ECOLOGY AND MANAGEMENT OF BOBOLINKS IN HAYFIELDS OF QUÉBEC AND ONTARIO

Barbara Frei

Department of Natural Resource Sciences

McGill University, Montreal

April 2009

A thesis submitted to McGill University in partial fulfilment of the requirements of the degree of Masters of Science

© Barbara Frei 2009

DEDICATION

For the rowdy of the meadow.

The Bobolink is Gone

The Bobolink is gone The Rowdy of the Meadow And no one swaggers now but me The Presbyterian Birds Can now resume the Meeting He boldly interrupted that overflowing Day When supplicating mercy In a portentous way He swung upon the Decalogue And shouted let us pray

- Emily Dickson

ABSTRACT

This study examines Bobolink (*Dolichonyx oryzivorus*) nest success, nest-site selection, and nestling growth and survival with the goal of establishing conservation and management plans for hayfields of Québec and Ontario. Bobolink nest survival increased with age of the nest and was higher in managed hayfields than at less-managed sites in close proximity to wetlands. Female bobolinks selected nests with higher forb composition and higher overhead concealment. If haying in the region is optimally delayed until 15 July and minimally until 1 July, this allows time for Bobolink young to fledge, as well as harvesting of hay late to use as animal fodder. For late-cut fields, increased forb composition provides high-quality nesting habitat. For early-cut fields, which ultimately lead to nest and nestling destruction, nesting may be deterred by a lack of forbs. Basic Bobolink nest ecology and nestling growth is described to serve as a baseline for further research on this understudied species.

RÉSUMÉ

Cette étude porte sur la réussite de la nidification, la sélection du site de nidification et l'écologie des oisillons du Goglu des Prés (Dolichonyx oryzivorus), pour objectif d'établir des plans de conservation et de gestion des champs de foin du Québec et de l'Ontario. La survie des nichées de Goglu des Prés a augmenté avec l'âge des nids et était supérieure dans un champ de foin géré que dans un site moins géré a proximité d'un milieu humide. Les femelles ont choisi des nids avec une plus grande composition en herbes nongraminéennes et un camouflage aérien plus important. Si la récolte dans la région est rapporte de façon optimale jusqu'au 15 juillet et au minimum jusqu'au 1^{er} juillet, il y aurait suffisamment de temps pour que les jeunes Goglus atteignent la phase d'envol et aussi si une récolte de foin tardif soit faite pour le fourrage. Pour les champs tardifs, une plus grande composition en herbes non-graminéennes fournit du habitat de haute qualité. Pour les champs coupées tôt, qui finalement cause la destruction des nids et l'oisillon, la nidification des Goglus peu être dissuadé par une absence des herbes non-graminées. Finalement, l'écologie du nid et la croissance de l'oisillon chez le Goglu des Prés ont été décrites afin de servir de référence pour de futures recherches sur cette espèce qui n'est pas suffisamment étudiée.

TABLE OF CONTENTS

DEDICATION	ii
ABSTRACT	iii
RÉSUMÉ	iv
TABLE OF CONTENTS	v
LIST OF TABLES v	'iii
LIST OF FIGURES	X
ACKNOWLEDGEMENTS	xi
PREFACE x	iii
CONTRIBUTION OF AUTHORS x	iii
CHAPTER 1: GENERAL INTRODUCTION AND LITERATURE REVIEW	1
RESEARCH SIGNIFICANCE AND OBJECTIVES	1
GRASSLANDS AND AGRICULTURE	2
Declines of Grassland Birds	3
Grassland Birds Use of Agricultural Land	4
THE BOBOLINK	6
Site Fidelity at Breeding Grounds	7
Edge Effect Sensitivity	8
Vegetation Characteristics at Breeding Grounds	9
Bobolink Declines in the Northeast	9
GRASSLAND BIRD CONSERVATION IN THE AGRI-ENVIRONMENT	10
Conservation Programs	11
Management: Rotational Grazing	13

Management: Delayed Hay-cropping	14
Management: Warm-season Grasses	. 15
Management: Landscape Perspective	16
LITERATURE CITED	17
CONNECTING STATEMENT	25
CHAPTER 2: BOBOLINKS NEST SUCCESS IN HAYFIELDS OF QUÉBEC AI	ND
ONTARIO	26
ABSTRACT	26
INTRODUCTION	27
STUDY AREA	28
METHODS	29
Statistical Analysis	. 31
Phenology	. 31
Nest Success	31
Nest-site Selection	33
RESULTS	34
Nest Success	34
Nest-site Selection	35
DISCUSSION	36
Nest Success	37
Nest Predation	38
Nest-site Selection	39
Management Implications	. 40

Managing Hayfields for Bobolinks	40
Minimizing Ecological Traps	41
ACKNOWLEDGEMENTS	42
LITERATURE CITED	47
CONNECTING STATEMENT	62
CHAPTER 3: NESTLING GROWTH OF BOBOLINKS	. 63
ABSTRACT	63
INTRODUCTION	64
Nestling Growth Patterns	. 64
STUDY AREA	65
METHODS	65
Nestling Measurement	. 65
Statistical Analysis	. 66
RESULTS	67
Clutch Size and Egg Measurements	67
Nestling Measurements and Growth	67
DISCUSSION	68
General Nest Ecology	68
Nestling Growth	69
ACKNOWLEDGEMENTS	72
LITERATURE CITED	72
APPENDIX A	80
Animal Care Committee-Approved Form	. 80

Banding License for B.F.		81
Junior Author Manuscrir	ot Permits	82

LIST OF TABLES

Chapter 2.

Table 1. Nesting ecology of Bobolinks at Atocas Bay, Ontario (AT), Bois-de-la	a-
Roche, Québec (BR) and Hemmingford, Québec (HM) for 2006 and 2007. Re-	
nests were excluded	49

Table 2. Apparent nest success for Bobolinks at Atocas Bay, Ontario (AT), Boisde-la-Roche, Québec (BR), and Hemmingford, Québec (HM) for 2006-2007... 50

Table 5. Bobolink daily survival rates (DSR) and Mayfield nest success calculatedover the 28-day nesting cycle for individual sites and years.54

Table 6. Nest-site vegetation variables tested for correlation with Pearson'sproduct-moment correlation coefficient.55

Table 7. Nest-site vegetation variables (mean \pm SE) for Bobolink nest and nonnest sites in 2006-2007 and the corresponding correlation coefficient with the first canonical discriminant function. 56

Chapter 3.

Table 1. Mean clutch size and egg measurements of Bobolinks at Atocas Bay,Ontario (AT), Bois-de-la-Roche, Québec (BR) and Hemmingford, Québec (HM)for 2006 and 2007 and significance values of non-parametric statistical tests.75

Table 2. Mean wing, tarsus, and mass measurements with standard error for 102Bobolink nestlings from three study sites for 2006 and 2007.76

LIST OF FIGURES

Chapter 2.

Chapter 3.

Figure 1. Nestling growth represented as a % of parameters of breeding adult	
male for wing length, tarsus length, and mass for bobolink nestlings pooled for	3
sites and 2 years	78

ACKNOWLEDGEMENTS

The experiences and memories over the last few years have left me with much and many to be thankful for.

I would like to thank first and foremost the wonderful people at McGill and who helped me, inspired me, and shared with me the triumphs and challenges of this project. My colleagues, the aptly named BirdCagers, were always there with me to share their insight and impressive wisdom and experiences. To BirdCagers past and present, you made my years at Mac the amazing journey it was. Special thanks to Marcel Gahbauer who helped set me down the path of birding and taking me under his 'wing', Sarah Marteinson for always looking at the bright side of things, Shawn Craik for his endless patience for stats (and so much else!) and for always turning to me with a smile in response to my questioning silences, and Marie-Anne Hudson, for being my friend, partner-in-crime, and pillar of strength. It never would have been the same without you. And to the patriarchs of the BirdCagers, my supervisors Rodger D. Titman and David M. Bird for their support and wisdom, I am so grateful. They never said no when I asked "Just one more question?" And to my field team, the "bobo-gals": Carine Lecoeur, Kate Robinson, Rachel Theoret-Gosselin, and Rachel Verkade, I thank you for all your smiles and stamina!

Funding for this project was provided by the Natural Sciences and Engineering Research Council (NSERC), la Fondation de la faune du Québec (FFQ), the Canadian Wildlife Service (CWS), with special thanks to Gilles Falardeau, Bird Protection Québec (BPQ), and McGill University.

xi

For me, my greatest feats lay not in these pages, but in the phone calls, emails, and in-person inquiries and stories that so many shared with me, about the bobolinks they knew, loved, and protected. Just one of these stories, one of the fields I was told that would be managed with a careful eye towards bobolinks, just makes it all worthwhile. For that, thanks go to A. Stairs, L. Laviolette, B. Mcfarlane, P. Meldrum, A. Pelletier, S. Cauchon, A. and A. Roth, G. Gruner, B. Macduff, R. Renfrew, and many, many more. And to Dr. J. Day, the champion of bobolinks on Wolfe Island --- we won't give up!

And most of all, I am grateful to those who have shaped me most, my family. To my wonderful parents, Kurt and Maria, and my brother Michael, I can never thank you enough. You always shared my dreams, my ups and downs, tears and triumphs. You nurtured my curiosity, tempered my strength, and supported me from blacklighting to bird-banding!!!

And to Daniel, my love. For walking with me all these steps and all those ahead.

PREFACE

This thesis consists of three chapters. It is manuscript-based, with scientific names and literature cited provided for each independent section. For consistency, the style of Journal of Field Ornithology is used throughout. The first chapter is a general overview and literature review (*Chapter 1: General introduction and literature review*). In the second chapter I explore nest success and nest-site selection of local Bobolink populations and formulate management recommendations for the conservation of this declining species, with planned submission to the Journal of Field Ornithology (*Chapter 2: Nest success of Bobolinks in hayfields of Québec and Ontario*). In the final chapter, I report Bobolink nest ecology and nestling growth (*Chapter 3: Nestling growth of Bobolinks*). This chapter is currently being edited following its submission and review to the Wilson Journal of Ornithology.

CONTRIBUTION OF AUTHORS

In chapters 2 and 3 the candidate is the senior author. I was responsible for the planning, experimental design, logistic support and fund acquisition, implementation and execution of field research, and performed the collection, compilation and analysis of the data, and wrote the manuscripts. R.D. Titman and D.M. Bird, junior authors in chapters 2 and 3, were involved in planning of the study and provided analytical and editorial guidance throughout the preparation of the manuscripts. In addition for chapter 2, G. Falardeau is a junior author and provided insight, financial support, and additional guidance for the study.

CHAPTER 1: GENERAL INTRODUCTION AND LITERATURE REVIEW RESEARCH SIGNIFICANCE AND OBJECTIVES

Recent findings of the Partners-in-Flight conservation plan (Ontario Partners in Flight 2005) estimate that 17% of the world's breeding Bobolink (*Dolichonyx oryzivorous*) population is supported by the St-Lawrence Plain, making it the largest population within the species' range. Most of this physiographic region is found in Canada and includes southwestern Québec and southern Ontario as well as northern New York and northwestern Vermont in the United States (Ontario Partners in Flight 2005).

Despite distinct changes in Québec agricultural practices and land use over the last 30 years, few studies have attempted to document their effects on farmland bird habitats and population trends (Jobin et al. 1996). Three major agricultural/land changes have occurred in the last three or four decades: (1) small farm abandonment and resulting land regeneration or urbanization, (2) intensification and growth of monocultures leading to destruction and cultivation of most fertile areas, and (3) slow decline of the dairy industry leading to the loss of many hayfields and pastures (Jobin et al. 1996).

Recent research concerning the Québec Bobolink population is lacking, despite findings from the Breeding Bird Survey (BBS) showing that it is undergoing one of the most severe breeding population declines across the species' entire range (Wells and Rosenberg 1999). Thus, there is an urgent need for research into the conservation and management of Québec's Bobolink population.

My aim was to assess the local breeding ecology of Bobolinks and enhance local conservation planning and management of the species. Private agricultural land provides important breeding habitat for Bobolinks (Bollinger et al. 1988, Bollinger and Gavin

1

1992, Bollinger 1995, Dale et al. 1997), thus conservation planning and implementation in these areas are critical. Publicly owned grasslands and prairie remnants are currently small in size, and will remain so, in contrast to the extensive privately owned grasslands (Cunningham 2005). Therefore, private land conservation based on an understanding of local wildlife populations and systems with adaptive strategies is the most complete and holistic approach to Bobolink conservation in the northeast part of the continent.

GRASSLANDS AND AGRICULTURE

The grasslands of North America historically constituted the largest ecosystem on the continent, spanning the middle of the landmass. This ecosystem is also the most altered by humans. Since the early 1800s, with the advent of agriculture, the grasslands have been modified to such an extent that they have become the continent's most endangered ecosystems (Vickery et al. 1999). Such extensive habitat destruction and alteration is not restricted to North America, as parallel grassland losses are occurring worldwide. The loss of the pampas and other grassland habitats in South America is now garnering attention; for example, the destruction of grasslands in Brazil has been considered 'one of the greatest ecological catastrophes in South America' (Collar et al. 1992).

The remaining grasslands are often significantly changed from their historical or natural state. For example, the plowing and overgrazing of the Canadian prairies has made them perhaps the most extensively altered biome on the planet (Gayton 1990); less than one quarter remains uncultivated. And, as it is with many grasslands remnants, the remaining natural prairie is altered through haying, grazing or both (Dale et al. 1997). The natural disturbance cycles have been halted or interrupted, such as beaver activity and fires, which are known to maintain or create early-successional habitats such as grasslands (Vickery and Dunwiddie 1997).

The presumed existence of naturally occurring and historical grasslands in northeastern North America has long been a point of contention among researchers. Botanists have argued since the early 20th century that the past perception of the east as a continuous blanket of forest is false, and that the forests were interspersed with scrublands, barrens, and large grassy areas (Askins 1999). There were some well-recognized eastern grasslands, such as the Hempstead Plains (20,000 ha) and Montauk Downs (2,400 ha), but such areas were swiftly altered by agriculture and urbanization by early settlers (Peterjohn and Sauer 1999).

Declines of Grassland Birds

A well-recorded consequence of worldwide grassland habitat loss is the parallel loss of grassland or farmland birds. In North America, this decline is widespread for many grassland bird species and encompasses both the midwestern prairies and northeastern grasslands and hayfields. As for the grasslands themselves, conservationists have questioned the historical presence of grassland birds in the northeastern North America. Agricultural increases in the northeast by European settlers created farmland habitat that was used by grassland birds in areas where prior to that, no such habitat was available. The common viewpoint that midwestern grassland birds expanded their ranges eastwards is supported by movement studies with several well-documented examples, such as the Horned Lark (*Eremophila alpestris*), Lark Sparrow (*Chondestes grammacus*), Western Meadowlark (*Sturnella neglecta*), and Dickcissel (*Spiza americana*) (Vickery and Dunwiddie 1997). This is especially evident in the case of the Dickcissel, where the expansion in the mid-1800s was retracted as the suitable farmland habitat disappeared due to agricultural intensification (Vickery and Dunwiddie 1997). Today, the Dickcissel has disappeared from the northeast and remains solely within its historical midwest range (Vickery and Dunwiddie 1997).

