density (cm)	22.48 ± 0.86	13.20 ± 0.20	16.65 ± 0.19	10.99 ± 0.10	**< 0.001**	**0.008**
Height (cm)	38.25 ± 1.47	24.95 ± 0.23	31.6 ± 0.24	21.51 ± 0.15	**< 0.001**	**0.007**
Litter depth (cm)	1.14 ± 0.04	1.80 ± 0.05	1.34 ± 0.02	1.70 ± 0.02	**0.009**	0.80
Bobolink abundance per point count ($F_{1,154}$)	6.77 ± 0.20	4.16 ± 0.11	2.27 ± 0.06	1.17 ± 0.04	**0.004**	**< 0.001**

*Significant interaction effect.

Table 3. Mean adult Bobolink abundance calculated for hayfields and pastures sites that contained reproductively success Bobolink and were untouched until after July 1 for each year on four privately owned beef-cattle farms in Renfrew County in 2012 and 2013.

Year	Field type	Number of sites	Mean Bobolink abundance per point count circle (100m radius)
2012	Hayfields	15	10.17 ± 0.67
2013	Hayfields	18	5.88 ± 0.17
2012	Paddocks	7	7.22 ± 0.52
2013	Paddocks	10	3.65 ± 0.22

Table 4. Percentage of variation explained and eigenvector coefficients for principal components retained for the logistic regression models describing the reproductive outcome of Bobolink (success=1; failure=0) on pasture paddocks on 4 beef-cattle farms in Renfrew County, ON, Canada, 2012-2013.

Vegetation Variable	PC1	PC2	PC3
Percentage explained	42	27	12
Eigenvector coefficients			
Grass cover	0.23	0.72	0.29
Forb cover	0.19	-0.62	0.45
Alfalfa cover	0.03	-0.03	-0.17
Dung cover	-0.02	0.002	-0.02
Bare ground cover	-0.13	-0.18	-0.17
Litter cover	-0.29	0.09	-0.37
Live vegetation cover	0.60	0.01	0.27
Vegetation height-density	-0.10	0.12	0.17
Litter depth	0.58	0.04	-0.53
Vegetation height	-0.31	0.18	0.37

Table 5. BIC model selection of logistic regression models (top models: ΔBIC< 2) describing the reproductive outcome of Bobolink (success=1; failure=0) on pasture paddocks predicted by vegetation characteristics (PCs) and farm management variables (entry date = date cattle entered a paddock, no. of entries = number of times cattle entered and grazed a paddock, stocking rate is measures by AU/acres/days) on 4 beef-cattle farms in Renfrew County, ON, Canada, 2012-2013.

BIC	Model	*n*	df	LogLik	BIC	ΔBIC	weight
2012	-30.05 + 0.155(entry date) – 0.053(PC2)	60	3	-9.553	31.4	0.00	0.218
	-20.84 + 0.106(entry date)	60	2	-11.627	31.4	0.05	0.212
	-24.06 + 0.126(entry date) + 0.106(PC3)	60	3	-10.017	32.3	0.93	0.137
	0.26 – 2.822(no. of entries)	60	2	-13.312	34.8	3.42	0.039
Global	-43.96 + 0.226(entry date) – 1.251(stocking rate) + 2.158(no. of entries) + 0.017(PC1) – 0.044(PC2) + 0.065(PC3)	60	7	-9.015	46.7	15.30	0.000
2013	-14.52 + 0.087(entry date) – 3.297(stocking rate)	60	3	-14.864	42.0	0.00	0.400
	-14.21 + 0.078(entry date)	60	2	-17.785	43.8	1.75	0.167
	-12.64 + 0.079(entry date) – 3.341(stocking rate) – 0.354(no. of entries)	60	4	-14.814	46.0	3.99	0.054
Global	-13.31 + 0.076(entry date) – 3.336(stocking rate) – 0.334(no. of entries) – 0.038(PC1) – 0.0005(PC2) + 0.027(PC3)	60	7	-14.757	58.2	16.16	0.000

