Effects of Landscape Structure and Agricultural Practices on Farmland Birds in Ontario

By Elena Kreuzberg

(Elena Mukhina)

Bachelor's Biology, Nizhny Novgorod, Russia, 1980

Doctorate, Conservation Biology, Moscow, Russia, 1993

A thesis submitted to the Faculty of Graduate and Postdoctoral Affairs

in partial fulfillment of the requirements for the degree of

Master of Science

in

Biology

**Carleton University
Ottawa, Ontario
© 2011 Elena Kreuzberg**

Library and Archives
Canada

Published Heritage
Branch

395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque et
Archives Canada

Direction du
Patrimoine de l'édition

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence
ISBN: 978-0-494-81702-5
Our file Notre référence
ISBN: 978-0-494-81702-5

NOTICE:

The author has granted a non-exclusive license allowing Library and Archives Canada to reproduce, publish, archive, preserve, conserve, communicate to the public by telecommunication or on the Internet, loan, distribute and sell theses worldwide, for commercial or non-commercial purposes, in microform, paper, electronic and/or any other formats.

The author retains copyright ownership and moral rights in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

AVIS:

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque et Archives Canada de reproduire, publier, archiver, sauvegarder, conserver, transmettre au public par télécommunication ou par l'Internet, prêter, distribuer et vendre des thèses partout dans le monde, à des fins commerciales ou autres, sur support microforme, papier, électronique et/ou autres formats.

L'auteur conserve la propriété du droit d'auteur et des droits moraux qui protègent cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

In compliance with the Canadian Privacy Act some supporting forms may have been removed from this thesis.

While these forms may be included in the document page count, their removal does not represent any loss of content from the thesis.

Conformément à la loi canadienne sur la protection de la vie privée, quelques formulaires secondaires ont été enlevés de cette thèse.

Bien que ces formulaires aient inclus dans la pagination, il n'y aura aucun contenu manquant.

Canada

Abstract

Agricultural expansion and intensification are considered major contributors to biodiversity loss worldwide. However, agricultural landscapes still contain considerable biodiversity, often providing ecosystem services crucial for production.

Farmland birds are recognized in Europe, but not in North America. Based on the EU approach, a list of farmland birds was compiled for Ontario using literature review and expert opinion. Regression analysis for 54 species using point counts from the 2001-2005 Ontario Breeding Bird Atlas with statistics for 181 subdivisions from the 2006 Census of Agriculture was conducted to validate retention and refine categorization of species. The final list for Ontario included 45 species, comprised of 34 specialists (6 row crop, 16 pasture and 12 farmstead) and 11 edge generalists. Landscape structure (especially composition but also configuration and heterogeneity) was more important than practices for richness and abundance of all farmland birds, specialists, generalists and Bird Conservation Region 13 priority species based on statistical comparison of regression models. Subsetting subdivisions (by % farmland) showed that effects of landscape structure (especially composition) on abundance of specialists and edge generalists varied in relation to agricultural extent and intensity. Effects of practices were also more evident. Because tradeoffs existed across the gradient in landscape composition, farmland bird abundance was optimized when row crop occupied 40% to 70% of subdivisions (with 8 to 10% pasture).

The “farmland bird” approach shows promise for monitoring, assessment and management of agricultural landscapes in North America as in Europe.

Acknowledgements

The current research was implemented under the wise direction of research supervisor, Adjunct Professor of the Carleton University and Landscape Ecologist with Environment Canada, Dr. Kathryn Lindsay. She, as a lodestar, always guided me in my work to finding the optimal ways and solutions. She permanently conducted a monitoring of the project; we discussed all details of the work, from its initial conception and methodical execution to the technical design of the manuscript. She also organized an approbation of study results at the 24th International Congress of the Society for Conservation Biology (Edmonton, AB, 03-07.07.2010). In fact, great and hard work has been done by Dr. Kathryn Lindsay and my gratitude to her may be only great and infinite.

Members of advisory committee Dr. Antoine Morin and Dr. Naomi Cappuccino presented valuable suggestions and recommendations which facilitated the execution of study. I am greatly thankful to them for their help.

Actually, for the opportunity of fulfilment of the project in Geomatics and Landscape Ecology Laboratory I am very much obliged to the Co-director of the Lab, Dr. Lenore Fahrig. Her lectures on landscape ecology had utmost importance for my education, and her great attention to my work was a crucial factor for its implementation. During last two years I always used all possible scientific assistance of the members of GLEL, viz: Dr. Adam Smith, Leif Olson, Dan Bert, Jude Jirard-Phillips, Sarah Overington, and Heather Coffey. I am tremendously grateful to Dr. Lenore Fahrig and all mentioned above colleagues and highly appreciate their help and support. My special thanks to perfect ornithologists Drs. David Kirk, Pierre Mineau and Ted Chesky for their critical revision of candidate farmland bird list for Ontario and our fruitful

conversations. Dr. David Sharp and Joel Rivard from the Maps & GIS division of the Carleton University Library assisted me with searching of materials for Census of Agriculture subdivisions and helped very much with technical suggestions and practical materials, particularly with Ontario Pesticide Survey.

The execution of this study would be impossible without comprehensive bird database of the Ontario Breeding Bird Atlas collected by efforts of many volunteers under leadership of Bird Studies Canada. I am deeply obliged to all of them, and especially, to Dr. Denis Lepage and Andrew Couturier for the opportunity to explore this database and to use point count data for testing of my assumptions.

My friends Drs Alexander Mischenko and Olga Sukhanova, Institute of Nature Conservation, Moscow, Russia, Dr. Todd Katzner, Director of Conservation and Field Research in National Aviary, Pittsburgh, USA, Dr. Victoria Kovshar, Zoological Institute of National Academy of Science, Almaty, Kazakhstan, and Dr. Roman Kashkarov, coordinator of IBA program in Uzbekistan supported my efforts sharing information on published works in Russia and Central Asia and practical recommendations. I appreciate their help and encouragements.

Finally, I realize fully that without permanent attentive support of my family this work would be profoundly laboured. Thanks to Alex and patient kids, Daniel and Elina.

Table of Contents

Abstract.....	ii
Acknowledgements.....	iii
Introduction.....	1
Chapter 1: Continental Comparison.....	6
1.1 Effects of farmland structure.....	8
1.2 Effects of agricultural practices.....	9
1.3 Effects of agricultural expansion, intensification and abandonment.....	10
1.4 Agri-environmental schemes.....	12
1.5 Summary.....	13
Chapter 2: Ontario Case Study Methods	15
2.1 Compilation of farmland birds.....	15
2.2 Census of Agriculture data.....	15
2.3 Ontario Breeding Bird Atlas data.....	16
2.4 Statistical analysis.....	17
Chapter 3: Ontario Case Study Results.....	23
3.1 Farmland characteristics.....	23
3.2 List of farmland birds for Ontario.....	24
3.3 Bird characteristics	26
3.4 Effects of farmland structure and agricultural practices.....	27
3.5 Effects of agricultural expansion and intensification	30
Discussion.....	53
Categorization of farmland birds.....	53
Effects of farmland structure and agricultural practices.....	54
Effects of agricultural expansion and intensification.....	56
Population trends	58
Conservation implications.....	59
References Cited	62
Appendix.....	82

List of Tables

Table 3.1	Descriptive statistics for explanatory variables across 181 subdivisions in Ontario	34
Table 3.2	Descriptive statistics for explanatory variables for subdivision subsets in Ontario.....	35
Table 3.3	Regression results for candidate farmland bird species in 181 subdivisions in Ontario.....	36
Table 3.4	List of farmland birds for Ontario	39
Table 3.5	Descriptive statistics for bird response variables for 181 subdivisions in Ontario	40
Table 3.6	Descriptive statistics for bird response variables for subdivision subsets in Ontario	41
Table 3.7	Regression results for bird abundance and richness in 181 subdivisions in Ontario for A. All farmland birds B. Farmland specialists C. Farmland generalists and D. BCR 13 priority species.	42
Table 3.8	Regression results for farmland bird abundance in 181 subdivisions and in subsets with different agricultural intensity in Ontario.....	46

List of Figures

Figure 1.1	Continental distribution of papers on bird-agriculture relationships	14
Figure 1.2	Comparison of bird studies in agricultural landscapes of Europe (EU) and North America (NA).....	14
Figure 2.1	Agricultural subdivisions (subsetted by percent farmland) used in the case study for Ontario.....	21
Figure 2.2	Bird point count density for agricultural subdivisions used in the case study for Ontario.....	22
Figure 3.1	Numerical response of farmland bird abundance and richness to farmland structure and practices in 181 subdivisions in Ontario.	48
Figure 3.2	Abundance-habitat relationship for row crop specialists (6 species) in 181 subdivisions in Ontario.....	49
Figure 3.3	Abundance-habitat relationship for pasture specialists (11 species) in 181 subdivisions in Ontario.....	49
Figure 3.4	Relationship between farmland bird abundance and richness per point count in 181 subdivisions in Ontario.....	50
Figure 3.5	Relationships between farmland bird abundance and row crop area for 181 subdivisions in Ontario.	51
Figure 3.6	Modeled responses of farmland birds to farmland composition in Ontario.....	52

List for Appendix

Table A1	Pearson correlations among explanatory variables.....	82
Table A2	Synopsis of studies on birds and agriculture in North America	83
Table A3	Candidate list of farmland birds for North America.....	87
Table A4	Characteristics of candidate farmland birds in Ontario.....	89
Table A5	Regression results for abundance of farmland birds on the final list for Ontario (45 species) using A. 181 subdivisions B. subdivisions with 5-40% farmland C. subdivisions with 40-60% farmland and D. subdivisions with 60-94% farmland.....	92

Introduction

Agriculture represents one of the most powerful driving forces determining the direction and intensity of biotic processes on Earth (MEA 2005). Agricultural intensification during the second half of the 20th century exceeded in scale all previous agricultural revolutions and has led to a widespread decline in many different wildlife taxa (Benton *et al.* 2003). In addition to intensification, two other processes have contributed to biodiversity-related conflicts: abandonment of marginally productive land of high habitat value for open-country biodiversity, and expansion of agricultural operations (Heinle *et al.* 2008).

Agriculture is also considered to be one of the major factors likely to impact biodiversity in the next 50 years (MEA 2005, Pagiola 2010) from direct and indirect effects mediated through deterioration of ecosystem resilience and exacerbation of stresses by climate change (Wallace & Brklacich 2009, NRC 2010). This is doubly problematic because biodiversity also provides valuable ecosystem services (e.g. pollination, pest control, nutrient cycling) that are important for promoting more sustainable agriculture (MEA 2005). Some recent modeling forecasts the loss of up 50% of bird species diversity worldwide by 2050 due largely to agricultural expansion (Teyssedre & Couvet 2007) and attendant loss and degradation of habitat (Walker *et al.* 2008). A better understanding of the relationships between bird diversity, farming practices and landscape structure at different spatial and temporal scales is still needed to inform mitigation of adverse impacts and implementation of more effective conservation measures to provide for both biodiversity and ecosystem services (McPherson *et al.* 2008).

In Canada, agriculture occurs mostly within the southern regions of the country where there are fertile soils and warmer climates. Agricultural expansion has transformed 65% of the prairies, 18% of the boreal plains, 9% of the mixedwood plains (in Ontario and Quebec) and 8% of other ecozones (AAFC 2009) through conversion of native habitats (e.g., tall-grass prairies, wetlands, savannah, upland woodlands) (OPF 2005). Ontario is one of the largest and most populated provinces of Canada. Due to environmental conditions, the population mainly inhabits the southern extents close to the border with the USA with attendant urban, agricultural and industrial development. Primary agricultural lands (class 1-3 soils) occupy 12% or 7.4 million hectares of the province (AAFC 2009) with over 50% of those primary lands concentrated south of the Canadian Shield (Turvey & Koney 2006). The most ecologically diverse landscapes occur in southern Ontario along with the most anthropogenic pressure largely from agriculture because it covers a larger area than that of urban and industrial development (OPF 2005). As a result of agricultural development, many natural landscapes, especially those of open country, have been converted to production. For example, tall-grass prairie (historically only in southern Ontario) has been almost completely lost, a pattern mirrored at the continental scale (Sampson & Knopf 1994).

Birds have been used extensively as indicators of biodiversity status and trends in agricultural landscapes (Burel *et al.* 1998, Donald *et al.* 2002, Sauberer *et al.* 2004, Gaston & Fuller 2007, Devictor & Jiguet 2007, Lemoine *et al.* 2007) for many reasons including: (1) their ecology is well understood; (2) they respond relatively rapidly to environmental changes that are difficult and expensive to measure directly; (3) they have a great resonance with the public and decision makers; (4) they are easily detected

allowing rapid and extensive data collection including by volunteers; and (5) the indicators are statistically robust, cost effective, relatively simple and easy to update and complementary to other biodiversity indicator (BLI 2004; Padoa-Schioppa *et al.* 2006). They have been used as focal species (species having spatial and resource requirements that define environmental conditions that provide for the protection of other species) in agricultural landscapes at local and landscape scales (Padoa-Schioppa *et al.* 2006).

Birdlife International (BLI 2004) has developed Common Bird Indices based on the population trends of bird species representative of various types of habitats in order to track changes in environmental conditions. The European Bird Conservation Council (EBCC 2009) uses a Common Bird Index and its derivative, the Farmland Bird Indicator, to track the ability of landscapes to support wildlife and advocates its use in Europe for conservation and management of bird populations. In the EBCC context, farmland refers to the areas under production within agricultural landscapes. The EBCC (2009) has categorized species occurring in farmland within agricultural landscapes as: “farmland specialists”, “farmland generalists” and “other”. Farmland specialists are defined as species that largely depend on areas under production within agricultural landscapes; indeed, many are restricted to farmland (Sanderson *et al.* 2009). They are typically food specialists and require specific types of farmland habitat for breeding or feeding. “Farmland generalists” are species that use the variety of different cover types as supplementary habitat, but equally inhabit adjacent native habitats. These are mostly the widely distributed, omnivorous species that have extended their habitat selection with the emergence of the new ecological niches and high productivity associated with

farmed landscapes. Birds categorized as “other” are species that only incidentally use farmland adjacent to their remnant native habitats.

The EBCC Farmland Bird Indicator has been adopted by the European Union (EU) as a structural and sustainable development indicator (Scholefield *et al.* 2010) and is being used to monitor progress in reversing the long-term decline of biodiversity in farmlands. According to recent results, the populations of 66% of farmland birds (116 species) across 21 countries are declining, at least to some degree, and this decline is more evident for the 36 species of farmland specialists (EBCC 2009). The Farmland Bird Indicator is also being used in land-use planning and decision making to model the response of biodiversity to potential or forecasted changes.

In North America, the Common Bird Indicator has been developed and used by the Audubon Society (2009) to show that many previously common species have experienced severe declines since 1967. The link to changes in farmland has not yet been discerned in part because species have not been categorized in terms of their relationship with farmland. The present study was intended to address this gap by developing the concept of a “farmland bird” for Canada and the USA (hereafter referred to as North America) and testing it in a case study for Ontario.

Because the concept of a “farmland bird” is not yet developed for North America, it was necessary to conduct a literature review of existing work elsewhere, but particularly in Europe, in order to answer the first research question:

➤ What is a farmland bird in North America and more particularly, in Ontario?

The farmland bird list was then refined through expert opinion prior to use in analyses to validate and refine the candidate list. The review of the existing literature was also

used to conduct a continental comparison of studies between Europe and North America (Chapter 1) and to inform the methods for the empirical case study in Ontario (Chapter 2) aimed at addressing the next two research questions:

- How do landscape structure and agricultural practices affect farmland birds?
- What are the effects of agricultural intensification on farmland birds?

The results of the Ontario case study (Chapter 3) were based on relating 2006 Census of Agriculture data (Statistics Canada 2009) to bird data collected by point counts in the 2001-2005 Ontario Breeding Bird Atlas (Cadman *et al.* 2007). Analyses were conducted at the scale of agricultural subdivisions over a gradient of farming intensity and using a variety of farmland bird response metrics.

The current research is a first effort to apply the “farmland bird” concept to North America to demonstrate relationships with landscape structure and agricultural practices and thereby inform initiatives such as Bird Conservation Region planning and the development of agri-environmental schemes for conservation of biodiversity and the ecosystem services that it provides. In addition, farmland birds could be used to monitor and assess effects of agriculture, and to model effects of projected changes in land-use on biodiversity to inform policy development, planning and decision making.

Chapter 1 Continental comparison

The existing literature was reviewed by sourcing papers from two electronic databases (Science Direct: Agricultural and Biological Sciences and JSTOR) using the key words: “farmland bird” and “birds and agriculture”. Searching efforts yielded about 500 papers from around the world since the 1950s until present, of which 195 met the following additional criteria for selection:

- Analyses of breeding bird-habitat relationships in agricultural landscapes;
- Focused on birds as indicators of agricultural effects on biodiversity;
- Used statistical models (e.g., General Linear Modeling) for the analysis.

The review showed that the interest in effects of agriculture on birds has increased substantially in the last decade, especially in Europe and North America relative to other continents (Fig. 1.1). The most studies were conducted in Europe (53% of 195 papers analyzed); North America was next with 28%. In North America, studies covered the most intensively developed agricultural regions in Canada (prairie-pothole and mixed-wood plain) and the USA (Great Plains, Midwest, north and central States).

Studies from Europe and North America reflected four crosscutting areas of inquiry related to:

- Effects of landscape (farmland) structure (composition, configuration and heterogeneity) on birds;
- Effects of agricultural practices on birds;
- Impact of land-use change (primarily agriculture intensification and abandonment) on birds; and
- Use of agri-environmental schemes to mitigate negative impacts on biodiversity.

The most common bird metrics used as response variables were species richness and species abundance (density or relative) followed by population trend, indicator species, or guilds (ecological groupings) with breeding success being the least common.

Grouping of species as “farmland birds” was commonly used in European studies. In contrast, North American studies were still focused on native habitat associations (e.g., grassland, forest, wetland) rather than on associations with farmland habitats (e.g., crops, pastures, farmstead). This difference reflected the long history of agriculture in Europe compared to North America (Kleijn & Baldi 2005). The first agricultural revolution (Neolithic revolution) occurred in the Fertile Crescent (including the Mediterranean region) about 10,000 B.C., and in Mesoamerica about 3,500 B.C. (Gupta 2004). According to Cadman *et al.* (2007), European settlers started clearing lands for agriculture production in southern and eastern Ontario about 150-200 years ago. Prior to that time, the Huron Nation practiced agriculture in only about 200 square kilometres.

In Europe, many bird species are now considered as farmland birds due to their historical relationship with traditional agrarian landscapes (O'Connor & Shrubbs 1986). Their composition is diverse and well known, and includes 173 bird species, more than any other habitat type in Europe (Tucker & Evans 1997). There are some geographical variations in farmland bird diversity arising from historical distribution patterns of many open grassland species as they followed the spread of agriculture into Europe from the Asian steppes and Mediterranean semi-deserts (O'Connor & Shrubbs 1986). Many forest species have become adapted to remnant woodland edges and plantations in open country and in some regions comprise about 80% of all farmland birds (O'Connor & Shrubbs 1986). Thus, European farmlands support an important community of forest

edge as well as open-country species. Currently, farmland provides the breeding and wintering habitats for nearly 120 bird species of conservation concern (Donald *et al.* 2002). Although not a focus of the current research, farmlands also play an important role in the dynamics of many migrant bird species in Europe (Farina 1989) and in North America (Boutin *et al.* 1996, Kirk *et al.* 2001, Ogden *et al.* 2008).

1.1 Effects of farmland structure

Studies conducted on both continents have shown the effect of habitat composition, configuration and heterogeneity of agricultural landscapes on bird species richness and abundance although from different perspectives (Figure 1.2). In Europe the value of farmland mosaics for biodiversity conservation is well recognized, especially those of traditional agrarian landscapes (Calvo-Iglesias *et al.* 2009). In North America, the primary focus has been on "patch-matrix" effects associated with the amount, patch size, vegetation composition and fragmentation of native habitat by "hostile" intervening production areas leading to the prevailing question of "How much habitat is enough?" (reviewed recently for grasslands by Ribic *et al.* 2009a). Relatively fewer studies have focused on the importance of farmland composition, configuration and heterogeneity associated with individual crop types, pasture and hayfields, field size, and crop and noncrop diversity and include Freemark *et al.* (1991), Best *et al.* (1995, 1998, 2001), Jobin *et al.* (1996, 2001), Duelli (1997), Vandermeer *et al.* (1998), Boutin *et al.* (1999), Perkins *et al.* (2000), Kirk *et al.* (2001), Freemark & Kirk (2001), Giuliano & Daves (2002), Jones *et al.* (2005), Woodhouse *et al.* (2005) and Winter *et al.* (2006). In Europe, more studies have been devoted to the effects of composition and

configuration of the farmland mosaic associated with field size, crop composition, and the presence of native habitats within farms (Berg 2002, Benton *et al.* 2003, Heikkinen *et al.* 2004, Hietala-Koivu *et al.* 2004, Belfrage *et al.* 2005, Piha *et al.* 2007, Anhstrom *et al.* 2008, Henderson *et al.* 2009). Importance of semi-natural habitats (e.g., hedgerows, field margins) to farmland species and avian diversity in farmland has been shown by many studies on both continents (Perkins *et al.* 2000, Fuller *et al.* 2001, 2004, Jobin *et al.* 2001, Kirk *et al.* 2001).

