EFFECTS OF DIFFERENT HABITATS VERSUS AGRICULTURAL PRACTICES ON FARMLAND BIRDS IN ONTARIO

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ABSTRACT

The extent and intensity of modern agriculture have significant adverse implications for farmland wildlife and their habitats. A comparative field study was conducted on organic farms and conventional (chemical) farms in Ontario to identify important crop and non-crop habitats and agricultural practices for different groups of farmland birds, and to quantify their effects on bird species richness and abundance. Birds were surveyed using 180° point counts from field edges in May and June, 1990, on 20 organic and conventional farms paired geographically for their similarity in crop and non-crop habitats. A total of 68 species were observed over all sites, 59 on each farm type. Numbers of species and birds per site averaged 13.9 and 16.9, respectively, for unlimited distance (but still on farm) surveys. Abundance was significantly higher on organic than conventional farms. Data from limited distance surveys (100-m radius semicircle) showed similar patterns between farm types and among bird classes and species.

Fourteen classes of birds and nine species had sufficient data for analysis. Compared to conventional farms, sites on organic farms had significantly more species of aerial feeders, ground nesters and grassland species of concern, and greater abundances of omnivores, ground feeders, ground omnivores, species that winter in the USA, Central and South America (SD2 migrants), ground nesters, and grassland species of concern. Savannah Sparrow, Song Sparrow and Red-winged Blackbird were the most widespread species. Vesper Sparrow and Brown-headed Cowbird were significantly more abundant on organic than conventional farms.

For each survey site, habitat at local (200-m radius semicircle) and landscape (400 ha rectangle) scales were characterized from air photos and field notes. At the local scale, crops accounted for about 50% of the area sampled per site with no significant differences between farm types. Non-crop habitats were fairly evenly distributed between organic and conventional sites. At the landscape scale, summary statistics were generally similar in total and by farm type when based on all 72 sites and 16 spatially-independent sampling regions. Agricultural practices were characterized from farmer interviews, field notes and air photos. Field size at survey sites averaged 18 ha overall but was significantly larger for conventional farms (23 ha) than organic farms (13 ha). Of the 36 conventional sites, 22 were treated with herbicides, 2 with insecticides, and 22 with synthetic fertilizers in 1990. Biodynamic sprays were used for weed control at 13 organic sites. Other practices (e.g. planting dates, number of tillages) were similar between farm types.

Multiple regression models explained 36% of variation in species richness and abundance in total and among 11 other bird classes. Richness of 7 classes (total, ground feeders, lower canopy feeders, ground-feeding omnivores, Neotropical migrants, SD2 migrants, grassland species of concern) and abundance of 9 classes (total, omnivores, ground feeders, lower canopy feeders, Neotropical migrants, SD2 migrants, residents, ground nesters, grassland species of concern) were affected by both habitat and farming practices. Local habitat was significant to species richness and abundance of most or all classes, accounting for 26% and 24% of variation, respectively. Non-crop habitats were more important to species richness than crop habitats, but were only slightly more important than crop habitats for abundance. Farming practices were significantly related to species richness and abundance for 9 of 12 classes, explaining 10% and 13% of variation, respectively. More hedgerow increased species richness for 67% of classes, explaining 23% of variation. Hedgerow was significantly related to abundance of 58% of classes, positively for half. Herbicide was negatively related to species richness and abundance for 33% and 58% of classes, respectively. Woodland, hay, winter grain and habitat heterogeneity were also important.

Variability in regression profiles among bird classes were examined to provide a different conservation focus. Regression models for omnivores and grassland species of concern were used to estimate risk from adverse changes in site conditions. For omnivores, a loss of woodiness (hedgerow and woodland), in conjunction with an increase in winter grain, was predicted to result in a decrease of six species per site. Omnivore abundance was decreased by 3.4 birds per site by use of herbicide. For grassland species of concern, use of herbicide was predicted to decrease richness by almost one species per site (10% of species in this class), and abundance by just over one bird per site. Spearman rank correlation analysis provided some insight into relationships between the abundance of individual bird species and local and site variables, and between landscape characteristics and species richness and abundance of bird classes and abundance of individual bird species.

These results help in assessing ecological risks posed by agriculture, and provide insights for alternative landscape designs and farm management systems that enhance farmland birds. However, tradeoffs exist so conservation objectives need to be clearly articulated and regionally appropriate.

KEYWORDS: breeding birds, cropping practices, habitat effects, organic, fertilizers, herbicides, Ontario, Canada

RÉSUMÉ

Effets de différents habitats et différentes pratiques agricoles sur les oiseaux des terres agricoles en Ontario

L'agriculture moderne, du fait de son ampleur et de son intensité, a d'importantes répercussions négatives sur la faune des terres agricoles et ses habitats. Une étude comparative portant sur des fermes biologiques et classiques (utilisant des produits chimiques) a été effectuée en Ontario afin de déterminer les habitats cultivés et non cultivés et les pratiques agricoles qui sont importants pour différents groupes d'oiseaux associés aux terres agricoles et d'en quantifier les effets sur la diversité et l'abondance des espèces présentes. En mai et juin 1990, dans 20 fermes biologiques et classiques appariées géographiquement et en fonction de la similarité des habitats cultivés et non cultivés, on a dénombré les oiseaux selon une méthode ponctuelle sur des placettes semi-circulaires à partir de la lisière des champs. On a recensé au total 68 espèces, dont 59 qui se trouvaient sur chaque type de ferme. Dans les dénombrements sur une distance illimitée (dans les limites de la ferme), on a relevé en moyenne 13,9 espèces et 16,9 oiseaux par site. L'abondance était nettement supérieure sur les fermes biologiques. Les données des relevés sur une distance limitée (demi-cercle d'un rayon de 100 m) indiquent des caractéristiques similaires pour les deux types de ferme et les différentes catégories et espèces d'oiseaux.

Pour 14 catégories et 9 espèces d'oiseaux, on a obtenu assez de données pour une analyse. Par comparaison aux fermes classiques, les sites des fermes biologiques se sont révélés nettement plus riches en espèces se nourrissant en vol, espèces nichant au sol et espèces des prés et pâturages en déclin; les oiseaux appartenant aux catégories suivantes y étaient aussi plus abondants: omnivores, espèces nichant au sol; omnivores se tenant au sol, espèces hivernant aux États-Unis, en Amérique centrale ou en Amérique du Sud (migrateurs SD2), nicheurs au sol et espèces des prés et pâturages en déclin. Le bruant des prés, le bruant chanteur et le carouge à épaulettes étaient les espèces les plus répandues. Sur les fermes biologiques, le bruant vespéral et le vacher à tête brune étaient significativement plus abondants.

À partir de photos aériennes et de notes prises sur le terrain, on a établi les caractéristiques de l'habitat à chaque site de dénombrement, à la fois à l'échelle locale (demi-cercle d'un rayon de 200 m) et à l'échelle du paysage (rectangle de 400 ha). À l'échelle locale, les champs cultivés représentent environ 50 % de la superficie échantillonnée de chaque site, et il n'y a pas de différence significative entre les types de ferme. Les habitats non cultivés sont assez également distribués entre les sites biologiques et classiques. À l'échelle du paysage, les statistiques sommaires sont généralement similaires, tant pour le total que pour chaque type de ferme, d'après l'ensemble des 72 sites et des 16 régions d'échantillonnage spatialement indépendantes.

Les pratiques agricoles ont été établies à partir de l'information fournie par les fermiers, des notes prises sur le terrain et de photos aériennes. La superficie moyenne des champs où ont eu lieu les dénombrements est de 18 ha au total; elle est toutefois plus grande sur les fermes classiques : 23 ha par comparaison à 13 ha sur les fermes biologiques. Les 36 sites des fermes classiques avaient reçu divers traitements en 1990 : herbicides à 22 endroits, insecticides à 2 endroits et engrais synthétiques à 22 endroits. Dans le cas des fermes biologiques, 13 sites avaient reçu des pulvérisations biodynamiques contre les mauvaises herbes. Les autres pratiques (dates de plantation, nombre d'opérations de travail du sol, p. ex.) sont similaires pour les deux types de ferme.

Les modèles de régression multiple expliquent 36 % de la variation de la diversité et de l'abondance pour l'ensemble des espèces et les 11 autres groupements (catégories) d'espèces. L'habitat et les pratiques agricoles influent tous deux sur la diversité pour 7 catégories d'oiseaux (toutes les espèces, espèces se nourrissant au sol, espèces se nourrissant dans la partie basse du couvert, omnivores se nourrissant au sol, migrateurs néotropicaux, migrateurs SD2, espèces des prés et pâturages en déclin) et sur l'abondance pour 9 catégories (toutes les espèces, omnivores, espèces se nourrissant au sol, espèces se nourrissant dans la partie basse du couvert, migrateurs néotropicaux, migrateurs SD2, résidants, nicheurs au sol, espèces des prés et pâturages en déclin). L'habitat local apparaît important pour la diversité et l'abondance des espèces de la plupart des catégories, sinon toutes, expliquant respectivement 26 et 24 % de la variation. Alors que les habitats non cultivés se sont révélés plus importants pour la diversité des espèces que les habitats cultivés, leur importance pour l'abondance n'est que légèrement supérieure. Les pratiques agricoles ont été corrélées significativement avec la diversité et l'abondance des espèces pour 9 des 12 catégories, expliquant respectivement 10 et 13 % de la variation.

Une plus grande étendue de haies augmente la diversité des espèces pour 67 % des catégories, expliquant 23 % de la variation. On a établi une corrélation significative entre les haies et l'abondance pour 58 % des catégories, la corrélation étant positive dans la moitié des cas. On a aussi établi une corrélation négative pour l'utilisation d'herbicide avec la diversité et l'abondance des espèces pour 33 et 58 % des catégories respectivement. En outre, on a constaté une influence importante des boisés, du foin, des céréales d'hiver et de l'hétérogénéité des habitats.