Table 6. Importance values for each variable (entry date = date cattle entered a paddock, no. of entries = number of times cattle entered and grazed a paddock, stocking rate is measured by AU/acres/days, PCs represent different vegetation variables) for BIC model selection of logistic regression in Renfrew County, ON, Canada, 2012-2013

Variable	Entry date	Stocking rate	No. of entries	PC1	PC2	PC3
2012	0.887	0.129	0.224	0.118	0.419	0.281
2013	0.952	0.690	0.158	0.119	0.125	0.119

Table 7. Parameter estimates and 95% confidence intervals for model variables (entry date = date cattle entered a paddock, stocking rate is measures by AU/acres/days, PCs represent different vegetation variables) in the model-averaged logistic regression equations for the reproductive outcome of Bobolink (success=1; failure=0) on pasture paddocks on 4 beef-cattle farms in Renfrew County, ON, Canada, in 2012 and 2013.

Year	Variable	Estimate	Lower 95% CI	Upper 95% CI
2012	Intercept	-25.159	-46.632	-3.687
	Entry date	0.130	0.017	0.243
	PC2	-0.053	-0.116	0.009
	PC3	0.105	-0.027	0.238
2013	Intercept	-14.426	-23.067	-5.785
	Entry date	0.085	0.031	0.138
	Stocking rate	-3.297	-6.772	0.178

CHAPTER 3: GENERAL DISCUSSION

My research contributes to existing knowledge on Bobolinks (*Dolichonyx oryzivorus*) and Eastern Meadowlarks (*Sturnella magna*) breeding within Ontario. My primary research finding indicates that farm management is the most important factor in determining the reproductive outcome of Bobolinks and Eastern Meadowlarks in agricultural landscapes. In rotational pasture management, the main factor influencing Bobolink reproductive success is the date cattle enter a paddock to graze; paddocks grazed later in the season have a higher likelihood of containing reproductively successful Bobolinks. Through the clay-pigeon target experiment, I determined that decreasing the stocking rate is not a practical management strategy to improve the reproductive success of grassland birds as it would require an impractically low stocking rate (<0.08 AU/acre/day). Nevertheless, nests not trampled when exposed to grazing cattle will likely be disturbed, which could result in nest abandonment and/or predation due to decreased nest concealment (Perlut and Strong 2011).

Similar to Temple et al. (1999), I recommend that the best method to increase the reproductive success of Bobolinks on rotationally grazed farms is to allow a proportion of paddocks to remain ungrazed until the nesting season is complete, thus serving as a reproductive refuge. The reproductive refuge area can be reintroduced into the grazing management regime once nesting is complete. Already, some paddocks and hayfields included in the study remained untouched until after 1 July, providing the suggested reproductive refuge for Bobolinks and Eastern Meadowlarks. The more paddocks that remain ungrazed until 1 July (minimally), the higher reproductive success Bobolinks experience.

My results support the existing farming management recommendation that for Bobolinks to be reproductively successful in hayfields, hay cutting should be delayed until at least 1 July. However, this management strategy may not be feasible for many farmers because delaying hay cuts diminishes the nutrient quality of hay used for cattle feed (Nocera et al. 2005, Diemer 2013). Although the government should compensate farmers if they experience an economic loss as a result of management measures implemented in the interest of grassland birds, this compensation is not a feasible long-term management plan. To maintain the current population of Bobolinks and Eastern Meadowlarks in Ontario, farming management practices beneficial to these grassland birds would need to be introduced across their Ontario breeding range. Introducing and enforcing alternative management practices throughout Ontario would be a challenge. Because farms occur on privately owned land, it would be a challenge to ensure alternative farm management is being practiced and to monitor whether Bobolink and Eastern Meadowlark are reproducing successfully. In addition, trying to formulate a compensation plan that ensures farmers are equally and fairly reimbursed for losses appears to be a near impossible task. Due to understandable resistance by farmers to alter farming practices, farmers will avoid managing for Bobolink and Eastern Meadowlark by converting hay and pasture land to row crop (e.g., corn and soybean). The conversion to row crops will accelerate the loss of breeding habitat for these declining grassland birds.

