Kirk, D. A., K. E. Lindsay, and R. W. Brook. 2011. Risk of agricultural practices and habitat change to farmland birds. *Avian Conservation and Ecology* **6**(1): 5
http://dx.doi.org/10.5751/ACE-00446-060105

Research Papers, part of a Special Feature on Conservation of Grassland Birds: Causes and Consequences of Population Declines

Risk of Agricultural Practices and Habitat Change to Farmland Birds

Risque des pratiques agricoles et des changements au plan de l'habitat sur les oiseaux des paysages agricoles

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ABSTRACT. Many common bird species have declined as a result of agricultural intensification and this could be mitigated by organic farming. We paired sites for habitat and geographical location on organic and nonorganic farms in Ontario, Canada to test a priori predictions of effects on birds overall, 9 guilds and 22 species in relation to candidate models for farming practices (13 variables), local habitat features (12 variables), or habitat features that influence susceptibility to predation. We found that: (1) Overall bird abundance, but not richness, was significantly ($p < 0.05$) higher on organic sites (mean 43.1 individuals per site) than nonorganic sites (35.8 individuals per site). Significantly more species of birds were observed for five guilds, including primary grassland birds, on organic vs. nonorganic sites. No guild had higher richness or abundance on nonorganic farms; (2) Farming practice models were the best (ΔAIC < 4) for abundance of birds overall, primary grassland bird richness, sallier aerial insectivore richness and abundance, and abundance of ground nesters; (3) Habitat models were the best for overall richness, Neotropical migrant abundance, richness and abundance of Ontario-USA-Mexico (short-distance) migrants and resident richness; (4) Predation models were the best for richness of secondary grassland birds and ground feeders; (5) A combination of variables from the model types were best for richness or abundance overall, 13 of 18 guilds (richness and abundance) and 16 of 22 species analyzed. Five of 10 farming practice variables (including herbicide use, organic farm type) and 9 of 13 habitat variables (including hedgerow length, proportion of hay) were significant in best models. Risk modeling indicated that herbicide use could decrease primary grassland birds by one species (35% decline from 3.4 to 2.3 species) per site. Organic farming could benefit species of conservation concern by 49% (an increase from 7.6 to 11.4 grassland birds). An addition of 63 m of hedgerow could increase abundance and richness of short distance migrants by 50% (3.0 to 4.8 and 1.3 to 2.0, respectively). Increasing the proportion of hay on nonorganic farms to 50% could increase abundance of primary grassland bird by 40% (6.7 to 9.4). Our results provide support for alternative farmland designs and agricultural management systems that could enhance select bird species in farmland.

RÉSUMÉ. De nombreuses espèces d'oiseaux ont décliné en raison de l'intensification des pratiques agricoles, mais ces déclins pourraient être atténués grâce à l'agriculture biologique. Nous avons apparié des sites (habitat et situation géographique) sur des fermes biologiques et des fermes non biologiques en Ontario, Canada, afin de tester des prévisions a priori d'effets sur l'avifaune dans son ensemble, 9 guildes et 22 espèces d'oiseaux, en relation avec des modèles candidats testant les pratiques agricoles (13 variables), les caractéristiques locales de l'habitat (12 variables) ou les caractéristiques de l'habitat qui influencent le risque de prédation. Nous avons trouvé que : 1) l'abondance totale d'oiseaux, mais pas la richesse, était significativement plus élevée ($p < 0,05$) aux sites biologiques (moyenne de 43,1 individus par site) qu'aux

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Sponsored by the Society of Canadian Ornithologists and Bird Studies Canada

Parrainée par la Société des ornithologistes du Canada et Études d'oiseaux Canada

sites non biologiques (moyenne de 35,8 individus par site). Un nombre significativement plus élevé d'espèces d'oiseaux ont été observées chez cinq guildes, dont celle des oiseaux spécialistes des prairies, aux sites biologiques. Aucune guilde n'a présenté une plus grande richesse ou abondance sur les fermes non biologiques; 2) les modèles prenant en compte les pratiques agricoles étaient les meilleurs (ΔAIC < 4) pour prévoir l'abondance totale d'oiseaux, la richesse des oiseaux spécialistes des prairies, la richesse et l'abondance des insectivores aériens qui chassent à l'affut et l'abondance des oiseaux nichant au sol; 3) les modèles prenant en compte l'habitat étaient les meilleurs pour prévoir la richesse dans l'ensemble, l'abondance des migrateurs néotropicaux, la richesse et l'abondance des migrateurs de courte distance (Ontario-É.-U.-Mexique) et la richesse des résidents; 4) les modèles prenant en compte la prédation étaient les meilleurs pour prévoir la richesse des oiseaux généralistes des prairies et des oiseaux se nourrissant au sol; 5) une combinaison de variables issues des modèles-types représentait la meilleure option pour prévoir la richesse ou l'abondance dans leur ensemble, chez 13 des 18 guildes (richesse et abondance) et 16 des 22 guildes examinées. Cinq des dix variables décrivant les pratiques agricoles (y compris l'utilisation d'herbicides et le type de fermes biologiques) et 9 des 13 variables touchant l'habitat (y compris la longueur des haies et la proportion de foin) étaient significatives dans les meilleurs modèles. La modélisation du risque a indiqué que l'utilisation d'herbicides pouvait toucher les oiseaux spécialistes des prairies, à raison d'une espèce (déclin de 35 %, de 3,4 à 2,3 espèces) par site. L'agriculture biologique pourrait favoriser les espèces dont la conservation est préoccupante, jusqu'à 49 % (augmentation de 7,6 à 11,4 oiseaux de prairie). Un ajout de 63 m de haie permettrait d'augmenter l'abondance et la richesse des migrateurs de courte distance de 50 % (de 3,0 à 4,8 et de 1,3 à 2,0, respectivement). Une hausse de 50 % de la proportion de foin sur les fermes non biologiques permettrait d'augmenter de 40 % l'abondance des oiseaux spécialistes des prairies (de 6,7 à 9,4). D'après nos résultats, une attention particulière portée à la configuration des fermes et à la gestion agricole permettrait d'améliorer le sort d'espèces d'oiseaux sélectionnées dans les paysages agricoles.

Key Words: *agricultural landscapes; birds; farming practices; habitat; information theoretic approach; risk modeling*

INTRODUCTION

Although traditional agriculture in temperate regions resulted in increased abundance of many open-country avian species and a decline in forest species, over the past 50 years modern farming practices have caused declines in avian diversity globally (Fuller et al. 1995, Donald et al. 2001, Murphy 2003, Green et al. 2005). Many species have become so rare that they have been designated as species at risk, while some other species have benefited from agriculture to the extent that they have been considered pests, e.g., Red-winged Blackbirds(*Agelaius phoeniceus*). Of equal concern is the dramatic decline in previously abundant species that may be critical to ecosystem structure and function (Gaston and Fuller 2007). According to recent analyses of the North American Breeding Bird Survey, dramatic declines have occurred in some of these species in Canada. For example, only about one fifth of the numbers of Vesper Sparrows (*Poocetes gramineus*) and one quarter to one third of Eastern Meadowlarks (*Sturnella neglecta*) and Bobolinks (*Dolichonyx oryzivorus*) were counted in the Canadian Lower Great Lakes/St. Lawrence Plain in 2006 compared to 1968, representing declines of 77%, 73%, and 71%, respectively (Collins and Downes 2009). Similarly in Europe, the UK Eurasian Tree Sparrow (*Passer montanus*) population decreased by 94%, the Eurasian Skylark (now Sky Lark; *Alauda arvensis*) by 54% and the Corn Bunting (*Miliara calandra*) by 89% between 1970 and 2001 (Gregory et al. 2004), though declines have now stabilized for the first two species (Baillie et al. 2010, Eaton et al. 2010).

Given that the next 50 years is predicted to be the final expansion phase of modern agriculture (Tilman et al. 2001) including for the bioeconomy, quantifying potential effects of agriculture on avian and other biodiversity is more pressing than ever. Reversing declines in grassland birds can be done by both restoring natural grasslands and promoting beneficial farming practices (Askins et al. 2007). Various initiatives are underway to monitor biodiversity indicators in agricultural landscapes, e.g., the farmland bird index in Europe (Gregory et al. 2005, Scholefield et al. 2009, EBCC 2011), to develop habitat standards, e.g., the National Agri-Environmental Standards Initiative NAESI in Canada (McPherson et al. 2009, Neave et al. 2009), and to implement agri-environmental schemes to enhance biodiversity in agricultural landscapes (Billeter et al. 2008 for Europe). Over the last 10 years, targeted research has pinpointed specific changes in agricultural practices and habitat that have led to declines in abundance of individual avian species (e.g., Bradbury et al. 2000, Brickle et al. 2000, Chamberlain and Wilson 2000, Whittingham et al. 2005). Identifying intrinsic and extrinsic traits most strongly associated with a decline in avian biodiversity is a critically important step and will highlight which species are most at risk (Gaston and Fuller 2007).

Among the many factors that can affect bird species composition and abundance in farmland, i.e., the area under production, within agricultural landscapes are the type of crops grown, the quality of seminatural habitats, their spatial configuration, and overall habitat heterogeneity (Rodenhouse et al. 1995, Kirk et al. 2001, Benton et al. 2003, Herzon et al. 2007, Herzon and O'Hara 2007). Agricultural practices, e.g., tillage, grazing, agrochemical use, are known to impact bird populations directly through mortality or indirectly by modifying food availability or nesting cover (O'Connor and Shrubb 1986, Newton 2004). The mechanism for this is believed to be primarily through plant-mediated reductions in food supply and altering habitat and landscape structure (Chamberlain and Fuller 2000). Supporting evidence for the negative influence of herbicides on bird populations comes from a 30-year study of the Grey Partridge (*Perdix perdix*) in the United Kingdom (Potts 1997), but there is little information for North America. However, correlative evidence that widespread use of granular insecticides may have contributed to declining bird populations in agricultural areas comes from a retrospective study done in the Canadian prairies (Mineau et al. 2005). In addition, research has demonstrated that organic farms generally have higher bird abundance or species richness than their nonorganic counterparts (Freemark and Kirk 2001, Bengtsson et al. 2005, Fuller et al. 2005), although the type of farming in the surrounding landscape matrix can influence this effect (Piha et al. 2007, Gabriel et al. 2010). Organic farmers do not use synthetic fertilizers and pesticides, and are likely to be more sensitive in the way they manage noncrop habitats (Hole et al. 2005). For example, they may be less likely to cut back hedgerows and fence lines, drain wetlands, or remove woody cover, which may have a positive effect on avian biodiversity. However, one negative consequence of this is that predators, such as corvids, may have higher abundance on organic farms and in turn depress the abundance of other birds (Gabriel et al. 2010).

Here, our objective was to relate the occurrence of bird species in farmland to a suite of local, i.e., an area of 6.3 ha around each point count site, habitat features and agricultural practices known to affect bird populations to assess differences between farm types. We developed candidate models to test hypotheses for richness and abundance overall and for 10 species group guilds in relation to farming practices, local habitat features, and habitat features thought to influence susceptibility to predation. We tested the same hypotheses for the abundance of 22 individual species where there was sufficient data to do so. We predict that:

1. Avian biodiversity is higher on organic than nonorganic farms;

2. Abundance of birds overall and the grassland guilds, and richness/abundance for insectivorous, ground feeder, or ground nester guilds are best explained by farming practices;

3. Richness of birds overall and the grassland guilds, and richness/abundance for nonbreeding location guilds are best explained by habitat;

4. Richness/abundance for the grassland, ground feeder, ground nester, and sallier guilds are best explained by predation. We included a predation model because numerous studies have demonstrated that predation associated with linear habitat features, e.g., corridors or fence lines, is a significant driver in agricultural landscapes (e.g., Bergin et al. 2000, Chalfoun et al. 2002).

5. Avian biodiversity is better explained by models including combinations of all variables created a priori for each guild or species.

Because even small changes in habitat or practices can have substantial long-term benefits for wildlife conservation (Shutler et al. 2000), we attempted to quantify the relationship between the amount of select habitat features, e.g., hedgerow length, woodland area, crop type, or farming practices, e.g., herbicide use, field size, and potential changes in bird species richness, composition, and abundance, while controlling for other important variables. Quantifying effects on bird numbers or species richness from changing specific features or practices in agricultural landscapes has important policy and management implications given recent focus, especially in the EU (Gabriel et al. 2010), on increasing ecologically friendly or low intensity farming as a mitigation measure for declining trends in farmland avian biodiversity.

METHODS

Study area

We conducted our study in the Mixedwood Plains ecozone of southern Ontario during the avian breeding season of 1990. We selected 10 certified organic farms and paired them with 10 nonorganic farms based on matching geographic location, field size and shape, crop type, and noncrop habitat features. To be considered organic, farms had to be certified either by the Ottawa Chapter of the Canadian Organic Growers or the Ecological Farmers Association of Ontario, with no use of fast release synthetic pesticides or fertilizers within the previous three years (OMAFRA 2010). In comparing organic and nonorganic farms, it is important to control for the effect of habitat that confounds comparisons between farm types (Chamberlain et al. 1999, Gabriel et al. 2010). We used a paired study design selecting sites on organic and nonorganic farms that were matched for crop and noncrop habitat. This limited some of the confounding effects of habitat features but constrained the range of variation in habitat between farm types. Thus, we could not include intensively farmed nonorganic sites or organic sites rich in noncrop habitat. Similar paired study designs were also used by Chamberlain et al. (1999), Chamberlain and Wilson (2000), and Gabriel et al. (2010) in the United Kingdom and Beecher et al. (2002) and Jones et al. (2005) in the United States.

We located five farm pairs in the southwest of the province, two pairs in the south, and three pairs in the southeast. Farm size averaged 84.2 ha (± 45.2 ha SD).

Birds

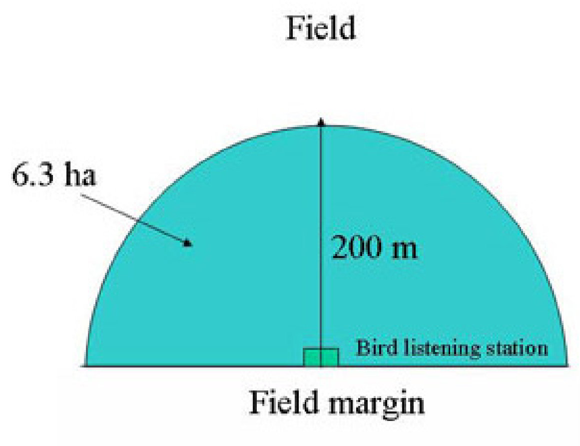
To reduce travel time and the need for more land owner permissions, we included as many bird survey sites as could be matched for habitat similarity per farm type pair (range 2-6 sites). We conducted surveys from a stationary position at the edge of a field and recorded all birds seen or heard, but still on-farm, in a semicircle for the 180° facing into the field during a 10-minute point count (Fig. 1; see Freemark and Rogers 1995). Sites within a farm were at least 150 m apart (mean 374 m, range 150-1410 m). To avoid double counting birds, we made sure that sites that were in close proximity within a farm were surveyed in opposite directions.

To help reduce the possibility of chemical contamination, we did not survey birds within a 100 m buffer of the outer boundary of organic farms. We also located nonorganic survey sites at least 500 m from organic farm boundaries to reduce potential spillover of birds.

We surveyed each farm pair on the same day and four times between 8 May and 28 June, 1990. We reversed the order in which pairs of farms and sites within a farm were visited between surveys to reduce biases in counts due to changes in bird vocalizations at different times of day. As well, observers alternated between visits to reduce possible bias attributable to variation in identification or aural acuity. We conducted point counts between dawn and 10:00 hours (EST), when there was little or no precipitation and winds were less than 10 kmph.

We assigned abundance values to each record based on territorial status, i.e., a singing male counted as two birds, a bird calling or seen as one. Although doubling the count for singing males was standard practice at the time (Welsh 1995), we now know that it could be overestimating abundance, at least for some species, and thus will make it harder to test our prediction that avian abundance is greater on organic than nonorganic farms. Because sites were paired by farm type and habitat similarity, we did not correct for detectability of species, and although there are now methods that could be used (Nichols et al. 2000, Farnsworth et al. 2002) these are still considered problematic (Johnson 2008, Dawson

Fig. 1. Diagram showing design for bird survey site at field edge, indicating the 6.3 ha semicircle in which habitat and practice variables were measured/evaluated.