La variabilité des profils de régression entre les catégories d'oiseaux a été examinée afin d'obtenir un éclairage différent aux fins des efforts de conservation. Pour les omnivores et les espèces des prés et pâturages en déclin, on a utilisé des modèles de régression pour estimer le risque associé à des changements négatifs des conditions au niveau du site. Dans le cas des omnivores, la perte de couvert arboré (haies et boisés), combinée à l'augmentation des céréales d'hiver, résulterait en une perte de 6 espèces par site, et l'utilisation d'herbicide réduirait l'abondance de 3,4 oiseaux par site. Dans le cas des espèces des prés et pâturages en déclin, l'utilisation d'herbicide entraînerait une réduction de près d'une espèce par site pour la diversité (10 % des espèces dans cette catégorie) et d'un peu plus d'un oiseau par site pour l'abondance.

Une analyse de corrélation de rang de Spearman a permis de mieux voir les rapports entre des variables locales et stationnelles et l'abondance d'espèces particulières, ainsi qu'entre des caractéristiques du paysage et la diversité et l'abondance des catégories d'oiseaux ainsi que l'abondance d'espèces particulières.

Ces résultats aideront à mieux évaluer les risques écologiques associés à l'agriculture et à définir les aménagements du paysage et systèmes de gestion agricole propices aux oiseaux sur les terres agricoles. Toutefois, il y a des compromis: il importe donc que les objectifs de conservation soient clairement formulés et adaptés régionalement.

MOTS CLÉS : oiseaux nicheurs, pratiques agricoles, effets sur l'habitat, agriculture biologique, engrais, herbicides, Ontario, Canada

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INTRODUCTION

The extent and intensity of modern agriculture have significant adverse implications for farmland wildlife and their habitats (O'Connor and Shrubb 1986; McLaughlin and Mineau 1995; Freemark and Boutin,1994, 1995; Freemark 1995). In recent years, the abundance of game and non-game bird species have been declining in agricultural areas of North America and Europe (Potts1997, Dunn 1991, Herkert 1991, O'Connor and Shrubb 1986, Fuller *et al.* 1991). The decline of landbirds that winter in the Neotropics has been of particular concern most recently (Finch and Stangel 1993, Martin and Finch 1995).

The composition and relative availability of different habitats and their spatial configuration affect the variety and abundance of bird species in farmland (Freemark 1995). Remnant woodlands, riparian areas and wetlands support a unique complement of bird species in farmland (Best *et al.* 1995). Farmsteads are also important to a variety of birds as sources of food, cover and nesting sites (Yahner 1983, Møller 1984, Robertson *et al.* 1990, Best *et al.* 1995). While a few bird species are primarily associated with cropland, more are associated with grasslands, pasture, abandoned fields, and uncultivated edge vegetation such as roadside verges and grassed waterways, and especially hedgerows and wooded fencerows (O'Connor and Shrubb1986, Rodenhouse *et al.* 1995, Best *et al.* 1995). In Europe, hedgerow networks support more species and greater abundances of birds than their extent alone would suggest (Lack 1988, Fry 1991). In North America, smaller areas of grassland, forest and wetland support fewer bird species and a limited subset compared to larger areas (reviewed by Freemark *et al.* 1995). In contrast, larger row-crop fields have been found to support fewer species and lower abundances of birds than narrower and/or more irregularly shaped fields because larger fields have proportionately less edge and more birds and species use the perimeter of fields compared to the center (O'Connor and Shrubb 1986, Best *et al.* 1990). Croplands in proximity to woody habitat (e.g. woodlots, hedgerows, shelterbelts, isolated trees) generally support more species and a greater abundance of birds (Arnold 1983, Best *et al.* 1990, O'Connor and Shrubb 1986). Agricultural landscapes with a greater diversity of crop and non-crop habitats support a greater richness and abundance of bird species (Best *et al.* 1995, Freemark 1995 and references therein).

Farming practices (e.g. tillage, grazing, use of pesticides and fertilizers) also affect birds, directly (e.g. through mortality) or indirectly via modification of food, nesting and protective cover (McLaughlin and Mineau 1995, Rodenhouse *et al.* 1995). Effects from the use of agricultural pesticides have been of particular concern (O'Connor 1992, Mineau 1993). More intensive and extensive use of herbicides have contributed to population declines of farmland birds primarily through plant-mediated reductions in food supply and alterations in habitat and landscape structure (see review by Freemark and Boutin 1995). The few field studies that have been conducted to date indicate that conventional farming adversely impacts the abundance and nest success of breeding and wintering birds, primarily by reducing habitat quality and food supply (Ducey and Miller 1980, Gremaud and Dahlgren 1982, Gremaud 1983, Brae *et al.* 1988, BTO/IACR-R 1995) but also possibly by acute toxicity (Fluetsch and Sparling 1994). Reduced pesticide inputs on field margins in the UK have resulted in significant increases in abundances of certain birds (Rands 1986).

To quantify the relative impact of habitat versus agricultural practices on birds breeding in farmland, we conducted a comparative field study on organic farms and conventional (chemical) farms in Ontario, Canada. A pilot study in Ontario by Rogers and Freemark (1991) suggested that organically-managed farms supported more bird species and more individuals than conventional farms. We expanded their study to better identify important crop and non-crop habitat features and agricultural practices for different groups of farmland birds, and to quantify their effects on bird species richness and abundance. The results should not only contribute to our understanding of the ecological risks to birds posed by agriculture, but also provide insights for alternative landscape designs and farm management systems to enhance the conservation of wildlife biodiversity in farmland (Freemark 1995).

METHODS

Selection of Survey Sites

Study farms were selected as in Rogers and Freemark (1991). Certified organic farms in eastern Ontario were identified primarily through the Ottawa Chapter of the Canadian Organic Growers and associated publications (Anon. 1988, 1989). Farms in south-western Ontario were found through the Ecological Farmers Association of Ontario (L. Andres, pers. comm.). Characterization of farms with respect to operation and habitat features was achieved first by telephone interviews, then by site visits. Suggestions for suitable conventional farms in the vicinity for pairing were obtained from organic farmers, and were followed up with telephone interviews and site visits.

To control for variation caused by differences between farm types which were not associated with the management system, farm pairs were selected so as to minimize differences in geographic location, farm operation (e.g. crops, livestock), field shape and size, and non-crop habitat features (especially those which have been shown to have significant effects on birds, for example wooded edges). Habitat matching between survey sites was particularly stringent within 100 m of bird survey sites. By pairing farms, extreme examples of intensive conventional agriculture or of organic farmland that was extremely rich in non-crop habitats were excluded. The farms selected tended to be within the normal range of variation for organic and conventional systems for their geographic region.

In order to minimize the possibility of chemical contamination from adjoining farms, all survey sites on organic farms were located at least 100 m from the outer boundaries of the farm. To the extent possible, sites on conventional farms were located at least 500 m from the boundaries of organic farms to ensure that birds recorded at these sites were typical of conventional farms.

In 1990, 72 survey sites were established in cropland on 10 farm pairs in eastern (3 pairs) and south-western Ontario (7 pairs). Three of the farm pairs (10 pairs of survey sites) were replicated from the 1989 pilot study by Rogers and Freemark (1991). Farm size averaged 84.2 ha (± 45.2 ha SD). Two to six survey sites were established on each farm. Field size at survey sites averaged 18.1 ha (± 13.8 ha SD). The minimum distance between survey sites on a farm averaged 374 m (range 150-1410 m).

Bird Surveys
Birds were surveyed using point counts from field edges as in Freemark and Rogers (1995). Each farm pair was surveyed 4 times between May 8 and June 28, twice in May and twice in June. One farm pair was surveyed on a given day. Diurnal variation was standardized by reversing the order of visitation for farms in a pair and for the study sites on each farm between surveys. Surveys were run by two observers; observers alternated between visits to standardize for observer variation.

Point counts were done between dawn and 10:00 hours, primarily in good weather (i.e. no precipitation and wind less than12 kph). All birds seen or heard in and adjacent to croplands or feeding over fields during a 10-minute period were mapped for the 180° direction along the field edge and into the field. Registrations were mapped such that data could be separated into limited (100 m radius) and unlimited distance (but still on farm).

After a point count visit, each species was given an index of abundance based on the territorial status of the individual observed using behavioural criteria (e.g. a singing male counted as two birds, a bird calling or seen counted as one) and simultaneous observation of individuals (cf. Welsh 1995). In retrospect, it may have been better to simply count birds detected because of difficulty in distinguishing calling from singing in some species. This bias was consistent between farm types because observers were alternated between farm pairs. Potential error also arises in assuming that singing birds were paired since recent research on forest birds suggests that unmated males sing more than mated ones (cf. Porneluzi *et al.* 1993). This bias is likely consistent between farm types since there is no evidence to suggest differential mating success between farm types although some species do appear to reproduce more successfully on organic than conventional farms (Fluetsch and Sparling 1994; Evans, Wilson and Browne 1995). Individuals comprising flocks were noted. The number of species per survey site was accumulated over visits (see Appendix 1 for species list). The number of individuals per survey site was averaged over visits, except that a flock of 80 birds sighted at one organic site were not included in order to meet assumptions of statistical analyses. This did not affect species richness at that point.