Bobolink and Eastern Meadowlark should be protected as populations, individual birds, and their nests under the Migratory Bird Convention Act, 1994. These two species are also listed as Threatened in Ontario (COSSARO 2010, 2011), and should receive general habitat protection and protection from being harmed or harassed under the Ontario Endangered Species Act 2007. Agricultural operations are currently exempt from these laws until October 2014. When the exemption is over, long-term species management plans that include compensation for farmers who experience financial loss is necessary. If government compensation is refused and farmers cannot be persuaded to voluntarily alter farming practices, then these threatened populations may continue to decline. One possible solution is citizen-funded initiatives such as The Bobolink Project that was established in 2007 in Rhode Island, USA. This non-profit organization uses community contributions to compensate farmers for altered hay management practices that protect nesting Bobolinks (Swallow et al. 2012). Educational outreach programs that inform farmers and other landowners of threatened grassland species are critical. Focus should be placed on communicating breeding phenology, how landowners can assist in the bird's management, and the benefits of the birds. For example, Bobolink feed their altricial young insects (Wittenberger 1980, Wiens 1969, Skipper and Kim 2013), removing 8.65 grams of insects a day for every Bobolink nest (Peck and James 1987). Farmers must be informed that current policy does not allow government interference if the species are located on their property. With a lack of compensation, future strategies should attempt to capitalize on farms that have agricultural lands untouched prior to 1 July under typical management. We should ensure these farmers are aware of adjustments they can make to their management plan that will benefit nesting grassland birds without compromising their operation.

With approximately 661,000 ha of pasture in Ontario, the recommended management practices on rotationally grazed farms could have significant impacts on threatened grassland bird populations (Statistics Canada 2011). Because Eastern Meadowlarks have such large territories, ranging 3-15 acres (most commonly 7-8 acres) (Lanyon 1995 in Wisconsin), too few were nesting in the study area to confidently evaluate methods to best manage for their success. Future studies should focus on the nesting phenology of Eastern Meadowlarks in Ontario for best management plans to be developed.

LITERATURE CITED

Althoff, D.P., P.S. Gipson, J.S. Pontius, and R.D. Japuntich. 2009. Evaluation of a reproductive index to estimate grasshopper sparrow and eastern meadowlark reproductive success. Wildlife Biology in Practice 5:33-44.

Askins, R.A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11:2-34.

Askins, R.A. 1999. History of grassland birds in eastern North America. Studies in Avian Biology 19:60-71.

Barton, K. 2012. MuMIn: Multi-model inference. R package version 1.7.11. http://CRAN.R-project.org/package=MuMIn

Beintema A.J., G.J. Müskens. 1987. Nesting success of birds breeding in Dutch agricultural grasslands. Journal of Applied Ecology 24:743–758.

Bollinger, E.K., P.B. Bollinger and T.A. Gavin. 1990. Effects of hay-cropping on eastern population of the Bobolink. Wildlife Society Bulletin 18:142-150.

Bollinger, E.K. and T.A. Gavin. 1992. Eastern Bobolink populations: ecology and conservation in an agricultural landscape. Pp. 497 506 *in* J.M. Hagan III and D.W. Johnston (eds.). Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Institute Press, Washington, D.C.

Brennan, L. A., and W. P. Kuvlesky. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69:1–13.

Burnham, K. P., and D. R. Anderson. 2003. Model selection and multimodel inference: A practical information-theoretic approach, 2nd ed. Springer-Verlag, New York.

Cadman, M.D., D.A. Sutherland, G.G. Beck, D. Lepage, and A.R. Couturier (eds.). 2007. Atlas of the Breeding Birds of Ontario, 2001-2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto. xxii + 706 pp.