1.2 Effects of agricultural practices

Studies conducted on both continents showed effects of agricultural management on birds including weed control and application of pesticides, time and intensity of agricultural operations, and grazing intensity (Spark *et al.* 1996, Paskual *et al.* 1999, Martin & Forsyth 2003, Chapman *et al.* 2004, McMaster *et al.* 2005, Woodhouse *et al.* 2005, Buckingham *et al.* 2006, Puckett *et al.* 2009, Swagemakers *et al.* 2009). Organic farming is emerging as one of the ways to mitigate the negative effects of chemical-based farming (Chamberlain *et al.* 1999, Henderson *et al.* 2009, Freemark & Kirk 2001, Beecher *et al.* 2002, Belfrage *et al.* 2005, Jones & Sieving 2006, Piha *et al.* 2007, Kragten *et al.* 2008). In both Europe and North America, studies conducted in the last two decades have shown that practices are relatively less important than farmland structure to birds (Chapman *et al.* 2004, Jobin *et al.* 1996, Martin & Forsyth 2003, Mineau *et al.* 2005, McMaster *et al.* 2005, Woodhouse *et al.* 2005, Billeter *et al.* 2008, Perlut *et al.* 2008, Henderson *et al.* 2009, Ribic *et al.* 2009b, Gabriel *et al.* 2010).

1.3 Effects of agricultural expansion, intensification and abandonment

In recent times, the most rapid and extensive changes of agricultural lands were observed both in Western Europe and in North America after the Second World War as a result of agricultural expansion and intensification. The main effects included: 1) conversion to agriculture of marginal lands including remnants native habitats such as woodlands, wetlands and grasslands 2) simplification and homogenization of farmland from local to regional scales from production specialization (livestock or cropping), development of monocultures, simplified rotations, , increasing of farm size through tenure consolidation, increasing of field sizes with the removal of field margins and hedgerows, and alteration of hydrological flows from field drainage and irrigation, and 3) intensified management of production areas including increases in chemical inputs (fertilizers and pesticides) and more frequent disturbances such as tillage and mowing and more efficient harvest (less wastage on fields) (O'Connor & Shrubbs 1986, Freemark & Boutin 1995, Matson *et al.* 1997, Benton *et al.* 2003, Herzon *et al.* 2008).

Sharp declines in birds observed during the last several decades in Europe and North America have been attributed to rapid agricultural intensification (Benton *et al.* 2003, Murphy 2003, Freemark 2005, Heinle *et al.* 2008, Herzon *et al.* 2008) initially as a result of loss of habitat and farmland heterogeneity (Fuller 2000, Benton *et al.* 2003, Hietala-Koivu *et al.* 2004, Van Turnhout *et al.* 2007, Buenestado *et al.* 2008) followed by more subtle, indirect, adverse effects of increased chemical inputs and mechanisation during the breeding and overwintering seasons (Peach *et al.* 2001, Anderson *et al.* 2002, Peterjohn 2003, Newton 2004, Nocera *et al.* 2005, Herzon & O'Hara 2007). Since the 1970s, farmland bird populations have declined by about 0.8% per year in Western

Europe and about 0.3% per year in Eastern Europe (Sotherton 1998; Chamberlain & Fuller 2000; Donald *et al.* 2001, 2006; Siriwardena *et al.* 2001; Chamberlain 2002; Jepsen *et al.* 2005; Baldi & Farago 2007; Sirami *et al.* 2008; Rodriguez & Wiegand 2009). Farmland specialists in particular have exhibited significant population declines (Noble & Raven 2002, Kujawa 2002). While farmland birds are still abundant in many Eastern European countries, increasing intensification is beginning to result in population declines similar to those that have occurred in Western Europe (Verhulst *et al.* 2004, Herzon & O'Hara 2007). In North America, effects of agricultural intensification have also been linked to landscape transformation (sometimes as a result of land conversion) and farming practices (Freemark 1995, Rodriguez 2002, Martin & Forsyth 2003, Warren & Anderson 2005, Askins *et al.* 2007, Perlut *et al.* 2008).

Abandonment of marginal farmlands has been observed in many regions of Europe, the eastern United States (Hart 2005) and eastern Canada (OMAFRA 2009). Abandonment in Europe has occurred mostly in mountainous regions (Pueyo & Begueria 2007) and in former socialistic countries. From 13% to 20% of farmland has been abandoned in the Carpathians area of Poland, Slovakia and Ukraine (Kuemmerle *et al.* 2008), up to 30% in Estonia (Herzon *et al.* 2008) and up to 45% in Russia (Mischenko & Sukhanova 2008). In Ontario, farmland area declined by almost 13% between 1976 and 2006 (OMAFRA 2009) largely from abandonment of pastures.

The abandonment of marginal farmlands has had direct adverse effects on biodiversity, birds in particular, from loss of habitat through succession (Nikolov 2010) and increased fragmentation of the remaining farmland area, in addition to indirect effects from changes in the abundance, composition and availability of food resources,

destruction of drainage systems and land bogging (Mischenko & Sukhanova 2008). In the USA, grassland bird declines have also been associated with farmland abandonment (Brennan & Kuvlevsky 2005, Askins 2007).

1.4 Agri-environmental schemes

In Europe, agri-environmental schemes have been recognized as an important instrument to mitigate the negative effects of intensive agriculture on biodiversity (Vandermeer *et al.* 1998, Hietala-Koivu *et al.* 2004, Kleijn *et al.* 2004, Vickery *et al.* 2004, Mattison & Norris 2005, Donald *et al.* 2006, Herzog & O'Hara 2007). They play an important role in the management of biodiversity, focal species and species of conservation concern (Benton *et al.* 2003, Herzog *et al.* 2005; Swagemakers *et al.* 2009). Organic and integrated farming is central in such schemes in conjunction with countryside stewardship (Vickery *et al.* 2004). Other practices include set-aside schemes, integrated crop management, and arable stewardship pilot schemes (Bracken & Bolger 2006, Bradbury & Kirby 2006, Field *et al.* 2007, Stevens & Bradbury 2006).

In the USA, the Conservation Reserve Program (CRP) was introduced as an agri-environmental scheme to reduce soil erosion but has had beneficial effects on biodiversity including birds (Best *et al.* 1998, Horn & Koford 2000, Veech 2006, Perlut *et al.* 2008, Ribic *et al.* 2009b). Habitat-based standards for biodiversity have recently been developed in Canada under the National Agri-Environmental Standards Initiative (NAESI; McPherson *et al.* 2008). The NAESI recommendation was retention of 25% to 30% of natural habitats within agricultural watersheds to support biodiversity of forest,

riparian and grassland species. The role of farmlands (i.e. the area under production) for biodiversity conservation and management was not considered by NAESI.

1.5 Summary

In reviewing the literature on birds and agriculture in Europe and North America, several major similarities and differences were apparent (Fig. 1.2):

- The concept and use of “farmland birds” is not yet developed in North America in contrast to Europe;
- Landscape structure (composition, configuration, heterogeneity) has a primary influence on bird diversity. However, in North America, farmlands are typically viewed as a hostile matrix, rather than habitat. Agricultural landscapes are not yet viewed as mosaics with a gradient in suitability among cover types and farming regimes as is the case in Europe;
- Effects of agricultural practices are secondary to those of landscape structure. Many practices, especially chemical inputs and mowing, have adverse effects, some of which can be mitigated by changes in farming regime (e.g., organic farming);
- Land-use changes (expansion, intensification and abandonment) are affecting bird populations on both continents;
- Agri-environmental schemes on both continents are conserving biodiversity and thereby sustaining ecological services in farmland. However, the application of such schemes explicitly for biodiversity conservation in North America has not yet occurred. Nor is the role of farmlands as a base for conserving birds yet a focus of North-American studies.

Figure 1.1 Continental distribution of papers reviewed on bird-agriculture relationships.

Figure 1.2 Comparison of bird studies in agricultural landscapes between Europe (EU) and North America (NA).

Chapter 2: Ontario Case Study Methods

2.1 Compilation of farmland bird lists

A literature review (Appendix Table A2) was conducted to compile and characterize a candidate list of farmland birds for North America (Appendix Table A3). Following the EBBC (2009) guidelines, species were classified as “farmland specialists”, “farmland generalists” or “other”. Farmland specialists were species primarily associated with only one habitat (e.g., row crop, pasture or farmstead). Farmland generalists were species associated with a variety of habitats including native remnants (trees, woods, grasslands, wetlands or their edges), row crop, pasture and farmstead. The candidate list for Ontario (Appendix Table A4) included only farmland generalists or specialists that were detected in the most recent Ontario Breeding Bird Atlas (Cadman *et al.* 2007) and validated in reviews by six local bird experts.

2.2 Census of Agriculture data

The 2006 Census of Agriculture (Statistics Canada 2009) was the source of farmland and agricultural practice information. There were 269 subdivisions in Ontario. Subdivisions with 5% - 94% of farmland area were used for analysis. Fourteen variables derived from the subdivision statistics had high loadings and relatively low colinearity based on Principal Component Analysis (PCA).

Farmland composition had six variables (percent area of each subdivision): row crop, natural pasture, seeded pasture, summer fallow, farmstead and native remnants. Row crop included corn, soybean, spring/winter wheat, oats, barley, and other field crops; natural pasture included areas used for pasture that have not been cultivated and

seeded; seeded pasture was grazeable land that has been improved from its natural state by seeding, draining, fertilizing and weed control and includes hay and fodder crops; summer fallow was cultivated land left free of vegetation for one growing season; farmstead included roads, native remnants were within farmland only.

Farmland heterogeneity was measured as a Shannon-Wiener diversity index using the 6 composition variables. Crop heterogeneity was measured as a Shannon-Wiener diversity index using statistics for 24 crop types.

Farmland configuration had two variables: average farm size (farmland area divided by the number of farms per subdivision) and average crop per farm (crop area divided by the number of farms per subdivision).

Agricultural practices had four variables: intensity of livestock grazing, pesticide input, fertilizer input and machinery per farm. Grazing intensity was the total number of “grazing” animals (cows, horses, sheep, goats) divided by the area of natural pasture per subdivision. Machinery per farm was a count of machinery used for production (e.g., tractors, mowers, combines) divided by the number of farms per subdivision. Pesticide input was a percent based on the summed area treated with herbicides, fungicides or insecticides divided by the area of row crop plus seeded pasture per subdivision. Fertilizer input was a percent based on the summed area treated with fertilizers divided by the area of row crop plus seeded pasture per subdivision.

2.3 Ontario Breeding Bird Atlas data

The point count data of the Ontario Breeding Bird Atlas (OBBA) survey conducted in 2001-2005 (Cadman *et al.* 2007) was used as the source of information on

bird species, richness and abundance. Each 10 x 10 km atlas square had 50 points randomly placed on roadsides (excluding provincial highways) at least 500 m apart. The proportional representation of habitats in the sample was evaluated against the habitat distribution for the atlas square and off-road points were added for under-sampled habitats. Points were numbered 1-50 with the first 25 to be covered by surveyors; if a point could not be surveyed then it was replaced by the next point in the sequence.

Point were surveyed for birds in good weather during the peak of the breeding season (May 24 – July 10) between dawn and 5 hours after by the collective efforts of thousands of experienced volunteers across Ontario (Cadman *et al.* 2007). All birds seen and heard during 5 minutes within and beyond 100 m from observer were recorded. For the purpose of this study, the unlimited-distance point count data for each species on the candidate list of farmland birds were used for analysis.

2.4 Statistical analysis

The set of agricultural subdivisions selected was overlaid with OBBA point count locations. Subdivisions that had a bird survey effort less than 1 point count per 500 hectares were removed, leaving 181 subdivisions (Fig. 2.1) with 29,116 point counts (Fig.2.2) for analysis. The dataset was also partitioned into subdivision subsets (Fig.2.1) with 5-39.9% farmland (59 subdivisions), 40-59.9% (54 subdivisions) or 60-94% (68 subdivisions) for analysis of effects of agricultural intensification.

All statistical analyses were conducted in SPSS. General linear modeling (GLM) was used to explore the relationship between farmland birds and landscape structure and farming practices using regression analysis (Grafen & Hails 2002). Best- fitted models

were selected based on the Akaike Information Criteria (AIC) corrected for small sample size (i.e., <100) (Akaike 1974) and significance ($p \leq 0.05$). The adjusted R^2 coefficient of determination (as a percent or proportion) was also used as a goodness-of-fit measure (Grafen & Hails 2002).

Regression models for candidate farmland birds: Analyses were conducted to examine the validity of the inclusion and specialist or generalist categorization of species in Ontario. Multiple regression with forward selection was used with the 181 subdivision dataset, all explanatory variables and the abundance of individual species (mean number of birds per point count per subdivision). If that failed, backward selection was used (which was the case for 3 species). Of the 66 candidate farmland birds (Appendix Table A4), 54 species had sufficient data for analysis. Based on the results, some species were removed from the candidate list and some species were re-categorized. Model results were also used to categorize habitat association for specialist species based on the strength of their association with row crop, pasture, or farmstead; and generalists on their association with habitat edges.

Species were also categorized in relation to their priority for conservation in Bird Conservation Region (BCR) 13 from the list in OPF (2005) refined with information provided by the Canadian Wildlife Service (Ken Tuininga pers. comm. 2010). BCR 13 covers the same region as the Census of Agriculture subdivisions selected for analysis. The species included in the current study represent 12% of all landbirds that regularly occur in southern Ontario. Some BCR 13 priority species are of concern continent-wide and have important populations in southern Ontario (e.g., Short-eared Owl). Many are relatively abundant and widespread but are declining rapidly with continued declines a

strong possibility (e.g., Eastern Kingbird, Brown Thrasher, Vesper Sparrow, Eastern Meadowlark). Other species are listed because southern Ontario has a high global responsibility for the species' population in combination with other concerns (e.g., Northern Harrier, Bobolink, Baltimore Oriole). BCR 13 is also home to many of Canada's, and Ontario's, listed Endangered and Threatened species (e.g., Northern Bobwhite, Barn Owl, Loggerhead Shrike, Henslow's Sparrow), which are also included as priority species.

Regression models for farmland birds: To explore alternative hypotheses of effects of landscape structure and agricultural practices on farmland birds, best-fit regression models were produced using the 181 subdivision dataset for explanatory variables grouped by composition, configuration, heterogeneity, agricultural practices or all combined. For the latter group, the best-fit model (i.e., the most parsimonious model) was used as the basis for comparison and is hereafter referred as the “base” model. For each model, a proportional partial regression coefficient (PPRC) was calculated for each variable as a strength metric (as proposed by Smith, 2010) and tabled in relation to composition, configuration, heterogeneity or agricultural practices. The PPRC was calculated by multiplying the regression coefficient in the model by the range in variation for the explanatory variable in the dataset used. The result is interpreted as a numerical change per point per subdivision in response to the observed variability of an explanatory variable.

Mean abundance and/or mean richness per point count per subdivision were analysed for all farmland birds, specialists, generalists and BCR 13 priority species.

Regression models for agricultural expansion and intensification: Best-fit regression models using all explanatory variables were produced for abundance (mean number of birds per point count per subdivision) of edge farmland generalists, BCR 13 priority species, farmland specialists, row crop specialists, and pasture specialists using subdivisions subsetting by percent farmland. For each base model, the PPRC was calculated for each explanatory variable and tabled by composition, configuration, heterogeneity and practices. Modelled abundances were graphed against row crop because it was the most extensive cover type and was significant in many base models.

Figure 2.1 Agricultural subdivisions (subsetted by percent farmland) used in the case study for Ontario.

Figure 2.2 Bird point count density for agricultural subdivisions used in the case study for Ontario.

Chapter 3: Ontario Case Study Results

3.1 Farmland characteristics

The 181 subdivisions included in the analysis represented 84% of farmland in Ontario. On average, farmland occupied 53% of each subdivision (Table 3.1). Crop was the most extensive cover type accounting for, on average, 38% of each subdivision. Native remnants were next at 6.3% on average, with a high of 14%. Configuration within farmland showed an average farm size of 92 ha with an average of 71 ha of crop per farm. Crop heterogeneity was higher on average than farmland heterogeneity. Agricultural practices within subdivisions included, on average, a grazing intensity of 11.1 animals per hectare of pasture, 66% and 56% of crop and seeded pasture treated with pesticides and fertilizers, respectively, and 3.4 units of machinery per farm. While significant correlations existed among explanatory variables, most had low values (Pearson correlation <0.500 ; Appendix, Table A1). Exceptions were between the configuration metrics (negative), between farmland heterogeneity and row crop (+), native remnants (-) and average crop size (+) and between pesticide use and fertilizer use (-).

Subsetting subdivisions based on percent farmland (Table 3.2) was used to examine effects of agricultural expansion and intensification on farmland birds. Percent farmland per subdivision expanded from a mean of 28% in the least intensive subset (5-40% farmland) to 76 % in the most intensive subset (60-94% farmland). Crop increased from an average of 16% to 61% reflecting a simplification in production consistent with intensification effects. Pasture remained about the same across subsets, on average,

although the proportion of natural (versus seeded pasture) declined from 0.7 to 0.5 from the least to the most intensive subset. Averages for summer fallow, farmstead and native remnants were similar across subsets. Farmland heterogeneity decreased between the least and most intensive subsets whereas crop heterogeneity remained the same. Mean average farm size was similar across subsets whereas mean average crop per farm increased from 57 to 87 ha, the latter consistent with intensification. The average for agricultural practices (except for machinery per farm) increased from the least to the most intensive subset.

3.2 List of farmland birds for Ontario

A total of 159 species have been observed in agricultural landscapes based on the review of studies in five provinces in Canada and 18 states in the USA (Appendix Table A2). Of these, 79 breeding species were categorized in the current study as farmland specialists (43 species including 5 introduced) or farmland generalists (36 species) (Appendix Table A3). The remaining 80 species were categorized as “other” and excluded from further consideration because they occurred in non-breeding seasons or during the breeding season were primarily associated with more extensive areas of native habitat within agricultural landscapes rather than native remnants in farmland.

Of the 79 species of specialists or generalists, 66 breed in Ontario (Appendix Table A4). Four of these species were not detected in the subdivisions used for the case study (which represented 84% of the agricultural area in the Census of Agriculture for Ontario) and were thus removed from the candidate list. Eight species of farmland specialists (3 row crop and 5 pasture specialists based on the literature review) did not

have sufficient point count data for analysis but were retained in the candidate list because they are considered species of conservation concern.

Regression models for the 54 species with sufficient point count data (Table 3.3) generally supported categorizations from the literature; specialists showed significant positive correlations with crop, pasture or farmstead, and generalists showed no correlations with cover types or significant positive correlation with a variety of cover types (including native remnants). However, two species originally categorized as generalists (Northern Mockingbird and Common Grackle) were re-categorized as specialists based on models with high explained variance and positive correlations with farmstead. Three species (Mallard, Turkey Vulture, Red-tailed Hawk) with insignificant or low variance explained ($<3\%$) were removed from the final list (Table 3.3). Despite low variance explained, Blue-winged Teal and Baltimore Oriole were retained for analysis and Eastern Wood-pewee excluded based on the literature and expert opinion.

Model results (coupled with expert opinion) indicated that three species had positive association with row crop (RCS, Table 3.3) and eleven species with pastures (PSS, Table 3.3). Twelve species were categorized as farmstead specialists (FSS, Table 3.3), including the Brown-headed Cowbird (despite its historical association with grasslands). Twelve generalist species were further categorized as “edge farmland generalists” (EFG, Table 3.3) based on the literature, expert opinion, and models with reasonable variance explained and significant positive correlations with farmland heterogeneity and remnants of native habitats.