Yet, according to detailed reports from early ornithologists, certain species of grassland birds are 'commonly' found in the northeast, such as the Upland Sandpiper (*Bartramia longicauda*), Grasshopper Sparrow (*Ammodramus savannarum*), Savannah Sparrow (*Passerculus sandwichensis*), Eastern Meadowlark (*S. magna*), and Bobolink (Askins 1997). For these species the lack of range expansions from the midwest prairies (Vickery and Dunwiddie 1997) points to a historical presence in the northeast.

Grassland Bird Use of Agricultural Habitat

The term 'farmland bird' has become, at times, synonymous with 'grassland bird' since many grassland species have found farmlands, particularly hayfields and pastures, to be surrogate grassland habitats. These surrogate habitats have provided breeding habitat for several species, but intensification of agriculture in the last 50 years has made much of the habitat unsuitable or unusable, which has proven to be a threat for populations of several grassland species (Warner 1994, Herkert 1997, Vickery et al. 1999).

The initial land clearing by European settlers in eastern North America resulted in pastures and hayfields to support livestock (Askins 1999). These large and infrequently disturbed grassy habitats were ideal for most grassland bird species (Askins 1999). A distinct shift has occurred in the last 50 - 60 years with the advent of new technology and 'improved' farming techniques, namely a shift from a mixed farm and dairy farm system

to an intensively arable, mainly cereal and monocrop system (Krebs et al. 1999). Factors associated with this shift have been implicated as causes for decreased breeding success and population declines in farmland species. These include increased use of pesticides and chemical fertilizers, increased mechanization, earlier planting and harvesting, and loss of traditional crop rotations (Bollinger and Gavin 1992, Knopf 1994, Jobin et al. 1996, Krebs et al. 1999, Chamberlain et al. 2000).

The same factors that caused declines of grassland bird species in the midwestern grasslands are now causing declines in farmland habitats (Bollinger et al. 1990, Martin and Gavin 1995, Jobin et al. 1996, Dale et al. 1997, Herkert 1997). In certain areas hayfields have decreased by 95% due to regeneration, urbanization, and replacement by monoculture (Herkert 1997). One of the most significant changes has involved earlier mowing or grazing resulting from the increased use of exotic cool-season grasses (Bollinger et al. 1990, Giuliano and Daves 2002). These non-native species such as Orchard Grass (Dactylis glomerata), Timothy (Phleum pretense), and Smooth Brome (Bromus inermis) produce a majority of their biomass before 1 June (Giuliano and Daves 2002). This has caused the median hay cutting date to occur two - three weeks earlier over a 50-year span, and it now overlaps the bird-nesting season with disastrous results (Bollinger et al. 1990, Martin and Gavin 1995, Herkert 1997). In comparison, native warm-season grasses produce a majority of their biomass after 1 June, and thus having of these fields is conducted in July or August, after the breeding season of most birds (Giuliano and Daves 2002).

THE BOBOLINK

The Bobolink is a neotropical migrant and obligate grassland passerine that breeds in southern Canada and northern United States and over-winters in Bolivia, Paraguay, and Argentina (Martin and Gavin 1995). It is one of the few grassland species that migrates to overwinter outside North America (Murphy 2003). It makes a 20,000 km trans-equatorial flight between nesting and wintering grounds (Martin and Gavin 1995). Historically, Bobolinks bred in the tallgrass and central mixed-grass prairies of North America, but due to the destruction and alteration of these ecosystems, a larger proportion of the breeding population can now be found on agricultural land such as hayfields and pastures (Martin and Gavin 1995, Herkert 1997). Despite tremendous habitat loss, this adaptive nesting behavior has allowed the Bobolink to persist, albeit in a declining state.

Male Bobolinks return to breeding grounds in northeastern North America in early May approximately one week prior to females (Martin and Gavin 1995). Older males precede younger males, thus territories initially formed are large but often shrink in size once additional males arrive. Polygyny has been recorded in Bobolinks. Nest building and incubation is performed solely by the female. During this time males are occupied with almost continual territorial displays and flights. Bobolinks are, for the most part, single-brooded, as a consequence of their long migration and short nesting season. The rearing of a second brood is typically a result of early failure or destruction of the first nest (Martin and Gavin 1995).

Clutch size varies from three to seven eggs, with one egg deposited per day, usually in the early morning (Martin and Gavin 1995). Incubation by the female is initiated upon laying of the penultimate egg (Martin 1974) and takes 11 - 12 days, with most eggs hatching within 24 - 48 hours of each other (Martin and Gavin 1995). Both males and females feed the growing nestlings a variety of insects, primarily Lepidoptera and sawfly larvae. Young Bobolinks fledge around day nine - 10; yet due to partly sheathed flight feathers at this time, remain poor fliers for several days after fledging (Martin and Gavin 1995).

Site Fidelity at Breeding Grounds

Bobolinks, both males and females, show high levels of site fidelity, returning to the same field or grassland to nest year after year (Martin and Gavin 1995). Male and female Bobolinks are influenced in their choice of breeding sites by their breeding success at a site in the previous year (Gavin and Bollinger 1988). As a single-brooded species, the female must be very choosy to ensure that her chances are maximized to produce a successful brood, for there is no 'second chance' later in the season. Due to the resource-defence nature of the Bobolink mating system, territory acquisition is paramount for the male's reproductive success (Bollinger and Gavin 1989).

Breeding site fidelity for Bobolinks is the outcome of experience-based choices and not a simple reflection of mortality (Bollinger and Gavin 1989) where fewer birds return to a poor-quality site due to a higher mortality at that site the previous year. These experience-based choices are especially apparent at poor-quality sites. Successful birds return to breed at both good-quality and poor-quality sites, yet unsuccessful birds were far more likely to return to good-quality sites than poor-quality sites (Bollinger and Gavin 1989). This suggests that Bobolinks may discern a site's 'productivity' despite individual lack of success, from habitat use outside the nesting season, i.e., during pre-migration aggregations (Bollinger and Gavin 1989). The act of an unsuccessful individual returning to a good-quality breeding site is adaptive, since the probability of breeding success in the following years is high in comparison to returning to a poor-quality site (Bollinger and Gavin 1989). Young Bobolinks survey for the following year's breeding sites between the end of the current breeding season and their departure for migration through the use of inadvertent social information (ISI) such as the number and density of territory-holding males (Nocera et al. 2006).

Edge-Effect Sensitivity

Negative effects of habitat edges were first described for interior-nesting forest birds but recently have been documented for several grassland bird species (Winter et al. 2000, Herkert et al. 2003). Edge effects in grassland habitats, including increased predation from mammalian predators, higher rates of Brown-headed Cowbird (*Molotrus ater*) parasitism and general edge avoidance may be contributing to declines occurring in grassland birds (Bollinger and Gavin 1992, Knopf 1994, Herkert 1997).

To determine whether edge avoidance is an adaptive and learned response to lower reproductive success near edges or an innate attraction to large, open areas that mimic the historical prairie habitat is not easy to discern. The Bobolink has consistently been reported as an area-sensitive species (Bollinger 1995, Johnson and Igl 2001) that actively avoids wooded edges and roads (Fletcher and Koford 2003). Bobolinks reportedly suffer elevated rates of predation and parasitism near forested edges (Johnson and Temple 1990). Edge avoidance by Bobolinks is inconsistent, as there is no discernible avoidance of edge near agricultural land (Bollinger and Gavin 2004). Edge avoidance may be a combination of learned avoidance of certain edge habitats as well as other factors, such as

innate attraction to larger grassland tracts.

Vegetation Characteristics of Breeding Grounds

Vegetation characteristics are viewed as the most important variable in avian breeding habitat selection (Rotenberry and Wiens 1980, Bollinger 1995). In grassland habitats, nests are highly vulnerable to the elements such as rainfall, wind, and sun exposure as well as predation. Thus, the choice of the right habitat, and within that habitat, the best microhabitat, is of vital importance for breeding success of the individual.

In northeastern North America, hayfields appear to be the largest available tracts of suitable habitat for nesting Bobolinks (Bollinger and Gavin 1992). In a comparison of hayfields, pastures, and native prairie habitats, older hayfields had far more Bobolinks associated with them than any other habitat and thus, they appeared to be an 'optimum' habitat (Bollinger and Gavin 1992). Older hayfields were associated with higher litter cover, sparser vegetation cover, and a higher % grass to % legume ratio, especially a distinct lack of alfalfa (*Medicago sativa*) (Bollinger and Gavin 1992). The early cutting of alfalfa creates a highly disturbed habitat. Other microhabitat selections and fooddriven selections remain mostly unknown.

Bobolink Declines in the Northeast

Since the inception of the Breeding Bird Survey (BBS) in 1966, which remains the only continental grassland bird survey, Bobolink populations in central and eastern North America have been documented as declining across their range. In many regions their decline has intensified in the last decade (Martin and Gavin 1995, Herkert 1997, Murphy 2003). This may be due to a combination of several factors of increasing importance, e.g., habitat degradation, fragmentation, and anthropogenic disturbance (Bollinger et al. 1990, Johnson and Igl 2001).

Agricultural intensification, especially earlier and more frequent mowing, appears to be a major factor causing the Bobolink decline (Bollinger et al. 1990, Bollinger and Gavin 1992, Herkert 1997). Reduced breeding success by grassland birds in fields that are mowed during the breeding season has been established in several studies (Bollinger et al. 1990, Bollinger 1995, Dale et al. 1997). The mowing, raking, and baling of hay followed by Bobolink nest abandonment and predation were found to account for more than 50% of the mortality of recent fledglings and a crippling 94% of the mortality of nestlings in a study in upper New York State (Bollinger et al. 1990).

GRASSLAND BIRD CONSERVATION IN THE AGRI-ENVIRONMENT

Until recently, most grassland birds were of comparatively low rank for global extinction, since it was assumed that despite declines occurring in the northeast, grassland species had a high global abundance (Vickery and Dunwiddie 1997). When it became apparent that declines of grassland birds were widespread across the continent in prairie remnants and farmlands alike, concern grew. It was speculated that for some species, such as the Bobolink, the farmland habitat of the northeast provided important breeding grounds (Peterjohn and Sauer 1999). Some researchers and managers argue that grassland birds should be a conservation priority in northeastern North America because the national or global abundance of several species is indeed tied to that region (Peterjohn and Sauer 1999).

Conservation planning within the farmland landscape has occurred in western Europe over the last decade, where 116 species of farmland birds are of conservation concern (Krebs et al. 1999). In Britain, an estimated 10 million individuals from 10 farmland bird species have disappeared (Krebs et al. 1999). These losses have been attributed to an 'intensification and industrialization of agriculture' (Green et al. 1997, Krebs et al. 1999, Chamberlain et al. 2000, Vickery et al. 2001, Vickery and Herkert 2001, Chamberlain 2004, Newton 2004). These terms are rather general and for certain species the specific variables causing their decline have been delineated. For example, the decline of the Corncrake (*Crex crex*) is due to earlier and more frequent hay-cropping in hayfields and increased pesticide use has led to the decrease of the Grey Partridge (*Perdix perdix*) (Wilson et al. 2005). These declines and others, such as that of the Stone Curlew (*Butrhinus aedicnemus*) and Cirl Bunting (*Emberiza cirlus*) have been reversed through planning and institution of careful management plans (Wilson et al. 2005). This has provided irrefutable evidence of the direct effect of agriculture on the state of grassland birds within the farmland landscape.

Conservation programs

North America has seen some effort to manage or restore grasslands. The two largest programs are the Conservation Reserve Program (CRP) in the United States and the Permanent Cover Program (PCP) in Canada.

The CRP, initiated in 1985, was primarily designed to reduce soil erosion in the midwestern agriculture fields and crop surpluses (Koford 1999). The discovery that leaving large fields in permanent cover provided habitat for grassland wildlife species in decline swiftly changed the design of the land conservation plan. By the late 1980s, CRP had increased the amount of grassland in the midwestern states by taking millions of hectares of cropland out of production for 10- or 15-year contracts (Koford 1999). The

conservation benefits of the CRP are mixed. A majority of the fields involved are in the midwestern agricultural sector and thus, do not impact the northeastern population of grassland birds. Many owners pasture or hay their CRP fields, but a majority of the states only allow such activities after breeding of most grassland birds have passed.

Where they are located, CRP fields provide habitat for grassland birds. Several studies have reported similar grassland bird species on native grasslands as on the 'restored' CRP grasslands (Koford 1999, Fletcher and Koford 2002). In some cases the abundance and/or diversity of grassland birds in CRP has exceeded that in natural grassland (Cunningham 2005). Yet, bird abundance, density or other population trends may be poor predictors of habitat quality (Vickery et al. 1992). The CRP lands may attract a number of grassland species but actually could be sink rather than source habitats (McCoy et al. 1999). The conservation value of CRP lands appears to be highly dependent upon the species concerned. McCoy et al. (1999) found that CRP habitat was a sink habitat for some species and a source for others.

Agriculture Canada's Permanent Cover Program (PCP) was also established primarily for soil conservation but was secondarily found to provide additional wildlife habitat (Acton and Gregorich 1995). As with the United States CRP program, the Canadian PCP paid landowners to keep their cropland in permanent perennial cover for the duration of a land lease. Unlike the CRP, the PCP had a short sign-up period, a brief three years from 1989-1991. As well, the sign-up was a one-time contract of either 10 or 21 years (Acton and Gregorich 1995). This resulted in roughly half a million hectares of additional grassland, albeit for a rather short period of time. The benefits to grassland wildlife conservation on PCP grassland are questionable. Most fields in the PCP program are heavily grazed, mowed or both (McMaster and Davis 2001) and these activities are unquestionably detrimental to breeding bird success. Today, most of the fields used for the PCP have returned to crop rotations. Although the idea had merit for its work towards the conservation of grassland habitat for wildlife, the execution was short-term and suffered from poor planning and management.

Management: Rotational Grazing

Grassland researchers and public managers have suggested various management and agricultural practice changes. As continuously grazed pastures have proven to be both less attractive to nesting birds as well as the cause for heightened nest disturbance and failure, rotational grazing has been viewed as an alternative approach (Temple et al. 1999). A comparison between ungrazed, continuously grazed, and rotationally grazed midwestern fields showed that ungrazed and rotationally grazed grasslands supported significantly more species than continually grazed grassland of similar size and composition. Nest survival rates (thus grassland bird productivity) were lowest in rotationally grazed grasslands. Prior to grazing, these grasslands are very attractive to returning breeders and support a large number and diversity of grasslands birds. But when the grasslands are stocked with a high density of cattle, trampling destroys many nests and surviving nests are more susceptible to predation due to the loss of the protective cover. Certain changes to the methods of rotational grazing can help to create higher productivity habitat, rather than the current ecological traps that rotationally grazed fields appear to be. If the intervals between grazing periods are increased to 25 -

13

30 days, this will allow a greater proportion of nests to be completed. This may result in a decrease in the quality of forage, since the longer cycle leaves older rather than new vegetation to be grazed (Temple et al. 1999). Temple et al. (1999) suggested that the best scenario would include a refuge or portions of grassland area set aside during the peak breeding season which could then be re-installed in the rotationally grazed system. However, even with this pro-bird system, it is questionable whether the increase in productivity is enough to counter the nestling mortality that turns many grazed grasslands habitat into sinks (Temple et al. 1999).