COSEWIC. 2010. COSEWIC assessment and status report on the Bobolink *Dolichonyx oryzivorus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 42 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSEWIC. 2011. COSEWIC assessment and status report on the Eastern Meadowlark *Sturnella magna* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 40 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSSARO. 2010. COSSARO Candidate Species at Risk Evaluation Form for Bobolink (*Dolichonyx oryzivorus*). Committee on the Status of Species at Risk in Ontario. 7pp. http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@species/

documents/research/stdprod_086353.pdf

COSSARO. 2011. COSSARO Candidate Species at Risk Evaluation for Eastern Meadowlark (*Sturnella magna*). Committee on the Status of Species at Risk in Ontario. 15 pp. http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@species/documents/research/stdprod_091154.pdf

Dale, B.C., P.A. Martin, and P.S. Taylor. 1997. Effects of hay management on grassland songbirds in Saskatchewan. Wildlife Society Bulletin 25: 616-626.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43-64.

Diemer, K.M. 2013. Evaluation of hayfield management strategies and Bobolink territorial habitat in southern Ontario. M.Sc. thesis, Trent University, Peterborough. 103 pp.

Drought in Central, Eastern Canada baking crop. (2012, July 15). CBC News. http://www.cbc.ca/news/canada/drought-in-central-eastern-canada-baking-crops-1.1184619

Fletcher, R.J. and R. Koford. 2003. Spatial responses of Bobolinks (*Dolichonyx oryzivorus*) near different types of edges in Northern Iowa. Auk 120:799–810.

Freemark, K. E., and D. A. Kirk. 2001. Birds on organic and conventional farms in Ontario: partitioning effects of habitat and practices on species composition and abundance. Biological Conservation 101:337-350.

Frei, B. 2009. Ecology and management of Bobolinks in hayfields of Quebec and Ontario. M.Sc. thesis, McGill University, Montreal. 79 pp.

Hannah, L., L. Carr, and A. Lankerani. 1995. Human disturbance and natural habitat: a biome level analysis of a global data set. Biodiversity and Conservation 4:128-155.

Harrison, G. 2004. Renfrew County State of the Environment Report. Renfrew County Stewardship Council, Ontario, Canada.

Herkert, J. R., R. E. Szafoni, V. M. Kleen, and J. E. Schwegman. 1993. Habitat establishment, enhancement and management for forest and grassland birds in Illinois. Illinois Department of Conservation, Division of Natural Heritage, Natural Heritage Technical Publication 1, Springfield, Illinois. 20 pages.

Jaster, L.A., William E. Jensen and Wesley E. Lanyon. 2012. Eastern Meadowlark (*Sturnella magna*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology.

Jolliffe, I.T. 2002. Principal component analysis. 2nd ed. Springer Series in Statistics. Springer-Verlag New York Inc. 489 p.

Joyner, D. E. 1978. Use of an old field habitat by Bobolinks and Red-winged Blackbirds. Canadian Field-Naturalist 92:383-386.

Kershner, E. L., J. W. Walk, and R. E. Warner. 2004. Breeding-Season Decisions, Renesting, and Annual Fecundity of Female Eastern Meadowlarks (*Sturnella magna*) in Southeastern Illinois. The Auk 121:796 805.

Koerth, B.H., W.M. Webb, F.C. Bryant, and F.S. Guthery.1983. Cattle trampling of simulated ground nests under short duration and continuous grazing. Journal of Range Management 36:385–386

Lanyon, W. E. 1957. The comparative biology of the meadowlarks (Sturnella) in Wisconsin (No. 1). The Club.

Lanyon, W. E. 1995. Eastern Meadowlark (*Sturnella magna*). A. Poole and F. Gill, editors. The Birds of North America, No. 160. The Academy of Natural Sciences, Philadelphia, PA.

MacPhail, V and J. Kyle. 2012. Rotational Grazing in Extensive Pastures. Ontario Ministry of Agriculture, Food and Rural Affairs, Guelph, ON. 30 pp.

Manitoba Forage & Grassland Association. 2009. Animal Unit Months, Stocking Rate and Carrying Capacity. Manitoba Agriculture, Food and Rural Initiatives. Winnipeg, Manitoba, Canada.