Species were categorized according to primary food source and foraging substrate during breeding (DeGraaf *et al.* 1985), nesting strata (Ehrlich *et al.* 1988), and migratory status in the region (Freemark and Collins 1992)(Appendix 2). An additional grouping of birds included ten grassland species (Appendix 3) found to be declining in the midwest (Best *et al.* 1996, Herkert 1991) and/or Ontario (Dunn 1991, Morrison 1993/94) in order to measure habitat and farming practice effects on these species of concern.

Habitat Surveys
Study farms were located on aerial photographs (1:50,000 or 1:15,000 scale) which were then enlarged to a scale of approximately 1:10,000. From these enlargements, survey sites on each farm were located, and habitat features identified from the existing literature as important to farmland birds (Appendix 4) were delineated and transferred to 1:10,000-scale Ontario Base Maps using a zoom transfer scope. Field notes taken prior to and at the time of the surveys were consulted to achieve detailed and accurate transfer of habitat features. Habitat information in the surrounding landscape was inferred from the air photos (taken between 1978 and 1989) and the

base maps (1987). Since no ground-truthing was done beyond survey sites, the more recent source was consulted to complete the maps. Habitat features were digitized from the enhanced base maps with an electronic digitizer and coordinates were stored in a computer. Customized software was designed to collect and transform digital input for habitat dimensions into linear distances and area measures.

Habitat was measured at two scales. Local habitat features at each survey site were measured within a 200m-radius semi-circle (6.3 ha) along the edge and facing into the surveyed field. Local habitat measurements were restricted to the study farm to coincide with bird survey data. Habitat in the agricultural landscape was measured within a 2 X 2 km square (400 ha) centered on each survey site and included local scale features. As much as possible, efforts were made to group crop and non-crop habitat variables into classes with sufficient sample sizes for analysis. At the local scale, 12 habitat features were analyzed: proportion of row-crop, spring grain, winter grain, hay, pasture, farmstead and woodland; length of hedgerow, stream, road and fenceline; habitat heterogeneity. Six habitat characteristics were analyzed at the landscape scale: proportion of farmstead and woodland; length of woodland edge, hedgerow, stream; and habitat heterogeneity.

Crops were assigned to broad habitat classes. Barley, oat, and spring wheat were classified as spring grain. Winter wheat and winter rye were grouped together under winter grain. Soybean, white bean (1 site) and corn were classified as row-crop. Grass, alfalfa, clover, and trefoil were grouped with hay. Pasture included both grazed and ungrazed.

In this study, a field was defined as any expanse of agricultural land, cultivated or uncultivated, bordered by non-crop boundaries such as fences, hedgerows, water or non-agricultural land. Abutting crop edges were not considered boundaries, so that a field could consist of more than one crop type. Fields within the landscape were measured if at least half of their surface area occurred within the 4 km^2 boundary for a given survey site. Hence, the total area measured at the landscape scale varied from site to site but generally approached 400 ha. For this reason, all measurements were expressed as a proportion of the total area measured at the appropriate scale with the exception of habitat heterogeneity (H').

Woodland was comprised of both upland and riparian areas. At the local scale, isolated trees, often in the vicinity of woodlots, were converted to an area measurement by multiplying the number of trees per site by an estimated crown diameter of 10m, and included in woodland. Isolated trees were not considered at the landscape level. Hedgerow included wooded fencerows and other woody strip cover between fields. Fenceline included grassy strips between fields usually with a fence.

Streams at the local scale constituted any waterway such as small rivers, streams, and ditches. Roads, railways and transmission corridors were grouped together under road to increase sample size. Ditches, roads and transmission corridors were not measured at the landscape scale. Farmstead included houses barns and adjoining gardens and yards.

Habitat heterogeneity (expressed as a Shannon-Weaver index; Barbour et al., 1980) at both local and landscape scales was derived from variables expressed as an area measure. In addition, an area approximation of hedgerow was calculated by multiplying hedgerow length by an estimated width of 3m, and was included in the calculation of the index.

Agricultural Practices Surveys

Farmers were interviewed by telephone in the fall of 1990 to characterize farming practices. The information collected included: tillage, planting and harvesting dates (for hay), and other treatments of fields (e.g. scuffling, discing); compound names, rates and dates of application for all pesticides and fertilizers applied in 1989 and 1990. Information gathered while conducting bird surveys (height of crops, and the presence of crop residue (stubble) from the previous growing season) supplemented data in the calendars and was used to calculate metrics which were reported but not used in final analyses because of insufficient sample size (stubble) or lack of significance in preliminary analyses (crop growth).

A total of 22 local and landscape scale farming practices were defined and quantified. Once again variables were combined to increase sample sizes and others were dropped if sample sizes were deemed inadequate. In total, 8 local (field size, number of tillages, number of passes, herbicide, chemical fertilizer, manure, biodynamic spray, farm type) and 2 landscape practices (number of cultivated fields, numbers of uncultivated fields) were used in final analyses.

Tillage and planting dates were not analyzed because of difficulties in assigning values to fall-sown (in 1989) and no-till sites. Harvesting during the survey period was applicable to hay crops only, and was therefore too poorly represented in the dataset to be included in our analyses. The number of tillages per site, which included discing, was tallied for spring-sown crops.

Herbicides, insecticides, biodynamic sprays and chemical or alternative fertilizers were analyzed as categorical variables according to 1990 application, where a value of 1 represented a 1990 application and 0 represented an absence of chemicals in 1990. Insecticides were applied at only 2 sites and therefore omitted from further analysis. Chemical pesticides and fertilizers applied on study farms in 1990, and their recommended or actual application rates were tabulated in Appendix 5.

The alternative fertilizers category, which grouped green manures, liquid manure, and solid/semi-solid manure (including excrement from grazing cattle at 2 sites) was analyzed as a categorical variable as well. Stubble (crop residue) was present at too few study sites to be analyzed.

Variables measuring crop growth were derived from measurements of crop height during bird surveys (Appendix 6) and tested in preliminary analyses. These variables were tabled but excluded from further analyses because they rarely impacted significantly on bird abundance or species richness, nor were t-tests comparing means by farm type significant for these variables.

The number of passes at each site including tillages, cultivations (i.e. mechanical weed control), planting, pesticide applications, fertilizer applications, haying, and other treatments, were tallied and expressed as the total number of disturbances, or passes, at each site during and just prior to the survey period.

The size of the field containing each study site was measured at the local scale and analyzed as a proportion of the local sampling area. The number of cultivated and uncultivated fields in the landscape were tallied and field size measured if at least half of their surface area occurred within the 4 km^2 boundary for a given study site (definition of field as above). Field shape (area:perimeter ratio) and average field size in the landscape were dropped because of difficulties in the interpretation of results within our experimental design.

Farm type was considered at both the local and landscape scales and was treated as a categorical variable; organic = 0, and conventional (chemical) = 1. A farm identification variable was created to permit testing of among-farm effects. Farms were assigned a numerical (farm i.d.) value of 1 to 20, arbitrarily, and then based on their geographical location by longitude for comparison.

Statistical Analysis

Statistical analyses were conducted for species number and mean abundance per point from unlimited distance (ULD) surveys. ULD surveys were used rather than limited distance (LD) because the former afforded a 13% increase in species detection (Freemark and Rogers 1995) and a larger number of sample sites for analyses with most bird parameters. In practice, ULD surveys translated to within 200 m of survey points.

Data were tabulated by different classes for analysis of habitat and practice effects at both local and landscape scales including: total assemblage, 7 foraging and/or foraging substrate guild classes, 4 migratory status classes, 2 nest location classes, a declining grassland species class, and 9 individual species. To facilitate interpretation of results, percent similarity in species composition between classes was calculated using the Jaccard Index as follows: 100 (species in both A and B)/(all species in A plus all species in B minus species in common). The index was not scaled by species number because differences contributed to variation among bird classes.

All analyses were conducted using SAS statistical software (1985). Multiple linear regression was used to analyze relationships between local habitat features, farming practices and bird species patterns at class and species levels. The distribution of each dependent and independent variable was examined for extreme values that could bias regression results. Subsequently scatterplots of dependent versus independent variables were generated and viewed for values which appeared to deviate from overall distributions as suggested by Belsley *et al.* (1980) and Sokal and Rohlf (1969). Referring to the scatterplots, pairs of dependent (Y) and independent (X) variables were assessed for linear improvement by square root or logarithmic transformation of one or both variables. Bivariate distributions which showed potential for substantial linear improvement were further examined by comparing p-values for regressions of Y on X for untransformed and appropriately transformed variable(s) within pairs. Transformed variables showing substantial linear improvement in simple and multiple linear regressions (partial regression leverage plots) were analyzed as such.

Bird abundance and species richness parameters were regressed on 21 independent variables at the local scale based on a maximum of 72 observations. Careful consideration of the regression method employed was necessary because of the limited sample size relative to the number of independent variables entered. Rather than removing variables from the datasets and risk eliminating important predictors, we opted to use a stepwise forward regression with significance levels to enter (SLE) and stay (SLS) in the model of $\alpha = 0.05$. This narrow window of entry ensured that spurious results were minimized and functioned to limit the final number of variables remaining in the models. SLE and SLS levels were set at the same value to prevent cyclical variable entry and removal (Draper and Smith 1981).

The normal distribution of model residuals was verified using a statistical test derived by D'Agostino *et al.*(1990). The test measured both residual skewness and kurtosis and tested for significance of each condition and that of a combined measure of deviation from normality. A second assumption that the error variances (residuals) were homogeneous for each observation (set of independent variables) was also tested. A test for heteroscedasticity or heterogeneity of variances was conducted for each model generated. Lastly, model fit was verified in two ways. First, confirmation that a significant proportion of the variance in bird values was explained by the independent variables in the model was determined by an analysis of variance and significant F-test.