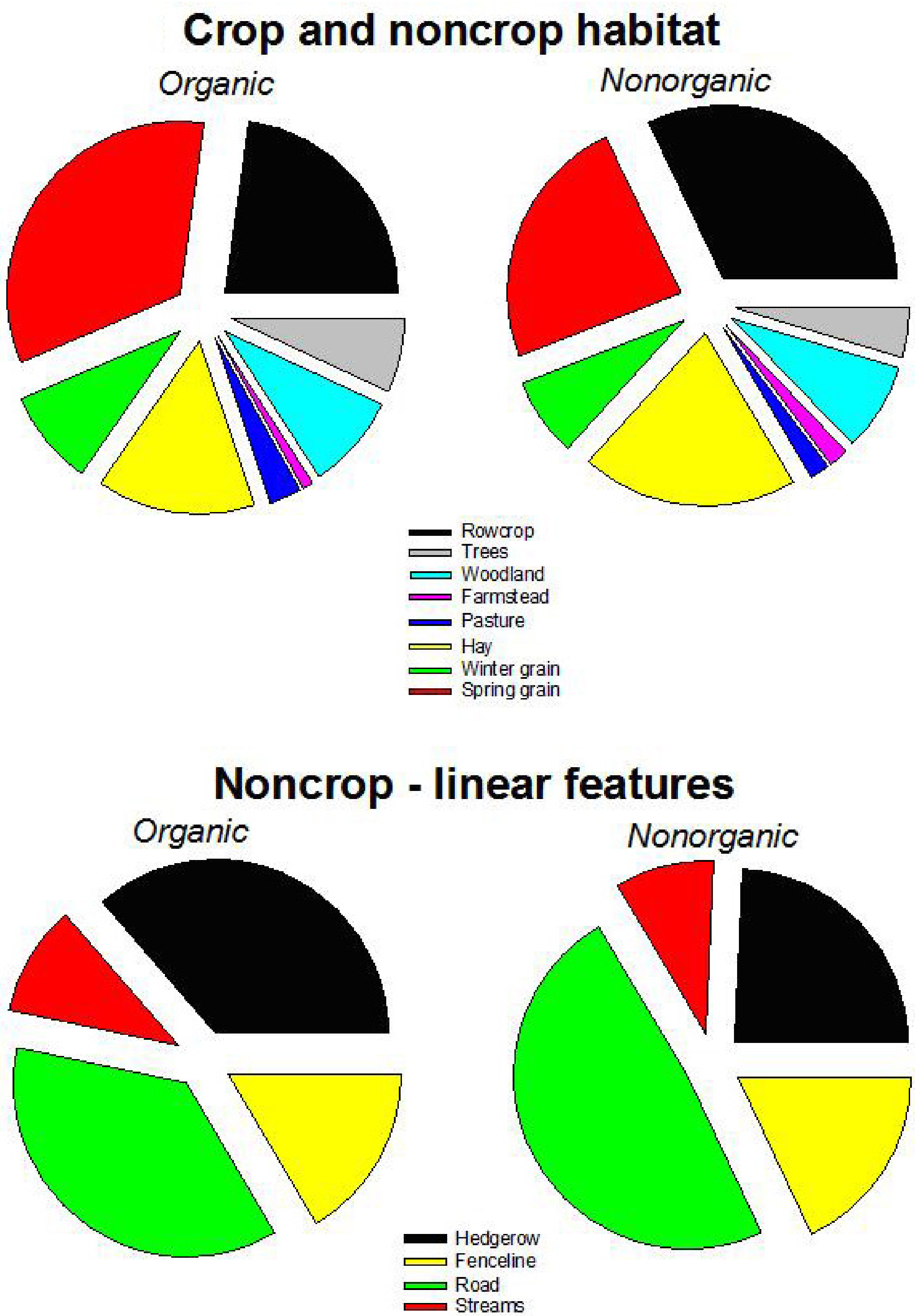
and Efford 2009). We averaged counts across the four visits.

As well as retaining information for each species, we also assigned each species to guilds (details in Appendix 1), as did Beecher et al. (2002) in a study of birds on organic and nonorganic farms in Nebraska. Guilds are groups of species that have similar primary food type, food location, nesting stratum, nonbreeding location, or use the same habitat type and may respond similarly to change in habitat and agricultural practices. For example, it may be predicted that insectivorous species would be more likely affected by pesticides than noninsectivorous species, or that ground feeders or aerial insectivore guilds would be more affected by numbers of tillages. Combining species into guilds also improved the distribution of species' survey data, which had many zeros, low counts, and skewed distributions, and enabled species with insufficient information for individual species modeling to be included. We also included species primarily associated with grassland/agricultural habitats, species secondarily associated with grassland/agricultural habitats, and aerial insectivores (salliers and screeners – see Appendix 1), all guilds that are showing significant population declines in North America (Askins et al. 2007, Nebel et al. 2010, Sauer et al. 2011). For each of the guilds, we summed counts of all species within the guild and calculated species richness per bird survey site by accumulating the number of species over visits, i.e., richness was calculated from the mean counts. Note that this was done separately for each site within a farm.

Habitat

To measure coarse habitat features, we located study farms on aerial photographs (1:50,000 or 1:15,000 scale), enlarged them to 1:10,000, delineated habitat variables within the 200 m semicircle facing into the field from the bird count site (6.3 ha; Fig. 1), and transferred these to 1:10,000 base maps using a zoom transfer scope, supplemented by habitat mapping at each site during bird survey visits. We used an electronic digitizer to calculate linear distance and area measures. We grouped crop and noncrop variables into 12 classes that provided adequate sample sizes (Fig. 2). However, we also checked original habitat features to help explain some of the correlational relationships between bird species composition and abundance and explanatory variables, for example, riparian vs. upland woodland. We pooled the collective area of riparian and upland woodland and included wooded edges with hedgerows to reduce the number of variables, to increase sample size, and improve data distributions. Except for habitat heterogeneity, all

Fig. 2. Pie charts showing percentage of crop and noncrop habitats on organic and nonorganic farms.



habitat variables were expressed as a proportion of the total area measured. Hedgerow length was multiplied by 3 m, an average width observed in the field, to obtain an area measure for calculating habitat heterogeneity.

Because within-field vegetation structure can influence bird species composition and abundance (O'Connor and Shrubb 1986), we also measured biomass of crops and crop growth profiles over the four bird survey visits. However, we included these vegetation structure variables with agricultural practices because these factors are so strongly influenced by farming practices, e.g., tillage, haying, etc.

Agricultural practices

We collected information on farming practices (Table 1) by interviewing farmers and while doing point-count surveys and vegetation measurements. We pooled some variable categories to increase sample sizes and dropped those with insufficient information. We defined a field as any expanse of agricultural land, cultivated or uncultivated, bordered by noncrop boundaries such as fences or woody fencerows, water, or nonagricultural land. Abutting crop edges were not considered as boundaries, so a field could comprise more than one crop.

We did not include tillage and planting dates because of difficulties in assigning values to fall-sown (in 1989) and no-till sites. The only crop harvested during the study period was hay, and sample sizes were insufficient for analysis to include harvesting dates. However, we tallied the number of tills, including disking, for spring-sown crops because tillage can have important effects on farmland birds (Cunningham et al. 2004).

For herbicides, insecticides, biodynamic sprays, chemical fertilizers, and manure, we used binary variables, based on use or nonuse in 1990. The predictive modeling for herbicide use was in relation to use or nonuse of herbicides at the site level, i.e., the area surveyed by the semicircular point counts, about 6.3 ha. While the counts were unlimited, this area was effectively within a few hundred meters of the point where the observer was standing. We omitted insecticide use from analyses because these pesticides were applied at only two sites out of 72; this is an insufficient sample size to show any statistical effect. Those sites were retained in the current analyses because they did not appear as outliers in ordination analyses (sites 33 and 35 in Fig. 1 of Freemark and Kirk 2001).

Although we measured crop growth at each point-count site, averaged over the four visits, because some studies have shown crop height or stubble residue can influence bird use (Butlers et al. 2006), it had little effect on richness or abundance, so we omitted it from guild models. However, we did include crop biomass as a measure of local vegetation structure and included it among the suite of farming practice variables. Clustering of sites within farms contravened rules of statistical independence and had a significant effect in ordinations (Freemark and Kirk 2001), so we controlled for within-farm effects in models.

Candidate models

Based on data distributions and percent occurrence, sufficient data for modeling were available for 22 species (Appendix 1; models run for nine other species did not converge - Appendix 2). We derived a series of candidate models for each that described individual species, guilds, or overall responses to variable subsets (see Appendix 2 for candidate models). Candidate model subsets, specific to each species and guild, included: (1) farming practice variables (see Table 1 for list); (2) habitat features measured at the local scale and that included crop and noncrop habitat; (3) a predation model that included various natural features associated with predation in agricultural landscapes; (4) combination model(s) for each species or guild with habitat and/or practices; and (5) a global model containing all a priori selected variables. We did not include highly correlated variables (i.e., those Pearson correlations of > 0.5) in the same model, e.g., "trees" and "woods".

Statistical analysis

To test our predictions, we use an information theoretic approach to rank different subsets of models and to determine which best fit the data, both for individual species and guilds. We combined counts of individual species into guilds because this has proved useful in other recent studies of farmland birds in North America (see Beecher et al. 2002). We used Akaike's Information Criterion (AIC_c

Table 1. Summary statistics for habitat and farming practices at organic and nonorganic farms in southern Ontario in 1990. * denotes significant ($p < 0.05$) Mann Whitney U tests on 36 pairs of matched sites on organic vs. nonorganic values/sites. Variables unique to a farm type are denoted by *u*. n/a = not applicable or data not available.

			Organic				Nonorganic		
		Measure	n	Mean	SE		n	Mean	SE
A. Habitat at survey sites (based on about 6.3 ha)									
Crop									
Rowcrop	Soybean, white bean (1 field), corn	ha/ha	15	0.23	0.06		21	0.35	0.06
Spring grain	Barley, oats, spring wheat	ha/ha	25	0.34	0.06		16	0.26	0.06
Winter grain	Winter wheat, winter rye	ha/ha	9	0.09	0.03		4	0.08	0.04
Hay	Grass, alfalfa, clover, trefoil	ha/ha	11	0.15	0.05		15	0.22	0.06
Pasture	Grazed and ungrazed grassland	ha/ha	8	0.03	0.02		4	0.02	0.01
Farmstead	Houses, barns, adjoining houses, gardens	ha/ha	8	0.01	0.01		9	0.02	0.01
Noncrop									
Hedgerow	Wooded fencerow and woody strip cover between fields	m/ha	18	23.22	5.69		14	16.86	5.90
Woods	Riparian and upland woods	ha/ha	22	0.09	0.02		22	0.09	0.02
Trees	Crown diameter (10 m) x No. of isolated trees	ha/ha	16	0.07	0.02		14	0.05	0.01
Streams	Small rivers, streams, ditches	m/ha	8	6.62	2.61		8	6.44	2.36
Corridor	Roads, railways, electricity transmission corridors	m/ha	18	23.47	4.36		24	33.71	5.97
Fence	Grassy strips between fields usually with fence	m/ha	9	10.54	3.59		9	12.52	4.20
Habitat heterogeneity	Shannon index; includes hedgerow length x 3 m width	H'	36	0.25	0.03		36	0.23	0.03
B. Farming practices at survey sites (based on about 6.3 ha).									
Field size	Proportion of area surveyed	ha/ha (ha)	36.0	2.21 (13.92)	0.26 (1.63)	*	36	3.72 (23.44)	0.44 (2.77)
# tillages	Number tillages	#	24	0.94	0.14		22	0.89	0.15
# passes	Tillages, cultivation (weed control), planting, pesticide applications, fertilizer applications, haying and other treatments	#	32.0	2.44	0.24		33	2.78	0.28
Herbicide	Use or no use in 1990	categ	0	0.00	0.00	*u*	22	n/a	n/a
Fertilizer	Chemical use or no use in 1990	categ	0	0.00	0.00	*u*	22	n/a	n/a
Manure	Use or no use in 1990	categ	10	n/a	n/a		7	n/a	n/a
Biodynamic spray	Use or no use for weed control in 1990	categ	13	n/a	n/a	*u*	0	n/a	n/a
Farm type		categ	36				36		
Biomass	Derived from crop growth profiles	cm-day	36	830.24	157.87		36	753.20	97.78
Growth rate 2	Deviation between mean growth rate per interval and actual crop growth rate for second interval (planting to second survey)	cm/day	36	-0.01	0.06		36	0.01	0.06
Growth rate 3	Deviation between mean growth rate per interval and actual crop growth rate for third interval (planting to third survey)	cm/day	36	-0.02	0.10		36	-0.01	0.08
Growth rate 4	Deviation between mean growth rate per interval and actual crop growth rate for fourth interval (planting to fourth survey)	cm/day	36	-0.09	0.11		36	0.02	0.12

corrected for small samples size; Anderson et al. 2000, Burnham and Anderson 2002) to rank candidate models for each species or guild subset. Those models with the fewest parameters that explained the greatest amount of variation in the data were considered the most parsimonious. We calculated AIC_c, ΔAIC and Akaike weights and then ranked models by ΔAIC. Generally models with ΔAIC < 2 are best supported for inference, whereas models with ΔAIC of between 4 to 7 have less support. Models with ΔAIC > 10 have no support or fail to explain substantial variation in the data and are not to be considered further (Burnham and Anderson 2002). Here, we considered all models with ΔAIC < 4, high Akaike weights, and significant model fit for inference but present ΔAIC values for all models for comparison. We also tested the effects of eliminating noninformative variables from models given recent concerns (Arnold 2010), but found that this had little effect so do not discuss this further.

Because the global model includes all of the a priori variables from the candidate models, it is over-fitted and would not be expected to be the best overall model. However, we included it here to assess how well the candidate models performed and to assess model fit before proceeding (χ^2 values around 1). Where several competing models (ΔAIC < 4) occurred, we based inference on common variables among them and examined significance (confidence limit not including 0).

To compare habitat features and farming practice variables between farm types we used Mann Whitney *U*-tests or Student *t*-tests, depending on data distributions. For the comparisons of guilds between farm types we also used *t*-tests, controlling for the clustering of sites within farms.

For the main (AIC) analyses, we used a Generalized Linear Mixed Model (GLMM) with a Poisson error term or a normal error depending data distribution (PROC NLMIXED; SAS Institute 2008). We checked for count overdispersion (SD/mean > 1) and heterogeneity of variance by calculating and graphing Poisson and negative binomial probabilities for each species and guild. The variance in counts was never greater than the mean, so we used a Poisson distribution, except for total richness and total abundance where we used a normal (Gaussian) error distribution. For all of the GLMM models (single species and guilds), we used 'farm' as a random effect variable to account for the fact that sites were clustered within farms; thus the unit of replication in these comparisons is the 'farm'.

To demonstrate how models could be used to quantify risk from farming practices or changes in habitat, significant explanatory variables were tabulated by their frequency of occurrence in best models. We then used the best models (AIC < 4) with these focal variables to predict effects for each guild. We held all variables constant in the model at their mean across all sites and examined the effect of manipulating the focal variable, thus means presented for the predictive models are adjusted means. For binary variables, we held all other variables constant and examined predicted scenarios based on presence or absence. We considered results to be statistically significant at $p \leq 0.1$ (see Johnson 1999). All means are reported ± SE, unless otherwise noted.