Martin, S.G. and T.A. Gavin. 1995. Bobolink. 24 pp., in A. Poole and F. Gill (eds.). The Birds of North America. Life Histories for the 21st Century, No.176. The Academy of Natural Sciences of Philadelphia, Philadelphia.

McCracken, J.D., R.A. Reid, R.B. Renfrew, B. Frei, J.V. Jalava, A. Cowie, and A.R. Couturier. 2013. Recovery Strategy for the Bobolink (*Dolichoyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*) in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources, Peterborough, Ontario. viii+ 88 pp.

Murphy, M.T. 2003. Avian population trends within the evolving agricultural landscape of eastern and central United States. Auk 120:20-34.

National Research Council (NRC). 1996. Nutrient requirements of beef cattle. Seventh revised edition, updated 2000. National Academy Press, Washington, D.C. 248 pp.

Nocera, J.J., G. Forbes, and G. Milton. 2007. Habitat relationships of three grassland breeding bird species: broadscale comparisons and hayfield management implications. Avian Conservation and Ecology 2:1-7.

Nocera, J.J., G.J. Parsons, G.R. Milton, and A.H. Fredeen. 2005. Compatibility of delayed cutting regime with bird breeding and hay nutritional quality. Agriculture, Ecosystems & Environment 107:245-253.

Norment, C.J., C. D. Ardizzone and K. Hartman. 1999. Habitat relations and breeding biology of grassland birds in New York. Studies in Avian Biology 19:112-121.

Norment, C. J., M.C. Runge and M.R. Morgan. 2010. Breeding biology of grassland birds in western New York: Conservation and Management Implications. Avian Conservation and Ecology 5(2):3.

Paine, L., D.J. Undersander, D.W. Sample, G.A. Bartelt, and T.A. Schatteman. 1996. Cattle trampling of simulated ground nests in rotationally grazed pastures. Journal of Range Management 49:294-300.

Pavel, V. 2004. The impact of grazing animals on nesting success of grassland passerines in farmland and natural habitats: a field experiment. Folia Zoologica 53:171-178.

Peck, G.K. and R.D. James. 1987. Breeding Birds of Ontario: Nidiology and Distribution. Vol. 2. Royal Ontario Museum, Toronto.

Perlut, N. G., A. M. Strong, T. M. Donovan, and N. J. Buckley. 2006. Grassland songbirds in a dynamic management landscape: behavioral responses and management strategies. Ecological Applications 16:2235-2247.

Perlut, N.G. and A. M. Strong. 2011. Grassland birds and rotational-grazing in northeast: breeding ecology, survival and management opportunities. Journal of Wildlife Management 75:715-720.

Perlut, N.G., A. M. Strong, and T. J. Alexander. 2011. A model for integrating wildlife science and agri-environmental policy in the conservation of declining species. Journal of Wildlife Management 75:1657-1663.

Peterjohn, B.G., and D.L. Rice. 1991. The Ohio Breeding Bird Atlas. Ohio Department of Natural Resources. Columbus, OH.

Posada, D. and T.R. Buckley. 2004. Model selection and model averaging in phylogenetics: advandtages of Akaike information criterion and Bayesian approaches over likelihood ratio tests. Systematic Biology 53:793-808.

Renfrew, R.B. and A.M. Saavedra. 2007. Ecology and conservation of Bobolinks in rice production regions in Bolivia. Ornitologia Neotropical 18:61-73.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-298.

Samson, F., and F. Knopf. 1994. Prairie conservation in North America. BioScience 44:418–421.

Schroeder, R. L., and P. J. Sousa. 1982. Habitat Suitability Index: Eastern Meadowlark. FWS/OBS 82/10. U.S. Fish and Wildlife Service. 9 pages.

Skipper, B.R. and D.H. Kim. 2013. Provisioning rate, dietary composition, and prey selection of breeding bobolinks and grasshopper sparrows. Western North American Naturalist 73:35-40.