The list of farmland birds for Ontario used for analysis with the 181 subdivision dataset included 54 species overall comprised of 23 farmland generalists and 34

farmland specialists (Table 3.4). Twenty-one species were also BCR 13 priority species (18 had sufficient data for analysis). In relation to life history, 13 species are resident, 32 are short-distance migrants, 14 are long-distance migrants and 23 are ground nesters (Appendix Table A4). Farmland specialists were comprised mostly of species that historically inhabited grasslands (Appendix Table A3) as well as 5 species introduced by European settlers (and currently categorized in the EU as farmland birds; EBCC 2009). Farmland generalists were composed of species associated historically with woods, grasslands, shrub, wetlands and their edges (Appendix Table A3). Of species that were categorized by habitat association, 6 were row crop specialists (RCS), 16 pasture specialists (PSS), 12 farmstead specialists (FSS) and 11 edge farmland generalists (EFG). Of the 18 BCR 13 priority species with sufficient data for analysis, over half were pasture specialists. The final proposed list of farmland birds for Ontario was culled to only include the 45 species comprised of all 34 farmland specialists and the 11 edge farmland generalists (bolded in Table 3.4).

3.3 Bird characteristics

Mean abundance for all farmland birds in the 181 subdivision dataset was 12.0 birds per point per subdivision; mean richness was 5.6 species per point per subdivision (Table 3.5). On average, generalists had higher abundance and more species per point than specialists. BCR 13 priority species were relatively uncommon both in abundance and richness per point. For subdivision subsets, abundance of birds in all groups increased across the gradient of increasing percent farmland (Table 3.6). Distributional data for individual species are provided in the Appendix (Table A4).

3.4 Effects of farmland structure and agricultural practices

Results of regression models for abundance and richness in the 181 subdivisions were summarized by model fit ($p \leq 0.05$; ΔAICc , variance explained) and strength metrics (proportional partial regression coefficient or PPRC) to characterize relationships between farmland birds and farmland structure and agricultural practices.

Base models (i.e., regression models with the lowest AICc) for abundance and richness of all farmland birds explained 28 % and 14% of variation, respectively, and showed correlations with farmland structure but not practices (Table 3.7A). The numerical response (PPRC) to composition was a gain of 8.3 birds from an increase of natural pasture (from 0.1 to 16.5%) and 3.7 birds from an increase of farmstead (from 0.1 to 11.5 %) and 1.8 species per point as crop area increased (from 1.2 to 84.2%). Configuration resulted in a decrease of 5.1 birds per point in response to an increase in average farm size (from 18 to 194 ha). Increasing heterogeneity of farmland resulted in a decrease of 10.4 birds per point. Models partitioned by composition, heterogeneity, configuration or practices for abundance had AICc values well above the base model ($\Delta\text{AICc} > 2$ or 4, the cut-offs recommended by Anderson and Burnham 2002). For richness, the base model was the same as the best-fit model for composition. All other partitioned models had AICc values well above the base model.

There were two competing best-fit models for the abundance of farmland specialists (Table 3.7B), one based on practices (the lowest AICc) and the other on landscape structure ($\Delta\text{AIC} = 3.4$). The latter was used as the base model because it explained twice as much variation as the former. With that, the base models for farmland specialist abundance and richness explained 50% and 47% of variation,

respectively, and showed correlations only with farmland structure (Table 3.7B). Birds and species increased in response to composition (crop, natural and seeded pasture for both metrics; abundance also with farmstead) and decreased with configuration (average crop size for abundance; average farm size for richness) and heterogeneity (crop for abundance, farmland for both). Other than the result noted above, all other partitioned models had AICc values well above the base model.

Base models for farmland generalist abundance and richness explained a low amount of variation (9% and 6%, respectively) and showed correlations with farmland structure but not practices (Table 3.7C). For abundance, the numerical response to composition was a gain of birds per point as natural pasture increased, and a decrease with configuration (average farm size) and heterogeneity (farmland). For richness, the base model was the same as the best-fit model for composition and the numerical response to composition was a gain of species per point as native remnants and summer fallow increased. Partitioned models (other than composition) had AICc values well above the base model for abundance.

There were two competing best-fit models for the abundance of BCR 13 priority species (Table 3.7D), one based on composition and the other on composition and heterogeneity. The latter was used as the base model because it had the lower AICc. With that, the base models for BCR 13 priority species abundance and richness explained 30% and 38% of variation, respectively. Species richness showed correlations with both farmland structure and practices. Abundance and richness increased with composition (both metrics with seeded and natural pasture, richness with crop) and decreased with heterogeneity (farmland). Richness also decreased with configuration

(farm size) and practices (grazing intensity). Partitioned models (other than composition) had $\Delta AICc$ values more than 4 above the base model.

The variation explained by base models for abundance (Fig 3.1) was highest for specialists (50%) and lowest for generalists (9%). Except for BCR 13 priority species, response patterns to composition, configuration, heterogeneity and practices were similar across groups although explanatory variables and strengths of the numerical response varied. BCR 13 priority species had no correlation with configuration and the effect of heterogeneity was absent from a competing best-fit model. For other groups, composition and heterogeneity had numerical effects that were in opposite directions, positive and negative, respectively. Heterogeneity had the strongest numerical response of all explanatory variables with negative effects on all categories of farmland birds and especially specialists. Agricultural practices had no effect on farmland bird abundance.

The variation explained by base models for richness (Fig 3.1) was also highest for specialists (47%) and lowest for generalists (6%). Composition was the most important for all categories of farmland birds. It was the only set of explanatory variables significant for all birds and for generalists. Both specialists and BCR 13 priority species responded negatively to configuration and heterogeneity. Composition and heterogeneity had the strongest and equal numerical effects among variables with a positive effect of row crop on all farmland birds and a negative effect of heterogeneity on specialists. Practices were important for BCR 13 priority species having a negative effect on richness.

The abundance of row crop specialists was positively correlated with crop area within subdivisions (Fig. 3.2; Appendix Table A5A). Visual inspection indicated that

subdivisions with more than 40% crop supported a higher than average abundance of these species. A similar pattern was observed for pasture specialists, with higher than average abundances for subdivisions with more than 8-10% of pasture (Fig. 3.3).

3.5 Effects of agricultural expansion and intensification

After removal of outlier species, the abundance of the remaining 41 species of farmland birds were analyzed (bolded species in Table 3.4); richness was not because it was highly correlated with abundance overall (Fig.3.4) and especially for specialists (Pearson correlation = 0.79) and BCR 13 priority species (0.81). Regression analyses were conducted with the three subdivision subsets with differing percent farmland and intensification (Appendix Table A5B,C,D). Regression results for the 181 subdivision dataset were also tabulated for comparative purposes (Appendix Table A5A). Base models (i.e., the most parsimonious regression models with the lowest AICc) were used for comparisons.

In the least intensive subset (5-40% farmland), the base model for edge farmland generalists (Table 3.8A) explained 34% of variation in abundance with increases in response to composition (native remnants) and configuration (more edge from smaller farm size and larger crop size per farm) and a decrease with practices (fertilizer input). In the moderate subset (40-60% farmland), only practices were significant with a negative effect on abundance related to pesticide inputs. In the most intensive subset (60-94% farmland), abundance increased in response to composition (natural pasture) and decreased with practices (grazing intensity). There was no observed effect of heterogeneity in any subset. Compared to the full dataset (181 subdivisions), subsetting

showed the importance of native remnants within farmland in the least intensive subset and natural pasture in the most intensive subset, and the important, and negative effects of practices that were not otherwise evident.

For BCR 13 priority species (Table 3.8A), the base models explained 13% of variation in abundance in the least intensive subset, 25% in the moderate and 50% in the most intensive. Only composition was significant, with a positive effect on abundance related to natural pasture (least intensive subset), seeded pasture (moderate subset) and both pastures plus crop (most intensive subset). The strength of response (PPRC) increased gradually from the least to the most intensive subset. There was no observed effect on abundance of configuration, heterogeneity or practices in any subset. Subset results showed no effects of heterogeneity in contrast to the full dataset.

For farmland specialists, the base model for the least intensive subset (Table 3.8A) explained 56% of variation in abundance with an increase in response to composition (crop) and decreases with configuration (crop size) and heterogeneity (farmland). In the moderate subset (11% variance explained), only configuration was important, with a negative effect from farm size. In the most intensive subset (20% variance explained), abundance decreased in response to composition (native remnants) and heterogeneity (crop). There was no observed effect of practices in any subset or the full dataset. Subsetting showed that composition was not as important as it was in the full dataset and that its effect varied among cover types across subsets. Effects of configuration and heterogeneity also varied across subsets, a result not evident in the full dataset.

Regression analyses for species grouped by habitat association (Appendix Table A5) helped to explain the variability within farmland specialists. The base model for row crop specialists in the least intensive subset (Table 3.8B) explained 56% of variation in abundance, with a response only to composition (positive to crop and summer fallow and negative to native remnants). In the moderate subset, abundance decreased in response to composition (native remnants) and increased in response to practices (grazing intensity). In the most intensive subset, abundance increased in response to composition (crop). There was no observed effect of configuration in any subset. Subsetting showed that composition was the most important factor for row crop specialists. A negative response to heterogeneity (crop) was detected only in the full dataset.

The base models for pasture specialists explained 22% to 55% of variance (Table 3.8B). In the least intensive subset, composition (crop and natural pasture) had a positive effect and practices (fertilizer inputs) had a negative effect. In the other subsets, only composition was significant with a positive response to seeded pasture in the moderate subset and both pastures and crop in the most intensive subset. In contrast to the full dataset, native remnants were not significant. Configuration and heterogeneity had no effects in any subset or the full dataset.

For farmstead specialists (Table 3.8B), base models explained 21% to 59% of variance. In the least intensive subset, composition (farmstead) had a positive effect and configuration (average crop size) and heterogeneity (farmland) had strong negative effects. In the moderate subset, composition (seeded pasture) and configuration (crop size) had negative effects. In the most intensive subset, configuration (crop size) had a

negative effect and practices showed a positive effect of pesticide use and negative effect of fertilizer use. Subsetting showed similarities between the least intensive and full datasets.

Farmland specialists categorized by habitat association and BCR 13 priority species (Table 3.8) responded most often across subsets to landscape structure (composition, configuration and heterogeneity) compared to practices. Mostly positive responses to composition were evident in the least and most intensive subsets. Heterogeneity and configuration were generally less important across subsets for BCR 13 priority species and farmland specialists except farmstead specialists in all subsets and edge farmland generalists in the least intensive subset. When detected, effects of practices were negative for edge farmland generalists and pasture specialists, positive for row crop specialists and mixed for farmstead specialists.

To further explore responses in relation to landscape structure, farmland birds were graphed against percent row crop per subdivision (Fig.3.5) because it was the most extensive cover type and was significant in many base models, especially for specialists. When responses were combined (Fig. 3.6), it was evident that there were tradeoffs in abundance of species across the gradient in landscape composition. The abundance of farmland birds was optimized when crop occupied between 40-70% of subdivisions.

Table 3.1 Descriptive statistics for explanatory variables across 181 subdivisions in Ontario.

Explanatory variables	Code	181 subdivisions		
		Mean	SD	Range
Subdivision area (ha)		48,214	42,160	7,000-347,000
Farmland (% subdivision area)		53.0	22.0	5.0-94.0
Composition (% subdivision area)				
Row crop	CROP	37.8	21.5	1.2-84.2
Summer fallow	SFALP	0.14	0.20	0-1.28
Tame/seeded pasture	TSPP	2.8	2.3	0.1-21.3
Natural pasture	NPP	3.4	2.6	0.1-16.5
Native remnants (trees, woods, wetlands in farmland)	TWWP	6.3	2.9	0.2-14.4
Farmstead (includes road)	FSAP	2.2	1.1	0.1-11.5
Heterogeneity				
Farmland	SWDIFR	0.97	0.30	0.24-1.51
Crop	SWDICR	1.40	0.30	0.20-2.07
Configuration				
Average farm size (ha)	AVFS	92.4	26.2	18.0-194.0
Average crop per farm (ha)	AVCRS	70.6	24.0	16.0-152.0
Agricultural Practices				
Livestock grazing (head/ha natural pasture)	CTPHA	11.1	11.4	1.0-58.5
Fertilizer input (%)	FERTIN	55.9	19.8	0.0-94.6
Pesticide input (%)	PESTIN	66.2	38.5	21.0-296.0
Machinery per farm (no.)	AMPF	3.4	0.4	2.4-4.8

Explanatory note: Pesticide input and fertilizer input calculated as summed area treated divided by total area of crop and seeded pasture per subdivision

Table 3.2 Descriptive statistics for explanatory variables for subdivision subsets in Ontario.

Explanatory variables	Code	59 subdivisions			54 subdivisions			68 subdivisions		
		Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Farmland (% subdivision area)		28.0	10.0	5.0-39.9	50.0	6.0	40.0-59.9	76.0	10.0	60.0-94.0
Composition (% subdivision area)										
Row crop	CROP	16.0	7.5	1.2-37.0	32.6	8.1	16.0-47.0	61.0	11.7	34.0-84.0
Summer fallow	SFALP	0.14	0.20	0-1.30	0.16	0.17	0-1.00	0.10	0.19	0-1.10
Tame/seeded pasture	TSPP	1.9	1.3	0.1-6.5	3.6	2.0	0.3-9.6	3.0	2.9	0.3-21.3
Natural pasture	NPP	3.7	2.9	0.1-16.5	4.4	2.5	1.2-12.8	2.5	2.2	0.2-12.0
Native remnants	TWWP	5.2	3.1	0.2-13.1	7.0	2.4	1.9-13.7	6.8	2.7	1.6-14.4
Farmstead	FSAP	1.5	0.8	0.1-4.8	2.4	1.0	1.1-6.2	2.6	1.2	1.0-11.5
Heterogeneity										
Farmland	SWDIFR	1.20	0.30	0.40-1.51	1.10	0.20	0.60-1.46	0.73	0.20	0.20-1.30
Crop	SWDICR	1.40	0.30	0.20-1.90	1.60	0.30	0.60-2.10	1.50	0.25	0.70-2.00
Configuration										
Average farm size (ha)	AVFS	89.0	30.1	18.0-194.0	89.7	23.7	22.0-162.0	98.5	24.0	24.0-161.0
Average crop per farm (ha)	AVCRS	56.8	20.5	16.0-152.0	65.6	18.8	19.0-113.0	87.0	21.1	19.0-148.0
Agricultural Practices										
Livestock grazing (head/ha natural pasture)	CTPHA	4.5	3.8	1.0-21.7	7.2	4.4	1.0-25.0	20.2	13.9	2.0-58.5
Fertilizer input (%)	FERTIN	43.8	19.6	0.01-87.6	52.1	16.0	20.0-81.0	69.6	13.8	11.5-94.6
Pesticide input (%)	PESTIN	44.0	34.9	0.1-213.0	59.0	36.0	7.0-205.0	91.8	27.5	16.0-173.0
Machinery per farm	AMPF	3.1	0.4	2.4-4.8	3.3	0.3	2.8-4.5	3.7	0.3	3.0-4.5

Table 3.3 Regression results for candidate farmland bird species in 181 subdivisions in Ontario. Explanatory notes below.

Species code	Regression model	Category	aR2 (%)	P
1.RIPH	0.003 – 0.00 TWWP	FG [RCS]	4.3	0.003
2.WITU	-0.007 -0.00 CTPHA +0.00 FERTIN +0.8 NPP	FG	5.7	0.004
3. CAGO	0.67 – 0.9 AVFS	FG	8.2	0.000
4. MALL*	No significant model	FG [O]	1.3	0.118
5. BWTE	-0.005 – 0.00 CROP +0.00 NPP + 0.002 AMPF	FG	2.6	0.026
6. TUVU*	No significant model	FG [O]	0.1	0.350
7. AMKE	0.002 +0.2 TSPP	FS [PSS]	9.3	0.000
8. NOHA	0.002 +0.05 CTPHA	FS [PSS]	6.5	0.000
9. RTHA	0.018 – 0.0001 AVFS	FG [O]	2.3	0.024
10. KILL	0.121 + 0.3 CROP – 0.1 TWWP -0.1 SWDICR	FS [RCS]	47.5	0.000
11. UPSA	0.000 + 0.1 NPP	FS [PSS]	11.1	0.000
12. RBGU	0.067 + 0.8 SFALP	FG	6.1	0.000
13. RODO	0.56 + 0.3 CTPHA -0.3 SWDIFR -0.3 FERTIN	FS [FSS]	16.6	0.000
14. MODO	1.6 -1.1 SWDIFR -0.5 CTPHA -0.5 AVCRS +0.3 NPP	FS [FSS]	37.7	0.000
15. CONI	0.00 +0.05 NPP – 0.04 TWWP	FS [PSS]	8.0	0.000
16. RHWO	0.014 +0.003 SFALP -0.1AVCRS – 0.01 FERTIN -0.01 SWDIFR	FG [EFG]	3.8	0.038
17. NOFL	0.08 – 0.1 CROP	FG	14.6	0.000
18. EAPH	-0.007 + 0.1 SWDIFR +0.1 TWWP -0.05 FSAP -0.03 TSPP – 0.03 SWDICR +0.01 AVFS	FG [EFG]	40.3	0.000
19. EAWP*	0.11 – 0.001 AVCRS	FG [O]	4.6	0.002
20. EAKI	0.128 + 0.2 NPP -0.3 PESTIN +0.1 CROP -0.1 AVFS	FG [EFG]	29.6	0.000
21. GCFL	0.073 + 0.1 SWDIFR – 0.07 SWDICR -0.1 FSAP	FG [EFG]	30.4	0.000
22. BLJA	0.54 – 0.2 CROP -0.2 AMPF +0.1 FERTIN – 0.1 SWDICR	FG	24.5	0.000
23. AMCR	-0.22 +0.5 SWDIFR +0.3 FERTIN -0.3 FSAP -0.4 AVFS +0.4 AVCRS	FG	16.2	0.000
24. CEDW	0.31 – 0.1 AVCRS + 0.1 SFALP	FG	4.5	0.006
25. TRES	0.21 + 0.3 NPP	FS [FSS]	5.0	0.001

Species code	Regression model	Category	aR2 (%)	P
26. BARS	0.77 + 0.2 CROP -0.3 AVFS +0.6 NPP -0.7 SWDIFR	FS [FSS]	22.8	0.000
27. CLSW	-0.016 + 0.2 CROP	FS [FSS]	10.1	0.000
28. HOLA	0.1 + 0.7 CROP -0.2 SFALP -0.2 FSAP -0.2 SWDICR -0.1 TWWP	FS [RCS]	58.6	0.000
29. HOWR	0.06 + 0.1 CROP -0.1 CTPHA +0.1 NPP	FS [FSS]	6.8	0.001
30. NOMO	0.03 – 0.00 AVFS +0.008 FSAP -0.001 TWWP -0.009 SWDICR +0.015 SFALP – 0.001 CROP	FG [FSS]	47.0	0.000
31. BRTH	0.004 + 0.1 NPP	FG [EFG]	33.0	0.000
32. EUST	5.1 -3.4 SWDIFR -2.2 AVCRS +2.1 FSAP -1.0 CTPHA	FS [FSS]	34.5	0.000
33. EABL	0.009 +0.1 TSPP	FG [EFG]	7.5	0.000
34. AMRO	1.6 – 0.4 AVFS -0.6 SWDIFR -0.4 CTPHA +0.5 NPP	FG	12.0	0.000
35. HOSP	4.5 – 3.4 SWDIFR -0.8 AVCRS – 1.4 CROP -0.8 SWDICR + 0.9 FSAP +0.8 TSPP	FS [FSS]	51.1	0.000
36. AMGO	0.545 + 0.4 TSPP + 0.2 SFALP	FG	5.9	0.002
37. HOFI	0.67 +0.03 TWWP – 0.2 AVFS +0.3 PESTIN -0.5 CROP – 0.5 SWDIFR +0.1 NPP+0.2 TSPP-0.1 SWDICR	FS [FSS]	45.9	0.000
38. COYE	-0.18 +0.3 SWDIFR +0.2 AVFS -0.3 TSPP +0.1 TWWP	FG [EFG]	38.8	0.000
39. BAOR	0.109 + 0.2 FSAP	FG	2.9	0.013
40. OROR	0.069 – 0.05 SWDIFR -0.1 CTPHA – 0.01AVCRS	FG	7.3	0.001
41. BHCO	0.1 + 0.3 CROP + 0.3 FSAP -0.2 CTPHA	FS [FSS]	22.0	0.000
42. RWBL	2.26 + 0.9 AVCRS +0.9 NPP – 1.2 SWDIFR -1.3 FERTIN +1.0 FSAP	FG [EFG]	16.4	0.000
43. COGR	1.98 – 1.3 SWDIFR + 0.9 FSAP	FG [FSS]	30.6	0.000
44. EAME	0.007 + 0.3 NPP + 0.3 TSPP	FS [PSS]	45.6	0.000
45. BOBO	-0.037 + 1.4 TSPP + 0.2 AVFS -0.3 TWWP + 0.4 NPP + 0.2 CROP	FS [PSS]	43.7	0.000
46. SOSp	0.48 + 0.2 CROP + 0.3 NPP	FG [EFG]	9.2	0.000
47. SAVS	0.081 + 0.5 CROP + 1.1 TSPP -0.2 TWWP	FS [PSS]	43.3	0.000
48. GRSP	0.000 + 0.03 NPP	FS [PSS]	12.4	0.000
49. CHSP	0.135 + 0.3 TWWP + 0.2 PESTIN	FG [EFG]	13.0	0.000
50. CCSP	0.000 +0.01 NPP	FS [PSS]	6.8	0.000

Species code	Regression model	Category	aR ² (%)	P
51. FISP	0.018 + 0.1 NPP – 0.06 TSPP	FS [PSS]	10.7	0.000
52. VESP	0.021 + 0.2 CROP – 0.1 CTPHA -0.1 SWDICR	FS [RCS]	23.6	0.000
53. EATO	0.008 + 0.06 NPP – 0.06 TSPP	FS [PSS]	17.7	0.000
54. INBU	0.065 + 0.2 FERTIN – 0.06 SWDICR	FG [EFG]	8.5	0.000

Explanatory notes:

Species code explained in Appendix Table A4

Best-fitted models ($p \leq 0.05$, lowest AICc) using forward regression (except when * denotes backward regression); variable coefficient as partial proportional regression coefficient (PPRC)

Explanatory variables: CROP = row crop percent per subdivision, SFALP = summer fallow percent per subdivision, NPP = natural pasture percent per subdivision, TSPP = tamed and seeded pasture percent per subdivision, TWWP = trees, woods and wetlands in farmland as percent per subdivision, FSAP = farmstead area percent per subdivision; AVFS = average farm size per subdivision, AVCRS = average area of crop per farm per subdivision; CTPHA = livestock per hectare per subdivision, PESTIN = pesticide input, FERTIN = fertilizer input; AMPF = machinery per farm per subdivision, SWDIF = farmland diversity index; SWDICR = crop diversity index.