RESULTS

Habitat

Mean cover of crop habitat, e.g., row crop or spring grain, and noncrop habitat, e.g., woodland or farmstead, and mean length of linear noncrop habitat, e.g., hedgerow or road, were similar on organic and nonorganic sites (Table 1). About half of the area sampled at survey sites was in row crop, spring grain, winter grain, and hay; spring grain was the most extensive on organic sites, row crop on nonorganic sites. Pasture and winter grain cover occurred infrequently, but were included because they were deemed potentially important. Hedgerow length ranged from 100-150 m per site and was not significantly different between farm types (Table 1). Woodland covered 15% of survey sites on average. Although combined woodland area (ha) did not differ between farm types, riparian woodland and riparian woodland edge was significantly greater on nonorganic than organic farms (riparian woodland mean 10.2 ± 1.5, organic 6.1 ± 0.96; riparian woodland edge nonorganic 0.05 ± 0.01, organic 0.01 ± 0.002; $p < 0.05$ for both *t*-tests). Habitat heterogeneity was similar between farm types.

Agricultural practices

Field size was significantly ($p < 0.05$, *t*-test) larger on nonorganic than organic farms (Table 1). Nineteen fields on nonorganic farms, and 18 fields on organic farms were in pasture or hay with field size again significantly larger ($p < 0.05$, *t*-test) on nonorganic (mean = 25.58 ± 4.25 ha; range 2.39 to 60.80 ha) than organic (mean = 9.51 ± 5.83 ha; range 2.77 to 26.71 ha). Herbicides, insecticides, and chemical fertilizers were applied at nonorganic farm survey sites only and biodynamic sprays at organic sites only. Seed treatments, e.g., fungicide, insecticide, were probably used on nonorganic farms but were not specifically noted. All other practices were similar between farm types.

We visited 21 sites before first tillage; stubble was present at seven (nonorganic n = 5, organic n = 2). First tillage occurred between 1 April and 6 June and was not significantly different between farm types. Spring planting dates averaged almost one week after first tillage (mean = 12 May). Of 26 hay fields, seven (organic n = 1, nonorganic n = 6) were harvested once during the survey period.

P1: Avian biodiversity is higher on organic than nonorganic farms

We counted 68 species overall, 59 on nonorganic and 58 on organic farms (Appendix 1). Overall bird abundance was significantly higher at sites on organic (mean 43.1 ± 0.52) than nonorganic (35.8 ± 0.38) farms; species richness per site did not differ between farm types (Table 2). No guild had significantly more species of birds on nonorganic than organic sites. In contrast, significantly more species of primary grassland birds, sallier aerial insectivores (hereafter salliers), and ground nesters were observed on organic than nonorganic sites. In addition, abundances of primary grassland birds, salliers, ground feeders, and U.S.-Neotropical migrants were significantly higher on organic than nonorganic sites.

P2: Abundance of birds overall and the grassland guilds, and richness/abundance for insectivorous, ground feeder, or ground nester guilds are best explained by farming practices

Models with only farming practice variables (Tables 3 and 4) were among the best models (ΔAIC < 4) for:

- Abundance: overall, ground nesters, U.S.-Neotropical migrants, residents;
- Richness: primary grassland birds;
- Abundance/richness: salliers;
- Abundance of 6 of 22 species analyzed including Brown Thrasher (*Toxostoma rufum*), Cedar Waxwing (*Bombycilla cedrorum*), Common Grackle (*Quiscalus quiscula*), Common Yellowthroat (*Geothlypis trichas*), Northern Flicker (*Colaptes auratus*), and Yellow Warbler (*Dendroica petechia*).

The practice model had the lowest AIC of all of the best models for overall abundance, resident abundance, and sallier richness.

P3: Richness of birds overall and the grassland guilds and richness/abundance for nonbreeding location guilds are best explained by habitat

Habitat models (Tables 3 and 4) were among the best for:

- Abundance: Neotropical migrants;
- Richness: overall, ground feeders, residents;
- Abundance/richness: screener aerial insectivores, Ontario-USA-Mexico migrants;
- Abundance of 10 of 22 species analyzed including Bank Swallow (*Riparia riparia*), Barn Swallow (*Hirundo rustica*), Black-capped Chickadee (*Poecile atricapillus*), Bobolink, Cedar Waxwing, Common Grackle, Eastern Meadowlark, Red-winged Blackbird, Vesper Sparrow, and Yellow Warbler.

Table 2. Survey results for bird guilds (see Appendix 1 for definitions) in and adjacent to fields on organic and nonorganic farms in southern Ontario, 1990 (tests show results of Student t-test controlling for clustering of sites within farms).

	Organic		Nonorganic			
Guild	Mean	SE	Mean	SE	*t*	*p*
Overall richness	14.64	0.74	12.99	0.70	-0.71	0.478
Overall abundance	43.09	0.52	35.76	0.38	-2.12	0.039
Primary grassland bird richness	4.21	0.32	3.18	0.27	2.22	0.030
Primary grassland bird abundance	12.67	0.92	9.27	0.70	2.63	0.011
Secondary grassland bird richness	3.69	0.32	3.46	0.31	0.51	0.613
Secondary grassland bird abundance	9.70	0.64	8.98	0.59	0.84	0.403
Sallier aerial insectivore richness	0.78	0.19	0.22	0.08	3.18	0.002
Sallier aerial insectivore abundance	0.93	0.28	0.23	0.10	3.12	0.003
Screener aerial insectivore richness	1.06	0.17	1.08	0.17	-0.10	0.922
Screener aerial insectivore abundance	1.28	0.28	1.72	0.36	-1.03	0.305
Ground feeder richness	9.46	0.47	8.36	0.36	-0.90	0.373
Ground feeder abundance	31.23	0.80	24.93	0.50	-2.31	0.025
Ground nester richness	5.73	0.13	4.94	0.12	-1.86	0.069
Ground nester abundance	21.95	1.03	17.33	0.79	-1.46	0.150
Neotropical migrant richness	3.13	0.16	2.41	0.11	-1.31	0.20
Neotropical migrant abundance	6.76	0.72	6.15	0.83	0.02	0.99
U.S.-Neotropical migrant richness	10.77	0.39	9.57	0.29	-1.09	0.280
U.S.-Neotropical migrant abundance	33.77	2.11	26.94	1.12	-1.77	0.083
Ontario-USA-Mexico migrant richness	1.96	0.08	1.61	0.06	-0.92	0.361
Ontario-USA –Mexico migrant abundance	5.42	0.82	4.50	0.72	-0.76	0.453
Resident richness	2.13	0.19	2.13	0.15	0.08	0.938
Resident abundance	7.81	2.23	6.00	0.99	-1.07	0.290

Table 3. Rank of candidate models (ΔAIC < 4.0 in bold) used to evaluate guild abundance and richness for habitat, farming practices, predation, and custom models for avian guilds on organic and nonorganic farms in Ontario.

Response	Minimum AIC[†]	Model[‡]	-2LL[§]	K[|]	ΔAIC[¶]	W_i[#]
Overall richness	38.96	**Combination2 (+organic farm type, -rowcrop, -field size**)**	25.67	6	0.00	0.58
		Habitat (-habitat heterogeneity, +woods, +rowcrop, +hedge**)**	24.37	7	1.15	0.33
		Combination1	30.30	6	4.63	0.06
		Global	15.89	12	6.22	0.03
		Practices	84.01	7		
Overall abundance	55.13	**Practices (-biomass, +organic farm type, -field size, +number tills*, -number passes, -herbicide, +fertilizer, +manure)**	28.73	11	0.00	0.99
		Combination1	49.80	7	10.41	0.01
		Combination2	49.94	7	10.55	0.01
		Habitat	28.26	15	11.70	0.00
		Predator	58.21	5	13.99	0.00
		Global	33.76	23	47.63	0.00
Primary grassland bird richness	249.55	**Combination2 (-spring grain, -rowcrop, -field, -herbicide**)**	236.26	6	0.00	0.67
		Combination1 (-hedge, +hay, +pasture, +woods, +organic farm type**)**	236.85	7	3.05	0.15
		Practices (+biodynamic, +organic farm type, -field size, -herbicide, -fertilizer, -manure)	235.25	8	3.98	0.09
		Habitat	243.00	5	4.36	0.08
		Predation	257.09	5	7.53	0.02
		Global	275.67	16	26.12	0.00
Primary grassland bird abundance	411.81	**Combination1 (-hedgerow**, +hay**, -pasture, -woods, +organic farm type**)**	396.06	7	0.00	0.99
		Combination2	407.33	6	8.82	0.01
		Global	383.37	16	13.45	0.00
		Practices	409.71	8	16.19	0.00
		Habitat	417.15	5	16.26	0.00
		Predation	424.60	5	23.70	0.00
Secondary grassland bird richness	262.87	**Predation (+hedge, +trees, -woods)**	251.96	5	0.00	0.87
		Combination2	252.16	7	5.04	0.07
		Combination1	253.09	7	5.97	0.04

(con'd)

		Practices	252.71	8	8.12	0.01
		Habitat	251.93	9	9.96	0.01
		Global	248.92	17	31.38	0.00
Secondary grassland bird abundance	395.22	**Combination2 (+spring grain**, +pasture*, + rowcrop**, -field size, -herbicide)**	379.47	7	0.00	0.87
		Predation	389.18	5	4.87	0.08
		Combination1	386.63	7	7.16	0.02
		Practices	384.59	8	7.65	0.02
		Habitat	382.93	9	8.61	0.01
		Global	365.71	17	15.82	0.00
Sallier aerial insectivore richness	142.35	**Practices (+biodynamic, +organic farm type, -field, -number tills**, -herbicide, +fertilizer, + manure)**	121.44	9	0.00	0.51
		Combination1 (+hedge, +pasture, -habitat heterogeneity, +woods, -field, -herbicide**)**	124.99	8	0.93	0.32
		Combination2 (+hay, +pasture, -fence, -corridor, -trees, -fertilizer**)**	126.71	8	2.65	0.14
		Predation	137.71	5	6.27	0.02
		Habitat	132.06	9	10.62	0.00
		Global	107.70	17	10.69	0.00
Sallier aerial insectivore abundance	199.27	**Combination1 (+hedge, +pasture, -habitat heterogeneity, +woods*, -field, -herbicide**)**	180.99	8	0.00	0.47
		Practices (+biodynamic, +organic farm type, -field*, -number tills, -herbicide, +fertilizer, + manure)**	178.51	9	0.14	0.44
		Combination2	186.10	8	5.11	0.04
		Predation	193.85	5	5.48	0.03
		Global	160.29	17	6.35	0.02
		Habitat	189.58	9	11.21	0.00
Screener aerial insectivore richness	191.90	**Combination2 (-spring grain, +corridor, -rowcrop, +herbicide, -fertilizer)**	176.15	7	0.00	0.69
		Habitat (-spring grain, -hay, +pasture, -habitat heterogeneity, +corridor, -streams, -rowcrop)	173.81	9	2.81	0.17
		Combination1 (+hay, +pasture, -habitat heterogeneity, +corridor, -streams, +organic farm type, -manure)	174.57	9	3.57	0.12
		Practices	177.89	9	6.89	0.02
		Global	173.49	16	23.48	0.00
Screeners aerial insectivore abundance	297.65	**Combination2 (-spring grain*, +corridor, -rowcrop, +herbicide, -fertilizer)**	281.90	7	0.00	0.53
		Habitat (-spring grain, -hay, +pasture, -habitat heterogeneity, +corridor, -streams, -rowcrop)	278.30	9	1.55	0.24

(con'd)

		Combination1 (-hay, +pasture, -habitat heterogeneity, +corridor, +streams, -organic farm type, -manure)**	278.48	9	1.74	0.22
		Practices	285.95	9	9.21	0.01
		Global	272.09	16	16.34	0.00
Ground feeder richness	38.62	**Predation (+woods, +hedgerow, -field size**)**	25.32	6	0.00	0.79
		Habitat (-farmstead, +hedgerow, +spring grain, +pasture*, +habitat heterogeneity, -corridor, -trees, +woods*, +rowcrop**)**	12.40	12	3.07	0.17
		Combination2	31.20	6	5.88	0.04
		Global	4.68	19	18.68	0.00
		Practices	128.51	10	113.50	0.00
		Combination1	136.87	8	116.54	0.00
Ground feeder abundance	54.23	**Combination2 (+pasture, +number tills**, -herbicide**)**	40.94	6	0.00	0.99
		Practices	40.34	10	9.71	0.01
		Combination1	47.82	8	11.88	0.00
		Habitat	53.66	12	28.72	0.00
		Global	35.68	19	34.07	0.00
		Predation	96.09	6	55.15	0.00
Ground nester richness	45.36	**Combination2 (+pasture, +number tills*, -herbicide**)**	32.07	6	0.00	0.97
		Habitat	22.91	12	6.84	0.03
		Predation	112.14	6	80.07	0.00
		Practices	128.55	10	106.79	0.00
		Global	114.30	19	121.56	0.00
		Combination1	171.62	8	144.54	0.00
Ground nester abundance	95.02	**Combination2 (-pasture, +number tills**, -herbicide**)**	81.73	6	0.00	0.74
		Practices (+biomass, +organic farm type, +field size, +number tills**, +herbicide, -fertilizer, -manure)**	74.39	10	2.98	0.17
		Predation	86.77	6	5.04	0.06
		Combination1	83.91	8	7.18	0.02
		Habitat	74.82	12	9.09	0.01
		Global	62.19	19	19.79	0.00
Neotropical migrant richness	271.44	**Predation (-farmstead, +pasture**, -manure)**	260.54	5	0.00	0.89
		Global	250.37	11	5.33	0.06
		Habitat	257.48	9	6.94	0.03
		Combination2	268.40	5	7.86	0.02

(con'd)

		Practices	275.02	3	9.93	0.01
		Combination1	274.33	5	13.79	0.00
Neotropical migrant abundance	389.29	**Global (+farmstead**, -hedgerow, +hay**, -habitat heterogeneity, -streams**, -trees**, +woods**, +organic farm type, -field size)**	362.89	11	0.00	0.53
		Habitat (+farmstead, -hedgerow, +hay**, +habitat heterogeneity, -streams**, -trees**, +woods**)**	368.92	9	0.53	0.41
		Combination2	383.30	5	4.92	0.05
		Predation	386.38	5	8.00	0.01
		Practices	400.39	3	17.45	0.00
		Combination1	399.11	5	20.73	0.00
U.S.-Neotropical migrant richness	357.34	**Combination2 (+organic farm type +rowcrop**, +hedgerow**, +spring grain*)**	344.05	6	0.00	0.94
		Combination1	348.46	7	6.87	0.03
		Global	335.61	12	7.56	0.02
		Practices	358.33	5	11.90	0.00
		Habitat	346.75	10	13.02	0.00
U.S.-Neotropical migrant abundance	538.68	**Combination2 (+hedgerow, +spring grain, +rowcrop*, +organic farm type**)**	525.38	6	0.00	0.77
		Practices (+organic farm type, -herbicide, +manure)	530.51	5	2.74	0.19
		Combination1	529.05	7	6.12	0.04
		Global	521.92	12	12.53	0.00
		Habitat	531.00	10	15.93	0.00
Ontario-USA-Mexico migrant richness	221.09	**Habitat (+hedgerow**, -habitat heterogeneity, -trees, -streams, +woods)**	205.34	7	0.00	0.83
		Global	204.45	9	4.26	0.10
		Practices	217.39	4	4.90	0.07
Ontario-USA-Mexico migrant abundance	372.86	**Habitat (+hedgerow**, +habitat heterogeneity, -trees, +streams, +woods)**	357.11	7	0.00	0.80
		Global (+hedgerow, +habitat heterogeneity, +streams, -trees, +woods, +organic farm type, -number passes)**	354.83	9	2.87	0.19
		Practices	373.16	4	8.89	0.01
Residents richness	246.57	**Habitat (+farmstead**, +hedgerow**, -habitat heterogeneity, -streams*, -trees**, +woods**, +rowcrop**)**	225.66	9	0.00	0.97
		Combination3	244.77	5	9.11	0.01
		Combination1	244.78	5	9.12	0.01
		Global	223.67	13	9.38	0.01
		Combination2	246.62	5	10.96	0.00

(con'd)

		Practices	252.49	6	19.21	0.00
Residents abundance	433.28	**Practices (+organic farm type, +number tills, + number passes, -herbicide)**	419.99	6	0.00	0.73
		Global (+farmstead **, +hedgerow*, -habitat heterogeneity, -streams, -trees, +woods*, + rowcrop, +organic farm type, +number tills, + rowcrop*, -herbicide)	404.30	13	3.29	0.14
		Combination2	427.73	5	5.36	0.05
		Combination1	428.02	5	5.65	0.04
		Combination3	428.70	5	6.33	0.03
		Habitat	421.27	9	8.89	0.01

Legend:
† Minimum AIC is the lowest AIC score. AIC= (-2∗log-likelihood)+(2∗K).
‡ Model – these are the candidate models representing habitat, farming practices, predation, and ‘Combination’ models which were combinations of habitat and farming practices. “+” and “-” indicate the direction of the variable, ** indicate $P < 0.05$, * indicates $0.05 \le P \le 0.1$.
§-2LL is -2∗log-likelihood
ǀK = the number of model parameters used to calculate AIC.
¶ ΔAIC is a model’s AIC minus the best model’s AIC.
# wi or Akaike weights are calculated as follows: w = exp(-0.5∗ ΔAIC). This is the same as taking the inverse natural logarithm of (-0.5∗ ΔAIC).
wi (Akaike weights) are the normalized relative model likelihoods and are calculated as follows:
wi = exp(-0.5∗ ΔAICi) / ΣRr = 1 exp(-0.5∗Δr), where R is the set of candidate models. Note that this first part of the expression matches what is described above. These normalized Akaike weights can be used to compare the relative importance of the models as discussed in the text.