Statistics Canada. 2011. Census of Agriculture. Web site: http://statcan.gc.ca/ca-ra2011/index-eng.htm

Sullivan, B.L., C.L. Wood, M.J. Iliff, R.E. Bonney, D. Fink, and S. Kelling. 2009. eBird: a citizen-based bird observation network in the biological sciences. Biological Conservation 142:2282-2292.

Swallow, S.K., C.M. Anderson, and E. Uchida. 2012. The Bobolink Project: selling public goods from ecosystem services using provision point mechanisms. Department of Agricultural and Resource Economics, College of Agriculture and Natural Resources, University of Connecticut. 45 pp.

Teague W.R. and S.L. Dowhower. 2003. Patch dynamics under rotational and continuous grazing management in large, heterogeneous paddocks. Journal of Arid Environments 53:211-229.

Temple, S.A., Fevold, B.M., Paine, L.K., Undersander, D. J., and D. W. Sample. 1999. Nesting birds and grazing cattle: accommodating both on Midwestern pastures. Studies in Avian Biology 19:196-202.

Tews, J., D. G. Bert, and P. Mineau. 2013. Estimated mortality of selected migratory bird species from mowing and other mechanical operations in Canadian agriculture. Avian Conservation and Ecology 8:2-8.

Tucker, J.W. Jr., Robinson, W.D. and Grand, J.B. 2006. Breeding productivity of Bachman's sparrows in fire-managed longleaf pine forests. Wilson Journal of Ornithology 118: 131-280.

Undersander, D., B. Albert, D. Cosgrove, D. Johnson and P. Peterson. 2002. Pastures for profit: a guide to rotational grazing. Cooperative Extension Publishing, University of Wisconsin-Extension.

Vickery, P. D., M. L. Hunter, and J. V. Wells. 1992. Use of a new reproductive index to evaluate relationship between habitat quality and breeding success. Auk 109:697-705.

Vickery, P.D., P.L. Tubaro, J.M.C. Da Silvam B.G. Peterjohn, J.R. Herkert and R.B. Cavalcanti. 1999. Conservation of grassland birds in the western hemisphere. Studies in Avian Biology 19:2-26.

Wiens, J.A. 1969. An approach to the study of ecological relationships among grassland birds. Ornithological Monographs 8:1-93.

Wittenberger, J.F. 1980. Vegetation structure, food supply, and polygyny in Bobolinks (*Dolichonyx oryzivorus*). Ecology 61:140-150.

APPENDIX

Table 8. Farm management characteristics of four privately owned beef-cattle farms in Renfrew County, ON in 2012 and 2013. Animal unit (AU) represents one cow or heifer.

Year	Beef-cattle operation	Herd number	Herd size (AU)	No. of paddocks available	No. of paddocks grazed before 1 July
2012	Farm 1	1	43	5	5
		2	45	7	6
		3	45	2	2
2012	Farm 2	1	42	9	4
		2	67	7	3
2012	Farm 3	1	20	3	1
		2	102	4	4
2012	Farm 4	1	32	8	8
		2	25	3	3
		4	25	2	2
		5	34	7	7
		6	36	5	5
2013	Farm 1	1	67	5	5
		2	22	5	5
2013	Farm 2	1	39	5	4
		2	18	5	2
		3	59	7	6
2013	Farm 3	1	6	3	2
		2	108	4	4
2013	Farm 4	1	32	8	8
		2	30	3	3
		3	27	2	2
		4	27	2	2
		5	37	7	7
		6	33	4	4

Biomass Study

Biomass energy crop production is a growing agricultural sector within Ontario because the provincial government has committed to phase out the use of coal by the end of 2014 to reduce greenhouse gas emissions and air pollution (Ontario Power Generation). Biomass crops are grown to provide the material used to produce energy. Biomass energy is derived from converting organic matter such as wood, and agricultural and municipal waste to produce bioproducts (biofuel, bioenergy, biochemicals, bioplastics, biomaterials) (Ontario Power Generation). However, with the increased use of natural gas, the market for biomass in Ontario has switched to primarily animal bedding, mushroom growing substrate, and feed for cattle (Betts and Withers 2012). Miscanthus (Miscanthus sp.) and switchgrass (*Panicum virgatum*) are the major biomass crops currently used and studied within Ontario (Samson 2007) and may serve as breeding habitat for obligate grassland birds.