Category: FS = farmland specialist; RCS = row crop specialist, PSS = pasture specialist, FSS = farmstead specialist, FG = farmland generalist, EFG = edge farmland generalist, O = other, [] = additional category

aR² (%) = percent variance explained

Table 3.4 List of farmland birds for Ontario. Final in bold.

N	Farmland specialists	Category	N	Farmland generalists	Category
1	Northern Bobwhite*	RCS	1	Red-headed Woodpecker*	EFG
2	Ring-necked Pheasant	RCS	2	Eastern Phoebe	EFG
3	Gray Partridge	RCS	3	Eastern Kingbird*	EFG
4	Killdeer	RCS	4	Great crested flycatcher	EFG
5	Horned Lark	RCS	5	Brown Thrasher*	EFG
6	Vesper Sparrow*	RCS	6	Eastern Bluebird	EFG
7	American Kestrel*	PSS	7	Common Yellowthroat	EFG
8	Northern Harrier*	PSS	8	Song Sparrow	EFG
9	Upland Sandpiper	PSS	9	Chipping Sparrow	EFG
10	Barn Owl*	PSS	10	Indigo Bunting	EFG
11	Short-eared Owl*	PSS	11	Red-winged Blackbird	EFG
12	Common Nighthawk*	PSS	12	Blue-winged Teal	FG
13	Loggerhead Shrike*	PSS	13	Wild Turkey	FG
14	Eastern Meadowlark*	PSS	14	Canada Goose	FG
15	Bobolink*	PSS	15	Ring-billed Gull	FG
16	Savannah Sparrow	PSS	16	Northern Flicker*	FG
17	Grasshopper Sparrow*	PSS	17	Blue Jay	FG
18	Henslow's Sparrow*	PSS	18	American Crow	FG
19	Clay-colored Sparrow	PSS	19	Cedar Waxwing	FG
20	Field Sparrow*	PSS	20	American Robin	FG
21	Eastern Towhee*	PSS	21	American Goldfinch	FG
22	Dickeissel*	PSS	22	Baltimore Oriole*	FG
23	Rock Pigeon	FSS	23	Orchard Oriole	FG
24	Mourning Dove	FSS			
25	Tree Swallow	FSS			
26	Barn Swallow*	FSS			
27	Cliff Swallow	FSS			
28	House Wren	FSS			
29	Northern Mockingbird	FSS			
30	European Starling	FSS			
31	House Sparrow	FSS			
32	House Finch	FSS			
33	Brown-headed Cowbird	FSS			
34	Common Grackle	FSS			

Explanatory notes:

Species scientific names and codes in Appendix Table A4

* Priority species for BCR 13 in Ontario

Category codes: RCS = row crop specialists, PSS = pasture specialists, FSS = farmstead specialists, EFG = edge farmland generalists, FG = farmland generalists

Table 3.5 Descriptive statistics for bird response variables for 181 subdivisions in Ontario. n = number of species included in regression analyses.

Response variables	Mean	SD	Range
Abundance (mean no. birds per point count per subdivision)			
All farmland birds (n=53)*	12.0	4.0	4.1-30.1
Farmland generalists (n= 23)	7.0	1.9	3.2-15.2
Edge farmland generalists (n=11)	2.9	0.8	1.1-6.0
Farmland specialists (n=30)*	5.0	2.5	0.8-17.1
Row crop specialists (n=6)	0.3	0.4	0-2.1
Pasture specialists (n=12)	1.1	0.6	0.2-3.6
Farmstead specialists (n=12)	3.1	2.1	0.5-16.5
BCR 13 priority species (n=17)*	1.3	0.6	0.2-4.4
Richness (mean no. species per point count per subdivision)			
All farmland birds (n=53)*	5.6	1.2	2.7-9.8
Farmland generalists (n=23)	3.5	0.6	2.2-6.1
Farmland specialists (n=30)*	2.0	0.8	0.5-4.2
BCR 13 priority species (n=17)*	0.7	0.3	0.2-2.0

*Four species (all BCR 13 priority species) had no observations (Barn Owl, Loggerhead Shrike, Henslow's Sparrow, Dickcissel)

Table 3.6 Descriptive statistics for bird response variables for subdivision subsets in Ontario.

No. Species	Variable	Code	59 subdivisions			54 subdivisions			68 subdivisions		
			Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
	Farmland (% area per subdivision)		28.0	10.0	5.0-39.9	50.0	6.0	40.0-59.9	76.0	10.0	60.0-94.0
Abundance (mean no. birds per point count per subdivision)											
15*†	BCR 13 priority species	PRS	0.6	0.3	0-1.9	1.0	0.6	0.3-3.3	1.1	0.7	0.1-3.6
11	Edge farmland generalists	EFG	2.7	0.9	1.1-4.7	2.8	0.7	1.4-4.5	3.1	0.9	2.0-6.0
30*	Farmland specialists	FS	4.9	3.1	1-19	5.3	2.5	2-19.5	7.9	2.4	4.0-15.0
6	Row crop specialists	RCS	0.1	0.08	0-0.4	0.2	0.08	0.03-0.5	0.6	0.4	0.05-2.1
12*	Pasture specialists	PSS	0.5	0.3	0.03-1.8	0.9	0.5	0.3-3.2	1.0	0.6	0.05-3.4
12	Farmstead specialists	FSS	4.3	3.0	0.8-19.1	4.2	2.4	1.3-18.2	6.4	2.0	3.2-12.5

* BAOW, LOSH, HESP and DICK had no OBBA point count observations

† NOFL and BAOR not included because categorized as farmland generalists

Table 3.7 Regression results for bird abundance and richness in 181 subdivisions in Ontario for A. All farmland birds B. Farmland specialists C. Farmland generalists and D. BCR 13 priority species. Only best-fit models ($p \leq 0.05$, lowest AICc) tabulated. Base model generally had the lowest AICc. PPRC = partial proportional regression coefficient (no. birds or species per point per subdivision); sum bolded.

A. All farmland birds (No. species = 53)

Response Variables: Overall farmland birds	Abundance				Richness			
	Partitioned models			Base model:	Partitioned models			Base model
				aR ² (%) = 28 AICc = 968. Intercept=20.8				aR ² (%) = 14 AICc =562.1 Intercept = 5.3
Model statistics	PPRC	aR ² (%)	ΔAICc	PPRC	PPRC	aR ² (%)	ΔAICc	PPRC
Composition		18	20.1			14	0	
Crop %	5.0				1.8			1.8
Seeded pasture %								
Natural pasture %				8.3				
Native remnants %	-3.6							
Farmstead %	5.9			3.7				
Summer fallow %								
Configuration		15	25.2			9	13.5	
Average farm size	-8.6			-5.1	-2.1			
Average crop size	9.5				2.2			
Heterogeneity		19	15.1			10	10	
Farm	-7.1			-10.4	-1.6			
Crops								
Practices		9	33.8			9	12.0	
Livestock per hectare								
Average machinery								
Fertilizer input	5.6							
Pesticide input					1.6			

Table 3.7 Regression results for bird abundance and richness in 181 subdivisions in Ontario for A. All farmland birds B. Farmland specialists C. Farmland generalists and D. BCR 13 priority species. Only best-fit models ($p \leq 0.05$, lowest AICc) tabulated. Base model generally had the lowest AICc. PPRC = partial proportional regression coefficient (no. birds or species per point per subdivision); sum bolded.

B. Farmland Specialists (No. species = 30)

Response Variables: Farmland Specialists	Abundance				Richness			
	Partitioned models			Base model: aR²(%) =50 AICc=733.4 Intercept =17.6	Partitioned models			Base model aR²(%)=47 AICc =314.6 Intercept = 3.7
Model statistics	PPRC	aR ² (%)	Δ AICc	PPRC	PPRC	aR ² (%)	Δ AICc	PPRC
Composition		33	48.3			37	27.1	
Crop %	4.3			2.3	1.7			0.5
Seeded pasture %				5.9	1.0			1.4
Natural pasture %				4.3				1.6
Native remnants %	-3.2				-0.8			
Farmstead %	4.7			5.0				
Summer fallow %								
Configuration		23	72.3			23	59.7	
Average farm size	-7				-2.0			-1.4
Average crop size	7			-4.0	2.3			
Heterogeneity		35	41.8			30	40.7	
Farmland	-6.1			-13.4	-1.8			-2.2
Crops	-2.1			-1.8				
Practices		26	-3.4			28	49.1	
Livestock per hectare					0.9			
Average machinery								
Fertilizer input								
Pesticide input	6.0				1.4			

Table 3.7 Regression results for bird abundance and richness in 181 subdivisions in Ontario for A. All farmland birds B. Farmland specialists C. Farmland generalists and D. BCR 13 priority species. Only best-fit models ($p \leq 0.05$, lowest AICc) tabulated. Base model generally had the lowest AICc. PPRC = partial proportional regression coefficient (no. birds or species per point per subdivision); sum bolded. ns = no significant model

C. Farmland Generalists (No. species = 23)

Response Variables: Farmland Generalists	Abundance			Richness			
	Partitioned models			Base model:	Partitioned models		
				aR²(%) = 9 AICc =739.1 Intercept =10.0			
							aR²(%) = 6 AICc =340.5 Intercept = 3.1
Model statistics	PPRC	aR²(%)	ΔAICc	PPRC	PPRC	aR²(%)	ΔAICc
Composition		2	8.8			6	0
Crop %	1.0						
Seeded pasture %							
Natural pasture %				3.8			
Native remnants %					0.7		0.7
Farmstead %							
Summer fallow %					0.6		0.6
Configuration		4	8.1				
Average farm size	-2.3			-2.0			
Average crop size	2.0						
Heterogeneity		3	7.0				
Farmland	-1.4			-3.0			
Crops							
Practices		2	9.3				
Livestock per hectare							
Average machinery							
Fertilizer input							
Pesticide input	1.3						

Table 3.7 Regression results for bird abundance and richness in 181 subdivisions in Ontario for A. All farmland birds B. Farmland specialists C. Farmland generalists and D. BCR 13 priority species. Only best-fit models ($p \leq 0.05$, lowest AICc) tabulated. Base model generally had the lowest AICc. PPRC = partial proportional regression coefficient (no. birds or species per point per subdivision); sum bolded.

D. BCR 13 Priority Species (No. species = 17)

Response Variables: BCR 13 Priority Species	Abundance				Richness			
	Partitioned models			Base model:	Partitioned models			Base model
				aR²(%) = 30 AICc =272.5 Intercept=1.5				aR²(%) =38 AICc =-21.3 Intercept = 0.4
Model statistics	PPRC	aR²(%)	ΔAICc	PPRC	PPRC	aR²(%)	ΔAICc	PPRC
Composition		29	2.1			35	5.4	
Crop %	0.7				0.3			0.5
Seeded pasture %	1.2			1.8	0.5			0.9
Natural pasture %	1.4			1.9	1.0			0.6
Native remnants %								
Farmstead %								
Summer fallow %								
Configuration		2	56.5	0		2	76.1	
Average farm size	0.4				0.3			-0.4
Average crop size								
Heterogeneity		0.2	61.3			2	76.4	
Farmland	0.1			-1.0	0.2			-1.0
Crops								
Practices		1	58.4	0		3	74.6	
Livestock per hectare								-0.3
Average machinery								
Fertilizer input	-0.3				-0.3			
Pesticide input								

Table 3.8 Regression results for farmland bird abundance in 181 subdivisions and in subsets with different agricultural intensity in Ontario. Only base models ($p \leq 0.05$, lowest AICc) tabulated. PPRC = partial proportional regression coefficient (no. birds per point per subdivision); sum bolded. Additional details in Appendix Table A6.

B. Row crop specialists, Pasture specialists and Farmstead specialists

Variables (No spp.)	Row crop specialists (6)				Pasture specialists (12)				Farmstead specialists (12)			
% farmland	5-94	5-40	40-60	60-94	5-94	5-40	40-60	60-94	5-94	5-40	40-60	60-94
# subdivisions	181	59	54	68	181	59	54	68	181	59	54	68
aR ² (%)	56	56	23	24	46	27	22	55	42	59	21	32
PPRC												
Composition (Sum)												
Crop %	1.2	0.2		1.0	0.5	0.7		0.6				
Seeded pasture %					2.7		1.2	2.2			-3.3	
Natural pasture %					1.0	0.4		1.5				
Native remnants %	-0.2	-0.1	-0.1		-0.4							
Farmstead %	-0.4								3.9	3.3		
Summer fallow %		0.1										
Configuration (Sum)												
Average farm size											-4.2	
Average crop size									-4.4	-6.8		-3.5
Heterogeneity (Sum)												
Farmland									-7.5	-12.0		
Crops	-0.2											
Practices (Sum)												
Livestock per hectare			0.2									
Average machinery												
Fertilizer input						-0.6						-5.0
Pesticide input												9.4

Figure 3.1 Numerical response of farmland bird abundance and richness to farmland structure and practices in 181 subdivisions in Ontario. PPRC = partial proportional regression coefficient (change in the number of birds or species per point per subdivision). Legend: FB = all farmland birds, FG = farmland generalists, FS = farmland specialists, PRS = BCR 13 priority species, (%) = percent variance explained by base model.

Figure 3.2 Abundance-habitat relationship for row crop specialists (6 species) in 181 subdivisions in Ontario. R2 = proportion of variance explained.

Figure 3.3 Abundance-habitat relationship for pasture specialists (11 species) in 181 subdivisions in Ontario.. Pasture amount = percent area of subdivision in natural + seeded pasture. R2 = proportion of variance explained.

Figure 3.4 Relationship between farmland bird abundance and richness per point count in 181 subdivisions in Ontario.

Figure 3.5 Relationships between farmland bird abundance and row crop area for 181 subdivisions in Ontario. Amount = percent subdivision area in row crops. R^2 = proportion of variance explained. BCR 13 priority species ($R^2 = 0.10$).

Figure 3.6 Modeled responses of farmland birds to farmland composition in Ontario.
Crop amount = percent area of subdivision in row crop.

Discussion

Previous studies in North America have primarily focused on temporal trends in grassland birds in relation to agriculture. This thesis has extended this focus to one on farmland birds using a spatial framework at a single point in time for birds in Ontario and subsetting datasets to explore effects of agricultural intensification. Currently, agriculture is a dominant land use in southern Ontario, occupying two-thirds of all land cover. Historically, over 90% of southern Ontario was covered by deciduous and mixed woodlands even in the early 1800s. However, between the mid-1700s and the early 1900s about 90% of the landscape was converted to agricultural production. Not surprisingly, the statistics of natural habitat loss in southern Ontario reflect this trend with 68% of wetlands lost, 97% of prairie and savannah habitats, and 94% of the original upland woodland (OPF 2005). Despite the loss of natural grassland habitats, traditional small-scaled farming practices had created suitable surrogate habitats for grassland species, which have resulted in the expansion of historical ranges (Birds of North America 2009). Over the last 40 years, many grassland and other open-country species have shown negative population trends (OPF 2005).

Categorization of farmland birds

The European approach (EBCC 2009) differentiates farmland birds as either specialists or generalists in relation to their use of farmland within agricultural landscapes. This categorization was applied to species in North America based on the literature and expert opinion. Julliard *et al.* (2006) argue that a more powerful method is to use quantitative analysis of abundance patterns *a priori* to categorize species

specialization because it is more efficient and less subjective. In the present study, regression analysis was used to validate and refine species categorization and to further categorize species by association with row crop, pasture, farmstead and edges. This further categorization turned out to be important for understanding the differential distribution of species in response to landscape-scale effects within farmland.

The final list of farmland bird for Ontario includes 45 species, comprised of 34 specialists (6 row crop, 16 pasture and 12 farmstead) and 11 edge generalists. This is comparable to the list of farmland birds for EU which includes 36 specialists. As done in the current study, Ahnstrom *et al.* (2008) categorize species that use farmsteads in Sweden as specialists based on their dependence on human habitations for breeding. However, regression results for this set of species suggested that they could alternatively be categorized as farmstead generalists, because while strongly associated to farmstead, they also responded strongly to configuration, heterogeneity and practices as did edge generalists and farmland generalists overall. Furthermore, many farmstead species also occur in urban and suburban areas (Birds of North America 2009). Clavel *et al.* (2010) would likely categorize them as generalists based on the breadth of their habitat use. They might also re-categorize edge generalists as edge specialists given their preferred use of habitat edges. The choice of categorization is important because it influences what conservation actions are most appropriate when species become of concern.

Effects of farmland structure and agricultural practices

The current analysis represents 84% of all farmland in Ontario. Landscape structure (composition, configuration, heterogeneity) was found to be more important

than practices for richness and abundance of farmland birds, a finding consistent with the review of the existing literature. Within landscape structure, composition variables were significant in all base models for both the abundance and richness of farmland birds. The primary importance of farmland composition has been observed in other, more local studies in Ontario (Freemark & Kirk 2001) and in Europe (Billeter *et al.* 2008). At the same time, as it would be expected, farmland specialists showed a stronger response to farmland composition than generalists. Farmland specialists exhibited positive associations with crop, pastures and/or farmstead, and negative with native remnants, results that are consistent with other studies (e.g., Heikkinen *et al.* 2004; Ribic *et al.* 2009b). A habitat-based standard for row crop and pasture specialists was evident with higher than average abundances at about 40% crop and 8%-10% pasture, respectively. Both the richness and abundance of farmland generalists (including edge generalists) were associated with a variety of cover types in farmland including a positive association with native remnants.

Greater heterogeneity was found to have negative effects on both the average abundance and richness of farmland birds per point count per subdivision, especially specialists but also BCR 13 priority species. These findings appear contrary to other studies which have found that bird richness increases with farmland diversity (Benton *et al.* 2003, Van Turnhout *et al.* 2007, Vepsäläinen 2007, Herzog *et al.* 2008, Wretenberg *et al.* 2010) but may in part be due to methodological differences. The effect of heterogeneity on beta diversity (change in species composition among points) still needs to be investigated for Ontario. The observed negative effect of heterogeneity on farmland bird abundance is consistent with the existing literature (Herzog *et al.* 2008,

Wretenberg *et al.* 2010) and, based on the subset analysis, may be a result of negative effects particularly in the least intensively- farmed subdivisions, perhaps as a result of habitat patches being too small to be useful. Potential bias in the point count data analysis may also be a factor in subdivisions with low amounts of farmland. Farmland heterogeneity appeared to be more important than heterogeneity in crop types., a finding that is consistent with other studies (Fillipi-Codaccioni *et al.* 2010b). However, farmland heterogeneity was the variable with the most collinearity. The role of crop heterogeneity merits further research, especially at finer levels of resolution.

Configuration was important to those farmland birds that specialize on edge habitats (edge farmland generalists) or need production areas in close proximity to their breeding habitat (e.g. farmstead specialists). Larger field size has been found to have an adverse effect on bird richness in other studies in Ontario (Freemark and Kirk 2001) and in Europe (Vickery *et al.* 2004, Belfrage *et al.* 2005, Kati & Sekersioglu 2006, Herzon *et al.* 2008).