Table 4. Rank of candidate models (ΔAIC < 4.0 in bold) used to evaluate abundance for individual bird species on organic and nonorganic farms in Ontario. Variables with significant effect size; ** indicate P < 0.05, * indicates 0.05 ≤ P ≤ 0.1. See Table 3 footnote for explanation of column headers.

Response	Minimum AIC	Model	-2LL	K	ΔAIC	Wi
American Crow (*Corvus brachyrhynchos*)	183.01	**Combination1 (+spring grain, +rowcrop, -trees, -field size, -number tills**, +number passes**)**	164.72	8	0.00	0.60
		Combination2 (+farmstead, -corridor, -habitat heterogeneity, +woods)	171.01	6	1.29	0.31
		Practice	163.57	10	4.17	0.07
		Habitat	158.37	13	7.64	0.01
		Global	146.05	21	23.52	0.00
American Robin (*Turdus migratorius*)	223.53	**Predation (+hedgerow, -fence*, +corridor)**	212.61	5	0.00	0.55
		Combination1 (+pasture, -fence*, +woods, -corridor)	211.97	6	1.74	0.23
		Combination3 (-organic farm type, +woods, + hedgerow, +rowcrop, +pasture)	210.25	7	2.48	0.16
		Combination2	214.86	6	4.64	0.05
		Practice	215.46	8	10.22	0.00
		Habitat	210.09	11	12.97	0.00
		Global	206.40	17	28.21	0.00
Bank Swallow (*Riparia riparia*)	81.51	**Habitat[1] (-hay, +pasture**, -habitat heterogeneity**, -corridor, -streams)**	65.76	7	0.00	0.46
		Combination1 (+pasture, +fence, -corridor, +trees, -streams)**	70.71	7	0.00	0.46
		Combination2[1] (-herbicide, -streams, +pasture, -habitat heterogeneity**, -hay)**	69.07	7	3.31	0.09
		Practice	87.68	6	14.51	0.00
		Global[1]	100.07	13	50.84	0.00
Barn Swallow (*Hirundo rustica*)	232.50	**Habitat (-hedgerow*, -hay, +pasture, +trees, + farmstead*, +fence**, +habitat heterogeneity, + streams, -woods, +rowcrop)**	203.21	12	0.00	0.55
		Combination1 (+pasture, -habitat heterogeneity, + streams, -organic farm type*, -manure)**	217.52	7	0.77	0.38
		Practice	218.40	8	4.18	0.07
		Global	196.14	18	12.55	0.00
Black-capped Chickadee (*Poecile atricapillus*)	69.84	**Combination1 (+hedgerow**, +trees**, +woods**)**	58.93	5	0.00	0.37
		Habitat (+farmstead, +hedgerow, -corridor, -trees**, +woods**)**	54.19	7	0.10	0.35

(con'd)

		Combination2 (-farmstead, +hedgerow, +habitat heterogeneity)**	61.12	5	2.19	0.12
		Predation (+hedgerow, -trees, -corridor)	61.13	5	2.20	0.12
		Practice	67.96	4	6.72	0.01
		Global	53.26	10	7.02	0.01
Blue Jay (*Cyanocitta cristata*)	112.85	**Combination2 (-farmstead, -corridor, +hedgerow**, + woods**)**	99.55	6	0.00	0.49
		Combination1 (+hedgerow, -trees, +woods**)**	101.95	5	0.01	0.48
		Habitat	95.39	10	6.15	0.02
		Practice	112.48	4	8.24	0.01
		Global	94.96	12	11.41	0.00
Bobolink (*Dolichonyx oryzivorus*)	256.67	**Habitat (+hedgerow**, +spring grain**, +hay**, + pasture*, +fence, +habitat heterogeneity**, -corridor**, +trees)**	233.06	10	0.00	0.62
		Global (+hedgerow, +spring grain**, +hay**, + pasture*, +fence, +habitat heterogeneity**, -corridor**, +trees, +farm type, +field, -herbicide, -fertilizer)**	222.82	14	1.52	0.29
		Combination1	249.81	5	4.05	0.08
		Combination2	253.24	6	9.86	0.01
		Practice	258.25	6	14.87	0.00
		Predator	279.90	6	22.23	0.00
Brown Thrasher (*Toxostoma rufum*)	95.22	**Combination1 (+hedgerow**, +pasture, +woods, -trees)**	81.93	6	0.00	0.56
		Practice (-organic farm type, -field size, -herbicide)	86.95	5	2.64	0.15
		Predation (+hedgerow, -fence, -corridor)	87.04	5	2.73	0.14
		Combination2 (-corridor, +hedgerow, -herbicide, + habitat heterogeneity)	84.91	6	2.98	0.13
		Habitat	79.00	10	7.39	0.01
		Global	76.65	14	16.80	0.00
Cedar Waxwing (*Bombycilla cedrorum*)	138.72	**Practice (+organic farm type)**	132.37	3	0.00	0.43
		Combination2 (+hedgerow*, -trees, +woods)	129.50	5	1.69	0.19
		Global (-farmstead, +hedgerow, -pasture, -fence, + corridor**, -trees +woods, +organic farm type)**	116.98	10	1.86	0.17
		Habitat (-farmstead, +hedgerow, -pasture, -fence, +corridor**, -trees, +woods)**	120.05	9	2.23	0.14
		Combination1 (+corridor, -trees, +woods)	131.33	5	3.52	0.07
Common Grackle (*Quiscalus quiscula*)	187.26	**Habitat (+farmstead*, -hedgerow, +hay**, + pasture**, -trees**, +fence, +woods**, +rowcrop**, + spring grain*)**	160.86	11	0.00	0.50
		Combination1 (+farmstead, -spring grain, +hay, + pasture*, +trees)**	171.86	7	0.35	0.42

(con'd)

		Practice (-biomass, -organic farm type, -number tills, -number passes, -herbicide*, -manure)**	175.13	7	3.62	0.08
		Global	155.79	16	10.42	0.00
		Combination2	193.57	5	17.21	0.00
		Combination3	218.82	5	42.46	0.00
Common Yellowthroat (*Geothlypis trichas*)	102.26	**Practice (-organic farm type*, -herbicide)**	93.67	4	0.00	0.58
		Predation (-hedgerow, -fence, -corridor*)	93.03	5	1.67	0.25
		Combination2 (-hedgerow, -streams, -herbicide)	95.10	5	3.75	0.09
		Combination1	98.62	4	4.96	0.05
		Global	83.13	11	7.27	0.02
		Habitat	89.83	9	8.47	0.01
Eastern Meadowlark (*Sturnella magna*)	163.62	**Predation (-hedgerow**, -woods, +fence, -corridor**)**	150.33	6	0.00	0.66
		Habitat (-hedgerow, -spring grain, -hay, -pasture, + fence, -corridor**)**	146.90	8	1.57	0.30
		Combination2	157.23	6	6.90	0.02
		Combination1	156.38	7	8.51	0.01
		Global	136.14	15	11.09	0.00
		Practice	160.39	8	15.05	0.00
European Starling (*Sturnus vulgaris*)	203.24	**Combination1 (+farmstead**, -spring grain, -hay*, -pasture)**	189.94	6	0.00	0.60
		Combination2 (-manure, +farmstead, -pasture)**	193.21	5	0.89	0.39
		Habitat	187.64	10	8.02	0.01
		Practice	204.59	6	14.64	0.00
		Global	180.98	15	16.32	0.00
Horned Lark (*Eremophila alpestris*)	365.86	**Global (+spring grain**, -pasture, -fence, +habitat heterogeneity**, +rowcrop**, +biomass, +field size**, +organic farm type, +number tills, +number passes**, -herbicide, -fertilizer)**	330.49	14	0.00	1.00
		Combination1	375.69	8	28.11	0.00
		Practice	377.48	9	32.52	0.00
		Habitat	391.17	7	41.06	0.00
		Combination2	392.26	7	42.15	0.00
		Combination3	442.20	5	87.24	0.00
		Predation	466.39	6	113.82	0.00
House Sparrow (*Passer domesticus*)	115.73	**Combination1 (+farmstead**, -hedgerow, -spring grain)**	104.82	5	0.00	0.63
		Combination2 (+farmstead, +pasture, -hedgerow)**	106.16	5	1.34	0.32

(con'd)

		Habitat	102.89	8	5.44	0.04
		Global	99.15	11	9.82	0.00
		Practice	129.35	5	24.53	0.00
Northern Flicker (*Colaptes auratus*)	93.94	**Practice (+organic farm type)**	87.59	3	0.00	0.59
		Predation (-hedgerow, -fence, -corridor)	85.46	5	2.43	0.17
		Combination2 (-herbicide, +woods, -pasture)	85.61	5	2.58	0.16
		Combination1	85.99	6	5.34	0.04
		Habitat	78.79	9	5.75	0.03
		Global	76.89	12	12.24	0.00
Red-winged Blackbird (*Agelaius phoeniceus*)	312.78	**Combination1 (-fence, +corridor**, +streams, -hay)**	299.48	6	0.00	0.64
		Habitat (+spring grain, +hedgerow, +hay*, -pasture, -fence, +corridor**, -streams, -trees, +woods, +rowcrop**)**	285.38	12	1.90	0.25
		Predation	306.44	5	4.57	0.07
		Global	283.19	14	5.78	0.04
		Practice	312.96	4	8.78	0.01
Rock Pigeon (*Columba livia*)	238.03	**Global (+farmstead**, +spring grain*, +habitat heterogeneity, +hedgerow**, -trees, +woods**, +rowcrop**, -organic farm type, +field size, -number tills, +number passes**, +herbicide, -fertilizer*)**	199.46	15	0.00	1.00
		Practice	240.29	7	18.01	0.00
		Combination1	249.59	6	24.85	0.00
		Predation	266.64	5	39.52	0.00
		Habitat	280.62	6	55.88	0.00
		Combination2	284.44	6	59.70	0.00
Song Sparrow (*Melospiza melodia*)	306.54	**Predation (+hedgerow**, +woods, +trees)**	295.63	5	0.00	0.51
		Combination2 (-herbicide, +hedgerow, +woods, -farmstead)**	294.65	6	1.41	0.25
		Combination1 (+hedgerow, +pasture, -fence, -corridor)**	294.85	6	1.60	0.23
		Habitat	293.01	9	7.37	0.01
		Practice	307.72	4	9.78	0.00
		Global	289.41	14	18.24	0.00
Tree Swallow (*Tachycineta bicolor*)	155.48	**Global (+farmstead**, +hay, -pasture, +fence, -habitat heterogeneity**, +corridor*, +trees, +streams**, -biodynamic, +organic farm type, +number tillages*, -herbicide, -manure**)**	116.90	15	0.00	0.99
		Habitat	143.62	9	9.05	0.01
		Combination1	155.39	7	15.67	0.00

(con'd)

		Combination2	159.85	7	20.13	0.00
		Practice	160.99	7	21.27	0.00
Vesper Sparrow (*Pooecetes gramineus*)	249.68	**Habitat (+spring grain, +hedgerow*, +hay, -pasture*, +fence, -corridor**,+rowcrop)**	228.78	9	0.00	0.60
		Predation (+hedgerow, -wood)**	242.98	4	1.89	0.23
		Combination2 (+hedgerow, -pasture**, -herbicide, -fertilizer)**	239.49	6	3.10	0.13
		Combination1	237.37	8	5.97	0.03
		Practice	240.81	8	9.41	0.01
		Global	218.35	17	14.00	0.00
Yellow Warbler (*Dendroica petechia*)	144.22	**Practice (-organic farm type**, -herbicide**)**	135.63	4	0.00	0.59
		Habitat (+hedgerow, +pasture, +corridor, -streams, -trees**, +woods**)**	127.87	8	1.93	0.23
		Global (+hedgerow, +pasture, +habitat heterogeneity, -corridor, -streams, -trees*, +woods, -organic farm type*, -herbicide*)**	120.99	11	3.17	0.12
		Combination2	138.21	5	4.90	0.05
		Predation	142.18	5	8.86	0.01
		Combination1	143.40	5	10.09	0.00

The habitat model had the lowest AIC of the best models for Ontario-USA-Mexico migrant richness and abundance and resident richness.

P4: Richness/abundance for the grassland, ground feeder, ground nester, and sallier guilds are best explained by predation

Predation models (Tables 3 and 4) were among the best for:

- Richness: secondary grassland birds, ground feeders, Neotropical migrants;
- Abundance of 8 of 12 species analyzed including American Robin (*Turdus migratorius*), Black-capped Chickadee, Brown Thrasher, Common Yellowthroat, Eastern Meadowlark, Northern Flicker, Song Sparrow (*Melospiza melodia*), and Vesper Sparrow.

The predation model had the lowest AIC of all the best models for richness of secondary grassland birds, ground feeders, and Neotropical migrants.