Biomass fields appear to provide promising breeding habitat to grassland birds because biomass fields are generally harvested in late summer or fall, when the breeding season of grassland birds has mostly been completed (Murray et al. 2003, Roth et al. 2005). Comparatively, nests in hayfields and pastures are frequently destroyed by hay cutting or trampling by grazing cattle (Bollinger 1995, Paine et al. 1996, Temple et al. 1999, Perlut et al. 2006, Frei 2009). As the Ontario biomass energy industry is on the verge of expanding, research is required to investigate the potential of biomass crops to serve as successful breeding habitat for grassland birds, particularly two threatened species, the Bobolink (*Dolichonyx oryzivorus*) and the Eastern Meadowlark (*Sturnella magna*).

The objective of this research was to determine whether Bobolink and/or Eastern Meadowlark were using biomass crop fields for breeding habitat in Southern Ontario. Notwithstanding that biomass crops are harvested later in the season, I predicted that neither the Bobolink nor Eastern Meadowlark would use biomass crop fields for breeding habitat because biomass fields typically grow to over two meters in height by the end of May, a height less favorable for nesting grassland birds (Martin and Gavin 1995, Jaster et al. 2012). We collected bird abundance data from biomass plots located throughout southern Ontario.

We surveyed a total of 20 biomass sites: 8 switchgrass, 8 Miscanthus, and 4 tallgrass prairie sites and all sites were 1 or 2 years in production for the biomass target. Focal grassland birds and vegetation were surveyed within a single point count site throughout the field season. Five-minute, 100 m radius point counts were conducted on the edge of each field site forming a semi-circle. Semi-circles were employed to avoid entering the biomass fields. Point counts occurred between sunrise and 10:00h, weather permitting (no precipitation and wind speed $\leq$20 km/hr), from May to July in 2012 with approximately 10 visits to each site. Two focal species were recorded, the Bobolink and Eastern Meadowlark. We counted males, females, and fledglings, and recorded reproductive activity as a marker of reproductive success. Individual birds were visually monitored throughout the point count to limit double counting.

Vegetative surveys were conducted multiple times throughout the breeding season at each site. At each point count plot, four different square meter quadrats were placed at random. Within each quadrat, we measured percent cover of: live vegetation, dead vegetation, grass, forbs, alfalfa (*Medicago sativa*), litter, and bare ground. Vegetation height and litter depth were measured at the four corners of the quadrat and visual obstruction measurements were made (from a distance of 4 meters and a height of 1 meter) to determine vertical cover (height and density) using a Robel pole (Robel et al. 1970).

Neither Bobolinks nor Eastern Meadowlarks were present during any point count at any site. Although all 3 biomass field types had significantly different vegetation characteristics during Bobolink territory establishment, vegetation was poorly established providing unsuitable breeding habitat for Bobolink and Eastern Meadowlark (Table 7) (Martin and Gavin 1995, Jaster et al. 2012). However, Miscanthus sites became tall and dense and averaged a height of 186.6 cm between June 13 and July 5 at established Miscanthus sites.

We established that this sample of biomass fields are not used by the Bobolink and Eastern Meadowlark as breeding habitat and therefore should not be considered as an alternative habitat for these threatened birds in Ontario. However, we cannot rule out that some species such as Horned Lark (*Eremophila alpestris*), could perhaps benefit from the production of perennial biomasses (Roth et al. 2005, Robertson et al. 2012), as long as harvesting does not overlap with their breeding season. Future studies must incorporate all avian species on fully established biomass sites (>3 years).

Table 9. Mean vegetation characteristics (± standard error) measured during Bobolink territory establishment in three different biomass fields across southern Ontario in 2012. Two-way ANOVA indicates vegetative characteristics are significantly different in different biomass fields ($P<0.05$).