Agricultural practices were only significant to the richness of BCR 13 priority species but remain important to consider for conservation action because the effect was negative.

Effects of agricultural expansion and intensification

BCR 13 priority species, row crop specialists and pasture specialists showed the strongest response to change in farmland composition in the most intensively-farmed subdivisions in Ontario. Row crop specialists increased in abundance with the expansion of farmland and habitat simplification created by agricultural intensification, a finding

consistent with studies at field scales in Europe (Fillipi-Codaccioni *et al.* 2010a). BCR 13 priority species and pasture specialists showed that at least some pasture (between 8%-10%) in the most intensively farmed landscapes can have strong, positive effects on their abundance. Subsetting of subdivisions surfaced the importance of practices in relation to agricultural intensification, although still secondary compared to landscape structure as found by other studies (Freemark 1995, Freemark & Boutin 1995, Askins *et al.* 2007). Reduction in fertilizer use should benefit edge generalists, pasture specialists and farmstead specialists; reduction in pesticide use and grazing intensity should benefit edge generalists. The positive response of farmstead specialists to pesticide inputs continues to be hard to explain and is counter to conclusions that organic farming unequivocally benefits biodiversity from reductions in pesticide use.

In the least intensively-farmed subdivisions, increasing crop size (configuration) had a positive effect on the abundance of edge generalists as noted above, suggesting a minimum patch size may well exist when farmland is not predominant. Adverse effects of configuration were only observed for farmstead specialists and were evident in all subsets, presumably due to loss of suitable foraging areas in close proximity to farmsteads.

Tradeoffs were evident across the gradient in agricultural intensity. The abundance of farmland birds was optimized when crop occupied 40% to 70% of subdivisions, presumably because all farmland birds can find their required resources. This finding is consistent with the literature review on agricultural intensification which showed adverse impacts on avian biodiversity through simplification in farmland structure and intensified management (O'Connor & Shrubbs 1986, Herzog *et al.* 2008).

Population trends

Over the past 200 years, 80% of the species on the candidate list of farmland birds for North America (Appendix Table A3) have expanded their ranges in response to agricultural development based on a review of Birds of North America (2009) and is consistent with analyses by others (Murphy 2003, Peterjohn 2003, Veech 2006, Askins *et al.* 2007, Ribic *et al.* 2009a). Analysis at the continental scale of population trends since the 1960s indicated that 62% of 43 species of farmland specialists and 17% of 36 species of farmland generalists have been declining. Askins *et al.* (2007) have reported continental widespread population declines for most grassland species since the 1960s.

Based on a comparison of OBBA results from 1981-85 to 2001-2005 for BCR 13 in Ontario, 66% of the 45 species currently proposed as farmland birds have shown population declines (Appendix Table A4). This included all row crop specialists, 80% of pasture specialists, 64% of edge generalists and 33% of farmstead specialists. These findings are further evidence to suggest that farmstead species are better categorized as farmstead generalists rather than specialists and edge generalists as edge specialists.

Agricultural intensification (including conversion of pastures to cropland, and earlier and more frequent haying) and field abandonment have been posited as the main drivers of recent declines (Murphy 2003, Peterjohn 2003, Nocera *et al.* 2005, Perlut *et al.* 2008). Given the observed positive effect of agricultural expansion on the abundance of row crop specialists, their population declines are likely related to demographic effects of intensification of agricultural practices as has been observed in Europe (Fillipi-Codaccioni *et al.* 2010a). In other words, row crops in intensively farmed landscapes are functioning as “ecological traps” (Best 1986) in that they attract birds but

those birds are unable to reproduce at or above replacement. Edge generalists, pasture specialists, farmstead specialists and BCR 13 priority species were all found to have negative responses to practices (grazing intensity, inputs of fertilizers and inputs of pesticides except for farmstead specialists which showed a positive response) in addition to being adversely affected by loss of their preferred habitats in intensively-farmed landscapes. Monitoring and assessment of habitat and demography of farmland birds would help to elucidate underlying causes of population declines.

Conservation implications

One of the main problems of the 21st century is to achieve biodiversity conservation and agricultural production goals at the same time and often in the same place (McNeely & Scherr 2003). In Canada, the National Agri-Environmental Standards Initiative (NAESI) recently recommended retention of 25 to 30% of natural habitats within agricultural watersheds to support biodiversity of forest, riparian and grassland species (McPherson *et al.* 2008). In the present study, the abundance of farmland birds (including priority species and grassland species that now use pastures) was optimized when crop occupied 40% to 70% of subdivisions (with 8 to 10% pasture) leaving at least 30% of the landscape for non-farmed habitats. The current results also show that agri-environmental schemes should promote a combination of field size diversity, mixed cropping regimes, reduced grazing intensity, and reduced chemical inputs (unequivocally fertilizers) to benefit bird populations and mitigate negative effects of agricultural intensification, findings consistent with the existing literature (Fuller *et al.* 2004, Henderson *et al.* 2009, Sanderson *et al.* 2009).

Farmlands in Ontario can contribute to the conservation and management of priority bird species including many grassland species. However, 90% of all lands in southern Ontario are privately owned so conservation efforts need to support and motivate landowners' initiatives through stewardship organizations (OPF 2005). Some suggest that sustainable biodiversity conservation needs external support, such as payments for environmental services (Pagiola 2010).

The Farmland Bird Indicator in Europe is based on population trends of common breeding birds (BLI 2004). In the current study, a "space-for-time" analysis design was used to explore potential effects of land use change on farmland birds. The results suggest that a Farmland Bird Indicator would be a useful step forward for monitoring and assessment of biodiversity at multiple spatial scales in North America. The regression models produced in the present study can also be used to inform the development of conservation plans and actions for farmland birds, including for priority bird species within BCR 13.

Climate change is now recognized as one of the most powerful driving forces affecting habitats. Areas that are not currently farmed may become suitable in the future with more favourable climatic and soil conditions and increasing demand from a growing human population worldwide. Many birds including many categorized in the present study as farmland birds are beginning to expand their ranges in response to climate change (NABCI 2010). Edge generalists in particular may benefit given their flexibility to adapt and use habitats that may no longer be suitable for specialists.

The concept of environmental corridors assumes connecting of biodiversity core areas. Under climate change, agricultural areas will likely serve as range shift corridors

facilitating bird population persistence and their seasonal movements across landscapes especially for migratory species (Galatowitch *et al.* 2009). Farmlands can mitigate the negative consequences of climate change impact, because they can provide food and habitat resources not only for human population, but for biodiversity as well, if they are managed not too intensively and managed by design at the landscape scale using evidence-based approaches. Knowledge of farmland bird distribution patterns and species – agriculture relationship models should inform the development of strategies for biodiversity adaptation to climate change and the design and implementation of environmentally supportive agri-environmental schemes.

References Cited

- AAFC (Agriculture and Agri-Food Canada). 2009. Agriculture and Agri-Food Canada website <http://www.agr.gc.ca/> Accessed in December 2009.
- Akaike, H. 1974. A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, 19: 716-723.
- Anderson, G.Q.A., D.J. Gruar, N.I. Wilkinson and R.H. Field. 2002. Three sparrow *Passer montanus* chick diet and productivity in an expanding colony. *Birds and agriculture, Aspects of Applied Biology. Proceedings of the Association of Applied Biologists*, 67: 35-42.
- Anhstrom, J., A. Berg, and H. Soderlund. 2008. Birds on farmsteads – effects of landscape and farming characteristics. *Ornis Fennica*, 85: 98-108.
- Askins, R.A., F. Chavez-Ramirez, B.C. Dale, C.A. Haas, J.R. Herkert, F.L. Knopf, and P.V. Vickery. 2007. Conservation of grassland birds in North America: Understanding Ecological Processes in Different Regions. *Ornithological Monograph*, 64: 1-64.
- Audubon Society. 2009. State of the Birds. <http://stateofthebirds.audubon.org>, Accessed in September 2009.
- Baldi, A. and S. Farago. 2007. Long-term changes of farmland game populations in a post-socialist country (Hungary). *Agriculture, Ecosystems and Environment*, 118: 307-311.
- Beecher, N.A., R.J. Johnson, J.R. Brandle, R.M. Case, and L.J. Young. 2002. Agroecology of birds in organic and nonorganic farmland. *Conservation Biology*, 16: 1620-1631.

- Belfrage, K., J. Bjorklund, and L. Salomonsson. 2005. The effects of farm size and organic farming on diversity of birds, pollinators, and plants in a Swedish landscape. *Ambio*, 34: 582-588.
- Belanger, L., and M. Picard. 1999. Cattle grazing and avian communities of the St. Lawrence River Islands. *Journal of Range Management*, 52: 332-338.
- Belfrage, K., J. Bjorklund, and L. Salomonson. 2005. The effect of farm size and organic farming on diversity of birds, pollinators, and plants in a Swedish landscape. *Ambio*, 34: 582-588.
- Benton, T.G., J.A. Vickery and J. D. Wilson. 2003. Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology and Evolution*, 18: 182-188.
- Berg, A. 2002. Breeding birds in short-rotation coppices on farmland in central Sweden – the importance of *Salix* height and adjacent habitats. *Agriculture, Ecosystems and Environment*, 90: 265-276.
- Best, L.B. 1986. Conservation tillage: Ecological traps for nesting birds? *Wildlife Society Bulletin*, 14: 308-317.
- Best, L.B., K.E. Freemark, J.J. Dinsmore, and M. Camp. 1995. A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa. *American Midland Naturalist*, 134: 1-29.
- Best, L.B., H. Campa, K.E. Kemp, R.G. Robel, M.R. Ryan, J.A. Savidge, H.P. Weeks, and S.R. Wintershtein. 1998. Avian abundance and crop fields during winter in the Midwest. *American Midland Naturalist*, 139: 311-324.
- Best, L.B., T.M. Bergin, and K.E. Freemark. 2001. Influence of landscape composition on bird use of rowcrop fields. *Journal of Wildlife Management*, 65: 442-449.

- Billeter, R., J.Liira, D. Bailey, R. Bugter, P. Arens, I. Augenstein, S. Aviron, J. Baudry, R. Bukacek, F. Burel, M. Cerny, G. De Blust, R. De Cock, T., Diekötter, H. Dietz, J. Dirksen, C. Dormann, W. Dura, M. Frenzel, R. Hamersky, F. Henderickx, F. Herzog, S. Klotz, B. Koolstra, A. Lausch, D. Le Coeur, J.P. Maelfait, P. Opdam, M. Roubalova, A. Schermann, N. Schermann, T. Schmidt, O. Schweiger, M.J.M. Smulders, M. Speelmans, P. Simova, J. Verboom, W. van Wingerden, M. Zobel, and P. Edwards. 2008. Indicators for biodiversity in agricultural landscapes: a pan-European study. *Journal of Applied Ecology*, 45: 141-150.
- Birds of North America. 2009. Cornell Lab of Ornithology. American Ornithological Union. <http://bna.birds.cornell.edu/bna> Accessed online October 2009.
- BLI (BirdLife International). 2004. Birds in the European Union: a Status Assessment. Wageningen, The Netherlands, 59 p.
- Boutin, C., K.E. Freemark, D.V. Weseloh, G.M. Donaldson, M. Csizy, P.A. Martin, A. Wormington, J. McCracken, and D. Shepherd. 1996. Bird use of crops in Southern Ontario: Implications for assessment of pesticide risk. CWS Technical Report Series. No 284, Environment Canada, Ottawa, ON K1A 0H3. 110 p.
- Boutin, C., K. E. Freemark, and D.A. Kirk. 1999. Farmland birds in southern Ontario: field use, activity patterns and vulnerability to pesticide use. *Agriculture, Ecosystems and Environment*, 72: 239-254.
- Bracken, F., and T. Bolger. 2006. Effects of set-aside management on birds breeding in lowland Ireland. *Agriculture, Ecosystems and Environment*, 117: 178-184.

- Bradbury, R.B., and W.B. Kirby. 2006. Farmland birds and resource protection in the UK: Cross-cutting solutions for multi-functional farming? *Biological Conservation*, 129: 530-542.
- Brennan, L.A., and V.P. Kuvlesky. 2005. North American grassland birds: an unfolding conservation crisis? *Journal of Wildlife Management*, 69: 1-13.
- Buckingham, D.L., W.J. Peach, and D.S. Fox. 2006. Effect of agricultural management on the use of lowland grassland by foraging birds. *Agriculture, Ecosystems and Environment*, 112: 21-40.
- Buenestado, F.J., P. Ferreras, M. Delibes-Mateos, F.S. Tortosa, J.A. Blanco-Aguiar, and R. Villafuerte. 2008. Habitat selection and home range size of red-legged partridges in Spain. *Agriculture, Ecosystems and Environment*, 126: 158-162.
- Burger, L.W., D. Mackenzie, R. Thackston, and S.J. Demaso. 2006. The role of farm policy in achieving large-scale conservation: Bobwhite and buffers. *Wildlife Society Bulletin*, 34: 986-993.
- Burel, F., J. Baudry, A. Butet, Ph. Clergeau, Y. Delettre, D. Le Coeur, F. Dubs, N. Morvan, G. Paillat, S. Petit, C. Thenail, E. Brunel, and J-C. Lefeuvre. 1998. Comparative biodiversity along a gradient of agricultural landscapes. *Acta Oecologica*, 19: 47-60.
- Burnham, K. P., and D. R. Anderson, 2002. *Model Selection and Multimodel Inference: A Practical-Theoretic Approach*, 2nd ed. Springer-Verlag.
- Cadman, M.D., D.A. Sutherland, G.G. Beck, D. Lepage, and A.R. Couturier (eds.). 2007. *Atlas of the Breeding Birds of Ontario, 2001- 2005*. Bird Studies Canada,

- Environment Canada, Ontario Ministry of Nature Resources, and Ontario Nature. Toronto, ON, Canada 706 p.
- Calvo-Iglesias, M.S., U. Fra-Paleo, and R.A. Dias-Valera. 2009. Changes in farming system and population as drivers of land cover and landscape dynamics: The case of enclosed and semi-opened systems in Northern Galicia (Spain). *Landscape and Urban Planning*, 90: 168-177.
- Chamberlain, D.E., J.D. Wilson, and R.J. Fuller. 1999. A comparison of bird populations on organic and conventional farm system in southern Britain. *Biological Conservation*, 88: 307-320.
- Chamberlain, D.E., and R.J. Fuller. 2000. Local extinctions and changes in species richness of lowland farmland birds in England and Wales in relation to recent changes in agricultural land-use. *Agriculture, Ecosystems and Environment*, 78: 1-17.
- Chamberlain, D.E. 2002. Effect of agricultural intensification on birds: Evidence from monitoring data. *Birds and agriculture, Aspects of Applied Biology. Proceedings of the Association of Applied Biologists*, 67: 1-10.
- Chapman, R.N., D.M. Engle, R.E. Masters, and D.M. Leslie. 2004. Grassland vegetation and bird communities in the southern Great Plains of North America. *Agriculture, Ecosystem and Environment*, 104: 577 -585.
- Clavel, J., R. Julliard, and V. Devictor. 2010. Worldwide decline of specialist species: toward a global functional homogenization? *Front Ecol Environ* 2010; doi:10.1890/080216. www.frontiersinecology.org Accessed online November 2010.
- Colvin, B.A. 1985. Common Barn-Owl population decline in Ohio and the relationship to agricultural trends. *Journal of Field Ornithology*, 56: 224-235.

- Coppedge, B.R., D.M. Engle, R.E. Masters, and M.S. Gregory. 2001. Avian response to landscape change in fragmented Southern Great Plain grasslands. *Ecological Applications*, 11: 47-59.
- 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.
- Devictor, V. and F. Jiguet. 2007. Community richness and stability in agricultural landscapes. *Agriculture, Ecosystems and Environment*, 120: 179 -184.
- Devictor, V., J. Clavel, R. Julliard, S. Lavergne, D. Mouillot, W. Thuiller, P. Venail, S. Villeger, and N. Mouket. 2010. Defining and measuring ecological specialization. *Journal of Applied Ecology*, 47: 15-25.
- Donald, P.F., R.E. Green, and M.F. Heath. 2001. Agricultural intensification and the collapse of the Europe's farmland bird populations. *Proceedings: biological sciences*, 268: 25-29.
- Donald, P.F., G. Pisano, M.D. Rayment, and D.J. Pain. 2002. The common agricultural policy: EU enlargement and the conservation of Europe's farmland birds. *Agriculture, Ecosystems and Environment*. 89: 167-182.
- Donald, P. F., F.J. Sanderson, I.G. Burfield, and F.P.J. van Bommel. 2006. Further evidence of continent-wide impacts of agricultural intensification on European farmland birds, 1990-2000. *Agriculture, Ecosystems and Environment*, 116:189-196.
- Duelli, P. 1997. Biodiversity evaluation in agricultural landscapes: An approach at two different scales. *Agriculture, Ecosystems and Environment*, 62: 81-91.
- EBCC (European Bird Conservation Council). 2009. European Wild Bird Indicators. <http://www.ebcc.info/index.php?ID=382> Accessed in October 2009.

- Farina, A. 1989. Bird community patterns in Mediterranean farmlands: A comment. *Agriculture, Ecosystems and Environment*, 27: 177-181.
- Field, R.H., S. Benke, K. Badonyi, and R.B. Bradbury. 2007. Influence of conservation tillage on winter bird use of arable fields in Hungary. *Agriculture, Ecosystems and Environment*, 120: 399-404.
- Filippi-Codaccioni, O., V. Devictor, Yv. Bas, J. Clobert, and R. Julliard. 2010a. Specialist response to proportion of arable land and pesticide input in agricultural landscapes. *Biological Conservation*, 143: 883-890.
- Filippi-Codaccioni, O., V. Devictor, Yv. Bas, and R. Julliard. 2010b. Towards more concern for specialization and less for species diversity in conserving farmland biodiversity, *Biological Conservation*, 143: 1493-1500.
- Freemark, K., H. Dewar, and J. Saltman. 1991. A literature review of birds use of farmland habitats in the Great Lakes – St. Lawrence region. Technical Report Series, Canadian Wildlife Service, Environment Canada 114: 116 p.
- Freemark, K. 1995. Assessing effects of agriculture on terrestrial wildlife: developing a hierarchical approach for US EPA. *Landscape and Urban Planning*, 31: 99-115.
- Freemark, K. and C. Boutin. 1995. Impacts of agricultural herbicide use on terrestrial wildlife in temperate landscapes: A review with special reference to North America. *Agriculture, Ecosystems and Environment*, 52: 67-91.
- Freemark, K.E. and D.A. Kirk. 2001. Birds on organic and conventional farms in Ontario: partitioning effects of habitats and practices on species composition and abundance. *Biological Conservation*, 101: 337-350.

- Freemark, K.E. 2005. Farmlands for farming and nature. Pp. 193-200 In: J.A. Wiens and M.R. Moss (eds.). *Issues in Landscape Ecology*. Cambridge University Press, New York, USA.
- Fuller, R.J. 2000. Relationships between recent changes in lowland British agriculture and farmland bird populations: an overview. *Ecology and Conservation of Lowland Farmland Birds*. Tring: British Ornithologists' Union, p. 5–16.
- Fuller, R.J., D.E. Chamberlain, N.H.K. Burton, and S.J. Gough. 2001. Distributions of birds in lowland agricultural landscapes of England and Wales: How distinctive are bird communities of hedgerows and woodland? *Agriculture, Ecosystems and Environment*, 84: 79-92.
- Fuller, R.J., S.A. Hinsley, and R.D. Swetnam. 2004. The relevance of non-farmland habitats, uncropped areas and habitat diversity to the conservation of farmland birds. *Ibis*. 146: 22-31.
- Gabriel, D., S.M. Sait, J.A. Hodson, U. Schmutz, W.E. Kunin, and T.G. Benton. 2008. Scale matters: the impact of organic farming on biodiversity at different spatial scales. *Ecology Letters*. Blackwell Publishing Ltd. CNRS
- Galatowitch, S., L. Frelich, and L. Phillips-Mao. 2009. Regional climate change adaptation strategies for biodiversity conservation in a mid continental region of North America. *Biological Conservation* , 142: 2012 -2022.
- Gaston, K.J., and R.A. Fuller. 2007. Biodiversity and extinction: losing the common and the widespread. *Progress in Physical Geography*, 31: 213-225.
- 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.