Management: Delayed Hay-cropping

The recurring problem with all management plans in grazed or hayed grasslands is that nesting birds are highly attracted to the landscape when they arrive from migration in spring, when there is little disturbance (Bollinger et al. 1990). For a majority of grassland bird species to achieve breeding success, there should be no large disturbance of the habitat from mid-May to late July. This means that mowing or grazing needs to be delayed, potentially lowering the nutrient and mineral quality of the hay (Nocera et al. 2005), or stocking densities need to be reduced (Temple et al. 1999). The direct overlap of periods for biomass production of the field vegetation and the nesting of grassland birds does not occur in natural phenology, but as previously mentioned, it is a product of the widespread use of exotic, cool-season grasses introduced by early settlers (Best et al. 1997). Therefore, possible bird-friendly farming management would include use of native, warm-season grasses at least in portions of fields (Giuliano and Daves 2002). With native grass the majority of biomass is produced later than cool-season grass species and they are usually harvested in July or August, after the peak nesting period of grassland birds (Giuliano and Daves 2002).

Management: Warm-season Grasses

In matched cool-season and warm-season grass fields, it was found that warmseason fields supported a greater abundance and diversity of grassland bird species (Giuliano and Daves 2002). Furthermore, warm-season fields had a greater number of nesting species of grassland birds, and overall nests in these fields had greater success and fledging rates (Giuliano and Daves 2002). Since cool-season grasses have earlier biomass production, they have a greater amount of cover in the early spring in comparison to warm-season fields. Management for warm-season grasses stipulates that fields should be mowed or grazed down to 20 - 30 cm as opposed to cool-season fields that may be less that five cm (Giuliano and Daves 2002). Therefore, following mowing there is far larger residual coverage in warm-season fields, allowing the possibility of faster and more frequent re-nest attempts.

There are several possible economic benefits to incorporating warm-season fields into the farmland landscape. By providing a source of biomass later in the season, the total annual forage production can be maximized (Freese 1998, Giuliano and Daves 2002). Native warm-season grasses have greater tolerance to hot and dry conditions and fare better during drought conditions than cool-season grasses (Giuliano and Daves 2002). An ecologically and economically sound management plan is to plant a mixture of cool-season and warm-season fields. To omit cool-season fields might incur a loss in revenue (Giuliano and Daves 2002) and a loss of landscape diversity, since several studies have shown the value of cool-season fields as grassland bird habitats (Norment et al. 1999), depending on their management, i.e., delayed mowing (Delisle and Savidge 1997). Several programs in the United States as well as Canada provide warm-season species seeds and encourage their use.

Management: Landscape Perspective

Landscape perspectives in conservation and management of birds have become increasingly apparent within multiple spheres of study (Freemark et al. 1995). In the agriculture sector of the northeast region of North America, the transition to intensive 'cash crop' methods over the last 50 years has greatly altered the landscape (Bélanger and Grenier 2002, Jobin et al. 2003). A distinct majority of grassland bird studies has focused on patch-level dynamics, but these bird species may often not perceive their habitat on these smaller scales (Ribic and Sample 2005). A study performed in Wisconsin by Ribic and Sample (2005) on the associations of various landscape factors and grassland bird species concluded that the most common model predictor was cover diversity. In this case, the less diverse the surrounding area, the higher the densities of grassland birds (Bélanger and Grenier 2002, Ribic and Sample 2005). Therefore, the highest density of grassland birds occurs in a more homogenous, grassland-based landscape in comparison to a more heterogeneous landscape with additional habitats such as forests, shrubs, or marshy patches. In the latter landscapes, degradation of habitat quality for grassland species may occur due to fragmentation resulting in edge effects, and competition with edge species, e.g., Bobolinks and Red-winged Blackbirds (Agelaius phoeniceus) (Bollinger and Gavin 2004).

Recent findings demonstrate that field size was not an important variable in a landscape model tested for the density of various grassland birds, both as a group and per

species (Ribic and Sample 2005). This is consequential for management of grassland birds in the northeast, since it is unlikely that the size and composition of natural grassland bird habitats can be mirrored within the farmland landscape. Yet conservation of restored grasslands or farmlands should not be dismissed, since declining grassland species often occur within these habitats in high density (Herkert 1995). Furthermore, some species, such as the Bobolink, appear to nest in greater density in the eastern hayfields in comparison to native prairie habitats (Bollinger and Gavin 1992). If privately owned farmlands can be altered from the precipitous position as grassland bird habitat sinks, they hold great possibility in serving as breeding grounds for an array of declining species.

LITERATURE CITED

- ACTON, D. F. AND L. J. GREGORICH. 1995. The health of our soils Towards sustainable agriculture in Canada. Centre for Land and Biological Resources Research, Agriculture and Agri-food Canada. Ottawa, ON.
- ASKINS, R. A. 1997. History of grasslands in the northeastern United States: implications for bird conservation. Pages 119-136 *in* P. D. Vickery and P. W. Dunwiddle, editors. Grasslands of Northeastern North America. Massachusetts Audubon Society Lincoln, Massachusetts.
- ASKINS, R. A. 1999. History of grassland birds in eastern North America. Studies in Avian Biology **19**:60-71.
- BÉLANGER, L. AND M. GRENIER. 2002. Agriculture intensification and forest fragmentation in the St. Lawrence valley, Québec, Canada. Landscape Ecology 17:495-507.

- BEST, L. B., H. CAMPA, K. E. KEMP, R. J. ROBEL, M. R. RYAN, J. A. SAVIDGE,
 H. P. J. WEEKS AND S. R. WINTERSTEIN. 1997. Bird abundance and nesting
 in CRP fields and croplands in the Midwest: a regional approach. Wildlife Society
 Bulletin 25:864-877.
- BOLLINGER, E. K. 1995. Successional changes and habitat selection in hayfield bird communities. Auk **112**:720-7230.
- BOLLINGER, E. K., P. B. BOLLINGER AND T. A. GAVIN. 1990. Effects of haycropping on eastern populations of the Bobolink. Wildlife Society Bulletin 18:142-150.
- BOLLINGER, E. K. AND T. A. GAVIN. 1989. The effects of site quality on breedingsite fidelity in Bobolinks. Auk **106**:584-594.
- BOLLINGER, E. K. AND T. A. GAVIN. 1992. Eastern Bobolink populations: ecology and conservation in an agricultural landscape. Pages 497-506 *in* J. M. Hagan and D. W. Johnston, editors. Ecology and Conservation of Neotropical Migrants. Smithsonian Institute Press, Washington, D.C.
- BOLLINGER, E. K. AND T. A. Gavin. 2004. Responses of nesting Bobolinks (*Dolichonyx oryzivorus*) to habitat edges. Auk **121**:767-776.
- BOLLINGER, E. K., T. A. GAVIN AND D. C. MCINTYRE. 1988. Comparison of transects and circular-plots for estimating Bobolink densities. Journal of Wildlife Management 52:777-786.
- CHAMBERLAIN, D. E. 2004. Lowland farmland birds: the road to recovery. A report on the BOU's Annual Conference held at the University of Leicester, 26-28 March 2004. Ibis **146**:704-706.

- CHAMBERLAIN, D. E., R. J. FULLER, R. G. H. BUNCE, J. C. DUCKWORTH, AND M. SHRUBB. 2000. Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. Journal of Applied Ecology 37:771-788.
- COLLAR, N. J., L. P. GONZAGA, A. KRABBE, A. MASRONO NIETO, G. NARANJO, T. A. PARKER III, AND D. C. WEGE. 1992. Threatened birds of the Americas. Smithsonian Institution Press, Washington, D.C.
- CUNNINGHAM, M. A. 2005. A comparison of public lands and farmlands for grassland bird conservation. The Professional Geographer **57**:51-65.
- 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.
- DELISLE, J. M. AND J. A. SAVIDGE. 1997. Avian use and vegetation characteristics of conservation reserve program fields. Journal of Wildlife Management 61:318-325.
- Fletcher, R. J. J., and R. R. Koford. 2002. Habitat and landscape associations of breeding birds in native and restored grasslands. Journal of Wildlife Management 66:1011-1022.
- FLETCHER, R. J. J. AND R. R. KOFORD. 2003. Changes in breeding bird populations with habitat restoration in Northern Iowa. American Midland Naturalist 150:83-94.
- FREEMARK, K. E., J. B. DUNNING, S. J. HEJL AND J. R. PROBST. 1995. A landscape ecology perspective for research, conservation, and management. Pages

381- 421 *in* T. E. Martin and D. M. Finch, editors. Ecology and Management of Neotropical Migratory Birds. Oxford University Press, New York.

FREESE, B. 1998. Tips from a top grass manager. Successful Farming 96:24-25.

- GAVIN, T. A. AND E. K. BOLLINGER. 1988. Reproductive correlates of breeding-site fidelity in Bobolinks (*Dolichonyx oryzivorus*). Ecology 69:996-103.
- GAYTON, D. 1990. The wheatgrass mechanism: science and imagination in the western Canadian landscape. Fifth House, Saskatoon, SK.
- GIULIANO, W. M. AND S. E. DAVES. 2002. Avian response to warm-season grass use in pasture and hayfield management. Biological Conservation **106**:1-9.
- GREEN, R. E., G. A. TYLER, T. J. STOWE AND A. V. NEWTON. 1997. A simulation model of the effects of mowing of agricultural grassland on the breeding success of the Corncrake (*Crex crex*). Journal of Zoology 243:81-115.
- HERKERT, J. R. 1995. An analysis of midwestern breeding bird population trends: 1966-1993. American Midland Naturalist **134**:41-50.
- HERKERT, J. R. 1997. Bobolink (*Dolichonyx oryzivorus*) population decline in agricultural landscapes in the Midwestern USA. Biological Conservation 80:107-112.
- HERKERT, J. R., D. L. REINKING, D. A. WIEDENFIELD, M. WINTER, J. L. ZIMMERMAN, W. E. JENSEN, E. J. FINCK, R. R. KOFORD, D. H. WOLFE, S. K. SHERROD, M. A. JENKINS, J. FAABORG AND S. K. ROBINSON. 2003. Effects of prairie fragmentation on the nest success of breeding birds in the mid-continental United States. Conservation Biology 17:587-594.

- JOBIN, B., J.-L. DESGRANGES AND C. BOUTIN. 1996. Population trends in selected species of farmland birds in relation to recent developments in agriculture in the St. Lawrence Valley. Agriculture, Ecosystems & Environment 57:103-116.
- JOBIN, B., J. BEAULIEU, M. GRENIER, L. BÉLANGER, C. MAISONNEUVE, D. BORDAGE AND B. FILION. 2003. Landscape changes and ecological studies in agricultural regions, Québec, Canada. Landscape Ecology 18:575.
- JOHNSON, D. H. AND L. D. IGL. 2001. Area requirements of grassland birds: A regional perspective. Auk **118**:24-34.
- JOHNSON, R. G. AND S. A. TEMPLE. 1990. Nest predation and parasitism of tallgrass prairie birds. Journal of Wildlife Management **54**:106-111.
- KNOPF, F. L. 1994. Avian assemblages on altered grasslands. Studies in Avian Biology 15:247-257.
- KOFORD, R. R. 1999. Density and fledging success of grassland birds in conservation reserve program fields in North Dakota and west-central Minnesota. Studies of Avian Biology 19: 187-195.
- KREBS, J. R., J. D. WILSON, R. B. BRADBURY AND G. M. SIRIWARDENA. 1999. The second Silent Spring? Nature **400**:611-612.
- MARTIN, S. G. 1974. Adaptations for polygenous breeding in the Bobolink (*Dolichonyx oryzivorous*). American Zoologist **14**:109-119.
- 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.

- MCCOY, T. D., M. R. RYAN, E. W. KURZEJESKI AND L. W. J. BURGER. 1999. Conservation reserve program: source or sink habitat for grassland birds in Missouri? Journal of Wildlife Management 63:530-538.
- MCMASTER, D. G. AND S. K. DAVIS. 2001. An evaluation of Canada's Permanent Cover Program: Habitat for grassland birds? Journal of Field Ornithology 72:195-210.
- MURPHY, M. T. 2003. Avian population trends within the evolving agricultural landscapes of eastern and central United States. Auk **120**:20-34.
- NEWTON, I. 2004. The recent declines of farmland bird populations in Britain: an appraisal of causal factors and conservation actions. Ibis **146**:579-600.
- NOCERA, J. J., G. J. FORBES AND L.-A. GIRALDEAU. 2006. Inadvertent social information in breeding site selection of natal dispersing birds. Proceedings of the Royal Society of London B **273**:349-355.
- NOCERA, J. J., G. J. PARSONS, R. MILTON, G. AND A. H. FREDEEN. 2005. Compatibility of delayed cutting regime with bird breeding and hay nutritional quality. Agriculture, Ecosystems and 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.
- ONTARIO PARTNERS IN FLIGHT. 2005. Ontario Landbird Conservation Plan: Lower Great Lakes/St. Lawrence Plain (North American Bird Conservation Region 13), Priorities, Objectives and Recommended Actions. Environment Canada, Ministry of Natural Resources.
- PETERJOHN, B. G. AND J. R. SAUER. 1999. Population status of North American grassland birds from the North American Breeding Bird Survey, 1966-1996. Studies in Avian Biology 19:27-44.
- RIBIC, C. A. AND D. W. SAMPLE. 2005. Associations of grassland birds with landscape factors in Southern Wisconsin. American Midland Naturalist 146:105-121.
- ROTENBERRY, J. T. AND J. A. WIENS. 1980. Habitat structure, patchiness, and avian communities in North American steppe vegetation: A multivariate analysis. Ecology 61:1228-1250.
- 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. Studies in Avian Biology 19:196-202.
- VICKERY, J. A., J. R. TALLOWIN, R. E. FEBER, E. J. ASTERAKI, P. W. ATKINSON, R. J. FULLER AND V. K. BROWN. 2001. The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources. Journal of Applied Ecology 38:647-664.
- VICKERY, P. D. AND P. W. DUNWIDDIE. 1997. Introduction. Pages 1- 13 in P. D. Vickery and P. W. Dunwiddie, editors. Grassland birds of northeastern North America. Massachusetts Audubon Society, Lincoln, Massachusetts.
- VICKERY, P. D. AND J. R. HERKERT. 2001. Recent advances in grassland bird research: where do we go from here? Auk **118**:11-15.
- VICKERY, P. D., M. L. HUNTER AND J. V. WELLS. 1992. Is density an indicator of breeding success? Auk 109:706-710.

- VICKERY, P. D., P. L. TUBARO, J.M.C DA SILVA, 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.
- WARNER, R. E. 1994. Agricultural land use and grassland habitat in Illinois: future shock for midwestern birds? Conservation Biology **8**:147-156.
- WELLS, J. V., AND K. V. ROSENBERG. 1999. Grassland bird conservation in northeastern North America. Studies in Avian Biology 19:72-80.
- WILSON, J. D., M. J. WHITTINGHAM, AND R. B. BRADBURY. 2005. The management of crop structure: a general approach to reversing the impacts of agricultural intensification on birds? Ibis 147:453-463.
- WINTER, M., D. H. JOHNSON, AND J. FAABORG. 2000. Evidence for edge effects on multiple levels in tallgrass prairie. Condor **102**:256-266.