Various diagnostic tests were conducted to identify influential observations and to obtain indices of model robustness. These diagnostics, described in detail by Belsley *et al.*(1980), measured changes to regression coefficients (DFBETAS), model fit (residuals, RSTUDENT), predicted values of Y (DFFITS), and the covariance matrix of estimates (COVRATIO) when the *i*th observation was removed. These diagnostic tests were used in conjunction with partial regression leverage plots to identify statistically influential observations as well as additional problematic points which may not have been be detected by the diagnostics (Belsley *et al.* 1980, SAS 1985). Based on results of influence diagnostics and partial regression leverage plots, highly influential observations were removed in order to generate the most statistically robust models. Regression analysis was repeated where warranted.

The existence of variable collinearity was examined because the individual influence of explanatory variables which vary collinearly with each other can be difficult to separate, and may result in insignificant estimates for variables which are expected in theory to be important (Belsley *et al.* 1980). A test for collinearity (COLLINOINT, intercept adjusted out) was conducted in order to identify any such ill-conditioned data. Additional information was derived from correlation analysis of the parameter estimates, particularly if collinearity diagnostics revealed confounding dependencies. Methods for these tests are discussed in greater detail in Belsley *et al.*(1980) and SAS procedures manual (1985).

Alternative regression models were generated for each of the final stepwise regressions to examine model reliability and alternative regressors of interest. Models were evaluated to select "best" alternative model(s). The nature of our data and the inclusion of many explanatory variables made this component of the overall analysis particularly useful. Several methods available for obtaining and evaluating multiple sets of models are reviewed in Draper and Smith (1981). The "best subset regression" method based on examination of the model R^2 and adjusted R^2 (model R^2 adjusted for the number of parameters in the model) was used. Mallows C(p) statistic, which is related to both the model and adjusted R^2 (Draper & Smith 1981), was not as useful as the R^2 measures as a basis for selection of best alternative models, and was not used as a criterion for selection.

To save computation time and effort, K subsets were generated to include up to a maximum number of predictor variables equal to m+1, where m = the number of significant variables resulting from the earlier stepwise regression. This abbreviated step was found to produce a subset of single to m+1 variable models with reasonable R^2 and adjusted R^2 from which to choose. Alternative models were generated for the same set of observations used in the stepwise regression for basis of comparison. Levels of significance for variables entering and staying in the model were set to $p<.10$, to reduce the probability of making Type II errors which can be more environmentally costly than Type I errors in applied research (Smith 1995). New models were screened for highly influential observations and regressor multicollinearity using methods previously described.

A method of prediction based on simple linear regression is discussed in Sokal and Rohlf (1969). The standard error and 95% prediction limits are calculated based on a predicted mean obtained in a new experiment run at a given X_i value. The best estimate of the new mean Y is the predicted based on the selected X_i value to be tested. The standard error and prediction limits of the predicted mean are calculated based on a given number, k, of repetitions or samples. An adaptation of this method for multiple linear models was suggested by H.Lee (pers. comm.; Statistician, U.S. Environmental Protection Agency, Corvallis) in which the standard error of the predicted mean was calculated by creating or adding an indicator variable(s) to the data matrix, corresponding to a given test X or observation(s), and solving the multiple linear regression for the existent model including the indicator variable(s) with the added test observation(s). The solution for the indicator variable consisted of a unique parameter estimate and its standard error, without affecting the mean square error nor degrees of freedom of the original model. The 95% prediction intervals were then calculated on the basis of the indicator variable parameter estimate and its standard error.

Survey sites were chosen so as to be spatially independent at the local scale. However, the relative proximity of survey sites posed an analytical problem at the landscape scale because of sampling overlap among sites on a farm or sometimes between farms. In order to examine statistical problems associated with spatial autocorrelation and pseudoreplication (which increase the chance of making a Type I error when applying conventional statistical procedures, i.e., concluding there is an effect when there is not), points were grouped into 16 spatially-independent, same-farm type regions (8 organic, 8 conventional-conventional). In two cases farm pairs were adjoining. In order to preserve the integrity of same-farm type spatial independence, one farm from each pair, organic in one case and conventional in the other, was retained for analysis and its twin omitted. Farms to be retained were chosen at random, by farm type first, then farm. In total, 17 study sites out of 72 could not be designated to any one of the 16 independent groups.

Preliminary analysis of the habitat and agricultural practices at the landscape scale revealed that these data (n=16) did not meet assumptions for regression nor for parametric correlation analysis. Spearman rank tests of association between bird parameters and 8 landscape variables were conducted on all sample points (since assumptions of independence of observations are not violated) and on averages for sites grouped within 16 spatially-independent sampling regions. Preliminary analysis of individual species' abundances on local habitat and practices revealed that these data also did not meet assumptions for regression or parametric correlation analysis. Spearman rank correlations were conducted between a species abundance and local variables (n= 72), landscape variables (n=72), and for the 16 independent landscape regions.

RESULTS

All birds

A total of 68 species were observed over all sites (Appendix 1), 59 each on organic and conventional farms (Table 1). The number of species per site averaged 13.9 over all sites in unlimited distance surveys and was not significantly different between farm types. The total number of birds per site averaged 16.9 over all sites in unlimited distance surveys and was significantly higher on organic than conventional farms. Data from limited distance surveys (100-m radius semicircle) showed similar patterns between farm types and among bird classes and species (Table 1) but are not considered further in this report for the reasons given above. They are included here because they provide an estimate of density for each bird class which may be useful in other types of risk assessment.

Bird classes

Fourteen classes of birds had sufficient data for analysis including 2 food-types, 3 foraging substrates, 2 combinations of food and substrate, 4 migratory status, 2 nesting strata, and grassland species of concern (Table 1). Most classes shared less than 25% of their species (Table 2). Ground feeders and SD2 migrants (birds that winter in the USA, Central and South America) shared the most number of species at 50% similarity. Other notable exceptions were Neotropical migrants (birds that winter in Central and South America) and insectivores at 45% similarity, ground feeders and omnivores at 44%, and Neotropical migrants and above-ground nesters at 42%.

Insectivores and omnivores accounted for 51% and 35% of the species detected over all sites, respectively (Table 2), and were observed at all sites (Table 1). On average, insectivores and omnivores accounted for 30% and 62% of species per site, and 22% and 71% of birds per site, respectively. Omnivores were significantly more abundant per site on organic than conventional farms.

Ground feeders accounted for 51% of species detected over all sites (Table 2) and were observed at all sites (Table 1). On average, ground feeders accounted for 63% of species per site and 75% of birds per site. Aerial feeders and lower canopy feeders accounted for 18% and 16% of species over all sites, respectively (Table 2), and were absent from some sites (Table 1). Aerial feeders had significantly more species per site, and ground feeders were significantly more abundant per site on organic than conventional farms.

Ground feeding omnivores (hereafter, ground omnivores) and lower canopy feeding omnivores (hereafter, lower canopy omnivores) accounted for 26% and 6% of species over all sites (Table 2) and were detected at all or most sites, respectively (Table 1). About half of the ground feeding species were omnivores (Table 2); 75% of omnivores fed on the ground. Ground omnivores accounted for 46% and 57% of species and birds per site, respectively, over all sites, and were significantly more abundant on organic than conventional farms (Table 1). The numbers of species and birds per site of lower canopy omnivores were not significantly different between farm types (Table 1).

SD2 migrants were detected at all sites and accounted for 41% of species (Table 2), 52% of species per site and 61% of birds per site over all sites (Table 1). SD1 migrants (birds that winter in Canada, USA and Mexico), Neotropical migrants and permanent residents accounted for 10%, 34%, and 15% of species over all sites, respectively, and were absent from three to eight sites. SD2 migrants were significantly more abundant on organic than conventional farms.

Ground and above-ground nesters accounted for 26% and 41% of species over all sites, respectively (Table 2), and were detected at all or all but one site, respectively (Table 1). Ground nesters accounted for 39% of species per site and 57% of birds per site. Significantly more ground nesting species and birds were observed on organic than conventional farms.

When grouped together, grassland species of concern occurred at all sites accounting for 34% and 44% of species and birds per site, respectively, over all sites (Table 1). Organic farms had significantly more species and birds per site for this class than conventional farms.

Bird species

Nine species occurred at a sufficient number of sites (at least 42) for analysis (Table 1) with proportional representation among bird classes in line with the distribution of birds and species per point among classes. Savannah Sparrow occurred at all but two survey sites with an average of 3.3 birds per site over all sites. Song Sparrow and Red-winged Blackbird were the next most widespread occurring at 79% of sites with on average 1.7 and 1.9 birds per site over all sites, respectively. Vesper Sparrow and Brown-headed Cowbird were significantly more abundant on organic than conventional farms.

Local crop habitat

Cover of row-crop, spring grain, winter grain and hay accounted for about one half of the local area sampled at survey sites and was never significantly different between farm types (Table 3A). Spring grain was the most widespread crop habitat, occurring at 41 of 72 sites; row-crop occurred at 36 sites. Most crop habitats were confounded, at least to some extent, with farm type because of uneven distributions of survey sites. For example, 13 of 16 sites with corn were conventionally-farmed, while more sites with pasture and winter grain were located on organic than conventional farms (8 vs. 4, and 9 vs. 4, respectively). Although pasture and winter grain were not represented at many survey sites, they were included in analyses because preliminary tests indicated that they were significantly related to bird species richness and abundance.

Local non-crop habitat

Non-crop habitats were fairly evenly distributed between organic and conventional sites, with mean cover similar between farm types (Table 3A). Hedgerows were present at 32 sites (18 organic, 14 conventional) with an average length of 45 m/ha per site. Woodland occurred at 44 sites (split evenly between farm types) with an average of 15% cover per site. Road (including a few sites with railway and transmission corridors) occurred at 42 sites (18 organic, 24 conventional) with an average length of 49 m/ha per site. Habitat heterogeneity was also similar between farm types.