Characteristic	Miscanthus	Switchgrass	Tallgrass Prairie	Field Type ($F_{2,17}$)
Grass cover (%)	23.69 ± 2.55	10.00 ± 0.98	16.94 ± 5.92	0.001
Forb cover (%)	20.69 ± 2.82	41.38 ± 2.58	33.34 ± 7.55	0.02
Alfalfa cover (%)	0.28 ± 0.10	-	-	0.14
Bare ground cover (%)	25.94 ± 2.15	30.84 ± 1.68	30.56 ± 5.51	< 0.001
Dead vegetation cover (%)	29.69 ± 2.48	17.78 ± 1.83	19.13 ± 3.19	< 0.001
Live vegetation cover (%)	58.25 ± 3.25	74.43 ± 2.39	73.28 ± 3.26	< 0.001
Vegetation height and density (cm)	4.77 ± 0.52	2.38 ± 0.20	3.82 ± 1.34	0.002
Height (cm)	15.18 ± 1.59	9.64 ± 0.52	14.19 ± 1.34	< 0.001
Litter depth (cm)	0.45 ± 0.02	0.45 ± 0.02	0.36 ± 0.04	< 0.001

LITERATURE CITED

Betts, N. and K. Withers. 2013. Biomass growers' guide. Agricultural Management Institute. Ontario. 26 pp.

Bollinger, E.K., P.B. Bollinger and T.A. Gavin. 1990. Effects of hay-cropping on eastern population of the Bobolink. Wildlife Society Bulletin 18:142-150.

Frei, B. 2009. Ecology and management of Bobolinks in hayfields of Quebec and Ontario. McGill University.

Jaster, L.A., W.E. Jensen and W.E. Lanyon. 2012. Eastern Meadowlark (*Sturnella magna*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology.

Martin, S. G., and T. A. Gavin. 1995. Bobolink (*Dolichonyx oryzivorous*) in A. Poole and F. Gills, editors. The Birds of North America. The Birds of North America, Inc., Philadelphia, PA.

Murray, L. D., L.B. Best, T.J. Jacobsen, and M.L. Braster. 2003. Potential effects on grassland birds of converting marginal cropland to switchgrass biomass production. Biomass & Energy 25:167–175.

Ontario Power Generation, Summary Report: Biomass sustainability analysis (OPG, 2011)

Paine, L., D.J. Undersander, D.W. Sample, G.A. Bartelt, and T.A. Schatteman. 1996. Cattle trampling of simulated ground nests in rotationally grazed pastures. Journal of Range Management 49:294-300.

Perlut, N.G., A.M. Strong, T.M. Donovan, and N.J. Buckley. 2006. Grassland songbirds in a dynamic management landscape: behavioral responses and management strategies. Ecological Applications 16:2235-2247.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-298.

Roth, A. M., D.W. Sample, C.A. Ribic, L. Paine, D.J. Undersander and G.A. Bartelt. 2005. Grassland bird response to harvesting switchgrass as a biomass energy crop. Biomass & Energy 28:490–498.

Robertson, B.A., R.A. Rice, T.S., Sillett, C.A. Ribic, B.A. Babcock, D.A. Landis, J.R. Herkert, R.J. Fletcher, J.J. Fontaine, P.J. Doran, and D.W. Schemske. 2012. Are Agrofuels a Conservation Threat or Opportunity for Grassland Birds in the United States? Condor 114:679–688.

Samson, R. 2007. Switchgrass production in Ontario: A management guide. Online: Resource Efficient Agricultural Production (REAP)-Canada, Ste. Anne de Bellevue, Quebec.

Temple, S.A., B.M. Fevold, L.K. Paine, D.J. Undersander, and D.W. Sample. 1999. Nesting birds and grazing cattle: accommodating both on Midwestern pastures. in Perlut, N.G. and A. M. Strong. 2011. Grassland birds and rotational-grazing in northeast: breeding ecology, survival and management opportunities. Journal of Wildlife Management 75:715-720.