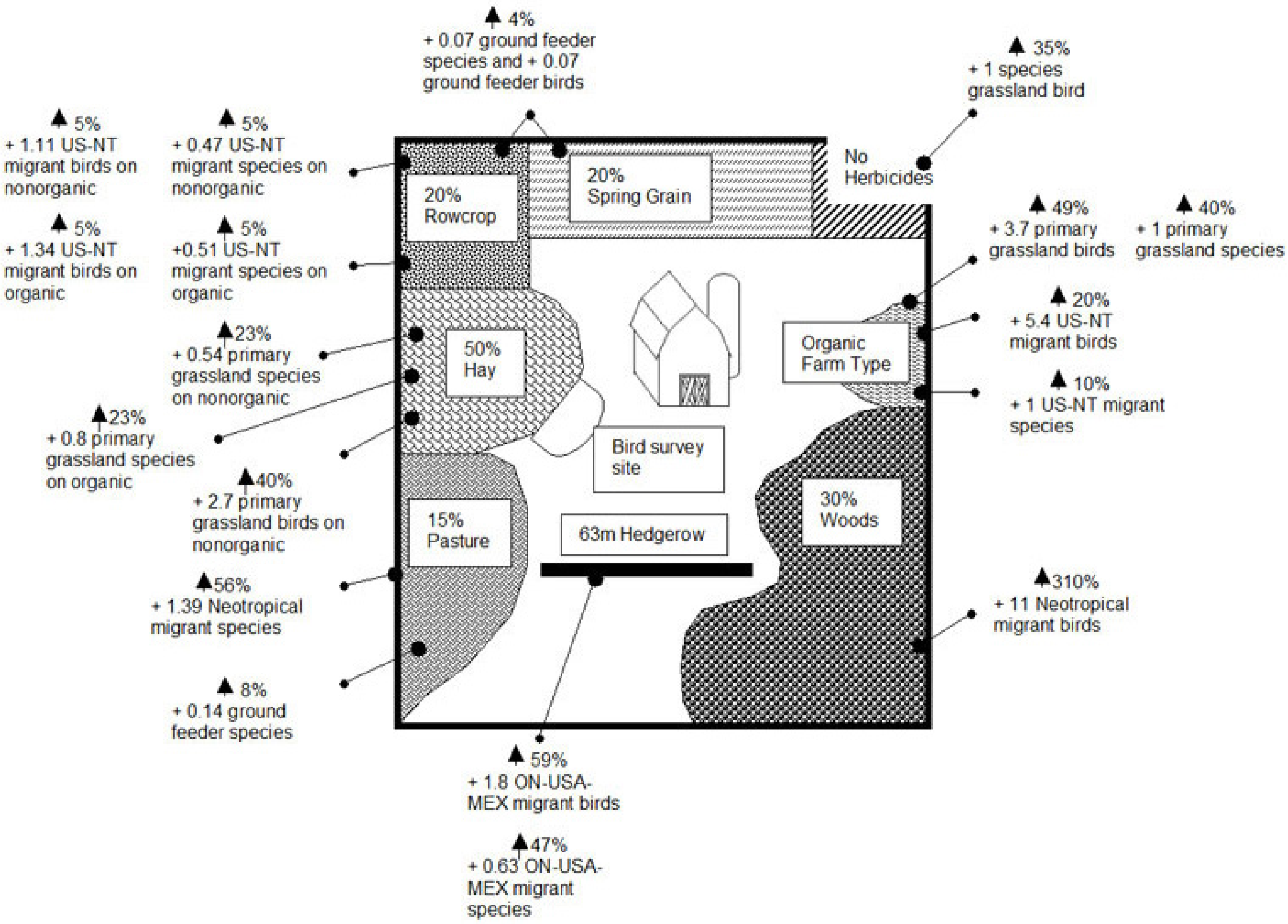
P5: Combination models (with habitat or a mix of habitat and practice variables) are better for explaining avian biodiversity

Combination models (Tables 3 and 4) were among the best for:

- Abundance: secondary grassland birds, ground feeders, ground nesters, U.S.-Neotropical migrants;
- Richness: overall;
- Abundance/richness - primary grassland birds, screeners, salliers, ground nesters, U.S.-Neotropical migrants;
- Abundance of 16 of 22 species analyzed.

Combination models had the lowest AIC of all best models for overall richness, richness of four of nine guilds, abundance of seven of nine guilds, and abundance of 6 of 22 species.

Fig. 3. Scenario model of effects of different landscape composition and farming practices on avian guilds. NT = Neotropical, ON = Ontario, MEX = Mexico.

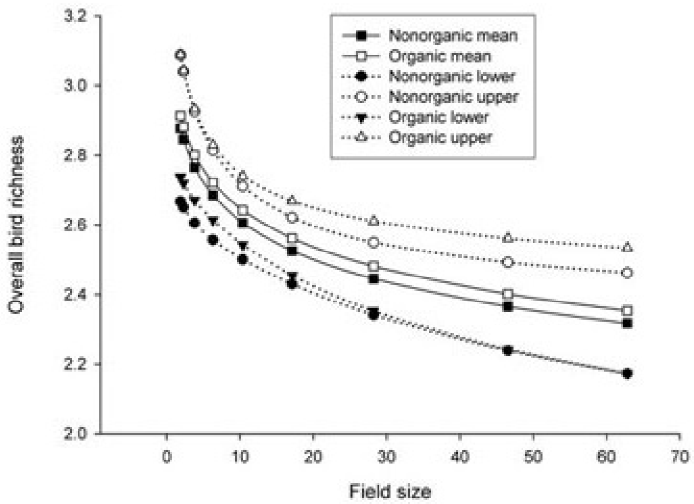


Assessing risk from changes in site conditions

Among practices, 5 of 10 variables were significant in the best models for richness or abundance of guilds (Table 3). Number of tills occurred most often (7 models out of 11 for guilds and 2 models out of 9 for species). The direction of the effect was mixed, being positive in five models (ground nester richness, abundance of ground feeders, ground nesters [2 models], and birds overall) and negative for sallier richness and abundance. For species (Table 4), it was positive for Tree Swallow (*Tachycineta bicolor*) and negative for American Crow (*Corvus brachyrhynchos*).

Herbicide use had a negative effect in 6 models out of 18 for guilds (richness of primary grassland birds, salliers and ground nesters; abundance of salliers, ground feeders, and ground nesters; Table 3). Two species (Common Grackle and Yellow Warbler) out of 20 showed a negative relationship with herbicide use (Table 4). Field size occurred in 4 models out of 14 for guilds (negative for ground feeder and overall richness and sallier abundance; positive for ground nester abundance; Table 3). Organic farm type occurred in 3 models out of 22 for guilds, being positive for richness and abundance of primary grassland birds and abundance of U.S.-Neotropical migrants (Table 3) but negative for 3 species out of

Fig. 4. Model predicting changes in overall bird richness with field size on organic and nonorganic farms (variable rowcrop was held constant, separate parameter estimates were done for each farm type). Field size unit is ha/ha. Solid line is the response with upper and lower 95% confidence limits shown as dotted lines for each farm type.

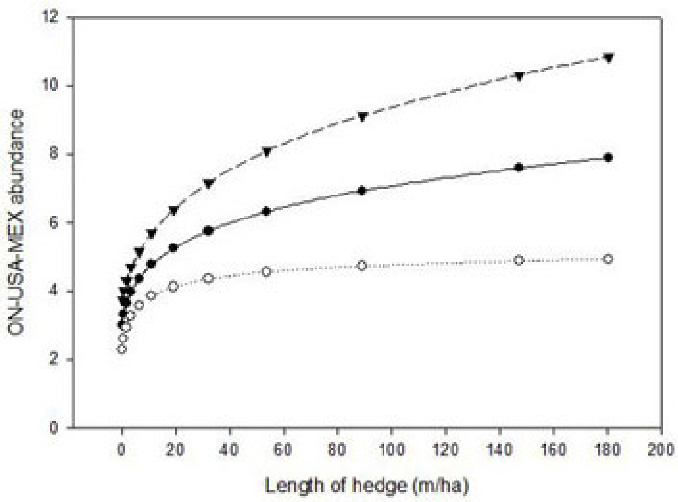


22, i.e., Barn Swallow, Common Yellowthroat, and Yellow Warbler (Table 4). Last, fertilizer use occurred in 1 model out of 13 for guilds (negative for sallier richness).

Among habitat, 9 of 13 variables were significant in the best models for richness or abundance (Table 3). Hedgerow and pasture occurred most often (6 models out of 20 for hedgerow and 6 out of 15 for pasture). Pasture was always positive for guilds (richness of salliers [2 models], ground feeders, and Neotropical migrants; abundance of screeners and secondary grassland birds; Table 3). It was significant for 5 species out of 20 showing a positive relationship with abundances of Bank Swallow, Bobolink, Common Grackle, and Yellow Warbler, and negative for Vesper Sparrow (Table 4). Hedgerow was positive in five models for guilds (richness and abundance of Ontario-USA-Mexico migrants; richness of U.S.-Neotropical migrants, residents, and overall richness), and negative for one (primary grassland bird abundance). It was also significant for 7 species out of 19; five were positive, Black-capped Chickadee, Bobolink, Cedar Waxwing, and Vesper Sparrow, and two, Barn Swallow and Eastern Meadowlark, negative.

Row crop occurred in 5 models out of 16 for guilds, and was always positive (richness and abundance of U.S.-Neotropical migrants; richness of ground feeders and residents and abundance of secondary grassland birds) and for Common Grackle and Red-winged Blackbird (2 out of 12 species). Spring grain and woods each occurred in four guild models (spring grain 13 models, woods 18 models). Woods was always positive in guild models (richness of ground feeders, residents and overall; sallier abundance) and for two species, Black-capped Chickadee and Common Grackle, out of 14. Spring grain was positive in three guild models (richness of ground feeders and U.S.-Neotropical migrants; abundance of secondary grassland birds) and 3 species, Bobolink, Common Grackle, and Red-winged Blackbird, out of 11, and negative in guild one model (screener abundance). Hay occurred in 3 models out of 13 for guilds, and was always positive (richness and abundance of primary grassland birds; abundance of Neotropical migrants); it had a positive effect on Bobolink, Common Grackle and Red-winged Blackbird (3 out of 11 models). Farmstead was positive and stream was negative for resident richness and Neotropical migrant abundance (farmstead 11 models, streams

Fig. 5. Model predicting changes in Ontario-USA migrant abundance at different length of hedgerow (variables for habitat heterogeneity, streams, trees, and woods were held constant). Middle line is response, with upper and lower 95% confidence intervals.



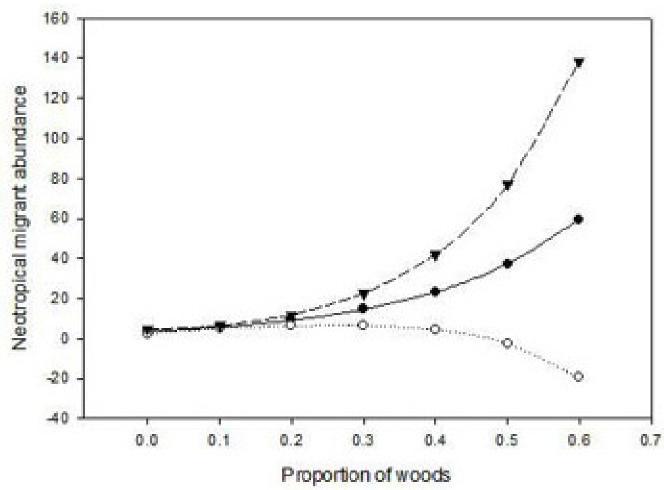
9 models); farmstead was also positive for Barn Swallow and Common Grackle (two of 14 models). Finally, trees were negative for resident richness (1 out of 17 models).

Figure 3 shows the full results for the predicted risk of differing farmland composition and farming practices on avian guilds. Based on a best combination model, herbicide use was predicted to result in the loss of one primary grassland species (a 35% decline from a mean of 3.44 ± 0.28 to 2.25 ± 0.35 per 6.3 ha site; Fig. 3). A change from nonorganic to organic farm type increased primary grassland bird abundance from 7.62 ± 0.56 to 11.35 ± 0.75 (49% increase) and richness from 2.58 ± 0.26 to 3.61 ± 0.32 (40% increase). Similarly, U.S.-Neotropical migrants increased in abundance with a switch to organic farming from 26.64 ± 1.47 to 32.02 ± 1.76 (20% increase) based on best models. Although the effects of field size were always negative, the result was significant for overall species richness; when field size increased from a proportion of 0.3 to 10, richness decreased from 2.88 ± 0.11 to 2.32 ± 0.07 on nonorganic farms and from 2.91 ± 0.09 to 2.35 ± 0.09 on organic farms (19% decrease in both cases; Fig. 4).

For noncrop habitat, the addition of 10 m/ha of hedgerow (i.e., 63 m per 6.3 ha) would increase both the abundance and richness of Ontario-USA-Mexico migrants by about 50% (from 3.01 ± 0.37 to 4.79 ± 0.46 and 1.33 ± 0.18 to 1.96 ± 0.18, respectively; see Fig. 5 for abundance). The abundance of this guild was predicted to reach a maximum of 7.89 birds or 2.98 species at 180 m/ha, of hedgerow but there was some evidence of a threshold or leveling out of effects after 50 m/ha (Fig. 5). When no woods were present, Neotropical migrant abundance was predicted at 3.54 ± 0.52 but when the proportion of woods was increased to 30% in the model it was tripled to 14.52 ± 4.02 (310% increase; Fig. 6). Similarly, Neotropical migrant species richness increased from 2.51 ± 0.23 when there was no pasture to 3.9 ± 0.51 when pasture increased to 15% of the area (or a 56% increase; Fig. 7).

For crop habitat on nonorganic farms, primary grassland bird richness was predicted to be 2.39 ± 0.27 when there was no hay, but it increased by 23% to 2.93 ± 0.32 when the proportion of hay was manipulated to 50% (Fig. 8). Abundance of primary grassland birds on nonorganic farms increased by 40% from 6.74 ± 0.55 with no hay to 9.40 ± 0.74

Fig. 6. Model predicting changes in Neotropical migrants with varying proportions of woodland (variables farmstead, hedge, hay, habitat heterogeneity, streams, and trees were held constant). Proportion of 6.3 ha. Middle line is response, with upper and lower 95% confidence intervals.



with 50% hay cover (Fig. 9). On organic farms, primary grassland bird richness was predicted to be 3.34 ± 0.32 with no hay but increased by 23% to 4.10 ± 0.44 when the proportion of hay was manipulated to 50% (Fig. 8).

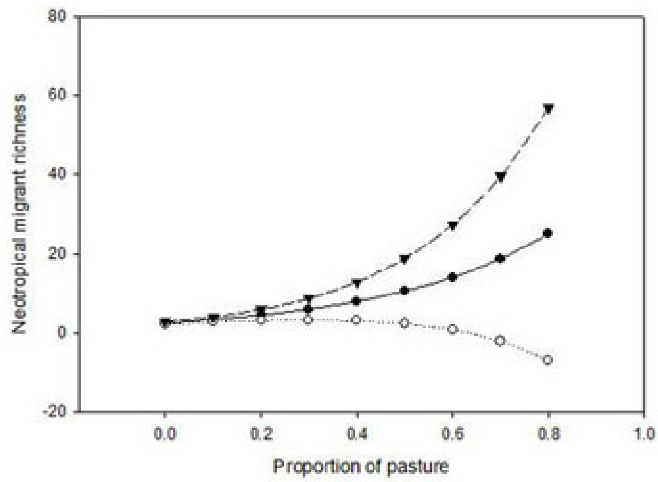
Relatively small changes were predicted on average from manipulating the area of spring grain or row crop from 0 to 20% in the landscape (Fig. 3). For example, species richness of ground feeders increased by about 4% (1.65 ± 0.46 to 1.72 ± 0.46) for both spring grain and row crop. Moreover, only small changes resulted for U.S.-Neotropical migrant abundance when row crop was increased from zero (organic 30.1 ± 1.84, nonorganic 25.04 ± 1.70) to 20% (organic 31.44 ± 1.74, nonorganic 26.15 ± 1.49), or a 5% increase for both. For U.S.-Neotropical migrant richness respective numbers were (organic 9.86 ± 0.61, nonorganic 8.95 ± 0.60) and (organic 10.37 ± 0.55, nonorganic 9.42 ± 0.53), or again a 5% increase for both. Note that in the above cases for spring grain and row crop, there could be no effect or the effect could be an order of magnitude larger because of the variability about the mean.

DISCUSSION

A recent meta-analysis demonstrated that in the vast majority of studies, organic farms have higher biodiversity than nonorganic farms (Hole et al. 2005). In the present study, overall bird abundance was significantly higher on organic than nonorganic farms. This is in spite of the bias introduced by doubling counts of singing males that were more likely to be unmated on nonorganic farms. The richness and abundance of primary grassland birds was also significantly higher on organic than nonorganic farms even though field size was larger on the latter farm type. For at least some grassland species, abundance has been found to increase with increasing grassland patch size (Davis 2004). Despite the current perception that small patch size has a negative effect on birds, except for a few species of crop specialists (Kreuzberg 2011), smaller row crop fields benefit more species than larger row crop fields and provide for more options in managing farmland heterogeneity for the conservation of biodiversity (Fahrig et al. 2011).

Richness of salliers and ground nesters, and abundance of ground feeders and U.S.-Neotropical migrants were also significantly higher on organic than nonorganic farms. With one exception, species

Fig. 7. Model predicting changes in Neotropical migrants with varying proportions of pasture (variables farmstead and manure were held constant). Proportion of 6.3 ha. Middle line is response, with upper and lower 95% confidence intervals.