Farming practices
Field size at survey sites averaged 18 ha overall but was significantly larger for conventional farms (23 ha) than organic farms (13 ha)(Table 3). This difference was not expected to differentially affect bird survey results between farm types because all fields were relatively large and bird surveys were conducted from field edges where bird activity is the highest.

Twenty-one of the 72 sites surveyed were visited before first tillage. Of these, stubble was present at 7 sites; 5 conventional and 2 organic.

Forty-six of 72 sites were tilled an average of 1.4 times (range 1 to 3 times) in the spring of 1990 (Table 3B). The mean number of tillages per site was not significantly different between farm types. First tillage occurred between April 1 and June 6 and was on average 5.2 days later on organic farms than on conventional farms, but varied to the extent that the difference was not statistically significant.

Spring planting dates averaged almost one week after first tillage at 12 May, and was the same for organic and conventional sites (Table 3B). The only crop harvested during the survey was hay. Of the 26 hay fields surveyed, 7 (1 organic, 6 conventional) were each harvested once during the survey. The remaining fields were mown for the first time after bird surveys were completed.

On average, 2.9 passes in total (range 1 to 6) were made through the 65 fields worked in spring 1990; organic and conventional sites were similar (Table 3B).

Pest Control
Both herbicides and insecticides were applied at survey sites (Table 3; see Appendix 5A for list of compounds). Seed treatments (e.g. fungicide, insecticide) were also likely used on conventional farms but were not specifically noted.

Herbicides were not applied at organic sites (Table 3). Twenty-two of the 36 conventional sites were treated with herbicides. Insecticides were not commonly used by farmers in this study and were applied to only 2 conventional sites. Biodynamic sprays were used for weed control at 13 organic sites.

Fertilizer
Synthetic chemical fertilizers (see Appendix 5B for list) were used at 22 conventional sites in 1990 (Table 3). Green manure was used at 7 sites; 6 were organic. Liquid manure (including 1 site sprayed with composted manure) was applied at 4 organic and 4 conventional sites. Solid and manure from grazing cattle were applied at 4 conventional sites and 1 organic site. All manure types were pooled for further analyses to increase sample size.

Crop growth
Crop growth patterns were similar between farm types (Table 3). Although total accumulated biomass, and growth during the third time interval, averaged higher on organic than conventional farms, differences were not significant. Crop growth variables were excluded from further analyses because preliminary tests suggested that these variables were relatively unimportant to birds, and because farm type differences were negligible.

Landscape characteristics
Summary statistics were generally similar in total and by farm type when based on all 72 sites and 16 spatially-independent sampling regions (Table 3C). For all sites, riparian woodland and riparian woodland edge occurred more frequently and had significantly higher means at conventional than organic sites. Farm type differences were not evident for combined woodlands and edges for all sites or by region. Farmstead mean was significantly higher on organic than conventional farms when averaged by region. Otherwise, all variables included in statistical analyses were similar and equally represented on both farm types.

Species richness and abundance with local site variables
Regression models were derived for species richness and abundance of each bird class on local habitat and farming practice variables (Table 4). Alternative models were generated for each of the final stepwise regressions to examine model reliability and to identify other independent variables of interest. Models are not reported for species richness of lower canopy-feeding omnivores, and winter residents, and for abundance of insectivore, aerial feeders, and ground-feeding omnivores, because at least one assumption for regression was not met, or influence tests indicated inadequacies in the data. All models reported met the assumptions for regression analysis, and were stabilized by removing highly influential observations, if necessary. Square root transformation of dependent variables was sometimes necessary to meet the assumption of normality of model residuals. The significant explanatory variables for each model are listed in descending order of importance by their partial R^2s and summarized in relation to either habitat or farming practice. Models within a class are listed in descending order of fit. The adjusted R^2 is reported for comparison among different sized models.

For the most part, the best alternative models were easily identified (Table 4). Generally, the most important explanatory variables (i.e., those which accounted most of the explained variance) in the final stepwise model were preserved and the least significant variable was replaced by one that was relatively less significant ($p<.10$). Models including variables that were not significant ($p>.10$) are presented for comparison only, and were not included in tabulations of results. In a few cases, many alternative models were derived with very similar total and adjusted R^2s (for example see total species richness, and abundance of grassland species). This suggests a limitation in the data in either the independent variables measured and/or the sample size. Use of alternative models is particularly helpful in these cases to elucidate which are the most important explanatory variables. Regression results will firstly be summarized in relation to habitat and farming practices to provide insight for alternative landscape and management designs. They will also be presented by bird class for a different conservation focus.

Regression models explained an overall average of 36% of the variation in species richness (range 23-57%) and abundance (range 25-64%) in total and among 11 other bird classes (Table 5, Figure 1). Species richness of 7 classes (including total) and abundance of 9 classes (including total) were affected by both habitat and farming practices. Local habitat was significant to species richness of all but two classes (insectivores, aerial feeders), and to abundance of all classes, accounting for 26% (range 0-56%) and 24% (range 1-57%) of variation averaged over all classes, respectively. Local habitat was particularly important to species richness in total and of omnivores, ground feeders, ground-feeding omnivores and SD1 migrants. For abundance, local habitat was particularly important for ground nesters, above-ground nesters, Neotropical migrants and grassland species of concern.

Non-crop habitats were substantially more important to species richness than crop habitats (10 vs. 8 classes; 22% vs. 5% of variation averaged over all classes, respectively) but were only slightly more important than crop habitats for abundance (9 vs. 8 classes; 14% vs. 11% of variation averaged over all classes, respectively)(Table 5). Non-crop habitats were particularly important to species richness in total and of omnivores and ground-feeding omnivores, and to abundance of ground nesters, and above-ground nesters. Crop habitats were more important to species richness of ground feeders and ground-feeding omnivores, and substantially more important to abundance of Neotropical migrants and grassland species of concern. Crop and non-crop habitats were equally important to species richness of Neotropical migrants and grassland species of concern. In contrast, there were no classes for which crop and non-crop habitats were equally important to abundance.

Farming practices were significant to species richness and abundance for 9 of 12 classes, explaining 10% (range 0-33%) and 13% (range 0-31%) of variation averaged over all classes, respectively (Table 5, Figure 1). Farming practices were particularly important to species richness of aerial feeders, insectivores, Neotropical migrants, and grassland species of concern, and to abundance of total, omnivores, ground feeders, and SD2 migrants.

Herbicide use was significant to species richness of 4 classes, and to abundance of 7 classes, accounting for 3% and 8% of variation averaged over all classes, respectively (Table 5). Other farming practices were significant to species richness and abundance of 9 classes, accounting for 9% and 8% of variation averaged over all classes, respectively.

Of all site variables analyzed, hedgerow was the most important to species richness and abundance (Table 6). Greater length of hedgerow increased species richness for 67% of classes explaining 23% of variation when significant. Hedgerow was important to abundance of 58% of classes. However greater length of hedgerow increased abundance for 57% of those classes (particularly lower canopy omnivores and SD1 migrants), and decreased abundance for the others (particularly ground nesters), explaining 15% and 7% of variation, respectively, when significant. Herbicide use was equally important to abundance, decreasing abundance for 58% of classes, and explaining 13% of variation, when significant. Herbicide use also decreased species richness for 33% of classes (including total and grassland species of concern) explaining 9% of variation on average when significant.

Woodland was the next most important site variable for species richness (Table 6). More woodland increased species richness for 50% of classes explaining 7% of variation, on average, when significant. Hay was significant to species richness of 25% of classes; more hay at a site increased species richness for grassland species of concern and lower canopy feeders, but decreased species richness of ground feeders. Hay was the second most important site variable for abundance. More hay increased abundance for 50% of classes explaining 17% of variation, on average, when significant. Woodland was important for abundance of 42% of classes; more woodland increased abundance for 80% of those classes (particularly above ground nesters), and decreased abundance for the other one (ground nesters), explaining 12% and 9% of variation, respectively, when significant.

All other non-crop habitats when significant increased species richness (except road on grassland species of concern), but decreased abundance (except stream which was not significant)(Table 6). Other crop habitats had mixed effects on species richness when significant. More winter grain at a site decreased species richness for 42% of classes, explaining 7% of variation, when significant. Greater habitat heterogeneity increased species richness for 25% of classes explaining 6% of variation, on average, when significant.

Other farming practices (except organic farm type) consistently decreased species richness but had mixed effects on abundance when significant (Table 6). More passes through a site decreased species richness of 42% of classes explaining 10% of variation, on average, when significant. Number of tillages was important to abundance of 50% of classes. More tillages increased abundance of 80% of those classes (particularly ground feeders and residents) and decreased abundance of lower canopy feeders, explaining 7% and 4% of variation, on average, when significant. Larger field size decreased species richness for 33% of classes explaining an average of 12% of variation, when significant. Organic farms (o/farm) had a residual positive effect on species richness of total, ground feeders, aerial feeders and ground-feeding omnivores which was not accounted for by any of the other site variables analyzed. Organic farm type was also important to abundance of 33% of classes; for 3 classes (particularly SD2 migrants, and omnivores), the effect was positive explaining 19% of variation, on average, when significant; the effect was negative for only Neotropical migrants explaining 5% of the variation in abundance.