CONNECTING STATEMENT

Chapter 1 reviewed the pertinent literature required to understand the current status of grassland birds in North America, especially Bobolinks in the northeast, the use of agricultural habitats by grassland birds and the ecology and past research on the Bobolink. Chapter 2 examines the nest success and nest-site selection of local Bobolink populations monitored in southwestern Québec and southeastern Ontario and suggests management recommendations specifically for these areas.

CHAPTER 2: BOBOLINK NEST SUCCESS IN HAYFIELDS OF QUÉBEC AND ONTARIO

ABSTRACT

Bobolink (Dolichonyx oryzivorus) populations are declining across North America due to habitat loss and degradation. This grassland bird continues to breed in hayfields and pastures of. St-Lawrence Great-Lakes physiogeographic region. Within this region, we estimated nest success and assessed nest-site selection of Bobolinks at locations in Québec and Ontario during 2006 and 2007. Bobolinks nests were located in areas with more forbs and greater overhead concealment compared to random locations, but vegetation characteristics did not differ between successful and unsuccessful nests. Daily nest survival was modelled as a function of year, site, nest age, season, and nest-site vegetation variables. The best-fit model suggested that daily nest survival increased with nest age and differed among sites. A model-averaged estimate of nest survival was 43.0% (95% CI: 13.7 - 69.3), which is slightly greater than the Mayfield estimate (38.8%; 95%)CI: 22.3 - 55.1). Because Bobolinks select specific vegetation characteristics for nest sites, various management schemes have the potential to increase habitat quality and nest success of this declining species. Management should be two-fold, including: ideally (1) delaying hay-cropping and planting a mixture of grass and forbs to attract nesting Bobolinks and, minimally (2) limiting ecological sinks of early-cut fields by reducing spring cover and avoiding field vegetation characteristics that attract Bobolinks.

INTRODUCTION

A consequence of worldwide grassland loss is the parallel decline of grassland birds (Krebs et al. 1999, Peterjohn and Sauer 1999). This decline is widespread among North American grassland birds, encompassing the midwestern prairies and northeastern grasslands and hayfields (Askins 1993, Samson and Knopf 1994). As native prairies and grasslands disappear, grassland birds are shifting towards habitats associated with agriculture. These surrogate habitats now support several declining species, such as Bobolinks (*Dolichonyx oryzivorus*), Savannah Sparrows (*Passerculus sandwichensis*), and Eastern Meadowlarks (*Sturnella magna*) (Peterjohn and Sauer 1999, Vickery et al. 1999, Norment 2002). Intensification of agriculture in the last 50 years altered the farmland landscape for grassland birds. Particularly during the breeding season the earlier and more frequent hay-cropping results in nestling mortality for grassland nesting species (Herkert 1997, Vickery et al. 1999).

Bobolinks are obligate grassland birds associated with the hayfields of northeastern North America. Historically, Bobolinks bred in the tallgrass and mixed-grass prairies of east-central North America, but due to destruction and alteration of these habitats, much of the population now breeds in agricultural land such as hayfields and pastures (Martin and Gavin 1995, Herkert 1997). This relative adaptability has allowed Bobolinks to persist, albeit in a declining state, despite tremendous loss and degradation native and surrogate habitat (Askins 1993, Peterjohn and Sauer 1999). Hay-cropping before nests fledge young has contributed to declining populations (Bollinger et al. 1990, Bollinger and Gavin 1992). Thus, effective Bobolink conservation requires hayfield management that is conducive to increased nest success. In this study, we sought to

determine nesting success of Bobolinks in hayfields and the influence of microhabitat variables on nest survival.

STUDY AREA

Our study took place in southwestern Québec and eastern Ontario at three sites with established Bobolink populations: a private hay farm near Hemmingford, Québec (45°05'N, 73°36'W), municipal hay fields (Bois-de-la-Roche) in Senneville, Québec (45°26'N, 73°56'W), and a wildlife conservation area (Atocas Bay) at Lefaivre, Ontario (45°36'N, 74°51'W). All sites were comprised of multiple hayfields that had been last re-seeded 5-30 yrs ago. During 2005, the year before our study, Atocas and Hemmingford were mowed for hay from 01 July - 15 July (late-cut) whereas Bois-de-la-Roche was mowed in mid-June (early cut). All sites were late-cut or uncut during the span of our study. Hemmingford hayfields were dominated by Timothy (*Phleum* pratense) and Smooth Brome (Bromus ramosus ssp. racemosus), whereas Atocas and Bois-de-la-Roche harboured a broader mixture of forbs and grasses. Atocas and Hemmingford sites were rural; the latter surrounded by forest and rowcrop monocultures (e.g., corn and soybean) and the former by perennial hayfields, pastures, and wet meadows. Bois-de-la-Roche was suburban and bordered by forest fragments, fallow land, and housing developments.

As Bobolinks exhibit area-sensitivity (Herkert 1994, Johnson and Igl 2001) and actively avoid woodland edges (Fletcher and Koford 2003), at each study location we chose one to two study fields that were \geq 4 ha and not adjacent to large woodlots in each year. Each of these hayfields was systematically searched for Bobolink nests.

The same sites were used in both years of study, save two changes in 2006: one

additional hayfield was surveyed at Bois-de-la-Roche that was not surveyed in 2005 and one site was switched to a site adjacent (~ 100 m) to the 2005 site at Atocas. The latter site at Atocas was uncut in 2005 resulting in very different field vegetation, and no Bobolinks were present in 2006. Thus, a nearby previously cut field was used instead.

METHODS

We observed Bobolink interactions beginning in late April with nest searches based on sightings of females with nesting material and flushing females from nests. Nest locations were plotted on maps and geographic coordinates determined with a handheld global positioning system (GPS). We marked each nest with flagging 3 m to the north and revisited it every three to five days to determine its fate. We estimated nest initiation dates by backdating, assuming one egg was laid per day (Martin and Gavin 1995) and that incubation began with the penultimate egg (Martin 1974). To minimize investigator effects, nest visits were usually <1-min in duration and we used different routes to access nests to limit formation of trails that might attract mammalian predators (Götmark 1992).

Young Bobolinks leave the nest at age nine to ten days, but disturbance may forcefledge nestlings at \geq 7 days (Martin and Gavin 1995). A nest was deemed successful if at least one Bobolink fledged. If living nestlings were present during the last nest visit, (i.e., from nestling day seven to ten), and if, during the next visit two to three days later, the male and female were seen bringing food to the vicinity or acting territorial, we concluded that the young had fledged and the nest was successful. If we visited a nest and found that nestlings \leq 7 days old had disappeared and the parents were absent, we concluded that the nest had been depredated. Nests that were active (i.e., laying or incubation) during a previous visit but during a subsequent visit eggs were cold and wet

were considered abandoned. We recorded the cause of nest failure and nestling mortality or disappearance whenever possible.

Vegetation microhabitat variables, including vertical cover, litter depth, lateral obstruction, and forb cover, were measured within one week of nest completion. Vertical cover was calculated by placing a 7 cm-diameter paper disk divided into eight pie-shaped sections into the nest bowl at nest sites and into the ground litter at non-nest sites (Davis and Sealy 1998). A vertical cover score was obtained 1 m from ground level, directly above the disk, and 1 m in each of four cardinal directions. The numbers of sections visible by \geq 50% were counted, therefore the higher the vertical cover score (i.e., number of sections seen), the lower the cover at a nest and the lower the nest concealment. Litter depth (cm) was calculated as the height of dead vegetation beside the nest and 1 m in each cardinal direction (Winter et al. 2004). Lateral concealment consisted of a Robel pole measurement (to nearest 5 cm) at the nest and each cardinal point (Robel et al. 1970). Forb cover was the ratio of forbs to grass in a 1-m square centred on the nest and at each cardinal point without overlap. The means of the five measurements of each vegetation variable were used for analysis. Lastly, we recorded the dominant vegetation type and whether the nest was placed beneath or adjacent to forbs.

Measurements identical to those at nests were made at random non-nest sites. Random sites were located at a random azimuth and distance (3 - 35 m) from each nest location. A replacement non-nest site was chosen when the random location was in inappropriate nesting habitat (i.e., marsh or shrubs).

Bobolinks, their eggs, and nests are protected under the Migratory Bird Convention Act, thus we complied with all federal and provincial laws during our study. We received approval from the Canadian Council of Animal Care through the McGill University Animal Care Committee (Protocol #: 5202).

Statistical Analysis

Phenology.— Nest initiation dates, hatching dates, and fledging dates for 2006 and 2007 were checked for normality and compared using a Mann-Whitney test. Only hatching dates were non-normally distributed and square-root transformed (SPSS Ver. 16.0, SPSS Inc., Chicago, IL). The cumulative percentage of nests fledged within each year was plotted as a function of day of year.

Nest success.— Nests that were abandoned (n = four) and nests that were depredated (n = 16) were grouped together and called unsuccessful. We used program MARK to model the daily survival of Bobolink nests, predominantly to interpret the effects of a number of biological and temporal factors and secondly to obtain an estimate of nest survival. For this, nest success was calculated as a product of daily nest survival over the course of the Bobolink's 28-day nesting cycle (White and Burnham 1999).

Models were considered using a three-step process of model selection and based on biological questions of interest. Firstly, we included temporal variables. Thus, our main effects models included daily survival rates (DSR) that: were constant over the 28-day nesting cycle {S.}, differed between years {S_{year}}, and differed linearly with nest age {S_{age}} or differed linearly across the nesting season {S_{season}}. Next, an effect of site was added to the top model as well as modelled on its own {S_{site}}. Lastly, various combinations of the four vegetation variables (i.e., vertical cover, litter depth, robel, and forb cover) were fitted to the most parsimonious model as covariates (White and Burnham 1999). We calculated model averaged parameters and their associated standard

errors for competing models that were included in the confidence set of candidate models (within 10% of best-supported model). Model weight (w_i) was used to evaluate the strength of evidence supporting each model. Lastly, we considered model-averaged estimates from the candidate model set for the comparison of DSR variation in order to accommodate model uncertainty (Burnham and Anderson 1998).

Model averaged parameters were only calculated from parameters included in the confidence set of candidate models (models within 10% of best supported model). The $\hat{\beta}$ -estimates for these parameters were individually calculated by:

(New Akaike's weight) * (raw β -estimates) = weighted β -estimates where new weights were calculated by summing all weights from models containing the parameter in question (e.g., nest age, site) and dividing each original model weight by the new parameter-specific weight sum. Thus, each model had a new Akaike weight. Weighted β -estimates for each model containing the parameters were then summed to obtained weighted model-averaged β -estimates for each parameter (Burnham and Anderson 1998). Likewise, a weighted unconditional standard error (SE) was calculated for each parameter. For each model a model selection variance (MSV) was calculated by:

 $MSV = (model-averaged estimate - raw parameter estimate)^2$ which in turn was used in the following calculation to create a weighted unconditional SE for each model by:

weighted unconditional SE = (New Akaike's weight) * $[(SE)^2 + MSV]^{-2}$ where the SEs for all models containing the parameter were summed to create the parameter-specific weighted unconditional SE and from this weighted unconditional 95% CI (Burnham and Anderson 1998).

Nest-site selection.— Again abandoned and depredated nests were grouped and considered unsuccessful. Observer disturbance was not believed to be a cause of nest abandonment since abandonment occurred following several days of cold, wet weather. Vegetation had been flattened by wind and heavy rain to the point that the nest bowl was unreachable by the female at two of the four abandoned nests.

Normality of the nest vegetation variables was tested using Shapiro Wilks' tests (SPSS Ver. 16.0, SPSS Inc., Chicago, IL). Vertical cover and litter depth were both square-root-transformed and lateral obstruction was log-transformed to improve normality. Ground cover data were not improved by transformation (Shapiro Wilks' test statistic = 0.973), so the untransformed data were used for analysis.

We used principal component analysis (PCA) (SPSS Ver. 16.0, SPSS Inc., Chicago, IL) to test for multi-colinearity among the four nest-site variables. This was necessary since subsequent statistical analyses assumed that data points were uncorrelated. The first principal component accounted for 35.5% of the variation, which was below what was expected to occur by chance alone (52.1%; Legendre and Legendre 1983, Jackson 1993). To ensure there was no correlation between variable pairs used, variables were tested pairwise with Pearson's product-moment correlation coefficient (SPSS Ver. 16.0, SPSS Inc., Chicago, IL). Once non-correlation was established, all four variables were included in two separate discriminant function analyses (DFA) (SPSS Inc., Chicago, IL). Discriminant function analysis was used to distinguish whether there was a difference in microhabitat between (1) successful and unsuccessful nests, and (2) nest and non-nest sites.

To remove season effects caused by growing vegetation we saved residuals from an

analysis of covariance (ANCOVA; SPSS Ver. 16.0, SPSS Inc., Chicago, IL) with the microhabitat measurements as dependent variables and day of year as the explanatory factor. To combine data from both years and remove year effects z-scores were created within years for residuals of each variable (Clark and Shutler 1999, Traylor et al. 2004). These values were then used in the DFA.

RESULTS

We found 53 Bobolink nests at the three study sites, 24 in 2006 and 29 in 2007 (Table 1). Across all sites and years, mean nest initiation (excluding three re-nests) was 29 May (\pm 0.7 d, range 21 May – 6 June, n = 50), mean hatching date was 13 June (\pm 0.6 d, range 7 June – 23 June, n = 39), and mean fledging date was 24 June (\pm 0.6 d, range 18 June – 3 July, n = 33). Initiation (t_{51} = -1.25, P = 0.211), hatching ($t_{39} = -0.79$, P = 0.429), and fledging ($t_{33} = -0.93$, P = 0.345) dates did not differ between years. The cumulative percentages of nests fledged over the breeding season were similar between years (Fig. 1).

Nest Success

Altogether, 33 (62%) Bobolink nests were successful and 20 (38%) failed, i.e. two during laying, five during incubation, nine during the nestling stage, and four were abandoned (Table 2). From the 42 nests that hatched \geq one nestling, 177 eggs (67%) hatched and 136 (51%) young fledged from 266 eggs. Overall, 136 (77%) young fledged from the eggs that hatched.

The most parsimonious nest survival model included a linear effect of nest age and site $\{S_{age + site}\}$ (Table 3). The top model alone had a weight of 28.8%, and models with $\Delta AIC_c \le 2$ had a cumulative weight of 79.6%. Nest survival increased slightly with

greater nest age (weighted $\hat{\beta}_{age} = 0.096$, weighted unconditional 95% CI: 0.017, 0.175; Table 4, Fig. 2), and differed among sites (weighted $\hat{\beta}_{site} = -0.914$, weighted unconditional 95% CI: -0.196, -1.631; Table 4) with Hemmingford having the highest DSR (0.994) and Atocas the lowest (0.949; Table 5). All other beta estimates for parameters in the confidence set of candidate models had 95% CI that included zero, suggesting a poor fit (Table 4). All the top models included the linear nest age and site parameters. Mayfield nest success calculated over the 28-day laying, incubation, and nestling periods for the constant model was 38.8%; 95% CI: 22.3 - 55.1. The modelaveraged nest survival was 43.0% (95% CI: 13.7 - 69.3).

Nest-site Selection

Bobolinks nested primarily in a mixture of grasses and forbs. The predominant grass species was Timothy and forb species included White (*Trifolium repens*) and Red (*T. pratense*) Clover, Birdsfoot Trefoil (*Lotus corniculatus*), Common Dandelion (*Taraxacum officinale*), and Purple Vetch (*Vicia americana*). Of the 53 nests, 35 (66%) were placed at the base or within a cluster of forbs.