- Gordon, C.E. (2000). Fire and cattle grazing on wintering sparrow in Arizona grasslands. *Journal of range management*, 53: 384 – 389.
- Grafen, A. and R. Hails. 2002. *Modern Statistics for the Life Sciences*. Oxford University Press Inc., New York, USA. 351 p.
- Gupta, A.K. 2004. Origin of agriculture and domestication of plants and animals linked to early Holocene climate amelioration. *Current Science*, 87: 54-59.
- Hart, J.F. 2005. Loss and abandonment of cleared farm land in the Eastern United States. *Annals of the Association of American Geographers*. 58: 417-440.
- Heikkinen, R.K., M. Luoto, R. Virkkala, and K. Rainio. 2004. Effects of habitat cover, landscape structure and spatial variables on the abundance of birds in an agricultural – forest mosaic. *Journal of Applied Ecology*, 41: 824 -835.
- Heinle, K., D. Alard, J. Clitherow, P. Cobb, L. Firbank, T. Kull, D. McCracken, R.F.A. Moritz, J. Niemela, M. Rebane, D. Wascher, A. Watt, and J. Young. 2008. Identifying and managing the conflicts between agriculture and biodiversity conservation in Europe – A review. *Agriculture, Ecosystems and Environment*, 124: 60-71.
- Henderson, I, N. Ravenscroft, G. Smith, and S. Holloway. 2009. Effects of crop diversification and low pesticide inputs on bird populations on arable land. *Agriculture, Ecosystems and Environment*, 129: 149-156.
- Herkert, J.R. (2009). Response of bird populations to farmland set-aside programs. *Conservation Biology*, 23: 1036–1040
- Herzog, F., S. Dreier, G. Hofer, C. Marfurt, B. Schupbach, M. Spiess, and T. Walter. 2005. Effect of ecological compensation areas on floristic and breeding bird diversity

- in Swiss agricultural landscapes. *Agriculture, Ecosystems and Environment*, 108: 189-204.
- Herzon, I., and R.B. O'Hara. 2007. Effect of landscape complexity on farmland birds in the Baltic States. *Agriculture, Ecosystems and Environment*, 118: 297-306.
- Herzon, I., A. Aunins, J. Elts, Z. Preiksa. 2008. Intensity of agricultural land-use and farmland birds in the Baltic States. *Agriculture, Ecosystems and Environment*, 125: 93-100.
- Hietala-Koivu, R., J. Lankoski, and S. Tarmi. 2004. Loss of biodiversity and its social cost in an agricultural landscape. *Agriculture, Ecosystems and Environment*, 103: 75-83.
- Horn, D.J. and R.R. Koford. 2000. Relation of grassland abundance to mowing of Conservation Reserve Program fields in North Dakota. *Wildlife Society Bulletin*, 28: 653-659.
- Hultquist, J.M. and L.B. Best. 2001. Bird use of terraces in Iowa rowcrop fields. *American Midland Naturalist*, 145: 275-287.
- Jepsen, J.U., C.J. Topping, P. Odderskair, and P.N. Andersen. 2005. Evaluating consequences of land-use strategies on wildlife populations using multiple-species predictive scenarios. *Agriculture, Ecosystems and Environment*, 105: 581-594.
- Jobin, B., J.-L. DesGranges, and C. Boutin. 1996. Population trends in selected species of farmland birds in relation to recent development in agriculture in the St. Lawrence Valley. *Agriculture, Ecosystems and Environment*, 57: 103-116.
- Jobin, B., L. Choiniere, and L. Belanger. 2001. Bird use of three types of field margins in relation to intensive agriculture in Quebec, Canada. *Agriculture, Ecosystem and Environment*, 84: 131-143.

- Jones, G.A., K.E. Sieving, and S.K. Jacobson. 2005. Avian diversity and functional insectivory on North-Central Florida farmlands. *Conservation Biology*, 19: 1234 – 1245.
- Jones, G.A., and K.E. Sieving. 2006. Intercropping sunflower in organic vegetables to augment bird predators of arthropods. *Agriculture, Ecosystems and Environment*, 117: 171-177.
- Johnson, D.H. and L.D. Igl. 1995. Contribution of the Conservation Reserve Program to populations of breeding birds in North Dakota. *The Wilson Bulletin*, 107: 709-718.
- Julliard, R., J. Clavel, V. Devictor, F. Jiguet, and D. Couvert. 2006. Spatial segregation of specialists and generalists in bird communities. *Ecology Letters*, 9. 1237-1244.
- Kati, V.I., and C.H Sekiroglu. 2006. Diversity, ecological structure, and conservation of the landbird community of Dadia reserve, Greece. *Diversity and Distribution*, 12: 620-629.
- Kirk, D. A., C. Boutin, and K.E. Freemark. 2001. A multivariate analysis of bird species composition and abundance between crop types and seasons in southern Ontario, Canada. *Ecoscience*, 8:173-184.
- Kleijn, D., F. Berendse, R. Smit, N. Gilissen, J. Smit, B. Brak, and R. Groeneveld. 2004. Ecological effectiveness of agri-environmental schemes in different agricultural landscapes in Netherlands. *Conservation Biology*, 18: 775-786.
- Kleijn, D., and A. Baldi. 2005. Effects of set-aside land on farmland biodiversity: comments on Van Buskirk and Willi. *Conservation Biology*, 19: 963-966.
- Kragten, S., K.B. Trimbos, G.R. de Snoo. 2008. Breeding skylarks (*Alauda arvensis*) on organic and conventional arable farms in The Netherlands. *Agriculture, Ecosystems and Environment*, 126: 163-167.

- Kuemmerle, T., P. Hostert, V.C. Radeloff, S. van der Linden, K. Perzanowski, and I. Kruhlov. 2008. Global change research in the Carpathian Mountain Region. *Ecosystems*, 11: 614-628.
- Kujawa, K. 2002. Population density and species composition changes for breeding bird species in farmland woodlots in western Poland between 1964 and 1994. *Agriculture, Ecosystem and Environment*, 91: 261 -271.
- Lemoine, N., H-G. Bauer, M. Peintinger, and K. Bohning-Gauser. 2007. Effect of climate and land-use change on bird abundance in a Central European Bird Community. *Conservation Biology*, 21: 495-503.
- Lokemoen, J.T. and J.A. Beiser. 1997. Bird use and nesting in conventional, minimum-tillage, and organic cropland. *The Journal of Wildlife Management*, 61: 644-655.
- Maisonneuve, Ch., L. Belanger, D. Bordage, B. Jobin, M. Grenier, J. Beaulieu, S. Gabor, and B. Filion. 2006. American Black Duck and Mallard distribution and habitat relationship along a forest-agriculture gradient in Southern Quebec. *The Journal of Wildlife Management*, 70: 450-459.
- Martin, P.A. and D.J. Forsyth. 2003. Occurrence and productivity of songbirds in prairie farmland under conventional versus minimum tillage regime. *Agriculture, Ecosystem and Environment*, 96: 107-117.
- Matson, P.A., W.J. Parton, A.G. Power, and M.J. Swift. 1997. Agricultural intensification and ecosystem properties. *Science*, 277: 504-509.
- Mattison, E.H.E., and K. Norris. 2005. Bridging the gaps between agricultural policy, land-use and biodiversity. *Trends in Ecology and Evolution*, 20: 610-616.

- McMaster, D.G., J.H. Devries, and S.K. Davis. 2005. Grassland bird nesting in haylands of Southern Saskatchewan: Landscape influence and conservation priorities. *The Journal of Wildlife Management*, 69: 211-221.
- McNeely, J.A., and S.J. Scherr. 2003. *Ecoagriculture: Strategy to Feed the World and Save Wild Biodiversity*. Island Press, Washington.
- McPherson, M., C. Nielson, and K. Proudlock. 2008. Tier one Standards – Generalized Habitat Standards for Ecozones within Agricultural Regions in Canada. National Agri-Environmental Standards Initiative Technical Series Report, No. 4-8: 277 p.
- MEA (Millennium Ecosystem Assessment). 2005. *Ecosystems and Human well-being. Biodiversity synthesis report*. World Resource Institute. Washington. DC. 85 p.
- Mineau, P., C.M. Downes, D.A. Kirk, E. Bayne, and M. Csizy. 2005. Patterns of bird species abundance in relation to granular insecticide use in the Canadian prairies. *Ecoscience*, 12: 267-278.
- Mischenko, A., and O. Sukhanova. 2008. Trends of bird numbers during the habitat successions in the farmlands of Central Russia. Changes in the bird populations and numbers in the result of anthropogenic transformation of habitats and succession processes. *Proceedings of the Russian Bird Conservation Union*, 128 – 137.
- Moulton, C.E., R.S. Brady, and J.R. Belthoff. 2006. Association between wildlife and agriculture: Underlying mechanisms and implications in Burrowing Owls. *The Journal of Wildlife Management*, 70: 708-716.
- Murphy, M. T. 2003. Avian population trends within the evolving agricultural landscape of Eastern and Central United States. *Auk*, 120: 20-34.

- NABCI (North American Bird Conservation Initiative U.S. Committee). 2010. The State of the Birds 2010 Report on Climate Change,. U.S. Department of the Interior: Washington, DC, USA.
- Newton, I. 2004. The recent declines of farmland bird populations in Britain: an appraisal of casual factors and conservation actions. *Ibis*, 146: 579-600.
- Nikolov S.C. 2010. Effects of land abandonment and changing habitat structure on avian assemblages in upland pastures of Bulgaria. *Bird Conservation International*, 20: 200-213.
- Noble, D.G. and M.J. Raven. 2002. Regional trends in farmland birds in UK. *Birds and agriculture, Aspects of Applied Biology. Proceedings of the Association of Applied Biologists*, 67: 141 – 146.
- Nocera, J.J., G.J. Parsons, G.R. Milton, and A.H. Fredeen. 2005. Compatibility of delayed cutting regime with bird breeding and hay nutritional quality. *Agriculture, Ecosystem and Environment*, 107: 245-253.
- NRC (Natural Resources Canada). 2010. Climate Change Impacts and Adaptation. <http://adaptation.nrcan.gc.ca/perspective/summary> Accessed in September 2010.
- O'Connor, R.J., and M. Shrubbs. 1986. *Farming and birds*. Cambridge university press. Oxford. UK. 290 p.
- Ogden, L.J.E., Sh. Bittman, D.B. Lank, and F.C. Stevenson. 2008. Factors influencing farmland habitat use by shorebird wintering in the Fraser River Delta, Canada. *Agriculture, Ecosystems and Environment*, 124: 252-258.

- OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs). 2009. Website: http://www.omafra.gov.on.ca/english/stats/agriculture_summary.htm#area Accessed in July 2010.
- OPF (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 Nature Resources. 15 p.
- Padoa-Schioppa, E., M. Baietto, R. Massa, and L. Bottoni. 2006. Bird communities as bioindicators: The focal species concept in agricultural landscapes. *Ecological Indicators*, 6: 83-93.
- Pagiola, S. 2010. Saving biodiversity – debate. IUCN – World Conservation Magazine. July 2010. http://www.iucn.org/knowledge/publications_doc/world_conservation/ Accessed online August 2010.
- Pascual, J.A., A.D.M. Hart, P.J. Saunders, H.V. McKay, J. Kilpatrick, and P. Prosser. 1999. Agricultural methods to reduce the risk to birds from cereal seed treatments on fenlands in Eastern England: Sowing depth manipulation. *Agriculture, Ecosystems and Environment*, 72: 59-73.
- Peach, W.J., L.J. Lovett, S.R. Wotton, and C. Jeffs. 2001. Countryside stewardship delivers ciril bunting (*Emberiza cirilus*) in Devon, UK. *Biological Conservation*, 101: 361- 373.
- Perkins, A.J., M.J. Whittingham, R.B. Bradbury, J.D. Wilson, A.J. Morris, and Ph. R. Barnett. 2000. Habitat characteristics affecting use of lowland agricultural grasslands by birds in winter. *Biological Conservation*, 95: 279-294.

- Perlut, N.G., A.M. Strong, T.M. Donovan, and N.J. Buckley. 2008. Regional population viability of grassland songbirds: Effects of agricultural management. *Biological Conservation*, 141: 3139- 3151.
- Peterjohn, B.J. 2003. Agricultural landscapes: can they support healthy bird populations as well as farm products? *Auk*, 120: 14-19.
- Piha, M., J. Tiainen, J. Holopainen, and V. Vepsäläinen. 2007. Effects of land use and landscape characteristics on avian diversity and abundance in a boreal agricultural landscape with organic and conventional farms. *Biological Conservation*, 140: 50 -61.
- Puckett, H.L., J.R. Brandle, R.J. Johnson, and E.E. Blankenship. 2009. Avian foraging patterns in crop field edges adjacent to woody habitat. *Agriculture, Ecosystem and Environment*, 131: 9-15.
- Pueyo, I., and S. Begueria. 2007. Modelling the rate of secondary succession after farmland abandonment in a Mediterranean mountain area. *Landscape and Urban Planning*, 83: 245-254.
- Ribic, Ch., R.R. Conford, J.R. Herkert, D.H. Johnson, N.D. Niemuth, D.E. Naugle, K.K. Bakker, D.W. Sample, and R.B. Ranfrew. 2009a. Area sensitivity in North American grassland birds: patterns and processes. *Auk*, 14: 233- 244.
- Ribic, Ch.A., M.J. Guzy, and D.W. Sample. 2009b. Grassland bird use of remnant prairies and Conservation Reserve Program fields in an agricultural landscape in Wisconsin. *American Midland Naturalist*, 161: 110-122.
- Rodgers, R.D. 2003. Effect of wheat-stubble height and weed control on winter pheasant abundance. *Wildlife Society Bulletin*, 30: 1099-1112.

- Rodriguez, J.P. 2002. Range contraction in declining North American bird populations. *Ecological Applications*, 12: 238-248.
- Rodriguez, C. and K. Wiegand. 2009. Evaluating the trade-off between machinery efficiency and loss of biodiversity-friendly habitats in arable landscapes: The role of field size. *Agriculture, Ecosystems and Environment*, 129: 361-366.
- Sampson, F.B. and F.L. Knopf. 1994. Prairie conservation in North America. *BioScience*, 44: 418-421.
- Sanderson, F.J., A. Kloch, K. Sachanowicz, and P.F. Donald. 2009. Predicting the effect of agricultural change on farmland bird population in Poland. *Agriculture, Ecosystems and Environment*, 129: 37-42.
- Sauberer, N., K. Zulka, M. Abensperg-Traun, H-M. Berg, G. Bieringer, N. Milasowszky, D. Moser, Ch. Plutzar, M. Pollheimer, Ch. Storch, R. Trostl, H. Zechmeister, and G. Grabherr. 2004. Surrogate taxa for biodiversity in agricultural landscapes of eastern Austria. *Biological Conservation*, 117: 181 -190.
- Scholefield, P., L. Firbank, S. Butler, K. Norris, L.M. Jones, and S. Petit. 2010. Modelling the European Farmland Bird Indicator in response to forecast land-use change in Europe. *Ecological Indicators*, 11: 46-51.
- Sirami, C., L. Brotons, I. Burfield, J. Fonderflick, and J-L. Martin. 2008. Is land abandonment having an impact on biodiversity? *Biological Conservation*, 141: 450-459.
- Siriwardena, G.M., S.R. Baillie, H.Q.P. Crick, and J.D. Wilson. 2001. Changes in agricultural land-use and breeding performance of some granivorous farmland passerins in Britain. *Agriculture, Ecosystems and Environment*, 84: 191 – 206.

- Smith, A.C. 2010. Prioritizing Management Options for Conservation, with Applications in Avian Landscape Ecology. Ph.D. Thesis. Dept. Biology, Carleton University, Ottawa, Canada. 175 p.
- Sotherton, N.W. 1998. Land use changes and the decline of farmland wildlife: an appraisal of the set-aside approach. *Biological Conservation*, 83: 259-268.
- Spark, T.H., T. Parish, and S.A. Hinsley. 1996. Breeding birds in field boundaries in an agricultural landscape. *Agriculture, Ecosystems and Environment*, 60: 1-8.
- Statistics Canada. 2009. Census of Agriculture 2006. www.statcan.gc.ca
- Stevens, D.K., and R.B. Bradbury. 2006. Effect of the Arable Stewardship Pilot Scheme on breeding birds at field and farm scales. *Agriculture, Ecosystems and Environment*, 112: 283-290.
- Swagemakers, P., H. Wiskerke, and J.D. Van Der Ploeg. 2009. Linking birds, fields and farmers. *Journal of Environmental Management*, 90: 185 –192.
- Teyssedre, A., and D. Couvet. 2007. Expected impact of agriculture expansion on the world avifauna. *C.R. Biologies*, 330: 247-254.
- Tucker, G.M., and M.I. Evans. 1997. Habitats for birds in Europe: a conservation strategy for the wider environment. BirdLife International. Cambridge, UK.
- Turvey, J. and B. Koney. 2006. Ontario's agricultural policies, sustainable urban communities and the greenbelt. Post World Planners Congress: Planning for food seminar. 39 p.
- Vandermeer, J., M. one Noordwijk, J. Anderson, Ch. Ong, and I. Perfecto. 1998. *Agriculture, Ecosystems and Environment*, 67: 1-22.

- Van Turnhout, Ch.A.M., R.P.B. Foppen, R.S.E.W. Leuven, H. Siepel, and H. Esselink. 2007. Scale-dependent homogenization: Changes in breeding bird diversity in the Netherlands over a 25-year period. *Biological Conservation*, 134: 505-516.
- Veech, J.A. 2006. A comparison of landscapes occupied by increasing and decreasing populations of grassland birds. *Conservation Biology*, 20: 1422-1432.
- Vepsäläinen, V. 2007. Farmland Birds and Habitat Heterogeneity in Intensively Cultivated Boreal Agricultural Landscapes. PhD thesis (Academic Dissertation), Helsinki University, Helsinki, Finland. 52 p.
- Verhulst, J., A. Baldi, and D. Kleijn. 2004. Relationship between land-use intensity and species richness and abundance of birds in Hungary. *Agriculture, Ecosystems and Environment*, 104: 465-473.
- Vickery, J.A., R.B. Bradbury, I.G. Henderson, M.A. Eaton, and Ph. V. Grice. 2004. The role of agri-environment schemes and farm management practices in reversing the decline of farmland birds in England. *Biological Conservation*, 119: 19-39.
- Walker, S., R. Price, and R.T.T. Stephens. 2008. An index of risk as a measure of biodiversity conservation achieved through land reform. *Conservation Biology*, 22: 48-59.
- Wallace, I. and M. Brklacich. 2009. Agriculture and Rural Resources. The Effects of Climate Change on Agriculture, Land Resources, Water Resources and Biodiversity. (Ed. M Walsh). Chapter 9: 234 – 297.
- Warner, R.E. 1994. Agricultural land use and grassland habitat in Illinois: Future shock for Midwestern birds? *Conservation Biology*, 8: 147-156.

- Warren, K.A., and J.T. Anderson. 2005. Grassland songbird nest-site selection and response to mowing in West Virginia. *Wildlife Society Bulletin*, 33: 285 -292.
- Winter, M., D.H. Johnson, J.A. Shaffer, T.M. Donovan, and W.D. Svedarsky. 2006. Patch size and landscape effects on density and nesting success of grassland birds. *The Journal of Wildlife Management*, 70: 158-172.
- With, K.A., A.W. King, and W.E. Jensen. 2008. Remaining large grasslands may not be sufficient to prevent grassland bird declines. *Biological Conservation*, 141: 3152-3167.
- Woodhouse, S.P., J.E.G. Good, A.A. Lovett, R.J. Fuller, and P.M. Dolman. 2005. Effect of land-use and agricultural management on birds of marginal farmlands: a case study in the Llyn Peninsula, Wales. *Agriculture, Ecosystems and Environment*, 107: 331-340.
- Wretenberg, J, T. Part, and A. Berg. 2010. Changes in local species richness of farmland birds in relation to land-use changes and landscape structure. *Biological Conservation*, 143: 375-381.

Appendix: Supplemental Information

Table A1 Pearson correlations among explanatory variables. All statistically significant ($p \leq 0.05$) correlations are shaded; those above 0.500 are bolded.