Regression profiles varied among bird classes. Total species richness was increased by more hedgerow and woodland, and decreased by farming practices, particularly use of herbicide (organic farm type had a residual positive effect). Total abundance increased with more hay, more pasture, less winter grain, more tillages and no use of herbicide. Species richness of birds which over-winter, at least in part, south of the USA (Neotropical migrants, SD2 migrants) increased with more hedgerow, more woodland, less winter grain, less row-crop, fewer passes through a field, smaller field size, and no use of herbicide or biodynamic spray. In contrast, their abundance increased with less hedgerow, more hay, less spring grain, lower habitat heterogeneity and, again, no use of herbicides; organic farm type had an opposite effect on abundance for these migrant classes. The number of grassland species of concern increased with more hay, more fenceline, less road, smaller field size, and no use of herbicide or chemical fertilizer. Abundance of grassland species of concern increased with more hay, more winter grain, and use of biodynamic spray, and decreased with more road, row-crop, and use of herbicide and chemical fertilizer.

Bird species with local site variables
Regression analyses at the species level yielded models which failed to meet all assumptions required, or at best, produced unreliable results, as indicated by associated influence diagnostics. Logistic regression would have been a more appropriate analysis method for data of this sort. In the interim, Spearman rank correlation was used to provide some insight into relationships between the abundance of individual bird species and local site variables (Table 7, details in Appendix 7). Relationships need to be interpreted with caution because the large number of variables analyzed increases the likelihood of spurious significant correlations.

Abundance of 5 of 9 species was significantly ($p<.10$) correlated with hedgerow, farm i.d. (i.e., same farm) and field size (Table 7). Greater length of hedgerow was negatively correlated with abundance of Horned Lark ($p<.05$) and Savannah Sparrow ($p<.05$), and positively with Song Sparrow ($p<.05$), American Robin ($p<.10$) and Brown-headed Cowbird ($p<.10$). Greater field size was positively correlated with abundance of Horned Lark ($p<.05$), Savannah Sparrow ($p<.05$) and Vesper Sparrow ($p<.10$), and negatively with Killdeer ($p<.05$) and American Robin ($p<.10$). Positive correlations with farm i.d. were most likely a result of spatial autocorrelation of habitat and farming practices within farms; negative correlations with Horned Lark and Savannah Sparrow are more puzzling.

Fenceline, row-crop and farmstead were significantly ($p<.10$) correlated with the abundance of 4 of 9 species (Table 7). Fenceline was positively correlated for Barn Swallow ($p<.05$) and Savannah Sparrow ($p<.05$), and negatively for American Robin ($p<.10$) and Song Sparrow ($p<.10$). Row-crop was positively correlated for Killdeer ($p<.05$), American Robin ($p<.10$) and Red-winged Blackbird ($p<.10$), and negatively for Savannah Sparrow ($p<.05$). Farmstead was positively correlated for American Robin ($p<.05$) and Barn Swallow ($p<.05$) and negatively for Savannah Sparrow ($p<.05$) and Vesper Sparrow ($p<.05$).

One unexpected outcome was that herbicide use was only significantly correlated with abundance of Savannah Sparrow ($p<.10$), despite its importance to abundances for omnivores and ground feeders in regression analyses (Table 7). Seven of the 9 species tested were omnivores and 6 were ground feeders.

Different correlation profiles were observed among the nine species analyzed (Table 7). Six species (American Robin, Horned Lark, Killdeer, Red-winged Blackbird, Savannah Sparrow and Vesper Sparrow) were significantly ($p<.10$) correlated with a suite of variables. All showed both positive and negative correlations with significant variables.

Species profiles can be illustrated by strong ($p<.05$) correlations between abundance and local site variables (Table 7). Savannah Sparrow was the most frequently occurring species in our sample and the second most abundant (Appendix 1). Savannah Sparrow increased with winter grain, hay, fenceline, biodynamic spray and field size, and decreased with hedgerow, stream, row-crop, farmstead, and habitat heterogeneity. In contrast, Song Sparrow increased with hedgerow. Vesper Sparrow was also less abundant at sites with farmstead as well as with road. In contrast, Barn Swallow increased with farmstead as well as with fenceline. American Robin also increased with farmstead along with pasture. Brown-headed Cowbird was more abundant on organic farms and where fields were tilled more often. Red-winged Blackbird also increased with the number of tillages per site along with road, and decreased with winter grain. Horned Lark increased with the number of tillages, number of passes and field size, and decreased with hedgerow and hay. Killdeer abundance was higher with more row-crop, more tillages, less hay and smaller field size.

Estimating magnitude of risk from local site change

For the most part, the explanatory variables in the final stepwise regression models (especially those which accounted most of the explained variance) were preserved in alternative models (Table 4). Typically, the least significant variable was replaced by one that was relatively less significant. Since the importance of regression parameters remained relatively unchanged, as did their estimates, we are confident that the final stepwise models, although based on a limited sample, are reliable and robust enough to use for estimating the magnitude of risk to different classes of birds from potential changes in local site conditions.

Final stepwise regression models for omnivores and grassland species of concern (Table 4, SAS output in Appendix 8) were used because confidence intervals should be computed on untransformed values (Sokal and Rohlf 1969). While it would be instructive to estimate risk for all classes with regression models (particularly total species richness and abundance), it is still unclear how to do this for multiple regression models which include variables which have been transformed for analysis. Further consultation is required before this can be accomplished.

For species richness of omnivores, hedgerow was initially set at 100 m/ha, woodland at 0.3 (30% of the local site scale) and winter grain was set at 0.2 (20% of local site scale). This set of conditions, while not average, were within the range of our sample (Table 3). Provided that our sample is an unbiased representation of the population, the 95% prediction interval for this set of site conditions was 13.7 species (± 4.0 species). To estimate the effect of "removing" important local habitat features such as woodland and hedgerow from a site and increasing a feature such as winter grain which impacts negatively on species richness, we set hedgerow to 20 m/ha, woodland to 0.1 and winter grain to 0.6, again a set of conditions within the range of our sample. The predicted species richness falls to 7.5 (± 3.8 species) representing a loss of 6.2 species per site, on average (range 6.0-6.3).

For omnivores, the 95% prediction interval was 9.7 birds (± 5.1 birds) for sites where herbicide was used compared to 13.1 birds (± 5.1 birds) where herbicide was not used. Thus, use of herbicide was estimated to have resulted in a loss of 3.4 bird per site, on average (range 3.4-3.5).

A similar analysis was also conducted for grassland species of concern (10 species in total). For initial conditions for species richness, herbicide was used, road was set at 49.01 m/ha, hay at 0.51, and proportional field size at 2.96. This set of site conditions was average for our sample (Table 3). The 95% prediction interval was 4.39 species (± 2.49 species). When herbicide was not used, the same set of habitat conditions resulted in a 95% prediction interval of 5.16 species (± 2.43 species). Thus, use of herbicide was estimated to have resulted in a loss of 0.78 species per site, on average (range 0.72-0.84).

For initial conditions for abundance of grassland species of concern, hay was set at 0.51, road at 49.01 m/ha, biodynamic spray and herbicide were used. This set of site conditions was average for our sample though unrealistic because herbicide and biodynamic spray were not typically used together. The 95% prediction interval was 9.4 birds (± 4.1 birds). When herbicide was not used, the 95% prediction interval was 10.6 birds (± 3.9 birds). Thus, use of herbicide was estimated to have resulted in a loss of 1.2 birds per site, on average (range 1.0-1.4).

Correlations with landscape characteristics
Landscape scale characteristics included those at the local scale. The initial analysis design was to use multiple regression to assess the importance of landscape versus local scale features by examining the magnitude of model and adjusted R^2. However, preliminary analyses revealed that landscape data did not meet assumptions for regression or conventional correlation analysis. Spearman rank correlation was used as an alternative to identify landscape characteristics potentially important to species richness and abundance of bird classes and to abundance of individual bird species. Analyses were conducted for 16 spatially-independent regions, and for all survey sites since we did not need to meet the assumption of spatial independence in using a nonparametric test. Results were similar for both datasets although level of significance ($p<.05$ vs. $p<.10$) varied in some cases (Table 8, details in Appendix 9). While we expected tests using spatial regions to be less sensitive because of smaller sample size, this was not always the result. For reasons given above, results were summarized firstly by habitat and farming practice and secondly by bird class or species. Relationships need to be interpreted with caution because the large number of variables analyzed increases the likelihood of spurious significant correlations.

Species richness and abundance with landscape characteristics
Overall, species richness was much more highly correlated with landscape variables than abundance (Table 8). Hedgerow was the most important to species richness and abundance based on patterns of correlation. Species richness increased with more hedgerow for all but two bird classes (ground nesters, grassland species of concern). Hedgerow was correlated with abundance for 9 of 15 birds classes, although negatively with 3 (ground omnivores, ground nesters, grassland species of concern). Counter to what would be expected, species richness increased with the number of cultivated fields in the landscape for 11 classes. Number of cultivated fields and stream were also important to abundance although effect varied among the 8 classes. Woodland edge appeared to be more important to species richness than woodland area (significant correlations with 9 vs. 7 classes, respectively). Neither of these habitat features were very correlated with bird abundance. Farm type was significantly correlated with both species richness and abundance for about half of the bird classes; in all cases the correlation was positive with organic farm type. Habitat heterogeneity had a significant positive correlation with species richness for 7 classes but was relatively unimportant to bird abundance. Farmstead had significant positive correlations only with abundance for 4 classes.

Class profiles can be illustrated by strong ($p<.05$) correlations with landscape variables at either the site or region level (Table 8). Total species richness increased with more hedgerow, woodland, woodland edge, number of cultivated fields, and organic farm type. In contrast, total abundance was correlated only with farm type, being higher on organic than conventional farms.