Nest-site variables were tested for pairwise correlation, with no significant correlations arising (Table 6). Vertical cover and forb cover (P = 0.052) as well as litter depth and Robel (P = 0.053) showed a degree of positive correlation. Ground cover type (% forbs) may influence vertical cover since forbs usually are a denser cover type than grasses. Likewise, a higher litter depth may contribute to a portion of lateral concealment. Since correlations were non-significant and the variables addressed different biological questions of interest, all variables were included in further tests.

In comparing nest and non-nest sites by DFA, the classification rate was 72.0%,

which was better than by chance alone (k = 0.44, 95% CL: 0.35 - 0.53, $z = 4.54, P \le 0.01$). The DFA indicated differences in vegetation characteristics at nest and non-nest sites (Wilks' $\lambda = 0.749$, $\chi^2_4 = 29.4$, P < 0.001, Table 8). Non-nest sites typically had half the overhead concealment compared to nest sites. Forb cover at nest sites was 25% greater than that at non-nest sites (Table 7,8). We found little difference in habitat characteristics between successful and unsuccessful nests (Wilks', $\lambda = 0.952$, $\chi^2_4 = 2.4$, P < 0.665), and site divisions were not amenable to statistical analysis due to small sample sizes. However, similar patterns appear, with successful nests occurring in microhabitats with higher concealment and percentage of forbs (Table 9). Hay-cropping occurred at the discretion of site landowners or managers. In 2006, hayfields were not cut at the Atocas and Bois-de-la-Roche sites, resulting in higher litter depth at these sites in 2007 (Fig. 3).

DISCUSSION

In southeastern Québec, the main conflict for breeding Bobolinks in local hayfields is the nearly complete overlap between the time the nestlings are in the nest and haycropping in the region. Nest initiation dates for the two years of the study ranged from 21 May to 12 June, including three apparent re-nests. These initiation dates were earlier than those reported for Bobolinks in remnants of northern tallgrass prairies in Minnesota and North Dakota, with the earliest initiation being 29 May and most occurring in mid-June (Winter et al. 2004). Most of the Bobolinks that hatched at our sites fledged around the third or fourth week of June (means: 23 Jun in 2006 and 27 Jun in 2007). This is similar to Bobolink phenology reported in the northeast; 20 June – 30 June in western New York (Norment et al. 1999) and moderately earlier than peak fledging in Nova Scotia (1 July – 6 July; Nocera et al. 2005). Our fledging dates and other reported dates coincide with or are later than hay-cropping for southeastern Québec and a majority of the northeast. Due to the predominant use of non-native cool-season grasses by hay-farmers in North America, hay-cropping has been advanced by two - three weeks in comparison to historical hay-cropping dates (Giuliano and Daves 2002). Mortality due to hay-cropping is nearly 100% for nestlings and >50% for fledglings (Bollinger et al. 1990, Perlut et al. 2006). Even after young Bobolinks leave the nest, they remain poor fliers due to undeveloped flight feathers and only by day 13 post-hatching are they capable of short flight (Martin and Gavin 1995). The consequence of this overlap is the nearly complete destruction of young Bobolinks fledging from early cut cool-season hayfields in the northeast. This is likely the leading cause of the decline in Bobolinks in the area over the last three decades (Bollinger et al. 1990, Herkert 1997).

Nest Success

Model-averaged nest success (43.0%, n = 53) in our study was higher than the rates calculated from DSRs reported and extrapolated over the 28-day nesting period in mixedgrass prairies of North Dakota (3.6%, n = 108; Kerns 2004), Conservation Reserve Program (CRP) fields, hayfields, and pastures in Wisconsin (19.3%, n = 29) (Guzy 2005), and northern tallgrass prairies of Minnesota and North Dakota (17.2% n = 314; Winter et al. 2004). Our proportion of successful nests (0.66, n = 53) was similar to that in hayfields of New York (0.54, n = 39; Norment et al. 1999).

We found that Bobolink nest survival increased with nest age. Differing environmental (nest-site) and behavioural (parental and nestling behaviour) variables between nest stages may lead to different survival rates (Davis 2003, Muchai and du Plessis 2005). When nest-site effects were accounted for, higher predation rates were correlated with higher parental nest attendance during later nest stages in one study (Muchai and du Plessis 2005). In contrast, many birds experience greater nest mortality, with predation accounting for a majority of this mortality at the egg-stage when parental nest attendance is low (Martin 1992). In grassland habitats, where nests are especially vulnerable and experience higher predation pressures than in other habitats (Martin 1993), poorly concealed nests are likely found early in the season by predators. Nests surviving this period likely have low predation at later stages as a result of environmental cues but this may depend on the predator community (Davis 2003).

Nest Predation

Predation of eggs or nestlings was the main cause of nest failure in this study. Grassland passerines face strong predation pressures (Martin 1993) and nest predation is often the principal factor responsible for nest failure (Davis 2003).

The highest predation rate was at Atocas, especially in 2007, while Hemmingford had the least number of predation events (Table 2). The resulting difference in DSR across the three study sites led to the relatively high weight of site in the nest survival models (Table 3). Hemmingford, as an actively managed hay farm, was the most homogeneous site, both at the site (inter-field) and landscape (intra-field) levels. As the youngest (i.e., most recently ploughed and re-sown fields) site surveyed, it was dominated by timothy with a scattering of forbs. The farm consisted of 26 grassdominated fields and pastures bordered by mixed-deciduous forest and monocultures of neighbouring farms. Atocas was composed of a heterogeneous matrix of hayfields, pastures, fallow fields, wetlands, and small woodlots, with high spatial heterogeneity within individual fields due to a prominent diversity of grasses and forbs.

Differing predation rates across the sites may be the result of several factors. Higher predation rates at Atocas may be explained by (a) enhanced predation pressures from a higher number of both predator species and individuals in nearby wetland habitats (Larivière and Messier 2000, Stephens et al. 2005), (b) higher predation and resulting lower success associated with higher nest density (Martin 1988, Larivière and Messier 1998), (c) mesopredator abundance in semi-wild, human-altered landscapes (Jiménez and Conover 2001), and (d) deeper litter (Fig. 3) leading to increased density or movement of small mammals since dense field vegetation provides cover against predators and weather (Eadie 1953, Whittaker et al. 1991). In comparison, lower predation rates at Hemmingford may have resulted from lower predator diversity in homogenous landscapes (monocultures) (Bowman and Harris 1980), and conversely to Atocas, suffered lower predation due to lower nest density, and lack of vegetation. Qualitative assessment based on observation suggests that overall higher numbers of rodents were encountered at less managed sites (Bois-de-la-Roche and Atocas), and especially in fields that were not haved the previous year. Small mammals such as mice and voles commonly depredate ground nests (Dion et al. 2000), and for species with small eggs the effects of this depredation can be significant (DeGraff and Maier 1996).

Nest-site selection

Bobolink nest sites had a greater percentage of forbs and overhead nest concealment than did non-nest sites, with most nests placed at the base of a large forb. Bobolinks in Oregon hayfields similarly placed nests beneath herbaceous cover (Martin 1971). The four abandoned nests we observed followed several days of wet, cool weather in early spring. The predominantly grass nest-site vegetation at abandoned nests

sites was flattened over the nest bowl, which appeared to deny the female access while other nests showed similar flattening of vegetation but forbs appeared to support the fallen grasses thereby retaining access to these nests. Other studies have suggested cover from surrounding vegetation affords protection from predators (nest-protection hypothesis; Martin and Roper 1988, Hernández et al. 2003) and from extreme weather events (Walsberg 1985).

Management Implications

Managing Hayfields for Bobolinks.— The primary cause of nestling mortality in Bobolinks is hay-cropping (Bollinger et al. 1990, Perlut et al. 2006). In southwestern Québec we recommend that hay-cropping be delayed minimally until 01 July to allow for young in all active nests to fledge or at a minimum until to allow a majority of fledglings to have enough mobility to survive hay-cropping. In our study, 91% of young pooled for both years fledged before 1 July (Fig. 1). Likewise, a study by Norment et al. (1999) in western New York found that > 90% of Bobolinks, Savannah Sparrows (Passerculus sandwichensis), and Eastern Meadowlarks (Sturnella magna) fledge by the end of the first week of July, and peak fledging periods for Bobolinks, Savannah Sparrows, and Nelson's Sharp-tailed Sparrows (Ammodramus nelsoni subvirgatus) in managed hayfields in Nova Scotia were reported for the first week of July (Nocera et al. 2005). Grassland bird management plans often suggest delaying mowing until late July-early August (Bollinger et al. 1990, Dechant et al. 2001). This suggestion may be unattractive or unreasonable for managers of cool-season grass hayfields, due to the resulting decrease in hay quality. Shorter delays show minimal nutrient loss (Nocera et al. 2005). Later-cut hay can be attractive to hay producers for several reasons, as it can be more

fibrous and facilitate ruminant digestion (A.F. Mustafa, McGill University, personal communication), have a lower risk of harvest damage due to rain (Nocera et al. 2005) and produce significantly increased quantity in a one-cut system (Mason and Lachance 1983).

Late-cut hayfields are ideal habitats for Bobolinks. A complete lack of hayfield management (i.e., yearly mowing) decreases habitat quality as litter depth increases and vegetation becomes sparser and shrubbier (Norment et al. 1999, Winter et al. 2004), leading to an increase in small mammal nest predation. Therefore, late-cut hayfields serve as quality breeding habitat since they are managed to an extent that maintains the grassland habitat, yet the delayed hay-cropping allows for nestling survival. To maximize habitat quality in hayfields for Bobolinks, managers should aim to create fields with higher percentages of forbs (e.g., Red and White Clover, Birdsfoot Trefoil, Common Dandelions) and vegetative concealment. This can be achieved initially through planting, but it is also often the result of grass die-off and opportunistic growth of forbs over the years. Bobolinks often prefer older fields for nesting compared to newly planted fields, a trend seen in New York hayfields where Alfalfa (*Medicago sativa*) fields age into grass and forb fields due to alfalfa plant winter die-offs (Bollinger and Gavin 1992).

Minimizing Ecological Traps.— Hayfields cut at a time that overlaps the breeding season of grassland birds represent ecological traps to these birds. Bobolinks may be dissuaded from nesting at high densities in such fields by making the habitat less attractive to them. This may be accomplished by cutting or grazing the fields late the previous year or early in the spring to minimize the amount of vegetative cover during mid-spring (May) when males are selecting territories (Nocera et al. 2007). Also, our study showed that Bobolinks select a higher percentage of forbs, thus fields with little or

no forbs, such as those with pure timothy or fields comprised of pure Alfalfa, support a lower number of nesting birds. Bobolink declines in the northeast have been attributed to the rising number of hayfields intensively and repeatedly planted and cropped, especially alfalfa monocultures (Bollinger and Gavin 1992). We do not advocate these intensive hayfield monocultures but recognize that if early hay-cropping must occur, it should be restricted to fields that support the least number of nesting grassland birds. Ideally, early-cut fields should be paired with late-cut fields that provide nesting habitat within the landscape as well as a refuge for grassland birds.

ACKNOWLEDGEMENTS

Funding for this project was provided by the National Science and Engineering Research Council (NSERC) through a CGS award to B. Frei, the Fondation de la faune du Québec (FFQ), the Canadian Wildlife Service (CWS), Bird Protection Quebec (BPQ), and McGill University. Field assistance was ably provided by C. Lecoeur, K. Robinson, R. Theoret-Gosselin, and R. Verkade. We are very grateful for the endless patience, insight, and support from M.-A.R. Hudson, S.R. Craik, M.A. Gahbauer, and Dr. J. Day. We thank A. Stairs, D. Fournier from the City of Montreal, and E. Armson from Ducks Unlimited Canada for use of their hayfields for this study. We are grateful to the McGill Bird Observatory (MBO) for training in banding and equipment use and the Avian Science and Conservation Centre for support.

LITERATURE CITED

- ASKINS, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11:1-34.
- BOLLINGER, E. K., P. B. BOLLINGER, AND T. A. GAVIN. 1990. Effects of haycropping on eastern populations 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. In: Ecology and conservation of Neotropical migrants. (J. M. Hagan and D. W. Johnston, eds.), pp. 497-506.
 Smithsonian Institute Press, Washington, D.C.
- BOWMAN, G. B., AND L. D. HARRIS. 1980. Effects of spatial heterogeneity on ground-nest depredation. Journal of Wildlife Management **44**:806-813.
- BURNHAM, K. P., AND D. R. ANDERSON. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, NY.
- CLARK, R., G., AND D. SHUTLER. 1999. Avian habitat selection: pattern from process in nest-site use by ducks? Ecology 80:272-287.
- DAVIS, S. K. 2003. Nesting ecology of mixed-grass prairie songbirds in southern Saskatchewan. Wilson Bulletin 115: 119-130.
- DAVIS, S. K., AND S. G. SEALY. 1998. Nesting biology of the Baird's Sparrow in southwestern Manitoba. Wilson Bulletin 110:262-270.
- DECHANT, J. A., M. L. SONDREAL, D. H. JOHNSON, L. D. IGL, C. M. GOLDADE, A.L. ZIMMERMAN, AND B. R. EULISS. 2003. Effects of management practices on grassland birds: Bobolink. Northern Prairie Research Centre,

Jamestown, N.D.

< http://www.npwrc.usgs.gov/resource/literatr/grasbird/bobo/bobo.htm> (24 March 2009)

- DEGRAFF, R. M., AND T. J. MAIER. 1996. Effect of egg size on predation by Whitefooted Mice. Wilson Bulletin 108:535-539.
- DION, N., K. A. HOBSON, AND S. LARIVIERE. 2000. Interactive effects of vegetation and predators on the success of natural and simulated nests of grassland songbirds. Condor 102:629-634.
- EADIE, W. R. 1953. Response of *Microtus* to vegetative cover. Journal of Mammalogy **34**:263-264.
- FLETCHER, R. J., AND R. R. KOFORD. 2003. Spatial responses of Bobolinks (*Dolichonyx oryzivorus*) near different types of edges in northern Iowa. Auk 120:799-810.
- GIULIANO, W. M., AND S. E. DAVES. 2002. Avian response to warm-season grass use in pasture and hayfield management. Biological Conservation 106:1-9.
- GÖTMARK, F. 1992. The effects of investigator disturbance on nesting birds. Current Ornithology 9:63-104.
- GUZY, M. J. 2005. Habitat use, nesting biology, and within-season movements of grassland birds in southwest Wisconsin. Ph.D. dissertation, University of Wisconsin, Madison, WI.
- HERKERT, J. R. 1994. The effect of habitat fragmentation on midwestern grassland bird communities. Ecological Applications 4:461-471.