A. Landscapes with 5 to 94% farmlands (181 subdivisions)

	CROP	SFALP	TSPP	NPP	TWWP	FSAP	AVFS	AVCRS	CTPHA	FERTIN	PESTIN	AMPF	SWDIFR	SWDICR
CROP	1.000													
SFALP	.006	1.000												
TSPP	-.333	.075	1.000											
NPP	-.214	.016	-.093	1.000										
TWWP	-.521	.035	-.016	.001	1.000									
FSAP	-.308	-.102	.064	-.151	-.009	1.000								
AVFS	-.216	.179	.118	-.234	.058	.191	1.000							
AVCRS	.060	-.115	-.111	.094	-.046	-.035	-.803	1.000						
CTPHA	-.444	.024	-.053	.237	.033	.074	.039	.122	1.000					
FERTIN	.107	.266	-.023	.194	-.209	-.053	.015	-.093	-.099	1.000				
PESTIN	-.233	-.172	.082	.049	.190	-.260	.118	.080	.294	-.564	1.000			
AMPF	.067	-.145	.031	.063	-.159	-.034	-.316	.095	-.043	-.121	-.147	1.000		
SWDIFR	.669	-.071	-.327	-.175	-.511	-.279	-.483	.533	.007	.126	.066	.215	1.000	
SWDICR	-.086	-.161	-.120	-.102	.196	.080	.353	-.397	-.014	-.298	.137	-.160	-.280	1.000

Table A2 Synopsis of studies on birds and agriculture in temperate North America

Study	Location	Research question	Years	Study scale	Studied/analyzed species	Study results
1. Askins <i>et al.</i> (2007)	USA grasslands – prairies	Impact of ag management	1966-2002	Regional	28 grassland specialists	Grassland birds depend on managed farm habitats: 3 of 28 species increased, 17 decreased
2. Beecher <i>et al.</i> (2002)	East-central Nebraska, USA	Effect of ag practices	1995-1996	Local	54 species on org. and conv. Farms	Bird abundance and richness were higher on organic farms
3. Belanger & Picard (1999)	St. Lawrence R. Is., QC, CAD	Impact of grazing pressure	1993-1994	Local (108 .5 ha sites)	13 species:	Moderately grazed prairies provide habitat for some spp
4. Best (1986)	Iowa, USA	Impact of ag management	1952-1986	Regional	15 species were found in corn or soybean fields	8 species nesting only in no-tillage fields
5. Best <i>et al.</i> (1995)	Iowa, USA	Landscape comp and structure	1963-1994	Landscape	144 species occur in ag landscapes	More habitats w/ diverse crop mosaic and uncropped habitat ⁸
6. Best <i>et al.</i> (1998)	6 Midwestern States, USA	Effect of ag practices	1992-1995	Local	Birds winter in crops	Benefit of CRP for declining species
7. Best <i>et al.</i> (2001)	Iowa, USA	Impact of landscape comp	1993-1994	Landscape	7 species	Bird species abundance depends on landscape context
8. Bethke & Nudds (1995)	Prairies of Alberta, Saskatchewan, Manitoba, Canada	Impact of ag intensification and land use	1955 - 1989	Regional (Canadian Prairie-parklands)	10 waterfowl species, incl. mallard and pintail	Ducks declined due to expansion of agriculture. Changes in management can benefit duck populations
9. Boutin <i>et al.</i> (1999)	Southern Ontario, Canada	Effect of habitat and ag practices	1987-1988	Local	138 spp. analyzed, 25 selected	13 species used crops, i.d. most at risk of pesticides
10. Brennan & Kuvlevsky (2005)	Texas, USA	Effect of land conversion to ag	Last century	Regional	Grassland bird species at risk	Needs coordinated grassland wildlife mgmt (ag schemes)
11. Burger <i>et al.</i> (2006)	USA farmlands	Agri-environmental schemes	1950 th – present days	Regional	Northern Bobwhite	Value of the buffer zones around ag fields (78% of population can be saved on ag

Study	Location	Research question	Years	Study scale	Studied/analyzed species	Study results
						lands)
12. Chapman <i>et al.</i> (2004)	Southern Great Plains, USA	Effect of ag practices	1998-1999	Local	Grassland bird species (GB)	Seeded grasslands benefit GB, but without disturbance regimes few species
13. Colvin (1985)	Ohio, USA	Impact of ag intensification	1931-1980	Regional	Barn Owl	Changes in land use impacted barn owl
14. Coppedge <i>et al.</i> (2001)	Oklahoma, USA	Impact of land use changes	1965-1995	Regional	Grassland bird (GB) community	Conversion crops to ag grassland provide suitable habitat for some GB
15. Delisle & Savidge (1997)	South-eastern Nebraska, USA	Effect of land use	1991-1995	Local	Grassland bird species	Effect of field size and shape on the wildlife benefit of CRP
16. Freemark <i>et al.</i> (1991)	The Great Lakes region, Canada	Literature review of habitat use within farm	Since 1950 th	Local – landscape	Birds use of farmland habitat	58 references used to identify birds in farmland habitats
17. Freemark & Kirk (2001)	Southern Ontario, Canada	Effect of habitat and ag practices	1990	Local	43 species observed on conventional and organic farms	Importance of non-cropped habitats and less intensive ag management
18. Giuliano & Daves (2002)	Southwest Pennsylvania, USA	Effect of ag practices	1996-1997	Local	15 commonly observed grassland birds	Warm-season grasses benefit birds in pastures and hayfields
19. Gordon (2000)	Southern Arizona, USA	Effect of grazing intensity	1997-1999	Local	Grassland sparrows (4 species)	Moderate cattle grazing can be compatible with species conservation
20. Herkert (2009)	12 state regions in USA	Effect of ag practices	1966-2007	Regional - Landscape	Grassland birds occur within farmlands	Set-aside lands provide population level benefits to grassland birds
21. Horn & Koford (2000)	North Dakota, USA	Effect of ag practices	1997-1998	Local	Grassland birds	Mowing of CRP field provide mosaic of habitats for birds
22. Hultquist & Best (2001)	Iowa, USA	Effect of adjacent habitat	1996-1997	Local	Grassland birds	Contribution of terraces to bird conservation is minor
23. Jobin <i>et al.</i>	Southern Quebec,	Impact of ag	1960-1992	Regional	Farmland bird	Many species declined in the

Study	Location	Research question	Years	Study scale	Studied/analyzed species	Study results
(1996)	Canada	intensification		- Local	community – 28 species	result of intensive farming, some benefited
24. Jobin <i>et al.</i> (2001)	Quebec, Canada	Effect of adjacent habitat	1995	Local	Farmland birds	Hedgerows, windbreaks and herbaceous field margins habitats for wildlife
25. Jones <i>et al.</i> (2005)	North-central Florida, USA	Effect of ag practices	2000-2001	Local	Birds on organic and con. farms	Farms supported 89-96% birds breeding in the region; abundances were influenced by crop type and heterogeneity
26. Jonson & Igl (1995)	North Dakota, USA	Effect of ag practices	1967; 1992-1993	Local	Grassland birds (GB)	Termination of CRP may cause population declines
27. Kirk <i>et al.</i> (2001)	Southern Ontario, Canada	Effect of habitat and ag practices	1988	Local	Farmland birds	Importance of non-cropped and cropped habitats for bird
28. Lokemoen & Beiser (1997)	Southeast North Dakota, USA	Effect of ag practice	1991-1993	Local	Grassland birds	Bird densities are higher on minimum tillage and organic fields
29. Maisonneuve <i>et al.</i> 2006	Southern Quebec, Canada	Impact of ag intensification	1998-1999	Local	Mallard and American black duck (ABD)	ABD was threatened by conversion of native habitats into cropland
30. Martin & Forsyth (2003)	Southern Alberta, Canada	Effect of ag practices	1995-1996	Local	Grassland bird species	Minimum tillage benefits to species that nested in farmlands
31. McMaster <i>et al.</i> (2005)	Southern Saskatchewan, Canada	Effect of ag practices	1999-2000	Local - landscape	Grassland bird species (26 species)	Conversion of cropland into hay benefits to a variety of grassland birds
32. Moulton <i>et al.</i> 2006	South-western Idaho, USA	Factors impacting the BO populations	2001-2002	Local - landscape	Burrowing Owl (BUOW)	Implications to management of BUOW in agricultural landscapes
33. Murphy (2003)	Eastern and Central USA	Impact of ag intensification	1980-1998	Regional	Grassland birds	Avian population changes are strongly linked to ag land use

Study	Location	Research question	Years	Study scale	Studied/analyzed species	Study results
34. Nocera <i>et al.</i> (2005)	Nova Scotia, Canada	Effect of ag practices	2000-2003	Local	3 grassland species	Delaying of hayfields cutting conserve breeding birds
35. Pukett <i>et al.</i> (2009)	Central Nebraska, USA	Effect of adjacent habitat	2005-2006	Local	Woodland birds	Role of edge habitat (field margins, etc.) for sustaining of birds and pest control by birds
36. Ribic <i>et al.</i> (2009b)	Wisconsin, USA	Effect of landscape	2002-2003	Local - landscape	Grassland species	Diversity of habitat types is needed conserve grassland birds as a group
37. Rodgers (2003)	North-western Kansas, USA	Effect of ag practices	1990-1995	Local	Ring-necked Pheasant (RIPH)	Row-crop stubble height and unsprayed field margins benefit to RIPH
38. Rodriguez (2002)	North America (USA, Canada)	High human impact (ag)	1968-1993	Regional	27 common bird species	Steep population declines as a result of ag impact
39. Veech (2006)	Midwest and Great Plains, USA	Landscape structure	1982 -2002	Regional - landscape	36 grassland-nesting bird species	Effect of landscape composition & habitat amount for grassland bird conservation
40. Warner (1994)	Illinois, USA	Impact of ag practices	1973-1981	Regional – Local	Ground nesting species in fields	Edge species declined significantly
41. With <i>et al.</i> (2008)	Flint Hills, Oklahoma & Kansas, USA	Impact of Landscape structure	1992-2005	Regional - landscape	3 grassland species: DICK, GRSP, EAME	Remnant grasslands managed for ag or live stock production are not sufficient to preserve birds: extinction debt

Table A3 Candidate list of farmland birds for North America (Canada and the USA).

Bird species	Native habitats	Farmland habitats
Northern Bobwhite <i>Colinus virginianus</i>	Grasslands	Crop/pasture
Ring-necked Pheasant <i>Phasianus colchicus</i>	Grasslands	Crop/pasture
Gray Partridge <i>Perdix perdix</i>	Grasslands	Crop/pasture
American Kestrel <i>Falco sparverius</i>	Grassland	Crop/pasture
Northern Harrier <i>Circus cianeus</i>	Grassland	Crop/pasture
Swainson's Hawk <i>Buteo swainsoni</i>	Grassland	Crop/pasture
Killdeer <i>Charadrius vociferous</i>	Wet meadow	Crop/pasture
Marbled Godwit <i>Limosa fedoa</i>	Grassland	Crop/pasture
Upland Sandpiper <i>Bartramia longicaudata</i>	Grassland	Crop/pasture
Rock Pigeon <i>Columba livia</i>	Grassland rock	Crop/farmstead
Mourning Dove <i>Zenaida macroura</i>	Forest openings	Farmstead/pasture
Common-Ground Dove <i>Columbina passerine</i>	Forest edge	Crop/pasture
Barn Owl <i>Tyto alba</i>	Grassland	Crop/pasture
Burrowing Owl <i>Athene cinicularia</i>	Grassland	Crop/pasture
Short-eared Owl <i>Asio flammeus</i>	Open meadow	Crop/pasture
Common Nighthawk <i>Chordeiles minor</i>	Openings	Crop/pasture
Loggerhead Shrike <i>Lanius ludovicianus</i>	Openings	Pasture/crop
Tree Swallow <i>Tachycineta</i>	Open wet areas	Farmstead/crop
Barn Swallow <i>Hirundo rustica</i>	Open hills	Farmstead/pasture
Horned Lark <i>Eremophila alpestris</i>	Open short grass	Crop/pasture
House Wren <i>Troglodytes aedon</i>	Open woodland	Farmstead/pasture
European Starling <i>Sturnus vulgaris</i>	Openings	Farmstead/pasture
House Sparrow <i>Passer domestica</i>	Grassland	Farmstead/crop
House Finch <i>Carpodacus mexicanus</i>	Open areas	Farmstead/crop
Brown-headed Cowbird <i>Molothrus ater</i>	Grassland	Pasture/crop
Brewer's Blackbird <i>Euphagus cyanocephalus</i>	Open habitats	Farmstead/pasture
Eastern Meadowlark <i>Sturnella magna</i>	Grassland	Pasture/crop
Western Meadowlark <i>Sturnella neglecta</i>	Grassland	Pasture/crop
Bobolink <i>Dolichonyx oryzivorus</i>	Grassland	Pasture/crop
McCown's Longspur <i>Calcarius mccowni</i>	Grassland	Grazed pasture
Chestnut-collared Longspur <i>Calcarius ornatus</i>	Grassland	Grazed pasture
Lark Bunting <i>Calamospiza melanocorys</i>	Grassland	Pasture/crop
Savannah Sparrow <i>Passereulus sandwichensis</i>	Grassland	Pasture/crop
Le Conte's Sparrow <i>Ammodramus leconteii</i>	Open meadow	Pasture/crop
Henslow's Sparrow <i>Ammodramus henslowii</i>	Grassland	Pasture/crop
Baird's Sparrow <i>Ammodramus bairdii</i>	Grassland	Pasture
Grasshopper Sparrow <i>Ammodramus savannarum</i>	Grassland	Pasture
Clay-colored Sparrow <i>Spizella pallid</i>	Shrubs/grassland	Pasture
Field Sparrow <i>Spizella pusilla</i>	Grassland	Pasture/crop

Vesper Sparrow <i>Poocetes gramineus</i>	Open habitats	Crop/pasture
Lark Sparrow <i>Chondestes grammacus</i>	Grassland	Pasture/crop
Eastern Towhee <i>Pipilo erythrophthalmus</i>	Grassland	Pastur
Dickeissel <i>Spiza Americana</i>	Grassland	Pasture/crop
Wild Turkey <i>Melleagris gallopavo</i>	Open forest	Edges
Canada Goose <i>Branta Canadensis</i>	Wetland/meadow	Wetland/crop
Mallard <i>Anas platyrhynchos</i>	Wetland/meadow	Range of habitats
Blue-winged Teal <i>Anas discors</i>	Wetlands/meadow	Wetland/pasture
Northern Pintail <i>Anas acuta</i>	Open meadow	Wetland/pasture
Cattle Egret <i>Bubulcus ibis</i>	Wetland	Pasture/ other
Turkey Vulture <i>Cathartes aura</i>	Forest openings	Pasture/ other
Red-tailed Hawk <i>Buteo jamaicensis</i>	Open habitats	Edges
Ring-billed Gull <i>Larus delawarensis</i>	Wetland	Disturbances
Great Horned Owl <i>Bubo virginianus</i>	Openings	Woods/pasture
Red-headed Woodpecker <i>Melanerpes erythrocephalus</i>	Open woods/ clearings	Wood edges
Northern Flicker <i>Colaptes auratus</i>	Open woodland	Wood edges
Eastern Phoebe <i>Sayornis phoebe</i>	Edge habitats	Woods
Eastern Wood-pewee <i>Contopus virens</i>	Woods	Woods
Western Kingbird <i>Tyrannus verticalis</i>	Open habitats	Woods
Scissor-tailed Flycatcher <i>Tyrannus forficatus</i>	Open savanna	Woods
Eastern Kingbird <i>Tyrannus tyrannus</i>	Open woodland	Woods
Great crested flycatcher <i>Myiarchus crinitus</i>	Open woodland	Woods
Blue Jay <i>Cyanocitta cristata</i>	Forest	Forest remnants
American Crow <i>Corvus brachyrhynchos</i>	Open habitats	Woods
Cedar Waxwing <i>Bombycilla cedrorum</i>	Open woodland	Woods
Cliff Swallow <i>Hirundo pyrrhonota</i>	Open valleys	Edges
Northern Mockingbird <i>Mimus polyglottos</i>	Shrub habitat	Farmstead/edges
Brown Thrasher <i>Toxostoma rufum</i>	Edge habitat	Woods
Eastern Bluebird <i>Sialia sialis</i>	Open woods/edges	Woods
American Robin <i>Turdus migratorius</i>	Open woods	Woods
American Goldfinch <i>Carduelis tristis</i>	Edge habitats	Field margins
Common Yellowthroat <i>Geothlypis trichas</i>	Thick shrubs	Woods
Yellow-breasted Chat <i>Icteria virens</i>	Shrub	Abandoned fields
Baltimore Oriole <i>Icterus galbula</i>	Woodland edges	Woods
Orchard Oriole <i>Icterus spurius</i>	Riparian woods	Park woodlands
Red-winged Blackbird <i>Agelaius phoeniceus</i>	Wetland	Pasture/others
Common Grackle <i>Quiscalus quiscula</i>	Wetland/woods	Farmstead/others
Song Sparrow <i>Melospiza melodia</i>	Wetland/woods	Woods
Chipping Sparrow <i>Spizella passerine</i>	Edge habitats	Woods
Indigo Bunting <i>Passerina cyanea</i>	Edge habitats	Woods

Table A4 Characteristics of candidate farmland birds in Ontario. Information from references in Table A2, Birds of North America (2009) and Ontario Breeding Bird Atlas (OBBA; Cadman *et al.* 2007).

Explanatory notes:

* Denotes introduced species

Bold denotes priority species in Bird Conservation Region (BCR) 13

Nesting traits: G = ground; O = over-ground

Migration pattern: R = resident, SM = short-distance migrant, LM = long-distance migrant

Category: FS – farmland specialist, FG = farmland generalist, O = other

No. subdivisions: number of Census of Agriculture subdivisions (max = 181) where species detected by OBBA point counts

No. OBBA point counts: number of point counts at which species was detected in the 181 subdivisions

Changes between 2 OBBA: Difference in % probability of observation between 1981-1985 and 2001-2005 in the regions covered by the 181 subdivisions.

Species	OBBA Species code	Nesting traits	Migration pattern	Category	No. Sub-divisions	No. OBBA point counts	Changes between 2 OBBA:
Northern Bobwhite <i>Colinus virginianus</i>	NOBO	G	R	FS	1	1	-65%
*Ring-necked Pheasant <i>Phasianus colchicus</i>	RIPH	G	R	FS	20	30	-40%
Wild Turkey <i>Melleagris gallopavo</i>	WITU	G	R	FG	40	70	+++
*Grey Partridge <i>Perdix perdix</i>	GRPA	G	R	FS	3	3	-44%
Canada Goose <i>Branta Canadensis</i>	CAGO	G	SM	FG	135	434	+++
Mallard <i>Anas platyrhynchos</i>	MALL	G	SM	FG	158	667	++15-20%
Blue-winged Teal <i>Anas discors</i>	BWTE	G	LM	FG	19	24	-36%
Northern Pintail <i>Anas acuta</i>	NOPI	G	LM	FG	1	1	-20%
Turkey Vulture <i>Cathartes aura</i>	TUVU	O	SM	FG	100	240	+ >50%
American Kestrel <i>Falco spraverius</i>	AMKE	O	SM	FS	76	153	-15 - -27%
Northern Harrier <i>Circus cianeus</i>	NOHA	G	SM	FS	64	104	++3-10%
Red-tailed Hawk <i>Buteo jamaicensis</i>	RTHA	O	SM	FG	105	207	++
Killdeer <i>Charadrius vociferous</i>	KILL	G	SM	FS	79	2196	-36- -39%
Upland Sandpiper <i>Bartramia longicauda</i>	UPSA	G	LM	FS	55	152	- 37%
Ring-billed Gull <i>Larus delawarensis</i>	RBGU	G	SM	FG	57	584	+30%

Species	OBBA Species code	Nesting traits	Migration pattern	Category	No. Sub-divisions	No. OBBA point counts	Changes between 2 OBBA's:
*Rock Pigeon <i>Columba livia</i>	RODO	O	R	FS	174	1411	+10%
Mourning Dove <i>Zenaida macroura</i>	MODO	O	SM	FS	181	6866	+15%
Barn Owl <i>Tyto alba</i>	BNOW	O	R	FS	N/A	N/A	-30%
Great Horned Owl <i>Bubo virginianus</i>	GHOW	G	R	FG	6	6	- 40%
Short-eared Owl <i>Asio flammeus</i>	SEOW	G	SM	FS	3	3	+50%
Common Nighthawk <i>Chordeiles minor</i>	CONI	G	LD	FS	10	13	-39%
Red-headed Woodpecker <i>Melanerpes erythrocephalus</i>	RHOW	O	R	FG	19	32	-64%
Northern Flicker <i>Colaptes auratus</i>	NOFL	O	SM	FG	174	1472	+10%
Eastern Phoebe <i>Sayornis phoebe</i>	EAPH	O	SM	FG	146	891	+5%
Eastern Wood-pewee <i>Contopus virens</i>	EAWP	O	LD	FG	175	2094	-6 – -15%
Eastern Kingbird <i>Tyrannus tyrannus</i>	EAKI	O	LD	FG	178	2663	-27- -34%
Great crested flycatcher <i>Myiarchus crinitus</i>	GCFL	O	LD	FG	176	2418	-8%
Loggerhead Shrike <i>Lanius ludovicianus</i>	LOSH	O	SM	FS	N/A	N/A	-70%
Blue Jay <i>Cyanocitta cristata</i>	BLJA	O	R- SM	FG	180	4345	++
American Crow <i>Corvus brachyrhynchos</i>	AMCR	O	R-SM	FG	181	4620	+46%
Cedar Waxwing <i>Bombycilla cedrorum</i>	CEDW	O	SM	FG	180	3163	-3- -5%
Tree Swallow <i>Tachycineta bicolor</i>	TRES	O	LD	FS	179	3548	- 17%
Barn Swallow <i>Hirundo rustica</i>	BARS	O	LD	FS	181	4227	-35%
Cliff Swallow <i>Hirundo pyrrhonota</i>	CLSW	O	LD	FG	113	344	-50%
Horned Lark <i>Eremophila alpestris</i>	HOLA	G	SM	FS	132	1929	-9%
House Wren <i>Troglodytes aedon</i>	HOWR	O	SM	FS	176	2715	0
Northern Mockingbird <i>Mimus polyglottos</i>	NOMO	O	SM-R	FG	31	103	+50%
Brown Thrasher <i>Toxostoma rufum</i>	BRTH	O	SM	FG	139	780	-24%
*European Starling <i>Sturnus vulgaris</i>	EUST	O	R- SM	FS	181	9446	-13%
Eastern Bluebird <i>Sialia sialis</i>	EABL	O	SM	FG	109	321	+60%
American Robin <i>Turdus migratorius</i>	AMRO	O	SM	FG	181	14316	+19 - +93%