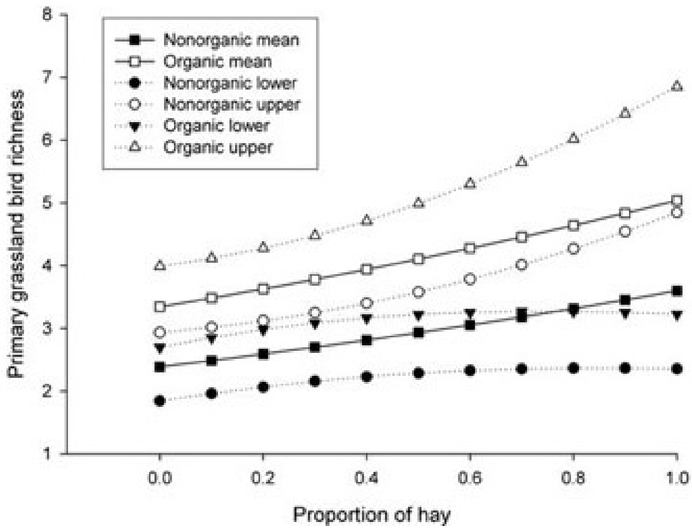


richness and abundance of guilds were all higher on organic than nonorganic farms although a few species, i.e., Barn Swallow, Common Yellowthroat, and Yellow Warbler, were found to have a negative relationship with organic farm type perhaps because nonorganic sites had significantly more riparian woodland, a habitat preferred by Common Yellowthroat and Yellow Warbler (Guzy and Ritchison 1999, Lowther et al. 1999). Barn Swallow abundance has been found to be strongly influenced by management practices on dairy farms (Møller 2001, Lubbe and de Snoo 2007), a factor not measured in our study. Based on our results, a switch to organic farming would particularly benefit primary grassland and birds that migrate to the neotropics, both guilds of current conservation concern (Rich et al. 2004).

The use of herbicides had a significantly negative effect on both bird species richness and abundance. To our knowledge, this field study is one of the first in North America to detect a negative correlation between herbicide use and avian diversity. Based on our results, herbicide use could decrease grassland bird species richness by 35% (or about 1 species equivalent) at a site. Other studies have suggested that herbicide use lowers habitat quality for birds, primarily through plant-mediated reductions in food supply (Wilson et al. 1999). Other agricultural practices had mixed effects on birds. Number of tillages was the most frequently significant variable in best models showing positive effects on birds feeding and nesting on the ground but negative effects on aerial insectivores. Increasing field size showed an adverse effect on species richness, overall and for ground feeders, perhaps through predation effects, as suggested by the best model for ground feeder richness. Visual inspection of data plots showed this effect irrespective of cover type, although it is important to point out that the range of field sizes was not large. In contrast to richness, increasing field size can have a positive effect on the abundance of at least some species, for example, in this study, ground nesters.

As expected, pasture and hay were important habitat for birds in farmland, especially grassland species. However, crops also largely had a positive effect on species richness and abundance indicating their importance as habitat for birds in farmland. Farmstead was also found to be an important habitat component for some guilds (residents, Neotropical migrants) and species known to use human structures, i.e., Barn Swallow, Common Grackle, European Starling (*Sturnus vulgaris*), and House Sparrow (*Passer domesticus*). As expected, noncrop habitats generally had positive effects on birds but not for all species, e.g., Barn Swallow,

Fig. 8. Model predicting changes in primary grassland bird richness with varying proportions of hay for organic and nonorganic farms (variables hedgerow, pasture, and woods were held constant). Proportion of 6.3 ha. Solid line is the response with upper and lower 95% confidence limits shown as dashed or dotted lines for each farm type.

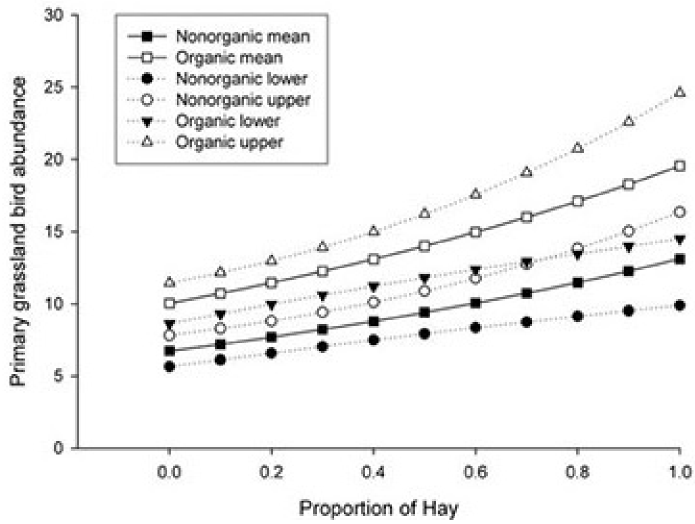


Eastern Meadowlark, Vesper Sparrow, with some evidence from best models that it may be related to predation as was found by Bergin et al. (2000) in Iowa and by Chalfoun et al. (2002) for Neotropical migrants in eastern North America. Although some of the species for which predation models were best are cavity nesters, e.g., Black-capped Chickadee and Northern Flicker, they are still vulnerable to predation through other behaviors such as foraging or defending their territory. Contrary to recent findings (Benton et al. 2003), habitat heterogeneity was not a significant variable in best models in this study, most likely because of the field scale at which it was measured.

Agricultural landscapes have the potential to play a more positive role in conservation of biodiversity, especially where competing, more disruptive land uses such as urbanization or industrial use are the alternative. Although some of the changes predicted by our modeling in relation to farming type or adoption of specific practices such as herbicide use may not be large at a single site, the effect has the potential to magnify when accumulated over large extents. Furthermore, predicted effect size may be conservative because the nonorganic farms we selected were not of the most intensively managed types. The current extent of organic farming in Canada is unlikely to have a marked positive effect on species at national or regional scales. However, it is possible that even a modest increase in organic farming, or other more ‘environmentally-friendly’ agricultural systems, could be of local, or possibly even regional significance for some bird populations, including some of current conservation concern (cf. Chamberlain et al. 1999). Recent research in the UK has shown that landscapes with 9-37% organic farming support more biodiversity than landscapes with 1-3% organic farming (Gabriel et al. 2010). In Ontario, organic farming acreage represented less than 1% of farmland in 1999 (Macey and Canadian Organic Growers 2010).

Conservation of common and rare bird species can be facilitated by integrating farming practices and agricultural land uses that have a positive effect on their abundance and richness (biodiversity). Integrating biodiversity concerns within farmland will help to maintain populations of common species, and possibly also preserve a few rare or endangered species with appropriate habitat conservation measures by farmers (Kerr and Deguise 2004), in addition to providing potential agronomic benefit through the provision of

Fig. 9. Model predicting changes in primary grassland bird abundance with varying proportions of hay for organic and nonorganic farms (variables hedgerow, pasture, woods were held constant). Proportion of 6.3 ha. Solid line is the response with upper and lower 95% confidence limits shown as dashed or dotted lines for each farm type.



ecosystem services such as insect pest control (Kirk et al. 1996). The main challenge continues to be finding appropriate compromises between human demands from agricultural lands and the requirements of native biota (Freemark 1995, 2005, Krebs et al. 1999, Peterjohn 2003). The results of this study emphasize that bird species richness and abundance in farmland are affected by a variety of factors associated with habitat patterns and disturbance imposed by agriculture. Although additional work is needed to determine relationships with productivity and survival, there is some evidence to suggest that density reflects habitat quality on different farm types (Fluetsch and Sparling 1994, Chamberlain et al. 1999). For the Eurasian Skylark, both density and measures of reproductive success, i.e., nestling weight, nestling survival rates, and clutch size, were higher on organic than nonorganic farmland (Wilson et al. 1997). Lokemoen and Beiser (1997) found that although the mean number of nesting bird species and mean nest densities were higher in organic and minimum-tillage fields than nonorganic fields, hatching success was low (0-18%) because of predation and agricultural activities, particularly tillage frequency, and could not be differentiated statistically among farm types.

In making recommendations for alternative farmland designs and farm management systems to enhance wildlife, it is important to clearly articulate conservation objectives that are regionally appropriate. Our models can be used to help assess the effects of different scenarios for abundance and species richness of different avian guilds in agricultural landscapes. In most cases, a key component will be reintroduction of farmland heterogeneity by protection and enhancement of important noncrop areas, smaller crop fields and possibly farms, and a greater mixture of crops, through rotation, intercropping, and regional diversification. Changes in farming practices, particularly conversion to organic farming and elimination of herbicides would further benefit farmland biodiversity including many species of conservation concern. A next step is to identify a set of farmland bird species, as is being done in Europe (Scholefield et al. 2009, EBCC 2011) to provide a barometer of environmental change and to evaluate potential effects of proposed or forecasted land use changes.

Responses to this article can be read online at:
http://www.ace-eco.org/vol6/iss1/art5/responses/

Acknowledgments:

We thank Cathy Rogers for assistance with fieldwork and data collection, and especially Myriam Csizy for compiling statistics, habitat mapping, and preliminary analyses. Recent versions were greatly improved by the comments of Nicky Koper, Tom Nudds, and two anonymous reviewers. We are indebted to the farm families for giving us perspective on their way of life.

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APPENDIX 1. Summary of primary food type, food location, nesting stratum, and non-breeding location for bird species observed at sites (n) on organic and nonorganic farms in southern Ontario, 1990. Abundance at sites given as mean and standard deviation (sd). See footnote for definitions of codes.

Common name[1,2]	Scientific name	Number of sites[3]	% of 72 sites	Mean	SD	Food Type[4]	Food Location[5]	Nesting Stratum[6]	Non-breeding Location[7]	Habitat[8]
Mallard	*Anas platyrhynchos*	2[c]	2.8	1	0.7	GR	GRD	GROUND	US-NT	WETLAND
American Bittern	*Botaurus lentiginosus*	1[c]	1.4	0.5	---	IN	FRSH	GROUND	US-NT	WETLAND
Turkey Vulture	*Cathartes aura*	1[o]	1.4	0.2	---	CA	GRD	NONE	US-NT	OTHER OPEN
Northern Harrier	*Circus cyaneus*	7	9.7	0.3	0.1	CA	GRD	GROUND	US-NT	PRIMARY GRASSLAND
Red-tailed Hawk[1]	*Buteo jamaicensis*	7	9.7	0.6	0.7	CA	GRD	ABOVE GRD	US-NT	SECONDARY GRASSLAND
American Kestrel	*Falco sparverius*	1[o]	1.4	0.5	---	IN	GRD	CAVITY	US-NT	PRIMARY GRASSLAND
Killdeer	*Charadrius vociferous*	46	63.9	1	0.8	IN	GRD	GROUND	US-NT	SECONDARY GRASSLAND
Spotted Sandpiper	*Actitis macularius*	3[c]	4.2	0.5	0	IN	GRD	GROUND	US-NT	WETLAND
Upland Sandpiper	*Bartramia longicauda*	6	8.3	0.6	0.2	IN	GRD	GROUND	NT	PRIMARY GRASSLAND
Common Snipe	*Gallinago gallinago*	6	8.3	0.5	0	VE	FRSH	GROUND	US-NT	WETLAND
Ring-billed Gull	*Larus delawarensis*	16	22.2	4.2	3.9	IN	GRD	GROUND	ON	WETLAND
Rock Pigeon	*Columba livia*	19	26.4	1.4	1.3	GR	GRD	OTHER	ON	URBAN/SUBURB

(con'd)

Mourning Dove[1]	*Zenaida macroura*	20	27.8	0.9	0.8	GR	GRD	ABOVE GRD	US-NT	URBAN/SUBURB
Yellow-billed Cuckoo	*Coccyzus americanus*	1[c]	1.4	0.5	---	IN	LOCA	ABOVE GRD	NT	WOODLAND
Black-billed Cuckoo	*Coccyzus erythropthalmus*	1[c]	1.4	0.5	---	IN	LOCA	ABOVE GRD	NT	WOODLAND
Chimney Swift	*Chaetura pelagica*	2[o]	2.8	0.2	---	IN	AIR (Screener)	OTHER	NT	URBAN/SUBURB
Downy Woodpecker	*Picoides pubescens*	2[c]	2.8	0.2	0	IN	BARK	CAVITY	ON	WOODLAND
Northern Flicker	*Colaptes auratus*	11	15.3	0.4	0.2	IN	GRD	CAVITY	US-NT	WOODLAND
Eastern Wood-Pewee[2]	*Contopus virens*	8	11.1	0.5	0.2	IN	AIR (Sallier)	ABOVE GRD	NT	WOODLAND
Alder Flycatcher	*Empidonax alnorum*	2[o]	2.8	0.5	0	IN	AIR (Sallier)	ABOVE GRD	NT	SCRUB/EARLY SUCCESSIONAL
Least Flycatcher	*Empidonax minimus*	1[o]	1.4	0.5	---	IN	AIR (Sallier)	ABOVE GRD	NT	WOODLAND
Eastern Phoebe	*Sayornis phoebe*	1[c]	1.4	0.5	---	IN	AIR (Sallier)	OTHER	ON-US-MEX	OTHER OPEN
Great-crested Flycatcher[1]	*Myiarchus crinitus*	5	6.9	0.5	0	IN	AIR (Sallier)	CAVITY	NT	WOODLAND
Eastern Kingbird[1]	*Tyrannus tyrannus*	22	30.6	0.5	0.2	IN	AIR (Sallier)	ABOVE GRD	NT	PRIMARY GRASSLAND
Warbling Vireo	*Vireo gilvus*	4	5.6	0.5	0	IN	UPCA	ABOVE GRD	NT	WOODLAND
Red-eyed Vireo[1]	*Vireo olivaceus*	5	6.9	0.4	0.1	IN	UPCA	ABOVE GRD	NT	WOODLAND

(con'd)

Blue Jay	*Cyanocitta cristata*	21	29.2	0.5	0.3	OM	GRD	ABOVE GRD	ON	URBAN/SUBURB
American Crow	*Corvus brachyrhynchos*	37	51.4	0.5	0.3	OM	GRD	ABOVE GRD	ON	URBAN/SUBURB
Horned Lark	*Eremophila alpestris*	42	58.3	2.4	3.7	OM	GRD	GROUND	US-NT	SECONDARY GRASSLAND
Tree Swallow	*Tachycineta bicolor*	22	30.6	0.7	0.9	IN	AIR (Screener)	CAVITY	US-NT	WETLAND
Bank Swallow	*Riparia riparia*	8	11.1	1.3	1.2	IN	AIR (Screener)	OTHER	NT	SECONDARY GRASSLAND
Cliff Swallow	*Petrochelidon pyrrhonota*	4	5.6	0.3	0.1	IN	AIR (Screener)	OTHER	NT	SECONDARY GRASSLAND
Barn Swallow	*Hirundo rustica*	42	58.3	0.8	0.8	IN	AIR (Screener)	OTHER	NT	SECONDARY GRASSLAND
Black-capped Chickadee	*Poecile atricapillus*	8	11.1	0.6	0.4	IN	LOCA	CAVITY	ON	WOODLAND
White-breasted Nuthatch	*Sitta carolinensis*	2[o]	2.8	0.4	0.2	IN	BARK	CAVITY	ON	WOODLAND
House Wren	*Troglodytes aedon*	3	4.2	0.8	0.3	IN	LOCA	CAVITY	ON-US-MEX	SCRUB/EARLY SUCCESSIONAL
Wood Thrush	*Hylocichla mustelina*	3	4.2	0.5	0	OM	GRD	ABOVE GRD	NT	WOODLAND
American Robin	*Turdus migratorius*	52	72.2	0.8	0.5	OM	LOCA	ABOVE GRD	US-NT	URBAN/SUBURB
Gray Catbird	*Dumetella carolinensis*	1[c]	1.4	0.5	---	OM	GRD	ABOVE GRD	US-NT	SCRUB/EARLY SUCCESSIONAL
Brown Thrasher	*Toxostoma rufum*	10	13.9	0.6	0.2	OM	GRD	ABOVE GRD	ON-US-MEX	SECONDARY GRASSLAND

(con'd)