- HERKERT, J. R. 1997. Bobolink (*Dolichonyx oryzivorus*) population decline in agricultural landscapes in the midwestern U.S.A. Biological Conservation 80:107.
- HERNÁNDEZ, F., S. E. HENKE, N. J. SILVY, AND D. ROLLINS. 2003. The use of Prickly Pear as nesting cover by Northern Bobwhites. Journal of Wildlife Management 67:417-423.
- JACKSON, D. A. 1993. Stopping rules in principal component analysis: a comparison of heuritical and statistical approaches. Ecology 74:2204-2214.
- JIMÉNEZ, J. E., AND M. R. CONOVER. 2001. Ecological approaches to reduce predation on ground-nesting gamebirds and their nests. Wildlife Society Bulletin 29:62-69.
- JOHNSON, D. H., AND L. D. IGL. 2001. Area requirements of grassland birds: A regional perspective. Auk 118:24-34.
- KERNS, C. K. 2004. Passerine nest ecology in managed, mixed-grass prairie. Thesis. University of Missouri-Columbia, Columbia.
- KREBS, J. R., J. D. WILSON, R. B. BRADBURY, AND G. M. SIRIWARDENA. 1999. The second Silent Spring? Nature 400:611-612.
- LARIVIÈRE, S., AND F. MESSIER. 1998. Effect of density and nearest neighbours on simulated waterfowl nests: can predators recognize high-density nesting patches? Oikos 83:12-20.
- LARIVIÈRE, S., AND F. MESSIER. 2000. Habitat selection and use of edges by Striped Skunks in the Canadian prairies. Canadian Journal of Zoology **78**:366-372.
- LEGENDRE, L., AND P. LEGENDRE. 1983. Numerical ecology. Elsevier, Amsterdam, NL.

- MARTIN, S. G. 1971. Polygyny in the Bobolink: habitat quality and the adaptive complex. Ph.D. dissertation, Oregon State University, Corvallis, OR.
- MARTIN, S. G. 1974. Adaptations for polygenous breeding in the Bobolink, *Dolichonyx oryzivorous*. American Zoologist 14:109-119.
- MARTIN, S. G., AND T. A. GAVIN. 1995. Bobolink (*Dolichonyx oryzivorous*). In: the Birds of North America (A. Poole and F. Gills, eds.) The Birds of North America, Inc., Philadelphia, PA.
- MARTIN, T. E. 1988. On the advantage of being different: nest predation and the coexistence of bird species. Proceedings of the National Academy of Science of the United States of America **85**:2196-2199.
- MARTIN, T. E. 1992. Breeding productivity considerations: what are the appropriate habitat features for management? In: Ecology and conservation of Neotropical migrant landbirds (J. M. Hagan and D. W. Johnstone, eds), pp. 455-473. Smithsonian Institution Press, Washington, D.C.
- MARTIN, T. E. 1993. Nest predation among vegetation layers and habitat types: revising the dogmas. American Naturalist 141:897-913.
- MARTIN, T. E., AND J. J. ROPER. 1988. Nest predation and nest-site selection of a western population of the Hermit Thrush. Condor 90:51-57.
- MASON, W., AND L. LACHANCE. 1983. Effects of initial harvest on dry matter yield, in vitro dry matter digestibility and protein in Timothy, Tall Fescue, Reed Canarygrass, and Kentucky Bluegrass. Canadian Journal of Plant Science 63:675-685.

- MUCHAI, M., AND M. A. DU PLESSIS. 2005. Nest predation of grassland bird species increases with parental activity at the nest. Journal of Avian Biology 36:110-116.
- NOCERA, J. J., G. J. FORBES, AND G. MILTON. 2007. Habitat relationships of three grassland breeding bird species: broadscale comparisons and hayfield management implications. Avian Conservation and Ecology **2**:7-20
- NOCERA, J. J., G. J. PARSONS, R. MILTON, G., AND A. H. Fredeen. 2005.

Compatibility of delayed cutting regime with bird breeding and hay nutritional quality. Agriculture, Ecosystems and Environment 107:245-253.

- NORMENT, C. 2002. On grassland bird conservation in the Northeast. Auk 119:271-279.
- 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.
- PERLUT, N. G., A. M. STONG, 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.
- PETERJOHN, B. G., AND J. R. SAUER. 1999. Population status of North American grassland birds from the North American Breeding Bird Survey, 1966-1996. Studies in Avian Biology 19:27-44.
- 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.

- STEPHENS, S. E., J. J. ROTELLA, M. S. LINDBERG, M. L. TAPER, AND J. K. RINGELMAN. 2005. Duck nest survival in the Missouri Coteau of North Dakota: landscape effects at multiple spatial scales. Ecological Applications 15:2137-2149.
- TRAYLOR, J. J., R. T. ALISAUSKAS, AND F. P. KEHOE. 2004. Nesting ecology of White-winged Scoters (*Melanitta fusca deglandi*) at Redberry Lake, Saskatchewan. Auk 121:950-962.
- VICKERY, P. D., P. L. TUBARO, J.M.C. DA SILVA, 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.
- WALSBERG, G. E. 1985. Physiological consequences of microhabitat selection *in* M. L. Cody, editor. Habitat selection in birds. Academic Press, Inc., Orlando, FL.
- WHITE, G. C., AND K. P. BURNHAM. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:S120-139.
- WHITTAKER, J. C., E. LIST, J. R. TESTER, AND D. P. CHRISTIAN. 1991. Factors influencing Meadow Vole, *Microtus pennsylvanicus*, distribution in Minnesota. Canadian Field-Naturalist 105:403-405.
- WINTER, M., D. H. JOHNSON, J. A. SHAFFER, AND W. D. SVEDARSKY. 2004.Nesting biology of three grassland passerines in the northern tallgrass prairie.Wilson Bulletin 116:211-223.

Table 1. Nesting ecology of Bobolinks at Atocas Bay, Ontario (AT), Bois-de-la-Roche, Québec (BR) and Hemmingford, Québec (HM) for 2006 and 2007. Re-nests were excluded.

Sites	AT		BR		HM	
Number of nests (<i>n</i>)	25		12		13	
Parameters	Mean	SE	Mean	SE	Mean	SE
Nest initiation date	30-May	0.8	29-May	1.7	26-May	1.0
Hatch date	15-Jun	0.6	13-Jun	1.6	11-Jun	0.9
Fledge date	25-Jun	0.7	24-Jun	1.9	22-Jun	0.8

Site and year	2006	2006	2006	2007	2007	2007	
Parameters	AT	BR	HM	AT	BR	HM	
Egg hatchability ¹ (%)	71.2	75.0	57.1	46.2	73.2	97.2	
SE	11.9	25.0	12.7	12.5	13.0	2.8	
Total fledge ² (%)	54.5	62.5	42.9	29.9	48.2	97.2	
SE	13.0	23.9	9.2	11.1	14.1	2.8	
Apparent nest success ³	9/13	3/4	6/7	5/13	6/10	6/6	

Table 2. Apparent nest success for Bobolinks at Atocas Bay, Ontario (AT), Bois-de-la-Roche, Québec (BR), and Hemmingford, Québec (HM) for 2006-2007.

¹ Calculated from the number of eggs hatched over the number of eggs laid for each nest

² Calculated from the number of nestlings fledged over the number of nestlings hatched for each nest

³ Calculated from the number of successful nests over the number of nests found

Model ⁴	AIC ⁵	ΔAIC_{c}^{6}	ω_i^{z}	Model Likelihood	K ⁸
$\{S_{age + site}\}$	116.673	0.000	0.288	1.000	4
$\left\{S_{age+site+robel}\right\}$	117.819	1.146	0.162	0.638	5
$\left\{S_{age+site+verticalcover}\right\}$	118.373	1.700	0.233	0.427	5
$\{S_{age+site+forbcover}\}$	118.466	1.793	0.117	0.407	5
$\left\{S_{age}+\text{site}+\text{litter depth}\right\}$	118.708	2.034	0.104	0.361	5
$\{S_{site}\}$	119.814	3.140	0.060	0.208	3
$\{S_{age + site + litter depth + itter dept$					
ground cover}	120.434	3.760	0.044	0.152	6
$\{S_{age+site+litterdepth+}$					
forb cover + robel }	121.030	4.356	0.032	0.113	7
$\{S_{age}\}$	121.687	5.014	0.018	0.081	2
$\big\{S_{age+site+litterdepth+}$					
forb cover + vertical cover}	122.212	5.539	0.018	0.062	7
$\big\{S_{age+site+verticalcover+}$					
litter depth + robel + forb cover}	122.826	6.153	0.013	0.046	8

Table 3. Summary of model selection results for Bobolink nest survival over the three study sites in 2006-2007.

 4 Models are ordered according to ascending ΔAIC_{c} . Model factors include constant daily

survival (S.), linear age trend (age), linear season trend (season), study site (site) and four vegetation

variables: vertical cover, litter depth, robel, and forb cover

⁵ Akaike's Information Criterion, adjusted for small sample size

 $^{^{\}rm 6}$ Difference between the AIC $_{\rm c}$ of current model and AIC $_{\rm c}$ of best model

⁷ Akaike weight: strength of evidence given the data, normalized to sum to one

⁸ Number of parameters estimated

{S.}	124.290	7.616	0.006	0.022	1
$\{S_{year}\}$	126.901	9.228	0.002	0.009	2
$\{S_{season}\}$	126.187	9.513	0.002	0.008	2

Table 4. Calculated weighted beta estimates for parameters found in the confidence model set (within 10% of best-supported model) and associated weighted unconditional standard errors (SE) and confidence intervals (CI) for Bobolink nest survival over the three study sites in 2006-2007.

Variabla	Beta	Weighted	Weighted unconditional 05%		
v allable	estimates	unconditional SE	weighted unconditional 95% CI		
			Upper	Lower	
Nest age	0.096	0.040	0.175	0.017	
Site	-0.914	0.367	-0.196	-1.631	
Vertical cover	-0.208	0.368	0.511	-0.927	
Litter depth	0.026	0.285	0.582	-0.530	
Robel	0.392	0.341	1.057	-0.273	
Forb cover	0.232	0.307	0.832	-0.367	

Site/ Year	DSR	SE	95% CL		Mayfield estimate
			Upper	Lower	
HM	0.994	0.005	0.961	0.999	75.0
BR	0.969	0.013	0.927	0.987	50.5
AT	0.949	0.013	0.914	0.970	19.9
2006	0.961	0.010	0.933	0.978	33.6
2007	0.973	0.010	0.942	0.988	47.1

Table 5. Bobolink daily survival rates (DSR) and Mayfield nest success calculated overthe 28-day nesting cycle for individual sites and years.

Variables	Vertical Cover	Litter Depth	Robel	Forb Cover
Vertical Cover	1.0000	-0.0397	-0.0308	-0.2710
	p =	p = 0.780	p = 0.828	p = 0.052
Litter Depth	-0.0397	1.0000	-0.2697	0.0684
	p = 0.780	p =	p = 0.053	p = 0.630
Robel	-0.3080	-0.2697	1.0000	-0.2024
	p = 0.828	p = 0.053	p =	p = 0.150
Forb Cover	-0.271	0.0684	-0.2024	1
	p = 0.052	p = 0.630	p = 0.150	p =

Table 6. Nest-site vegetation variables tested for correlation with Pearson's product-moment correlation coefficient.

in 2006-2007 and the con	rresponding correlat	ion coefficient with	the first canonical
discriminant function.			
Variables	Nest sites	Non-nest sites	DFA correlation coefficients
Vertical cover ⁹	1.8 ± 0.1	3.7 ± 0.3	0.919*
Litter depth (cm)	1.3 ± 0.2	1.8 ± 0.3	0.046

 42.9 ± 2.2

 40.2 ± 3.5

-0.120

-0.354*

 43.0 ± 1.6

 50.1 ± 2.9

Table 7. Nest-site vegetation variables (mean \pm SE) for Bobolink nest and non-nest sites

Robel (cm)

Forb cover (%)

⁹ Lower values for vertical cover signify higher concealment.

^{*} Coefficients < |0.35| were deemed not significant.

Table 8. Nest-site comparisons between nests and non-nests for Bobolinks at Atocas Bay, Ontario (AT), Bois-de-la-Roche, Québec (BR), and Hemmingford, Québec (HM) for 2006-2007. Shown are mean \pm SE values of untransformed variables and results for Mann-Whitney *U* comparisons.

Site and variable	Nest	Non-nest	U(p)
HM			
п	13	13	
Vertical cover	1.9 ± 0.3	1.9 ± 0.2	82.0 (0.88)
Litter depth	0.0	0.0	84.0 (1.00)
Robel	54.7 ± 3.5	46.7 ± 3.4	51.5 (0.09)
Forb cover	27.7 ± 4.4	28.0 ± 7.0	75.5 (0.64)
BR			
п	14	14	
Vertical cover	1.6 ± 0.3	4.1 ± 0.4	$16.0 (0.00)^1$
Litter depth	2.6 ± 0.3	3.4 ± 0.6	68.0 (0.17)
Robel	43.1 ± 2.6	45.1 ± 2.7	85.0 (0.55)
Forb cover	47.0 ± 5.3	34.9 ± 6.6	69.5 (0.19)
AT			
п	26	26	
Vertical cover	1.8 ± 0.2	4.3 ± 0.4	$119.0 (0.00)^1$
Litter depth	1.3 ± 0.2	1.8 ± 0.4	331.0 (0.89)
Robel	37.1 ± 1.4	39.8 ± 3.8	306.0 (0.59)
Forb cover	62.5 ± 2.8	$49.0\ \pm 4.6$	$225.5(0.04)^1$

¹ Values are significant at $p \le 0.05$.

Table 9. Nest-site comparisons between successful and unsuccessful nests for Bobolinks at Atocas Bay, Ontario (AT), Bois-de-la-Roche, Québec (BR), and Hemmingford, Québec (HM) for 2006-2007. Shown are mean \pm SE values of untransformed variables.

Site and variable	Successful	Unsuccessful
HM		
п	9	1
Vertical cover	1.8 ± 0.3	3.8
Litter depth	0.0	0.0
Robel	56.1 ± 4.8	38.0
Forb cover	29.8 ± 4.0	3.0
BR		
n	9	5
Vertical cover	1.6 ± 0.4	1.6 ± 0.6
Litter depth	2.3 ± 0.3	3.2 ± 0.5
Robel	45.2 ± 3.6	39.2 ± 3.6
Forb cover	50.1 ± 8.0	41.4 ± 3.8
AT		
n	12	14
Vertical cover	1.5 ± 0.3	2.0 ± 0.4
Litter depth	1.3 ± 0.3	1.4 ± 0.3
Robel	39.8 ± 2.3	34.8 ± 1.6
Forb cover	66.3 ± 4.7	59.1 ± 3.0


Figure 1. The cumulative percentage of nests fledged for 2006, 2007, and both years combined for Bobolinks at Atocas Bay, Ontario (AT), Bois-de-la-Roche, Québec (BR) and Hemmingford, Québec (HM).



Figure 2. Daily survival rate (DSR) of Bobolink nests during laying, incubation, and nestling stages for all three study sites and years combined. Estimates \pm 95% CI were calculated by using weighted averages based on a confidence model set and were weighted according to AIC_c values from each model.



Figure 3. Comparison of litter depth (cm) (± SE) at Bobolink nest sites in 2006 and 2007 at Atocas Bay, Ontario (AT), Bois-de-la-Roche, Québec (BR) and Hemmingford, Québec (HM). Note: Litter depth for HM was zero for nests and non-nests in both years of study.

CONNECTING STATEMENT

Chapter 2 examined the ecology of Bobolinks in hayfields and made specific recommendations on their management and conservation in these habitats based on nest success and nest-site selection. Chapter 3 describes the Bobolink's nest ecology in further detail, focusing on nestling growth.