Species richness of omnivores increased with more hedgerow, woodland, woodland edge, number of cultivated fields, and habitat heterogeneity. Omnivore abundance was positively correlated with organic farm type only. As one would expect, species richness of lower canopy feeders had strong positive correlations with woody habitat features (hedgerow, woodland, woodland edge) as well as habitat heterogeneity. Their abundance was positively correlated with hedgerow and habitat heterogeneity and negatively with stream. Species richness of Neotropical migrants was positively correlated with hedgerow and organic farm type; their abundance positively with stream and negatively with number of cultivated fields. Species richness and abundance of grassland species of concern was positively correlated with organic farm type; abundance was also negatively correlated with hedgerow.

Bird species with landscape characteristics

Number of cultivated fields was most often correlated with species abundance (6 of 9 species), and, except for Savannah Sparrow, positively (Table 9, see Appendix 9 for details). Hedgerow and stream were correlated with 5 species showing both positive and negative effects.

Abundance of individual species had relatively few strong ($p<.05$) correlations with landscape variables whether data were analyzed by site or by spatially-independent region (Table 9). Savannah Sparrow increased with less hedgerow, more stream and fewer cultivated fields. Red-winged Blackbird decreased with more stream and increased with more cultivated fields and farmstead. Song Sparrow increased with both more hedgerow and more cultivated fields. American Robin increased with hedgerow. Barn Swallow increased with stream while Vesper Sparrow decreased. Horned Lark had a strong negative correlation with farmstead. Killdeer was positively correlated with number of cultivated fields. Brown-headed Cowbird was only positively correlated to organic farm type.

DISCUSSION

Agricultural landscapes have the potential to play a more positive role in conservation of wildlife, especially where there are competing, more disruptive land uses such as urbanization. The integration of wildlife within farmland will help to keep common species common, and possibly also preserve a few rare or endangered species, in addition to providing potential agronomic benefit (Mineau & McLaughlin 1996). The main challenge will continue to be to find the right compromise between our demands from agricultural lands and the needs of our native biota. The results of this study re-emphasize that both bird species richness and abundance in farmland are related to a variety of factors associated with habitat patterns and disturbance regimes imposed by agriculture. While additional work is needed to determine relationships with productivity and survival, mounting evidence suggests that density reflects habitat quality on different farm types (Fluetsch and Sparling 1994, BTO/IACR-R 1995). In Britain, both density and measures of reproductive success (nestling weight, nestling survival rates and clutch size) for the Skylark (*Alauda arvensis*) were higher on organic than conventional cropland in Britain (Chamberlain *et al.* 1995, Evans *et al.* 1995).

In the present study, local habitat was generally more important than agricultural practices for both species richness and abundance. In turn, non-crop habitat was more important than crop habitat, particularly for species richness. For example, woody cover adjacent to fields (e.g. hedgerows, woodland) was positively related to species richness of many bird classes. For omnivores, a modeled loss of woodiness (hedgerow, woodland), in conjunction with an increase in winter grain, was predicted to result in a decrease of six species per site. While woodiness also had a positive effect on the abundance of some bird classes and species, it concomitantly had a negative effect on the abundance of others (notably ground nesters, Neotropical migrants, and Savannah Sparrow, a grassland species of concern). In addition, ground nesters, grassland species of concern, and Vesper Sparrow (a grassland species of concern) were all adversely affected by the presence of road. Roads and woody habitats can function as focal areas for a variety of vertebrate predators (Oehler and Litvaitis 1996, Bergin *et al.* 1997). Habitat characteristics at the landscape scale have been found to be important in understanding field-level use patterns in other studies (Arnold 1983, O'Connor and Shrubb 1986, Robertson *et al.* 1990, Best *et al.* 1995). In this study, landscapes surrounding study sites were similar between farm types. However, effects on bird species patterns could not be adequately examined with the current study design.

When significant, agricultural practices consistently had a negative relationship with species richness of farmland birds. Some practices (number of tillages, number of passes, field size) had both positive and negative relationships with the abundance of bird classes and species. The positive relationship between field size and abundance of Horned Lark, Savannah Sparrow and Vesper Sparrow was consistent with the positive area-sensitivity of these species (Best *et al.* 1996). In contrast, the negative relationship with the abundance of Killdeer was puzzling.

In contrast to other agricultural practices, the use of agrichemicals (particularly herbicides; insecticides could not be analyzed) consistently had a negative effect on both bird species richness and abundance. To our knowledge, this field study and its pilot (Rogers and Freemark 1991) are the first to detect an effect of herbicide use on species richness (cf. Gremaud and Dahlgren 1982, Brae *et al.* 1988, Chamberlain *et al.* 1995). Other studies suggest that herbicide use lowers habitat quality for birds, primarily through plant-mediated reductions in food supply (Brae *et al.* 1988, BTO/IACR-R 1995, Freemark and Boutin 1995).

In this study, herbicide use was predicted to decrease richness of grassland species of concern by almost one species per site (10% of species in this class), and abundance by just over one bird per site. For omnivores, herbicide use was predicted to decrease abundance by 3.4 birds per site. While the predicted decreases may not be large at a single site, the effect has the potential to magnify when accumulated over many sites in a given year. Furthermore, effects may be conservative because the conventional farms selected were not of the most intensive types. The current extent of organic farming in Canada (as elsewhere) is unlikely to have a marked positive effects on species at national or regional scales. However, it is possible that even a modest increase in organic farming (and/or other more environmentally-friendly farming systems) could be of local, or possibly even, regional significance for bird populations, including some of current conservation concern (cf. BTO/IACR-R 1995).

This study has demonstrated that both habitat and agricultural practices have important effects on the species richness and abundance of farmland birds that, along with other attributes such as survival and productivity, need to be considered in developing recommendations for alternative landscape designs and farm management systems that are more conducive to conservation of avian diversity. However, effects on species richness and abundance varied among habitats, practices, and classes and species of birds. Some habitats and agricultural practices had both positive and negative relationships with different classes of birds and species. Thus, in making recommendations for alternative landscape designs and farm management systems to enhance wildlife, it is important to clearly articulate conservation objectives that are regionally appropriate (Mineau and McLaughlin 1996). In most cases, a key component will be re-introduction of landscape heterogeneity by protection and enhancement of important non-crop areas, smaller fields (and possibly farms), and a greater mixture of crops, through rotation, intercropping and regional diversification. In the midwestern cornbelt ecoregion for example, woody habitats would be better adjacent to row-crops or other habitats in which avian diversity is low and nesting species are of low conservation priority than adjacent to grass habitats in which nesting species are of high conservation priority and potential losses from nest predation are of greater concern (Bergin *et al.* in review).

To enhance both bird species richness and abundance, use of existing herbicides (and other pesticides) should be reduced, eliminated or substituted with more selective products (cf. McLaughlin and Mineau 1995). Conservation headlands (Sotherton 1991) or other types of buffer zones could also help reduce adverse impacts on birds and other wildlife (including plants) in non-crop habitat adjacent to croplands from use of pesticides and chemical fertilizers, and potentially other farming practices (e.g. tilling, mowing, total number of passes through a field).

It is important to remember however, the data analyzed in this study were collected for spatial distribution patterns only, over one breeding season, from a small number of farms with a limited range of crop types in a single geographical area. Care should therefore be taken in extrapolating these results to other ecological attributes (e.g. survival and productivity) and agricultural regions, especially those with different cropping patterns, without more work to establish the generality of these findings.

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Table 1: Survey results for selected classes of birds in and adjacent to fields on organic (o) and chemical (c) farms in Ontario, 1990 for A. unlimited distance (but still on farm) surveys, B. limited distance (100m-radius semicircle) surveys and C. bird classifications. Averages (X) are based on number of sites at which class occurs (n, n_o and n_c). * denotes significant ($p<.05$) t-test on organic versus chemical means.

A. UNLIMITED DISTANCE (ULD)

CLASS (ULD)		n	X_n	sd	n_o	X_{no}	sd	n_c	X_{nc}	sd
Total										
	# species	72	68	----	36	59	----	36	59	----
	# spp/site	72	13.9	4.5	36	14.8	4.8	36	13.0	4.2
	# birds/site	72	16.9	5.0	36	18.7	5.5	36	15.1	4.0*
Insectivores										
	# spp/site	72	4.1	2.3	36	4.6	2.3	36	3.7	2.2
	# birds/site	72	3.8	3.4	36	4.2	3.9	36	3.5	4.2
Omnivores										
	# spp/site	72	8.6	2.5	36	9.1	2.7	36	8.2	2.3
	# birds/site	72	12.0	3.0	36	13.4	2.7	36	10.7	2.6*
Aerial Feeders										
	# spp/site	64	2.0	1.1	34	2.2	1.2	30	1.7	0.8*
	# birds/site	64	1.4	1.7	34	1.4	1.9	30	1.4	1.5
Ground Feeders										
	# spp/site	72	8.7	2.6	36	9.2	2.7	36	8.2	2.4
	# birds/site	72	12.6	4.4	36	14.2	4.6	36	11.0	3.6*
Lower Canopy Feeders										
	# spp/site	70	2.7	1.5	35	2.6	1.5	35	2.8	1.5
	# birds/site	70	2.7	2.0	35	2.7	2.1	35	2.8	1.9