European Starling	*Sturnus vulgaris*	34	47.2	0.7	0.6	OM	GRD	CAVITY	ON	URBAN/SUBURB
American Pipit	*Anthus rubescens*	1[o]	1.4	0.8	---	IN	GRD	N/A	US-NT	OTHER OPEN?
Cedar Waxwing	*Bombycilla cedrorum*	10	13.9	0.7	0.5	IN	AIR	ABOVE GRD	US-NT	WOODLAND
Yellow Warbler	*Dendroica petechia*	18	25	0.6	0.2	IN	LOCA	ABOVE GRD	NT	WOODLAND
Chestnut-sided Warbler	*Dendroica pensylvanica*	2	2.8	0.5	0	IN	LOCA	ABOVE GRD	NT	WOODLAND
Black-and-white Warbler[1]	*Mniotilta varia*	4	5.6	0.5	0	IN	BARK	GROUND	US-NT	WOODLAND
Ovenbird	*Seiurus aurocapilla*	2	2.8	0.5	0	MO	GRD	GROUND	US-NT	WOODLAND
Mourning Warbler	*Oporornis philadelphia*	2	2.8	0.8	0.4	IN	GRD	GROUND	NT	SCRUB/EARLY SUCCESSIONAL
Common Yellowthroat	*Geothlypis trichas*	10	13.9	0.7	0.4	IN	LOCA	ABOVE GRD	US-NT	SECONDARY
Chipping Sparrow	*Spizella passerina*	5	6.9	1.4	1	OM	GRD	ABOVE GRD	US-NT	URBAN/SUBURB
Vesper Sparrow	*Pooecetes gramineus*	53	73.6	1.1	0.7	OM	GRD	GROUND	US-NT	PRIMARY GRASSLAND
Savannah Sparrow	*Passerculus sandwichensis*	70	97.2	3.3	2.2	OM	GRD	GROUND	US-NT	PRIMARY GRASSLAND
Song Sparrow	*Melospiza melodia*	57	79.2	1.7	1	OM	LOCA	GROUND	ON-US-MEX	SCRUB/EARLY SUCCESSIONAL
White-throated Sparrow	*Zonotrichia albicollis*	3[o]	4.2	0.4	0.1	OM	GRD	GROUND	US-NT	SCRUB/EARLY SUCCESSIONAL

(con'd)

White-crowned Sparrow[2]	*Zonotrichia leucophrys*	7	9.7	0.4	0.3	OM	GRD	N/A	US-NT	SCRUB/EARLY SUCCESSIONAL
Lapland Longspur	*Calcarius lapponicus*	1[o]	1.4	0.5	---	OM	GRD	N/A	ON-US-MEX	
Scarlet Tanager	*Piranga olivacea*	1[c]	1.4	0.2	---	IN	UPCA	ABOVE GRD	NT	WOODLAND
Northern Cardinal	*Cardinalis cardinalis*	2[c]	2.8	0.5	0	OM	GRD	ABOVE GRD	ON	SCRUB/EARLY SUCCESSIONAL
Rose-breasted Grosbeak[1]	*Pheucticus ludovicianus*	4	5.6	0.6	0.3	OM	UPCA	ABOVE GRD	NT	WOODLAND
Indigo Bunting[2]	*Passerina cyanea*	5	6.9	0.6	0.2	OM	LOCA	ABOVE GRD	NT	SCRUB/EARLY SUCCESSIONAL
Bobolink	*Dolichonyx oryzivorus*	40	55.6	1.6	1.4	OM	GRD	GROUND	NT	PRIMARY GRASSLAND
Red-winged Blackbird	*Agelaius phoeniceus*	57	79.2	1.9	1.4	OM	GRD	OTHER	US-NT	SECONDARY GRASSLAND
Eastern Meadowlark	*Sturnella magna*	24	33.3	1	0.7	IN	GRD	GROUND	US-NT	PRIMARY GRASSLAND
Common Grackle	*Quiscalus quiscula*	25	34.7	0.8	1.2	OM	GRD	ABOVE GRD	ON-US-MEX	URBAN/SUBURB
Brown-headed Cowbird[1]	*Molothrus ater*	50	69.4	1.1	0.8	OM	GRD	NONE	US-NT	OTHER OPEN
Baltimore Oriole	*Icterus galbula*	13	18.1	0.6	0.3	OM	UPCA	ABOVE GRD	NT	WOODLAND
American Goldfinch	*Spinus tristis*	31	43.1	0.6	0.4	OM	LOCA	ABOVE GRD	ON-US-MEX	SECONDARY GRASSLAND
House Sparrow	*Passer domesticus*	21	29.2	1	1.2	GR	GRD	OTHER	ON	URBAN/SUBURB

[1] Species significantly more abundant on organic than nonorganic sites (Freemark and Kirk 2001).
[2] Species significantly more abundant on nonorganic than organic sites (Freemark and Kirk 2001).

[3] Species only observed on organic (o) or nonorganic (c) sites.
[4] Food Type: CA = Carnivore; GR = Granivore; IN = Insectivore; MO = Molluscivore; OM = Omnivore; VE = Vermivore.
[5] Food Location: FRSH = Fresh water shoreline; GRD = Ground; LOCA = Lower canopy; UPCA = Upper canopy.
[6] Nesting Stratum: ABOVE GRD = Tree/Shrub Nesters; OTHER = Man-made Structures or other nonagricultural habitat; N/A = Not local breeder,
[7] Nonbreeding Location: NT = Neotropics (Central and/or South America); US-NT = USA and Neotropics; ON-US-MEX = Ontario, USA and Mexico; ON = Ontario.
[8] Habitat was from the North American Breeding Bird Survey (Collins and Downes 2009) and for primary and secondary grassland birds from the 'Action plan for the grassland bird guild in southern Ontario' (Ken Tuininga, Canadian Wildlife Service, *personal communication*).

Appendix 2. Candidate models for guilds and individual bird species on Ontario organic and nonorganic farms (note that models for the following species did not converge: American Goldfinch, American Kestrel, Brown-headed Cowbird, Eastern Kingbird, Killdeer, Mourning Dove, Northern Harrier, Ring-billed Gull, Savannah Sparrow).

Primary grassland birds

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW	X		X		X	
SPRING GRAIN	X					X
WINTER GRAIN						
HAY	X	X			X	
PASTURE	X	X			X	
FENCE						
HABITAT HETEROGENEITY	X	X				
CORRIDOR						
STREAMS						
TREES	X		X			
WOODS	X		X		X	
ROWCROP	X					X
BIOMASS						
BIODYNAMIC	X			X		
ORGANIC	X			X	X	
NONORGANIC						
FIELD	X			X		X
NUMBER TILLS						
NUMBER PASSES						
HERBICIDE	X			X		X
FERTILIZER	X			X		
MANURE	X			X		

Secondary grassland birds

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW	X	X	X		X	
SPRING GRAIN	X	X				X
WINTER GRAIN						
HAY	X	X			X	
PASTURE	X	X			X	X
FENCE	X	X				
HABITAT HETEROGENEITY	X				X	
CORRIDOR						
STREAMS						
TREES	X		X			
WOODS	X	X	X		X	
ROWCROP	X	X				X
BIOMASS						
BIODYNAMIC	X			X		
ORGANIC	X			X		
NONORGANIC						
FIELD	X			X		X
NUMBER TILLS						
NUMBER PASSES						
HERBICIDE	X			X		X
FERTILIZER	X			X		
MANURE	X			X		

Sallier aerial insectivores

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW	X	X	X		X	

SPRING GRAIN						
WINTER GRAIN						
HAY	X	X				X
PASTURE	X	X			X	X
FENCE	X	X				X
HABITAT HETEROGENEITY	X	X			X	
CORRIDOR	X	X				X
STREAMS						
TREES	X		X			X
WOODS	X	X	X		X	
ROWCROP						
BIOMASS						
BIODYNAMIC	X			X		
ORGANIC	X			X	X	
NONORGANIC						
FIELD	X			X		
NUMBER TILLS	X			X		
NUMBER PASSES						
HERBICIDE	X			X	X	
FERTILIZER	X			X		X
MANURE	X			X		

Screener aerial insectivores

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW						
SPRING GRAIN	X	X				X
WINTER GRAIN						
HAY	X	X			X	
PASTURE	X	X			X	
FENCE						
HABITAT HETEROGENEITY	X	X			X	
CORRIDOR	X	X			X	X
STREAMS	X	X			X	
TREES						
WOODS						
ROWCROP	X	X				X
BIOMASS	X			X		
BIODYNAMIC	X			X		
ORGANIC	X			X	X	
NONORGANIC						
FIELD						
NUMBER TILLS	X			X		
NUMBER PASSES						
HERBICIDE	X			X		X
FERTILIZER	X			X		X
MANURE	X			X	X	

Ground feeders

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X	X				
HEDGEROW	X	X	X		X	
SPRING GRAIN	X	X			X	
WINTER GRAIN						
HAY						
PASTURE	X	X				X
FENCE						
HABITAT HETEROGENEITY	X	X				
CORRIDOR	X	X				
STREAMS						
TREES	X	X				
WOODS	X	X	X			

ROWCROP	X	X			X		
BIOMASS	X			X			
BIODYNAMI							
ORGANIC	X			X			
NONORGANIC							
FIELD	X		X	X			
NUMBER TILLS	X			X	X	X	
NUMBER PASSES							
HERBICIDE	X			X		X	
FERTILIZER	X			X			
MANURE	X			X	X		

Ground nesters

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD	X	X					
HEDGEROW	X	X	X		X		
SPRING GRAIN	X	X			X		
WINTER GRAIN							
HAY							
PASTURE	X	X				X	
FENCE							
HABITAT HETEROGENEITY	X	X					
CORRIDOR	X	X					
STREAMS							
TREES	X	X					
WOODS	X	X	X				
ROWCROP	X	X			X		
BIOMASS	X			X			
BIODYNAMIC							
ORGANIC	X			X			
NONORGANIC							
FIELD	X		X	X			
NUMBER TILLS	X			X	X	X	
NUMBER PASSES							
HERBICIDE	X			X		X	
FERTILIZER	X			X			
MANURE	X			X	X		

Neotropical migrants

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD	X	X	X				
HEDGEROW	X	X			X	X	
SPRING GRAIN							
WINTER GRAIN							
HAY	X	X				X	
PASTURE			X				
FENCE							
HABITAT HETEROGENEITY	X	X			X		
CORRIDOR							
STREAMS	X	X					
TREES	X	X					
WOODS	X	X			X		
ROWCROP							
BIOMASS							
BIODYNAMIC							
ORGANIC	X			X			
NONORGANIC							
FIELD	X					X	
NUMBER TILLS							
NUMBER PASSES							
HERBICIDE							
FERTILIZER							

MANURE			X				

Ontario-USA-Mexico migrants

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD							
HEDGEROW	X	X					
SPRING GRAIN							
WINTER GRAIN							
HAY							
PASTURE							
FENCE							
HABITAT HETEROGENEITY	X	X					
CORRIDOR							
STREAMS	X	X					
TREES	X	X					
WOODS	X	X					
ROWCROP							
BIOMASS							
BIODYNAMIC							
ORGANIC	X			X			
NONORGANIC							
FIELD							
NUMBER TILLS							
NUMBER PASSES	X			X			
HERBICIDE							
FERTILIZER							
MANURE							

US-Neotropical migrants

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD	X	X					
HEDGEROW	X	X			X	X	
SPRING GRAIN	X	X				X	
WINTER GRAIN							
HAY	X	X			X		
PASTURE	X	X			X		
FENCE	X	X					
HABITAT HETEROGENEITY	X	X			X		
CORRIDOR	X	X					
STREAMS							
TREES							
WOODS							
ROWCROP	X					X	
BIOMASS							
BIODYNAMIC							
ORGANIC	X			X		X	
NONORGANIC							
FIELD							
NUMBER TILLS							
NUMBER PASSES							
HERBICIDE	X			X	X		
FERTILIZER							
MANURE	X			X			

Residents

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD	X	X			X	X	
HEDGEROW	X	X					X
SPRING GRAIN							
WINTER GRAIN							
HAY							
PASTURE							

FENCE							
HABITAT HETEROGENEITY	X	X				X	
CORRIDOR							X
STREAMS	X	X					X
TREES	X	X					
WOODS	X	X			X		
ROWCROP	X	X					
BIOMASS							
BIODYNAMIC							
ORGANIC	X			X	X		
NONORGANIC							
FIELD							
NUMBER TILLS	X			X			
NUMBER PASSES	X			X			
HERBICIDE	X			X		X	
FERTILIZER							
MANURE							

Overall abundance

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD	X	X					
HEDGEROW	X	X	X				
SPRING GRAIN	X	X					
WINTER GRAIN							
HAY	X	X					
PASTURE	X	X					
FENCE	X	X					
HABITAT HETEROGENEITY	X	X			X		
CORRIDOR	X	X					
STREAMS	X	X					
TREES	X	X					
WOODS	X	X				X	
ROWCROP	X	X				X	
BIOMASS	X			X			
BIODYNAMIC							
ORGANIC	X			X			
NONORGANIC							
FIELD	X		X	X			
NUMBER TILLS	X			X	X	X	
NUMBER PASSES	X			X			
HERBICIDE	X			X	X	X	
FERTILIZER	X			X	X		
MANURE	X			X			

Overall richness

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD							
HEDGEROW	X	X			X		
SPRING GRAIN							
WINTER GRAIN							
HAY							
PASTURE							
FENCE							
HABITAT HETEROGENEITY	X	X			X		
CORRIDOR							
STREAMS							
TREES							
WOODS	X	X					
ROWCROP	X	X				X	
BIOMASS							
BIODYNAMIC							
ORGANIC	X			X	X	X	

NONORGANIC						
FIELD	X			X		X
NUMBER TILLS						
NUMBER PASSES	X			X		
HERBICIDE	X			X		
FERTILIZER						
MANURE	X			X		

American Crow

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X	X				X
HEDGEROW	X	X				
SPRING GRAIN	X	X			X	
WINTER GRAIN						
HAY	X	X				
PASTURE	X	X				
FENCE	X	X				
HABITAT HETEROGENEITY	X	X				X
CORRIDOR	X	X				X
STREAMS						
TREES	X	X			X	
WOODS	X	X				X
ROWCROP	X	X			X	
BIOMASS	X			X		
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD	X			X	X	
NUMBER TILLS	X			X	X	
NUMBER PASSES	X			X	X	
HERBICIDE	X			X		
FERTILIZER	X			X		
MANURE	X			X		

American Goldfinch

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X	X				
HEDGEROW	X	X			X	
SPRING GRAIN						
WINTER GRAIN						
HAY						
PASTURE	X	X				
FENCE	X	X			X	
HABITAT HETEROGENEITY	X	X				
CORRIDOR	X	X			X	
STREAMS	X	X				
TREES	X	X				
WOODS	X	X			X	
ROWCROP						
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD						
NUMBER TILLS						
NUMBER PASSES						
HERBICIDE	X			X		
FERTILIZER						
MANURE						

American Kestrel

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3

FARMSTEAD	X	X					
HEDGEROW	X	X					
SPRING GRAIN	X	X					
WINTER GRAIN							
HAY	X	X					X
PASTURE	X	X			X	X	
FENCE	X	X					
HABITAT HETEROGENEITY	X	X					X
CORRIDOR							
STREAMS							
TREES	X		X		X	X	
WOODS	X	X	X				X
ROWCROP	X	X			X		
BIOMASS	X			X			
BIODYNAMIC							
ORGANIC	X			X		X	
NONORGANIC							
FIELD	X			X		X	
NUMBER TILLS	X			X			
NUMBER PASSES	X				X		
HERBICIDE	X			X			
FERTILIZER							
MANURE							

American Robin

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD	X	X	X			X	
HEDGEROW	X	X					X
SPRING GRAIN							
WINTER GRAIN							
HAY	X	X					
PASTURE	X	X			X		X
FENCE	X	X	X		X		
HABITAT HETEROGENEITY	X	X					
CORRIDOR	X	X	X		X		
STREAMS							
TREES	X	X					
WOODS	X	X			X		X
ROWCROP	X					X	X
BIOMASS							
BIODYNAMIC							
ORGANIC	X			X			X
NONORGANIC							
FIELD	X			X			
NUMBER TILLS	X			X			
NUMBER PASSES	X			X			
HERBICIDE	X			X		X	
FERTILIZER	X				X		
MANURE							