CHAPTER 3: NESTLING GROWTH OF BOBOLINKS

ABSTRACT

Despite recent attention given to Bobolinks (Dolichonyx oryzivorus) in the conservation literature as a consequence of their rapid and widespread decline, little information exists concerning their basic nestling ecology, including egg and linear nestling measurements and descriptions of nestling growth. Fifty-three Bobolink nests were monitored at three study areas in Québec and eastern Ontario in 2006 – 2007. Egg measurements and weights were recorded for 194 eggs from 37 nests, and nestling wing length, tarsus length, and mass were measured for 169 nestlings ranging from ages two -10 days old. There were no differences between clutch size, egg size, and weight between years and sites, except egg width, which was found to be significantly different between years (t_{53} = -7.57 P < 0.001). Bobolink nestlings fledge well below adult size and weight, achieving a respective 83 %, 64 %, and 52 % of breeding adult male tarsus length, mass, and wing length. Maximum nestling growth occurred between days three to six for all variables with a tarsus growth inflection point around day eight to nine. We were unable to determine the mechanisms producing different egg widths and nestling growth. We suggest that fledging below adult size and weight is a consequence of the adaptive pressure to leave the vulnerability of the ground nest as quickly as possible and continue to grow to adult size while being fed by parents outside the nest. As well, rapid tarsus growth suggests a strategy to allow young to be able to leave the nest due to disturbance by running on the ground as early as day seven.

INTRODUCTION

The Bobolink is an obligate grassland species that has received much attention in the recent conservation literature concerning declines in North America, mainly due to habitat loss and agricultural intensification (Bollinger et al. 1990, Jobin et al. 1996, Dale et al. 1997, Herkert 1997). Studies have examined various aspects of breeding patterns and population-level ecology (Bollinger and Gavin 1992, Fletcher and Koford 2003, Winter et al. 2004), yet little information is available on eggs and nestlings, including linear nestling measurements, and values that are given are based on small sample sizes (e.g., mean egg mass, n = five) (Martin and Gavin 1995).

Bobolinks belong to the family *Icteridae*. Asynchronous hatching, resulting from incubation that begins as the penultimate egg is laid is a common occurrence in this family. This results in core nestlings (early-hatched) and marginal nestlings (late-hatched). Asynchronous hatching in Bobolinks was reported where one chick hatched 20-30 hours later than the rest of the nestlings (Martin 1974). To our knowledge this is the only study that has described nestling biology of Bobolinks.

Nestling Growth Patterns

Patterns of growth have been described using several different parameters: (a) growth rate, (b) percentage of adult weight attained by dependent young, and (c) shape of the growth curve (Ricklefs 1968). Patterns of growth may differ among species and within species (Ricklefs 1968), due to various environmental (weather, food availability), temporal (nest initiation, year), and biological variables (Ricklefs 1983, 1984, Amundsen and Stokland 1990, Ortega and Cruz 1992). Growth rates are usually 'standard' in shape, where weight increases throughout the nestling period to reach near adult level at

fledging. There are also two variants, where (a) nestlings attain a peak weight above adult weight and decrease to adult weight just before or after fledging, and (b) growth levels below adult values when growth is completed after young fledge (Ricklefs 1968).

Nestling growth rates and patterns of growth are useful measures with which to examine the influence of environmental, parental, and social parameters the nestlings are subjected to. They can also provide a time-frame of critical growth for various body components, which may provide insight into vulnerable periods during the nesting cycle.

STUDY AREA

This study was conducted at three sites chosen in southwestern Québec and eastern Ontario that had established Bobolink populations. The sites consisted of a private hay farm near Hemmingford, Québec (45° 05' N, 73° 36' W), an agricultural park (Bois-de-la-Roche) in Senneville, Québec (45° 26' N, 73° 56' W), and a wildlife conservation area (Atocas Bay) in Lefaivre, Ontario (45° 36' N, 74° 51' W).

METHODS

Nestling Measurements

This study was part of a larger project on nest-site selection and nest success (B. Frei et al. *submitted*). Eggs were measured on the day of discovery or as they were laid. They were numbered using a non-toxic permanent marker; length and breath were measured with dial calipers to the nearest 0.1 mm and weighed to the nearest 0.1 g with a portable electronic balance. Nestling measurements were taken twice during consecutive visits three - four days apart between 07:00 and 15:00 EST. Nestlings were individually marked on the initial visit by coloring their toenails using non-toxic permanent markers. Length of the unflattened wing chord (wing length) was measured to the nearest 0.5 mm

using a ruler with a wing stop. The tarsometatarsus (tarsus) length was measured to the nearest 0.1 mm with dial calipers. Lastly, nestlings were weighed to the nearest 0.1 g with a portable electronic balance. Weighing was performed last so that prior light handling during measurement could induce fecal sac release. These measurements were repeated around day seven or on the last day visited. All measurements were performed by BF. Nestlings were banded once they were seven days old or older using USFWS aluminum bands by a licensed bander (BF). Nests were followed until completion, and nests that fledged at least one young were deemed successful. Each nestling was aged separately during each visit, since asynchronous hatching resulted in different aged nestlings within the same nest. Nestlings were aged using a combination of amount of down, feather tracts and feather eruption from sheaths, and opening of eyes. Photos were taken at each visit and compared at the end of the study so comparisons between knowage nestlings could correct aging for unknown age nestlings.

Statistical Analysis

Clutch size, egg measurement, and nestling measurement data were checked for normality using Shapiro-Wilks' test (Zar 1999). Clutch size was non-normal and was not improved by square-root and log transformation, therefore raw data and non-parametric tests were used. Bobolink egg mass was log-transformed, but egg length and weight were not improved by transformation, thus untransformed data were used for analysis. Clutch size and egg measurements were compared between years using a Mann-Whitney test and between sites using Kruskal-Wallis test (Zar 1999). Nestling growth for wing length, tarsus length, and weight was normally distributed, yet wing length was square-root transformed for slight improvement. The three variables were tested across all age classes using the Kruskal-Wallis test and across each consecutive age class (i.e., day two to three, day three to four, ect.) using the Mann-Whitney test.

All mean values are reported \pm standard error and data analyses were performed using SPSS (SPSS16.0 Inc., Chicago, IL). Although male and female Bobolinks are dimorphic, they cannot be sexed as nestlings, therefore adult male measurements for the breeding season were used as general adult measurements (Martin and Gavin 1995).

RESULTS

Clutch Size and Egg Measurements

Measurements were taken on 194 eggs from 37 nests. Of the 53 nests monitored, 16 nests found either during the nestling stage or predated prior to measurements being taken, were excluded from egg calculations. Mean clutch size for all years and sites was $5.30 (\pm 0.1 \text{ egg}, \text{ range } 3 - 6 \text{ eggs}, N = 53)$. Clutch size did not differ between years (t_{53} = -0.47, P = 0.636) and sites (t_{53} = 0.43, P = 0.803) (Table 1). Mean egg length, width, and weight for all years and sites (N = 194) was: 1.97 ± 0.20 cm (range = 1.63 - 2.31 cm), 1.37 ± 0.02 cm, (range = 1.36 - 1.67 cm) and 2.69 ± 0.05 g (1.6 - 3.5 g), respectively. Although mean egg measurements were, for the most part, similar when compared over sites and years, egg width was found to differ significantly between years (t_{53} = -7.57 P <0.001) (Table 1).

Nestling Measurements and Growth

Measurements were taken from 169 nestlings opportunistically during nest visits for a nest success study (B.Frei et al. *submitted*). These data were used to calculate mean age measurements for nestling wing length, tarsus length, and mass at ages of two to 10 days (Table 2). All nestlings were measured once or twice over the span of 10 days. Due to predation and late nest discovery (with older nestlings), only a subset of the nestlings was measured twice (n = 102). Longitudinal data were collected for 102 nestlings from 25 nests over all years and sites. These means were used to calculate the % of adult size that was reached each day (Fig.1). Of the 25 nests from which linear nestling measurements were obtained, three nests hatched synchronously (12 %), 20 nests had one marginal nestling (80 %), and two nests had two marginal nestlings (8 %). In three of four re-nests, nestlings were one day apart, indicating that incubation began with the laying of the first egg, not the penultimate egg (Fig. 2).

DISCUSSION

General Nest Ecology

In general, Bobolink clutch size may vary from three to seven eggs (Martin and Gavin 1995). Clutch size in this study $(5.30 \pm 0.1 \text{ eggs}, \text{ range } 4 - 6 \text{ eggs}, N = 53)$ is similar to that in other populations of the midwest $(5.25 \pm 0.08 \text{ eggs})$ (Winter et al. 2004) and $(5.10 \pm 0.06 \text{ eggs})$ (Martin and Gavin 1995) and in eastern North America $(5.28 \pm 0.13 \text{ eggs})$ (Perlut et al. 2006). Re-nest clutches were smaller (4 eggs) than original nests (5 - 6 eggs).

Consistency of egg and clutch size is a consequence of selective pressures and energy expenditure limitations during egg laying, incubation, and nestling rearing stages (Lack 1947). Seasonal variations of clutch size occur in many bird species. When a single-brooded bird lays a second nest due to abandonment, predation, or destruction of the first nest, the second clutch is often smaller (Lack 1947). Bobolink females generally begin incubation with the laying of the penultimate egg, leading to brood asynchrony with the last laid egg hatching ~ 24 hours after the rest of the clutch (Martin 1974). In our study most re-nests had nestlings staggered in age, a result of incubation beginning with the first egg laid. This, paired with smaller clutch sizes, suggests that females shorten the cycle of the re-nest. As late nesters and long-distance migrants, Bobolinks face strong selective pressures for a short breeding season to allow young maximum growth before the long migration southward in late summer (Martin and Gavin 1995).

Bobolink egg size and weight were consistent over the two years and the three study sites, except for egg width; which was significantly wider in 2007 (1.43 ± 0.01) than in 2006 (1.33 ± 0.02 ; Table 1). Egg size variation within a population is commonplace for many species, with the largest egg ranging from 1.5 to two times as large as the smallest (Christian 2002). In our Bobolink populations egg weight ranged from 1.6 - 3.5 g. Larger eggs usually result in larger nestlings structurally due to larger energy reserves (Smith and Bruun 1998). This, along with hatching asynchrony, is a parentally induced method to ensure fledgling of at the least the strongest young at the expense of the weakest (Howe 1976, Amundsen and Slagsvold 1996). Egg sizes can differ within-clutch, with resulting nestling hierarchies, or between-clutch. Betweenclutch variation is far more common (Christian 2002) and may depend on environmental variables such as geographic location and food availability, but is largely the consequence of female physiological differences (Christian 2002).

Nestling Growth

Fledgling measurements (at day 10) for wing length, tarsus length, and mass were all well below breeding adult male values (Fig. 1). When Bobolink nestlings fledged, they measured, on average, a respective 83 %, 64 %, and 52 % of breeding adult male tarsus length, mass, and wing length (Fig. 1). The Bobolink growth curve is a variant of

69

the 'standard' growth curve, where growth increases to near adult level during the nestling cycle (Ricklefs 1968). In Bobolinks, fledging occurs prior to reaching adult size and weight, and is completed after the young leave the nest. This may be adaptive for ground-nesting birds such as the Bobolink, where young are especially vulnerable to predators and inclement weather. Nestlings of species with safe, well-protected nests generally remain longer in nests than young in exposed nests (Ricklefs 1968). Post-natal growth rates in birds vary between species, populations, and individuals, as a result of numerous factors, such as brood size, date of clutch initiation, habitat, and geographic locality (Ricklefs 1983), predation levels on young and amount of food available to parents for feeding of young (Ricklefs 1984), egg size (Amundsen and Stokland 1990), and nestling sex (Ortega and Cruz 1992).

Growth of wing, tarsus, and weight was greatest between nestling days three – six (Fig. 1, Table 3). The tarsus inflection point occurs around day eight – nine when growth levels off below adult values. Unpublished data from studies in New York and Wisconsin indicated that the Bobolink weight gain inflection point occurs eight days after hatching (Martin and Gavin 1995). Tarsus growth was more rapid and achieved a higher % of adult size. This accelerated growth of a nestling character is a type of 'growth strategy'. In Bobolinks this may be a reflection of the pressure to enable young to run from the nest by day seven if disturbed (Martin and Gavin 1995), but additional study is needed. Incomplete growth prior to fledging is associated with feeding by parents after the young leave the nest, where they complete their growth to adult size (Martin and Gavin 1995). Wing length at fledging is half of adult length due to incomplete feather development,

thus young Bobolinks are poor fliers for the first week following fledging until adult wing length is achieved (Martin and Gavin 1995).

Bobolink nestling growth is likely quite variable. It is subject to the previously mentioned variables as well as asynchronous hatching, a polygynous breeding system, and sexual dimorphism. Later hatched, marginal nestlings often have slower growth rates than their larger, older siblings due to a disadvantage in food competition (Lago and Johnson 2000). Secondary females in a Bobolink breeding system feed their young without help from the male, unlike a primary female where both parents feed the nestlings. Secondary females face time conflict between searching for food and brooding young early in the nestling period. This results in less food being made available to nestlings, which results in slower growth rates in young from nests of secondary females (Martin 1974). Female nestlings in sexually dimorphic species are smaller than male nestlings, yet in some species, such as the Yellow-headed Blackbird (Xanthocephalus *xanthocephalus*), female growth rates are faster and female nestlings achieve earlier feather maturation and a higher proportion of adult weight than their male siblings (Ortega and Cruz 1992). These traits in combination may create extremes in growth rates among individuals: a marginal male nestling from a secondary nest growing far slower than a core female nestling from a primary female nest. A long-term study is needed to elucidate these relationships.

Additional and daily nestling measurements, as well as data on egg-laying order, female social status, and the ability to sex nestlings would have allowed calculations of specific growth rates and comparisons between primary and secondary nests, core and marginal nestlings, sexes, and different nestling stages. Unfortunately, this was not

71

possible due to logistic and time constraints. However, this is the first report of linear nestling measurements for Bobolinks, which provides baseline data for future studies and comparisons as well as information vital for the management and conservation of this declining grassland species.

ACKNOWLEDGEMENTS

Funding for this project was provided by the Natural Sciences and Engineering Research Council (NSERC) through a CGS award to B. Frei, the Fondation de la faune du Québec (FFQ), the Canadian Wildlife Service (CWS), Bird Protection Quebec (BPQ), and McGill University. Field assistance was ably provided by C. Lecoeur, K. Robinson, R. Theoret-Gosselin, and R. Verkade. We are very grateful for the endless patience, insight, and support from our colleagues in the BirdCage. We thank A. Stairs, the City of Montréal, and Ducks Unlimited for use of their hayfields for this study. We are grateful to the McGill Bird Observatory for training in banding and equipment use and the Avian Science and Conservation Centre for support.