Species	OBBA Species code	Nesting traits	Migration pattern	Category	No. Sub- divisions	No. OBBA point counts	Changes between 2 OBBA's:
*House Sparrow <i>Passer domestica</i>	HOSP	O	R	FS	176	3761	-20%
American Goldfinch <i>Carduelis tristis</i>	AMGO	O	SM	FG	181	9746	+15%
House Finch <i>Carpodacus mexicanus</i>	HOFI	O	R	FS	144	970	+ >100%
Common Yellowthroat <i>Geothlypis trichas</i>	COYE	G	LD	FG	176	4310	+17 - +33%
Yellow-breasted Chat <i>Icteria virens</i>	YBCH	G	LD	FG	0	0	-45%
Baltimore (Northern) Oriole <i>Icterus galbula</i>	BAOR	O	LD	FG	179	3427	-20%
Orchard Oriole <i>Icterus spurius</i>	OROR	O	LD	FG	23	96	+50%
Brown-headed Cowbird <i>Molothrus ater</i>	BHCO	G, O	SM	FS	181	4661	- 35%
Red-winged Blackbird <i>Agelaius phoeniceus</i>	RWBL	G	SM	FG	181	13016	- 22%
Brewer's Blackbird <i>Euphagus cyanocephalus</i>	BRBL	G, O	SM	FS	1	1	- 30%
Common Grackle <i>Quiscalus quiscula</i>	COGR	OG	SM	FG	181	9926	-6%
Eastern Meadowlark <i>Sturnella magna</i>	EAME	G	SM	FS	167	2359	-13%
Western Meadowlark <i>Sturnella neglecta</i>	WEME	G	SM	FS	0	0	- >50%
Bobolink <i>Dolichonyx oryzivorus</i>	BOBO	G	LD	FS	171	3422	- 28%
Song Sparrow <i>Melospiza melodia</i>	SOSP	O	SM	FG	181	13199	+12%
Savannah Sparrow <i>Passerculus sandwichensis</i>	SAVS	G	SM	FS	178	6051	+12%
Henslow's Sparrow <i>Ammodramus henslowii</i>	HESP	G	SM	FS	N/A	N/A	-86%
Grasshopper Sparrow <i>Ammodramus savannarum</i>	GRSP	G	SM	FS	67	230	-2- -48%
Chipping Sparrow <i>Spizella passerine</i>	CHSP	O	SM	FG	181	6378	+21%
Clay-colored Sparrow <i>Spizella pallida</i>	CCSP	G	SM	FS	32	51	+100%
Field Sparrow <i>Spizella pusilla</i>	FISP	G	SM	FS	118	671	-17%
Vesper Sparrow <i>Poocetes gramineus</i>	VESP	G	SM	FS	133	763	-29%
Eastern Towhee <i>Pipilo erythrophthalmus</i>	EATO	O	SM	FS	91	407	-17 - -19%
Indigo Bunting <i>Passerina cyanea</i>	INBU	O	LD	FG	170	1808	-5%
Dickcissel <i>Spiza Americana</i>	DICK	O	LD	FS	N/A	N/A	+

Table A5 Regression results for abundance of farmland birds on the final list for Ontario (41 species) using A. 181 subdivisions B. subdivisions with 5-40% farmland C. subdivisions with 40-60% farmland and D. subdivisions with 60-94% farmland. Models presented using proportional partial regression coefficients (PPRC) for each explanatory variable. aR^2 is adjusted R square (as a proportion). Base model is the best fitted model (typically lowest AICc) using all explanatory variables. $\Delta AICc < 4$ bolded (as recommended threshold for competing models).

A. Landscapes with 5 to 94% farmlands (181 subdivisions)

Response variable (No. spp.)	Component	Final model with calculated PPRC	R ²	AICc	$\Delta AICc$	P
Row crop specialists (6)	Composition	0.95 +1.1 CROP -0.5 FSAP	0.531	26.7	7.3	0.000
	Configuration	0.02 -0.5 AVFS + 1.2 AVCRS	0.239	114.2	94.8	0.000
	Practice	0.04 +0.7 CTPHA +0.5 PESTIN	0.331	90.7	71.3	0.000
	Heterogeneity	1.0 – 0.8 SWDIFR	0.369	79.3	59.9	
	Base model	0.2 +1.2 CROP -0.2 SWDIFR -0.2 TWWP – 0.4 FSAP	0.564	19.4	0	0.000
Pasture specialists (12)	Composition	0.12 +2.7 TSPP +0.5 CROP +1.0 NPP -0.4 TWWP	0.46	178.1	0	0.000
	Configuration	0.4 +0.5 AVFS	0.04	280.3	102.2	0.007
	Practice	0.9 +0.6 CTPHA – 0.5 PESTIN	0.06	277.6	99.5	0.002
	Heterogeneity	No significant model	-	-	-	-
	Base model	0.12 +2.7 TSPP +0.7 CROP +1.0 NPP -0.4 TWWP	0.46	178.1	0	0.000
Farmstead specialists (12)	Composition	4.1 + 2.4 CROP -3.7 TWWP +5.0 FSAP	0.29	814.8	36.9	0.000
	Configuration	6.5 – 8.3 AVFS + 7.3 AVCRS	0.27	822.7	44.8	0.000
	Practice	2.6 +5.8 PESTIN	0.28	816.3	38.4	0.000
	Heterogeneity	10.0 – 5.6 SWDIFR	0.34	801.2	23.3	0.000
	Base model	13.3 – 7.5 SWDIFR – 4.4 AVCRS +3.9 FSAP	0.424	777.9	0	0.000

Farmland specialists (30)	Composition	4.5 +3.4 CROP -3.3 TWWP + 4.4 FSAP	0.33	843.6	27.6	0.000
	Configuration	6.9 + 8.6 AVCRS -8.1 AVFS	0.24	866.1	50.1	0.000
	Practice	3.3 +5.5 PESTIN +2.3 CTPHA	0.28	856.6	40.6	0.000
	Heterogeneity	11.7 – 6.3 SWDIFR	0.34	837.8	21.8	0.000
	Base model	16.2 – 10.4 SWDIFR+3.4 FSAP -5.1 AVCRS+3.1 NPP +3.5 TSPP	0.43	816.0	0	0.000
Edge farmland generalists (11)	Composition	1.9 +0.4 TWWP + 1.3 NPP + 0.5 CROP	0.127	452.0	1.3	0.000
	Configuration	2.1 + 1.1 AVFS	0.05	466.1	15.4	0.002
	Practice	No significant model	-	-	-	-
	Heterogeneity	No significant model	-	-	-	-
	Base model	1.6 + 0.7 TWWP +1.1 AVCRS +1.0 NPP	0.134	450.7	0	0.000
BCR 13 priority species (15)	Composition	0.14 +2.9 TSPP +0.5 CROP + 0.8 NPP -0.45 TWWP	0.45	220.9	0	0.003
	Configuration	0.5 +0.7 AVFS	0.036	320.3	99.4	0.006
	Practice	1.0 +0.7 CTPHA – 0.5 PESTIN	0.05	318.0	97.1	0.003
	Heterogeneity	0.5 + 0.4 SWDIFR	0.02	323.9	103.0	0.048
	Base model	0.14 +2.9 TSPP +0.5 CROP + 0.8 NPP -0.45 TWWP	0.45	220.9	0	0.003

Table A5 Regression results for abundance of farmland birds on the final list for Ontario (41 species) using A. 181 subdivisions B. subdivisions with 5-40% farmland C. subdivisions with 40-60% farmland and D. subdivisions with 60-94% farmland. Models presented using proportional partial regression coefficients (PPRC) for each explanatory variable. aR2 is adjusted R square (as a proportion). Base model is the best fitted model (typically lowest AIC) using all explanatory variables. $\Delta AICc < 4$ bolded (as recommended threshold for competing models).

B. Landscapes with 5 to 40% farmlands (59 subdivisions)

Response variable	Component	Final model with calculated PPRC	R2	AICc	$\Delta AICc$	P
All farmland birds (40)	Composition	7.7 + 12.2 CROP -7.8 TSPP	0.44	306.7	6.7	0.000
	Configuration	13.2 – 12.1 AVFS + 9.0 AVCRS	0.24	324.8	24.8	0.000
	Practice	8.3 + 11.9 PESTIN	0.21	325.8	25.8	0.000
	Heterogeneity	22.4 -11.0 SWDIFR	0.374	312.1	12.1	0.000
	Base model	22.3 -10.9 SWDIFR +7.2 CROP – 7.8 AVCRS	0.511	300.0	0	0.000
Row crop specialists (6)	Composition	0.037 +0.2 CROP -0.08 TWWP +0.1 SFALP	0.452	-160.0	0	0.000
	Configuration	0.148 -0.18 AVFS +0.14 AVCRS	0.188	-138.1	21.9	0.001
	Practice	0.036 + 0.2 PESTIN + 0.1 CTPHA	0.292	-146.2	14.8	0.000
	Heterogeneity	0.28 – 0.18 SWDIFR	0.249	-144.0	16.0	0.000
	Base model	0.037 +0.2 CROP -0.1 TWWP +0.1SFALP	0.564	-160.0	0	0.000
Pasture specialists (12)	Composition	0.2 + 0.8 NPP + 0.4 CROP	0.189	27.2	4.6	0.001
	Configuration	No significant model	-	-	-	-
	Practice	0.8 – 0.4 FERTIN	0.084	33.1	10.5	0.015
	Heterogeneity	No significant model				
	Base model	0.44 +0.4 NPP +0.65 CROP -0.6 FERTIN	0.266	22.6	0	0.000
Farmstead specialists (12)	Composition	3.7 +7.6 CROP -3.9 TWWP -4.2 TSPP	0.443	271.3	17.7	0.000
	Configuration	6.3 – 9.7 AVFS + 6.9 AVCRS	0.285	284.7	31.1	0.000
	Practice	2.1 +10.7 PESTIN	0.301	282.1	28.5	0.000
	Heterogeneity	14.0 -9.2 SWDIFR	0.501	263.2	9.6	0.000
	Base model	18.8 -12.0 SWDIFR -6.8 AVCRS +3.3 FSAP	0.587	253.6	0	0.000
Farmland	Composition	4.1 +7.9 CROP -4.0 TWWP - 3.7 TSPP	0.445	272.7	13.4	0.000

Response variable	Component	Final model with calculated PPRC	R ²	AICc	ΔAICc	P
specialists (30)	Configuration	6.9 –10.6 AVFS + 6.8 AVCRS	0.279	286.9	28.1	0.000
	Practice	2.8 +10.7 PESTIN	0.283	285.3	26.5	0.000
	Heterogeneity	14.5 -9.0 SWDIFR	0.461	268.4	9.6	0.000
	Base model	16.6 -10.0 SWDIFR -6.8 AVCRS + 4.0 CROP	0.562	258.8	0	0.000
Edge farmland generalists (11)	Composition	2.0 + 1.7 TWWP	0.189	148.8	8.6	0.000
	Configuration	No significant model				
	Practice	3.4 – 1.2 FERTIN	0.080	156.2	16.0	0.017
	Heterogeneity	No significant model				
	Base model	2.2 +2.2 TWWP +3.3 AVCRS -1.8 FERTIN – 1.8 AVFS	0.344	140.2	0	0.000
BCR 13 priority species (15)	Composition	0.44 +0.72 NPP	0.127	34.3	0	0.003
	Configuration	No significant model				
	Practice	0.8 -0.4 FERTIN	0.084	37.1	2.8	0.015
	Heterogeneity	No significant model				
	Base model	0.44 + 0.72 NPP	0.127	34.3	0	0.003

Table A5 Regression results for abundance of farmland birds on the final list for Ontario (41 species) using A. 181 subdivisions B. subdivisions with 5-40% farmland C. subdivisions with 40-60% farmland and D. subdivisions with 60-94% farmland. Models presented using proportional partial regression coefficients (PPRC) for each explanatory variable. aR^2 is adjusted R square (as a proportion). Base model is the best fitted model (typically lowest AIC) using all explanatory variables. $\Delta AICc < 4$ bolded (as recommended threshold for competing models).

C. Landscapes with 40 to 60% farmlands (54 subdivisions)

Response variable	Component	Final model with calculated PPRC	R ²	AICc	$\Delta AICc$	P
All farmland birds (41)	Composition	No significant model	-	-	-	-
	Configuration	15.2 – 6.3 AVFS	0.067	300.0	0	0.031
	Practice	No significant model	-	-	-	-
	Heterogeneity	No significant model	-	-	-	-
	Base model	15.2 – 6.3 AVFS	0.067	300.0	0	0.031
Row crop specialists (6)	Composition	0.03 + 0.12 CROP	0.117	-117.7	6.5	0.006
	Configuration	No significant model	-	-	-	-
	Practice	0.093 + 0.2 CTPHA	0.175	-121.4	2.8	0.001
	Heterogeneity	0.28 -0.1 SWDIFR	0.08	-115.4	8.8	0.021
	Base model	0.16 + 0.2 CTPHA – 0.1 TWWP	0.234	-124.2	0	0.000
Pasture specialists (12)	Composition	0.47 + 1.2 TSPP	0.217	77.5	0	0.000
	Configuration	No significant model	-	-	-	-
	Practice	1.2 – 1.0 PESTIN	0.90	85.3	7.8	0.015
	Heterogeneity	No significant model	-	-	-	-
	Base model	0.47 + 1.2 TSPP	0.217	77.5	0	0.000

Farmstead specialists (12)	Composition	3.9 – 3.4 TSPP + 3.3 FSAP	0.197	244.0	0.9	0.001
	Configuration	7.7 – 5.6 AVFS	0.142	246.4	3.3	0.003
	Practice	3.0 + 4.0 PESTIN	0.075	250.5	7.4	0.024
	Heterogeneity	8.0 -3.0 SWDIFR	0.09	249.6	6.5	0.015
	Base model	8.2 – 4.2 AVFS -3.3 TSPP	0.211	243.1	0	0.001
Farmland specialists (30)	Composition	+3.5 + 3.5 FSAP	0.069	257.7	2.1	0.03
	Configuration	8.6 – 5.6 AVFS	0.104	255.6	0	0.009
	Practice	No significant model	-	-	-	-
	Heterogeneity	8.6 – 2.6 SWDIFR	0.053	258.6	3.0	0.05
	Base model	8.6 – 5.6 AVFS	0.104	255.6	0	0.009
Edge farmland generalists (11)	Composition	+2.4 + 1.1 NPP	0.094	116.9	5.2	0.013
	Configuration	No significant model	-	-	-	-
	Practice	3.3 – 1.8 PESTIN	0.176	111.7	0	0.001
	Heterogeneity	1.7 + 0.9 SWDIFR	0.07	118.3	6.6	0.028
	Base model	3.3 – 1.8 PESTIN	0.176	111.7	0	0.001
BCR 13 priority species (15)	Composition	+0.53 + 1.3 TSPP	0.252	79.8	0	0.000
	Configuration	No significant model	-	-	-	-
	Practice	1.4 – 1.2 PESTIN	0.114	89.1	9.3	0.007
	Heterogeneity	+0.29 +0.6 SWDIFR	0.056	92.6	12.8	0.045
	Base model	+0.53 + 1.3 TSPP	0.252	79.8	0	0.000

Table A5 Regression results for abundance of farmland birds on the final list for Ontario (41 species) using A. 181 subdivisions B. subdivisions with 5-40% farmland C. subdivisions with 40-60% farmland and D. subdivisions with 60-94% farmland. Models presented using proportional partial regression coefficients (PPRC) for each explanatory variable. aR^2 is adjusted R square (as a proportion). Base model is the best fitted model (typically lowest AIC) using all explanatory variables. $\Delta AICc < 4$ bolded (as recommended threshold for competing models).

D. Landscapes with 60 to 94% farmlands (68 subdivisions)

Response variable	Component	Final model with calculated PPRC	R ²	AICc	$\Delta AICc$	p
All farmland birds (41)	Composition	No significant model	-	-	-	-
	Configuration	No significant model	-	-	-	-
	Practice	No significant model	-	-	-	-
	Heterogeneity	20.3 – 5.5 SWDICR	0.085	355.4	0	0.01
	Base model	20.3 – 5.5 SWDICR	0.085	355.4	0	0.01
Row crop specialists (6)	Composition	-0.53 + 1.0 CROP	0.239	68.5	0	0.000
	Configuration	No significant model	-	-	-	-
	Practice	0.25 + 0.6 PESTIN	0.056	82.9	14.4	0.03
	Heterogeneity	1.3 -0.9 SWDIFR	0.157	75.3	6.8	0.001
	Base model	-0.53 + 1.0 CROP	0.239	68.5	0	0.000
Pasture specialists (12)	Composition	-0.35 +2.2 TSPP +1.5 NPP +0.6 CROP	0.554	70.1	0	0.000
	Configuration	0.64 +3.7 AVFS, -3.5 AVCRS	0.308	98.2	28.1	0.000
	Practice	3.34 -1.7 PESTIN, -0.6 AMPF	0.368	98.3	28.2	0.000
	Heterogeneity	-0.12 +1.4 SWDIFR	0.239	103.4	33.3	0.000
	Base model	-0.35 +2.2 TSPP +1.5 NPP +0.6 CROP	0.554	70.1	0	0.000

Farmstead specialists (12)	Composition	7.9 – 3.0 TWWP	0.082	283.9	17.9	0.011
	Configuration	8.7 -3.3 AVFS	0.08	285.1	19.1	0.021
	Practice	6.2 +9.9 PESTIN, -6.7 FERTIN	0.221	274.1	8.1	0.000
	Heterogeneity	12.4 –3.6 SWDICR, -2.8 SWDIFR	0.187	276.9	10.9	0.000
	Base model	9.5 +9.4 PESTIN – 3.5 SWDICR – 5.0 FERTIN	0.322	266.0	0	0.000
Farmland specialists (30)	Composition	9.5 – 3.0 TWWP	0.058	305.0	9.3	0.028
	Configuration	No significant model	-	-	-	-
	Practice	8.8 +9.4 PESTIN, -7.6 FERTIN	0.117	301.9	6.2	0.007
	Heterogeneity	13.1 – 4.4 SWDICR	0.122	300.3	4.6	0.002
	Base model	15.0 -4.6 SWDICR- 3.0 TWWP	0.196	295.7	0	0.000
Edge farmland generalists (11)	Composition	2.7 + 2.0 NPP	0.131	178.3	1.8	0.002
	Configuration	No significant model	-	-	-	-
	Practice	4.7 – 1.2 CTPHA – 1.4 FERTIN	0.150	178.0	1.5	0.002
	Heterogeneity	No significant model	-	-	-	-
	Base model	3.2 + 1.6 NPP – 1.0 CTPHA	0.170	176.5	0	0.001
BCR 13 priority species (15)	Composition	-0.41+2.2 TSPP + 1.8 NPP +0.7 CROP	0.495	99.6	0	0.000
	Configuration	0.7 + 4.1 AVFS, -3.7 AVCRS	0.273	122.7	23.1	0.001
	Practice	4.0 – 1.9 PESTIN – 0.7 AMPF	0.364	113.7	14.1	0.000
	Heterogeneity	0.012 +1.6 SWDIFR	0.221	126.1	26.5	0.001
	Base model	-0.41+2.2 TSPP + 1.8 NPP +0.7 CROP	0.495	99.6	0	0.000