Barn Swallow

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD	X	X					
HEDGEROW	X	X					
SPRING GRAIN							
WINTER GRAIN							
HAY	X	X					
PASTURE	X	X			X		
FENCE	X	X					
HABITAT HETEROGENEITY	X	X			X		
CORRIDOR							
STREAMS	X	X			X		

TREES	X	X				
WOODS	X	X				
ROWCROP	X	X				
BIOMASS	X			X		
BIODYNAMIC	X			X		
ORGANIC	X			X	X	
NONORGANIC						
FIELD	X			X		
NUMBER TILLS						
NUMBER PASSES						
HERBICIDE	X			X		
FERTILIZER						
MANURE	X			X	X	

Bank Swallow

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW						
SPRING GRAIN						
WINTER GRAIN						
HAY	X	X				X
PASTURE	X	X			X	X
FENCE					X	
HABITAT HETEROGENEITY	X	X				X
CORRIDOR	X	X			X	
STREAMS	X	X			X	X
TREES					X	
WOODS						
ROWCROP						
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD						
NUMBER TILLS	X			X		
NUMBER PASSES						
HERBICIDE	X			X		X
FERTILIZER						
MANURE	X			X		

Black-capped Chickadee

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X	X				X
HEDGEROW	X	X	X		X	X
SPRING GRAIN						
WINTER GRAIN						
HAY						
PASTURE						
FENCE						
HABITAT HETEROGENEITY						X
CORRIDOR	X	X	X			
STREAMS						
TREES	X	X	X		X	
WOODS	X	X			X	
ROWCROP						
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD						
NUMBER TILLS						
NUMBER PASSES						

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
HERBICIDE	X			X		
FERTILIZER						
MANURE						

Blue Jay

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X	X				X
HEDGEROW	X	X			X	X
SPRING GRAIN						
WINTER GRAIN						
HAY						
PASTURE	X	X				
FENCE						
HABITAT HETEROGENEITY	X	X				
CORRIDOR	X	X				X
STREAMS						
TREES	X	X			X	
WOODS	X	X			X	X
ROWCROP	X	X				
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD						
NUMBER TILLS						
NUMBER PASSES						
HERBICIDE	X			X		
FERTILIZER						
MANURE						

Bobolink

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD							
HEDGEROW	X	X	X				
SPRING GRAIN	X	X					
WINTER GRAIN							
HAY	X	X			X	X	
PASTURE	X	X			X		X
FENCE	X	X	X		X	X	
HABITAT HETEROGENEITY	X	X					
CORRIDOR	X	X	X				
STREAMS							
TREES	X	X	X				
WOODS							
ROWCROP							
BIOMASS							
BIODYNAMIC							
ORGANIC	X			X			
NONORGANIC							
FIELD	X			X			X
NUMBER TILLS							
NUMBER PASSES							
HERBICIDE	X			X		X	
FERTILIZER	X			X			
MANURE							

Brown-headed Cowbird

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD	X	X					X
HEDGEROW	X	X			X		
SPRING GRAIN							
WINTER GRAIN							

HAY	X	X			X		X
PASTURE	X	X			X	X	
FENCE	X	X			X	X	
HABITAT HETEROGENEITY	X	X					
CORRIDOR	X	X			X		X
STREAMS	X	X			X		
TREES	X				X		X
WOODS	X	X					
ROWCROP	X	X					
BIOMASS	X			X			
BIODYNAMIC							
ORGANIC	X			X		X	
NONORGANIC							
FIELD							
NUMBER TILLS							
NUMBER PASSES							
HERBICIDE	X			X			
FERTILIZER							
MANURE	X			X		X	

Brown Thrasher

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X	X				
HEDGEROW	X	X	X		X	X
SPRING GRAIN						
WINTER GRAIN						
HAY						
PASTURE	X	X			X	
FENCE	X		X			
HABITAT HETEROGENEITY	X	X			X	X
CORRIDOR	X	X	X			X
STREAMS	X	X				
TREES	X	X			X	
WOODS	X	X			X	
ROWCROP						
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD	X			X		
NUMBER TILLS						
NUMBER PASSES						
HERBICIDE	X			X		X
FERTILIZER						
MANURE						

Cedar Waxwing

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X	X				
HEDGEROW	X	X				X
SPRING GRAIN						
WINTER GRAIN						
HAY						
PASTURE	X	X				
FENCE	X	X				
HABITAT HETEROGENEITY						
CORRIDOR	X	X			X	
STREAMS						
TREES	X	X			X	X
WOODS	X	X			X	X
ROWCROP						
BIOMASS						

BIODYNAMIC				
ORGANIC	X			X
NONORGANIC				
FIELD				
NUMBER TILLS				
NUMBER PASSES				
HERBICIDE				
FERTILIZER				
MANURE				

Common Grackle

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD	X	X			X	X	
HEDGEROW	X	X					X
SPRING GRAIN	X	X			X		
WINTER GRAIN							
HAY	X	X			X		
PASTURE	X	X			X		
FENCE	X	X					
HABITAT HETEROGENEITY							X
CORRIDOR							
STREAMS							
TREES	X	X			X		
WOODS	X	X					X
ROWCROP	X	X				X	
BIOMASS	X			X			
BIODYNAMIC							
ORGANIC	X			X			
NONORGANIC							
FIELD							
NUMBER TILLS	X			X		X	
NUMBER PASSES	X			X			
HERBICIDE	X			X			
FERTILIZER							
MANURE	X			X			

Common Yellowthroat

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW	X	X	X		X	X
SPRING GRAIN						
WINTER GRAIN						
HAY						
PASTURE	X					
FENCE	X	X	X			
HABITAT HETEROGENEITY	X	X				
CORRIDOR	X	X	X			
STREAMS	X	X			X	X
TREES						
WOODS	X	X				
ROWCROP						
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD						
NUMBER TILLS						
NUMBER PASSES						
HERBICIDE	X			X	X	X
FERTILIZER						
MANURE						

Eastern Kingbird

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW	X	X	X			X
SPRING GRAIN						
WINTER GRAIN						
HAY	X	X			X	
PASTURE	X	X			X	
FENCE	X	X			X	X
HABITAT HETEROGENEITY	X	X				
CORRIDOR	X	X				X
STREAMS						
TREES	X					
WOODS	X	X	X			
ROWCROP						
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD	X			X		
NUMBER TILLS	X			X		
NUMBER PASSES	X			X		
HERBICIDE	X			X		X
FERTILIZER						
MANURE	X			X	X	

Eastern Meadowlark

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW	X	X	X			
SPRING GRAIN	X	X			X	
WINTER GRAIN						
HAY	X	X			X	X
PASTURE	X	X			X	X
FENCE	X	X	X		X	X
HABITAT HETEROGENEITY						
CORRIDOR	X	X	X		X	X
STREAMS						
TREES						
WOODS			X			
ROWCROP	X					
BIOMASS	X			X		
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD	X			X		
NUMBER TILLS	X			X		
NUMBER PASSES	X			X		
HERBICIDE	X			X		
FERTILIZER						
MANURE						

European Starling

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD	X	X			X	X	
HEDGEROW	X	X					
SPRING GRAIN	X	X			X		
WINTER GRAIN							
HAY	X	X			X		
PASTURE	X	X			X	X	
FENCE	X	X					
HABITAT HETEROGENEITY							

CORRIDOR						
STREAMS						
TREES	X	X				
WOODS						
ROWCROP	X	X				
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD						
NUMBER TILLS	X			X		
NUMBER PASSES	X			X		
HERBICIDE	X			X		
FERTILIZER						
MANURE	X			X		X

Horned Lark

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD							
HEDGEROW			X				
SPRING GRAIN	X	X			X	X	X
WINTER GRAIN							
HAY							
PASTURE	X	X			X		
FENCE	X	X	X		X		
HABITAT HETEROGENEITY	X	X					
CORRIDOR							
STREAMS							
TREES			X				
WOODS			X				
ROWCROP	X	X			X	X	X
BIOMASS	X			X			
BIODYNAMIC							
ORGANIC	X			X			X
NONORGANIC							
FIELD	X			X	X		
NUMBER TILLS	X			X	X		
NUMBER PASSES	X			X		X	
HERBICIDE	X			X		X	
FERTILIZER	X			X		X	
MANURE							

House Sparrow

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X	X			X	X
HEDGEROW	X	X			X	X
SPRING GRAIN	X	X			X	
WINTER GRAIN						
HAY						
PASTURE	X	X				X
FENCE	X	X				
HABITAT HETEROGENEITY						
CORRIDOR	X	X				
STREAMS						
TREES						
WOODS						
ROWCROP						
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD	X			X		

NUMBER TILLS							
NUMBER PASSES							
HERBICIDE	X			X			
FERTILIZER							
MANURE							

Killdeer

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD							
HEDGEROW			X				
SPRING GRAIN	X	X					
WINTER GRAIN							
HAY							
PASTURE	X	X			X	X	
FENCE			X				
HABITAT HETEROGENEITY	X	X					
CORRIDOR							
STREAMS							
TREES			X				
WOODS			X				
ROWCROP	X	X					X
BIOMASS	X			X			
BIODYNAMIC							
ORGANIC	X			X			
NONORGANIC							
FIELD	X			X	X	X	X
NUMBER TILLS	X			X	X		
NUMBER PASSES	X			X			
HERBICIDE	X			X		X	
FERTILIZER	X			X			X
MANURE	X			X	X		

Mourning Dove

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD	X	X					
HEDGEROW	X	X					
SPRING GRAIN	X	X			X		X
WINTER GRAIN							
HAY							
PASTURE	X	X			X		X
FENCE	X	X					
HABITAT HETEROGENEITY	X	X					
CORRIDOR							
STREAMS							
TREES			X				
WOODS	X	X	X		X		X
ROWCROP	X	X			X	X	
BIOMASS	X			X			
BIODYNAMIC							
ORGANIC	X			X			
NONORGANIC							
FIELD	X			X			
NUMBER TILLS	X			X		X	
NUMBER PASSES	X			X	X		
HERBICIDE	X			X		X	
FERTILIZER							
MANURE							

Northern Flicker

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X	X				
HEDGEROW	X	X	X		X	

SPRING GRAIN						
WINTER GRAIN						
HAY						
PASTURE	X	X				X
FENCE	X		X			
HABITAT HETEROGENEITY	X	X			X	
CORRIDOR	X	X	X		X	
STREAMS						
TREES	X	X			X	
WOODS	X	X				X
ROWCROP						
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD						
NUMBER TILLS						
NUMBER PASSES						
HERBICIDE					X	
FERTILIZER						
MANURE						

Northern Harrier

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD							
HEDGEROW	X	X					X
SPRING GRAIN							
WINTER GRAIN							
HAY	X	X			X	X	
PASTURE	X	X			X	X	
FENCE	X	X					
HABITAT HETEROGENEITY	X	X			X		X
CORRIDOR	X	X			X		X
STREAMS							
TREES							
WOODS							
ROWCROP							
BIOMASS	X			X			
BIODYNAMIC							
ORGANIC	X			X		X	
NONORGANIC							
FIELD	X			X			X
NUMBER TILLS							
NUMBER PASSES							
HERBICIDE							
FERTILIZER							
MANURE							

Red-winged Blackbird

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW	X	X	X			
SPRING GRAIN	X	X				
WINTER GRAIN						
HAY	X	X			X	
PASTURE	X	X				
FENCE	X	X	X		X	
HABITAT HETEROGENEITY						
CORRIDOR	X	X			X	
STREAMS	X	X			X	
TREES	X	X				
WOODS	X	X	X			

ROWCROP	X	X				
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD						
NUMBER TILLS						
NUMBER PASSES						
HERBICIDE	X			X		
FERTILIZER						
MANURE						

Ring-billed Gull

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW						
SPRING GRAIN	X	X			X	
WINTER GRAIN						
HAY	X	X				
PASTURE	X	X				X
FENCE						
HABITAT HETEROGENEITY	X	X				X
CORRIDOR						
STREAMS						
TREES						
WOODS						
ROWCROP	X	X			X	
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD	X			X	X	
NUMBER TILLS	X			X	X	X
NUMBER PASSES	X			X	X	
HERBICIDE	X			X		
FERTILIZER	X			X		
MANURE	X			X		X

Rock Pigeon

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X	X			X	
HEDGEROW	X		X			
SPRING GRAIN	X	X			X	
WINTER GRAIN						
HAY						
PASTURE						
FENCE						
HABITAT HETEROGENEITY	X	X				
CORRIDOR						
STREAMS						
TREES	X		X			
WOODS	X		X			
ROWCROP	X	X			X	X
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD	X			X		
NUMBER TILLS	X			X		X
NUMBER PASSES	X			X	X	
HERBICIDE	X			X		X
FERTILIZER					X	

MANURE

Savannah Sparrow

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2	COMBINATION3
FARMSTEAD							
HEDGEROW	X		X		X		
SPRING GRAIN							
WINTER GRAIN							
HAY	X	X			X	X	
PASTURE	X	X			X	X	
FENCE	X	X	X				X
HABITAT HETEROGENEITY							
CORRIDOR							
STREAMS							
TREES	X		X				
WOODS							
ROWCROP							
BIOMASS	X			X			
BIODYNAMIC							
ORGANIC	X			X	X		X
NONORGANIC							
FIELD	X			X	X	X	
NUMBER TILLS							
NUMBER PASSES							
HERBICIDE	X			X			
FERTILIZER							
MANURE							

Song Sparrow

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X					X
HEDGEROW	X	X	X		X	X
SPRING GRAIN	X					
WINTER GRAIN						
HAY						
PASTURE	X	X			X	
FENCE	X	X			X	
HABITAT HETEROGENEITY	X	X				
CORRIDOR	X	X			X	
STREAMS						
TREES	X	X	X			
WOODS		X	X			X
ROWCROP	X					
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD						
NUMBER TILLS						
NUMBER PASSES						
HERBICIDE	X			X		X
FERTILIZER						
MANURE						

Tree Swallow

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD	X					
HEDGEROW						
SPRING GRAIN						
WINTER GRAIN						
HAY	X	X			X	X
PASTURE	X	X			X	X

FENCE	X	X			X	
HABITAT HETEROGENEITY	X	X				X
CORRIDOR	X	X			X	
STREAMS	X	X			X	X
TREES	X	X				
WOODS						
ROWCROP						
BIOMASS						
BIODYNAMIC					X	
ORGANIC	X			X		
NONORGANIC						
FIELD						
NUMBER TILLS		X			X	
NUMBER PASSES						
HERBICIDE	X			X		X
FERTILIZER						
MANURE	X			X		

Vesper Sparrow

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW	X	X	X			X
SPRING GRAIN	X	X			X	
WINTER GRAIN						
HAY	X	X			X	
PASTURE	X	X			X	X
FENCE	X	X			X	
HABITAT HETEROGENEITY						
CORRIDOR	X	X				
STREAMS						
TREES						
WOODS	X		X			
ROWCROP	X	X				
BIOMASS	X			X		
BIODYNAMIC						
ORGANIC	X			X		
NONORGANIC						
FIELD	X			X		
NUMBER TILLS	X			X	X	
NUMBER PASSES	X			X		
HERBICIDE	X			X	X	X
FERTILIZER	X					X
MANURE						

Yellow Warbler

	GLOBAL	HABITAT	PREDATION	PRACTICES	COMBINATION1	COMBINATION2
FARMSTEAD						
HEDGEROW	X	X	X			X
SPRING GRAIN						
WINTER GRAIN						
HAY						
PASTURE	X	X				
FENCE			X			
HABITAT HETEROGENEITY	X					X
CORRIDOR	X	X	X		X	
STREAMS	X	X			X	X
TREES	X	X			X	
WOODS	X	X				
ROWCROP						
BIOMASS						
BIODYNAMIC						
ORGANIC	X			X		

NONORGANIC		
FIELD		
NUMBER TILLS		
NUMBER PASSES		
HERBICIDE	X	X
FERTILIZER		
MANURE		