LITERATURE CITED

- AMUNDSEN, T. AND T. SLAGSVOLD. 1996. Lack's brood reduction hypothesis and avian hatching asynchrony: what's next? Oikos **76**:613-620.
- AMUNDSEN, T. AND J. N. STOKLAND. 1990. Egg size and parental quality influence nestling growth in the Shag. Auk **107**:410-413.
- BOLLINGER, E. K., P. B. BOLLINGER, AND T. A. GAVIN. 1990. Effects of haycropping on eastern populations 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. Pages 497-506 *in* J. M. Hagan and D. W. Johnston, editors. Ecology and Conservation of Neotropical Migrants.
 Smithsonian Institute Press, Washington, D.C.
- CHRISTIAN, J. K. 2002. Avian egg size: variation within species and inflexibility within individuals. Biological Reviews 77:1-26.
- DALE, B. C., P. A. MARTIN, AND T. P. S. 1997. Effects of hay management on grassland songbirds in Saskatchewan. Wildlife Society Bulletin **25**:616-626.
- FLETCHER, R. J. AND R. R. KOFORD. 2003. Spatial responses of Bobolinks (*Dolichonyx oryzivorus*) near different types of edges in northern Iowa. Auk 120:799-810.
- HERKERT, J. R. 1997. Bobolink (*Dolichonyx oryzivorus*) population decline in agricultural landscapes in the midwestern USA. Biological Conservation 80:107-112.
- HOWE, H. F. 1976. Egg size, hatching asynchrony, sex, and brood reduction in the common grackle. Ecology 57:1195-1207.
- JOBIN, B., J.-L. DESGRANGES, AND C. BOUTIN. 1996. Population trends in selected species of farmland birds in relation to recent developments in agriculture in the St. Lawrence Valley. Agriculture, Ecosystems & Environment 57:103-116.

LACK, D. 1947. The significance of clutch size. Ibis 89:302-352.

LAGO, K. AND L. S. JOHNSON. 2000. Growth of late-hatched, competitively disadvantaged nestling House Wrens relative to their older, larger nestmates. Journal of Field Ornithology 71:676-685.

- MARTIN, S. G. 1974. Adaptations for polygynous breeding in the Bobolink (*Dolichonyx oryzivorous*). American Zoologist **14**:109-119.
- 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.
- ORTEGA, C. P., AND A. CRUZ. 1992. Differential growth patterns of nestling Brownheaded Cowbirds and Yellow-headed Blackbirds. Auk **109**:368-376.
- PERLUT, N. G., A. M. STONG, 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.

RICKLEFS, R. E. 1968. Patterns of growth in birds. Ibis 110:419-451.

- RICKLEFS, R. E. 1983. Avian postnatal development. Pages 1-83 *in* D. S. Farner and J.R. King, editors. Avian Biology. Academic Press, New York, NY, USA.
- RICKLEFS, R. E. 1984. The optimization of growth rate in altricial birds. Ecology **65**:1602-1616.
- SMITH, H. G., AND M. BRUUN. 1998. The effect of egg size and habitat on Starling nestling growth and survival. Oecologia 115:59-63.
- WINTER, M., D. H. JOHNSON, J. A. SHAFFER, AND W. D. SVEDARSKY. 2004.Nesting biology of three grassland passerines in the northern tallgrass prairie.Wilson Bulletin 116:211-223.

ZAR, J. H. 1999. Biostatistical analysis. Prentice Hall, Upper Saddle River, N.J.

Table 1. Mean clutch size and egg measurements of Bobolinks at Atocas Bay, Ontario (AT), Bois-de-la-Roche, Québec (BR) and Hemmingford, Québec (HM) for 2006 and 2007 and significance values of non-parametric statistical tests.

Means		Years		S	ites (pool	ed across y	rears)
	2006	2007	Mann- Whitney	HM	BR	AT	Kruskal- Wallis
n	17	20	37	10	10	17	37
Clutch size	5.3	5.2	0.636	5.3	5.0	5.7	0.803
(± SE)	0.1	0.2		0.2	0.3	0.2	
Egg length	1.96	1.98	0.247	1.96	1.97	1.98	0.695
(± SE)	0.02	0.03		0.02	0.03	0.03	
Egg width	1.43	1.33	0.002	1.37	1.37	1.38	0.824
(± SE)	0.01	0.02		0.03	1.02	0.03	
Egg weight	2.74	2.65	0.247	2.61	2.75	2.70	0.676
(± SE)	0.07	0.07		0.11	0.07	0.08	

Nestling	Wing len	gth	Tarsus ler	ngth	Mass	
days	means (cm)	SE	mean (cm)	SE	mean (g)	SE
2	1.02	0.04	0.95	0.03	6.0	0.5
3	1.27	0.04	1.04	0.04	7.4	0.3
4	1.76	0.04	1.33	0.05	10.6	0.2
5	2.33	0.06	1.63	0.05	14.1	0.4
6	2.98	0.06	1.92	0.07	17.5	0.3
7	3.31	0.11	1.91	0.07	18.7	0.8
8	4.31	0.07	2.25	0.04	21.8	0.4
9	4.67	0.07	2.33	0.06	21.5	0.4
10	5.08	0.05	2.17	0.04	21.8	0.6

Table 2. Mean wing, tarsus, and mass measurements with standard error for 102Bobolink nestlings from three study sites for 2006 and 2007.

Table 3. Comparison of Mann-Whitney test results between consecutive age classes forBobolink nestling growth measurements from three study sites for 2006 and 2007.

Age classes	Wing length	Tarsus length	Weight
2-3	0.006	0.126	0.024
3-4	< 0.001	< 0.001	< 0.001
4 – 5	< 0.001	< 0.001	< 0.001
5-6	< 0.001	< 0.001	< 0.001
6 – 7	0.003	1.000	0.042
7 - 8	< 0.001	< 0.001	< 0.001
8 – 9	0.006	0.181	0.793
9 - 10	0.004	0.045	0.958



Figure 1. Nestling growth represented as a % of parameters for breeding adult male for wing length, tarsus length, and mass for Bobolink nestlings pooled for three sites and two years.



Figure 2. Three Bobolink nestling siblings from a re-nest in Bois-de-la-Roche in 2007; the three nestlings are one day apart in age.

APPENDIX A

-

Animal Care Committee-Approved

MeGill U RENH	PROVED University An EWAL of For: Rese	www.mcgiil.ca/research/compliance/animal/forms/ nimal Care Committee Animal Use Protocol arch Zeaching project	For O Protocol #: ² Approval end Facility Comm Renewal#:	ffice Use Only: 5705 date: Opwel 30, 80 nittee: MAC (17) 2nd
Principal Investigator	r: Dr. David I	Bird	Protocol #	5202
Protocol Title:	Aspects of Ecoryzivorus) in	cology and Management of Bobolinks (Dolichonyx n farmlands of southwestern Québec	Category:	B
Unit, Dept. & Addres	s: Macdonald C	Campus 21,111 Lakeshore Road, Ste-Anne-de-Belle	evue, Quebec, H9X	K 2E4
Email: david.bird@	megill.ca	Phone: 7760	Fax: 7990)
Funding source:	Canadian Wildlife	Service; Fondation de la faune du Quebec; Bird Pr	otection Quebec	96500
Start of Funding:	05/01/06	End of Funding:	04/31/08	
Emergency contact # work AND home pho	1 + Dr. Dav ne #s:	id Bird; work # 7760; home # (514) 457-6800		
work AND home pho 1. Personnel an List the names of the	ne #s:	ions rator and of all individuals who will be in contact	t with animals in	this study and their
work AND home pho 1. Personnel an List the names of the employment classifica the Principal Investig supervision received a <u>www.animalcare.mcgi</u>	ne #s: d Qualificati Principal Investig ation (investigator (ator is not handli must be described <i>il.ca</i> for details. 1	ions gator and of all individuals who will be in contact r, technician, research assistant, undergraduate/ ng animals. If an undergraduate student is invol I. Training is mandatory for all personnel listed Each person listed in this section must sign. (Spa Animal Balatad Training Information	t with animals in graduate student lved, the role of th here. Refer to ce will expand as no	this study and their , fellow). Indicate if ne student and the reded)
work AND home pho 1. Personnel an List the names of the employment classificz the Principal Investig supervision received i www.animalcare.mcgit Name	ne #s: d Qualificati Principal Investig ation (investigator (ator is not handli must be described must be described Classification	ger Titman; work # 7953; home # (514) 457-6480 ions gator and of all individuals who will be in contact ; technician, research assistant, undergraduate/ ng animals. If an undergraduate student is invol . Training is mandatory for all personnel listed Each person listed in this section must sign. <i>(Spa</i> Animal Related Training Information	t with animals in graduate student ved, the role of th here. Refer to cce will expand as no Occupational Health	this study and their , fellow). Indicate if ne student and the eeded) Signature "Has read the
work AND home pho 1. Personnel an List the names of the employment classifica the Principal Investig supervision received 1 <u>www.animalcare.mcgn</u> Name	ne #s:	ions gator and of all individuals who will be in contact , technician, research assistant, undergraduate/ ng animals. If an undergraduate student is invol . Training is mandatory for all personnel listed Each person listed in this section must sign. (Spa Animal Related Training Information UACC on-line Theory course	t with animals in graduate student here. Refer to <i>ice will expand as no</i> Occupational Health Program *	this study and their , fellow). Indicate if ne student and the seeded) Signature "Has read the original full protocop"
work AND home pho 1. Personnel an List the names of the employment classifica the Principal Investig supervision received 1 www.animalcare.mcgt Name Dr. David Bird P Barbara Frei G * Indicate for each perss http://www.mcgill.ca/re	ne #s:	ions gator and of all individuals who will be in contact r, technician, research assistant, undergraduate/ ng animals. If an undergraduate student is invol I. Training is mandatory for all personnel listed Each person listed in this section must sign. <i>(Spa</i> Animal Related Training Information UACC on-line Theory course gator (not handling animals) t UACC on-line course Bird banding permit in the local Occupational Health Program, see animal/occupational/ for details.	t with animals in graduate student ved, the role of th here. Refer to ce will expand as no Occupational Health Program *	this study and their , fellow). Indicate if ne student and the seded) Signature "Has read the original full protocol" Barbara Hu
work AND home pho 1. Personnel an List the names of the employment classific the Principal Investig supervision received Name Dr. David Bird P Barbara Frei G * Indicate for each pers http://www.megill.ea/re	ne #s:	ions gator and of all individuals who will be in contact r, technician, research assistant, undergraduate/ ng animals. If an undergraduate student is invol I. Training is mandatory for all personnel listed Each person listed in this section must sign. (Spandark) Animal Related Training Information UACC on-line Theory course gator (not handling animals) t UACC on-line course Bird banding permit in the local Occupational Health Program, see animal/occupational/ for details. Approved by:	t with animals in graduate student tved, the role of th here. Refer to cee will expand as no Occupational Health Program *	this study and their , fellow). Indicate if he student and the seded) Signature "Has read the original full protocof" Borbana Jus
work AND home pho 1. Personnel an List the names of the employment classific the Principal Investig supervision received 1 www.animalcare.mcgi Name Dr. David Bird P Barbara Frei G * Indicate for each pers- http://www.mcgill.ca/re 2. Approval Sig	ne #s:	ger Titman; work # 7953; nome # (514) 457-6480 ions gator and of all individuals who will be in contact ; technician, research assistant, undergraduate/ ng animals. If an undergraduate student is invol I. Training is mandatory for all personnel listed Each person listed in this section must sign. (Spa Animal Related Training Information UACC on-line Theory course gator (not handling animals) t UACC on-line course Bird banding permit in the local Occupational Health Program, see animal/occupational/ for details. Approved by: AMAM	t with animals in graduate student lived, the role of th here. Refer to cce will expand as no Occupational Health Program *	this study and their , fellow). Indicate if ne student and the seded) Signature "Has read the original full protocol" Barbana Hud
work AND home pho 1. Personnel an List the names of the employment classifice the Principal Investig supervision received 1 www.animalcare.mcgr Name Dr. David Bird P Barbara Frei G * Indicate for each pers- http://www.mcgill.ca/re 2. Approval Sig Principal Investigator Chair Eacility Anim	ne #s:	ger Titman; work # 7953; nome # (514) 457-6480 ions gator and of all individuals who will be in contact , technician, research assistant, undergraduate/ ng animals. If an undergraduate student is invol I. Training is mandatory for all personnel listed Each person listed in this section must sign. (Spa Animal Related Training Information UACC on-line Workshops + others Theory course gator (not handling animals) t UACC on-line course Bird banding permit in the local Occupational Health Program, see animal/occupational/ for details. Approved by: r Animal All theory of the section of th	t with animals in graduate student lved, the role of th here. Refer to ce will expand as ne Occupational Health Program *	this study and their , fellow). Indicate if ne student and the seded) Signature "Has read the original full protocof" Barbana. Fue Barbana. Fue
work AND home pho 1. Personnel an List the names of the employment classifice the Principal Investig supervision received 1 www.animalcare.mcgn Name Dr. David Bird P Barbara Frei C * Indicate for each perss http://www.mcgill.ca/re 2. Approval Sig Principal Investigatou Chair, Facility Anima	ne #s:	ger Titman; work # 7953; nome # (514) 457-6480 ions gator and of all individuals who will be in contact , technician, research assistant, undergraduate/ ng animals. If an undergraduate student is invol L Training is mandatory for all personnel listed Each person listed in this section must sign. (Spa Animal Related Training Information UACC on-line Workshops + others Theory course gator (not handling animals) t UACC on-line course Bird banding permit in the local Occupational Health Program, see animal/occupational/ for details. <i>Approved by:</i> r Mathematical State Stat	t with animals in graduate student lyed, the role of th here. Refer to cce will expand as no Occupational Health Program *	this study and their , fellow). Indicate if ne student and the seeded) "Has read the original full protocol" Barbano. Jul 2/07 31/07
work AND home pho 1. Personnel an List the names of the employment classifica the Principal Investig supervision received n www.animalcare.mcgn Name Dr. David Bird P Barbara Frei G * Indicate for each pers- http://www.mcgill.ca/re 2. Approval Sig Principal Investigatof Chair, Facility Anima UACC Veterinarian Chairperson, Ethics 5	ne #s:	ions gator and of all individuals who will be in contact t, technician, research assistant, undergraduate/ ng animals. If an undergraduate student is invol I. Training is mandatory for all personnel listed Each person listed in this section must sign. (Spa Animal Related Training Information UACC on-line Theory course gator (not handling animals) t UACC on-line course Bird banding permit in the local Occupational Health Program, see animal/occupational/ for details. Approved by: r AMAMANAS	t with animals in graduate student lved, the role of th here. Refer to cee will expand as no Occupational Health Program * Date: Date: Date: 21k Date: 21k	this study and their , fellow). Indicate if he student and the reded) Signature "Has read the original full protocof" Borbono Just 2/07 31/07

□ Renewal requires submission of full Animal Use Protocol form

Form version May 2006

3. Summary (in language that will be understood by members of the general public)

0 7 FEV. 2007

Banding License for B.F.

.

Junior Author Manuscript Permits

From: "Falardeau,Gilles [SteFoy]" <gilles.falardeau@ec.gc.ca> Date: August 13, 2008 9:20:35 AM EDT To: "Barbara Frei" <barbara.frei@mail.mcgill.ca> Subject: Bobolink

This email conveys my approval to permit the manuscript that I am a participating coauthor, *Ecology and management of Bobolinks in farmlands of Québec and Ontario*, as a chapter in the thesis entitled:

'NEST SUCCESS OF BOBOLINKS IN HAYFIELDS OF QUEBEC AND ONTARIO'

by

Barbara Frei, Department of Natural Resource Sciences, Wildlife Biology, McGill University-Macdonald Campus, Montréal, Québec.

Gilles Falardeau Biologist Canadian Wildlife Service 418-648-3926