Table 1A continued ...		n	X_n	sd	n_o	X_{no}	sd	n_c	X_{nc}	sd
CLASS (ULD)										
Ground Omnivores										
	# spp/site	72	6.4	1.8	36	6.8	2.1	36	6.0	1.5
	# birds/site	72	9.6	3.0	36	10.9	3.0	36	8.4	2.6*
Lower Canopy Omnivores										
	# spp/site	70	2.1	0.9	35	2.1	0.9	35	2.1	0.8
	# birds/site	70	2.3	1.5	35	2.4	1.7	35	2.2	1.4
Neotropical Migrants										
	# spp/site	69	2.9	1.8	36	3.2	2.0	33	2.5	1.6
	# birds/site	69	2.4	2.1	36	2.6	2.4	33	2.2	1.8
Short Distance 1 Migrants										
	# spp/site	66	2.1	1.2	34	2.3	1.3	32	1.9	1.1
	# birds/site	66	2.2	1.7	34	2.3	1.5	32	2.2	1.9
Short Distance 2 Migrants										
	# spp/site	72	7.2	2.0	36	7.5	2.2	36	7.0	1.8
	# birds/site	72	10.3	2.9	36	11.6	3.0	36	9.0	2.2*
Permanent Residents										
	# spp/site	64	2.4	1.4	31	2.5	1.4	33	2.4	1.3
	# birds/site	64	2.6	2.8	31	2.8	3.3	33	2.5	2.4
Ground Nesters										
	# spp/site	72	5.4	1.5	36	5.8	1.4	36	5.0	1.6*
	# birds/site	72	9.7	4.4	36	10.7	4.7	36	8.6	4.0*
Above-Ground Nesters										
	# spp/site	71	5.0	3.2	35	5.5	3.5	36	4.5	2.9
	# birds/site	71	3.4	2.6	35	3.7	2.7	36	3.0	2.6

Table 1A continued ... CLASS (ULD)		n	X_n	sd	n_o	X_{no}	sd	n_c	X_{nc}	sd
Declining Grassland Species										
	# spp/site	72	4.7	1.5	36	5.1	1.3	36	4.4	1.6*
	# birds/site	72	7.5	3.0	36	8.3	2.9	36	6.7	3.0*
American Robin										
	# birds/site	52	0.8	0.5	22	0.9	0.7	30	0.8	0.4
Barn Swallow										
	# birds/site	42	0.8	0.8	19	0.7	0.9	23	0.9	0.8
Brown-headed Cowbird										
	# birds/site	50	1.1	0.8	26	1.5	0.9	24	0.7	0.5*
Horned Lark										
	# birds/site	42	1.9	1.4	21	2.0	1.2	21	1.8	1.6
Killdeer										
	# birds/site	46	1.0	0.8	24	1.2	1.0	22	0.9	0.6
Red-winged Blackbird										
	# birds/site	57	1.9	1.4	31	2.0	1.6	26	1.8	1.1
Savannah Sparrow										
	# birds/site	70	3.3	2.2	36	3.4	2.2	34	3.3	2.2
Song Sparrow										
	# birds/site	57	1.7	1.0	31	1.7	1.0	26	1.7	1.0
Vesper Sparrow										
	# birds/site	53	1.1	0.7	27	1.3	0.8	26	0.9	0.6*

Table 1 continued: Survey results for selected classes of birds in and adjacent to fields on organic (o) and chemical (c) in Ontario, 1990 for A. unlimited distance (but still on farm surveys, B. limited distance (100m-radius semicircle) surveys and C. bird classifications. Averages (X) are based on number of points at which classes occur (n, n_o and n_c). * denotes significant ($p<.05$) t-test on organic versus chemical means.

B. LIMITED DISTANCE (LD)

CLASS (LD)		n	X_n	sd	n_o	X_{no}	sd	n_c	X_{nc}	sd
Total	# species	72	59	----	36	48	----	36	48	---
	# spp/point	72	9.7	3.8	36	10.1	3.6	36	9.3	4.0
	# birds/point	72	11.7	4.5	36	13.4	5.1	36	10.0	2.9*
Insectivores										
	# spp/point	68	2.8	1.6	35	2.9	1.6	33	2.8	1.7
	# birds/point	68	2.4	2.5	35	2.6	2.2	33	2.2	1.8
Omnivores										
	# spp/point	72	6.3	2.4	36	6.6	2.3	36	6.1	2.5
	# birds/point	72	8.8	3.4	36	10.2	4.0	36	7.5	2.0*
Aerial Feeders										
	# spp/point	64	1.5	0.9	34	1.5	1.0	30	1.5	0.8
	# birds/point	64	1.1	1.6	34	1.0	1.7	30	1.2	1.5
Ground Feeders										
	# spp/point	72	6.2	2.3	36	6.8	2.3	36	5.7	2.2*
	# birds/point	72	8.9	4.3	36	10.6	4.9	36	7.2	2.8*
Lower Canopy Feeders										
	# spp/point	57	2.2	1.4	28	2.0	1.1	29	2.5	1.5
	# birds/point	57	2.1	1.4	28	2.1	1.5	29	2.0	1.4

Table 1B continued ... CLASS (LD)		n	X_n	sd	n_o	X_{no}	sd	n_c	X_{nc}	sd
Ground Omnivores										
	# spp/point	72	4.8	1.6	36	5.2	1.6	36	4.4	1.6*
	# birds/point	72	7.3	3.7	36	8.6	4.3	36	6.0	2.4*
Lower Canopy Omnivores										
	# spp/point	57	1.8	0.8	28	1.7	0.8	29	1.9	0.8
	# birds/point	57	1.8	1.1	28	1.9	1.3	29	1.7	1.0
Neotropical Migrants										
	# spp/point	64	2.0	1.3	34	2.0	1.3	30	2.1	1.4
	# birds/point	64	1.8	1.8	34	1.8	2.0	30	1.7	1.5
Short Distance 1 Migrants										
	# spp/point	58	1.7	1.0	30	1.8	0.9	28	1.6	1.1
	# birds/point	58	1.6	1.1	30	1.7	1.2	28	1.5	1.0
Short Distance 2 Migrants										
	# spp/point	72	5.3	2.0	36	5.6	2.0	36	5.0	1.9
	# birds/point	72	7.6	3.6	36	8.8	4.5	36	6.4	1.9*
Permanent Residents										
	# spp/point	49	1.7	1.0	24	1.7	1.1	25	1.8	1.0
	# birds/point	49	1.8	1.8	24	2.0	2.0	25	1.5	1.6
Ground Nesters										
	# spp/point	72	4.2	1.2	36	4.6	1.1	36	3.8	1.2*
	# birds/point	72	7.2	3.8	36	8.6	4.3	36	5.8	2.7*
Above-Ground Nesters										
	# spp/point	54	3.5	2.4	27	3.6	2.2	27	3.4	2.6
	# birds/point	54	2.1	1.5	27	2.3	1.5	27	2.0	1.6
Declining Grassland Species										
	# spp/point	72	4.0	1.2	36	4.2	0.9	36	3.7	1.4*
	# birds/point	72	5.8	2.4	36	6.5	2.3	36	5.1	2.3*

Table 1B continued ... CLASS (LD)		n	X_n	sd	n_o	X_{no}	sd	n_c	X_{nc}	sd
American Robin	# birds/point	26	0.8	0.6	8	1.1	0.6	18	0.7	0.5
Barn Swallow	# birds/point	40	0.8	0.8	18	0.7	0.9	22	0.8	0.8
Brown-headed Cowbird	# birds/point	38	1.1	0.8	23	1.3	0.1	15	0.8	0.5*
Horned Lark	# birds/point	40	2.2	3.7	21	2.7	4.8	19	1.7	1.7
Killdeer	# birds/point	30	1.0	1.0	16	1.2	1.2	14	0.8	0.7
Red-winged Blackbird	# birds/point	48	1.4	1.1	24	1.5	1.3	24	1.3	0.9
Savannah Sparrow	# birds/point	70	2.9	1.9	36	3.0	2.0	34	2.7	1.8
Song Sparrow	# birds/point	49	1.3	0.7	25	1.4	0.8	24	1.2	0.6
Vesper Sparrow	# birds/point	43	0.9	0.6	23	1.1	0.6	20	0.7	0.5*

Table 1 continued: Survey results for selected classes of birds in and adjacent to fields on organic (o) and chemical (c) farms in Ontario, 1990 for A. unlimited distance (but still on farm) surveys, B. limited distance (100m-radius semicircle) surveys and C. bird classifications. Averages were based on 72 study sites.

C. BIRD CLASSIFICATION (Unlimited distance survey)

CLASS	#	% total spp	% spp analyzed	% birds per point analyzed	% spp per point (ULD)
Food Type					
Omnivore	24	35.3	77.8	71.0	61.9
Insectivore	35	51.5	22.2	22.5	29.5
Granivore	4	5.9	0	4.9	5.6
Food Substrate					
Air	12	17.6	11.1	7.4	12.8
Ground	35	51.5	66.7	74.6	62.6
Lower canopy	11	16.2	22.2	15.5	18.9
Upper canopy	5	7.4	0	1.2	2.6
Migratory Status					
Neotropical migrant	23	33.8	11.1	13.6	20.0
Short distance 2	28	41.2	77.8	60.9	51.8
Short distance 1	7	10.3	11.1	11.9	13.8
Resident	10	14.7	0	13.7	15.3
Nesting Stratum					
Ground	18	26.5	55.6	57.4	38.8
Above ground	28	41.2	11.1	19.8	35.5
Other	8	11.8	22.2	16.2	14.9
Not local breeder	3	4.4	0	0.4	0.9
Cavity	9	13.2	0	2.6	5.6
None	2	2.9	11.1	6.5	5.0
TOTAL	68	68	9	16.9	13.9

Table 2: Number (in parentheses) and % Jaccard similarity in species composition between classes of bird studied. See Appendix 2 for class abbreviations. a = total number of species over all surveys.

		SPECIES OF CONCERN	NESTING STRATUM		MIGRATORY STATUS				FOOD SUBSTRATE			
		Grassland	Above Grd	Ground	Res	SD1	SD2	Nt	Loca	Grd	Air	No. Sp.
FOOD	In	9.8 (4)	26.0 (13)	17.8 (8)	9.8 (4)	5.0 (2)	21.2 (11)	45.0 (18)	17.9 (7)	14.8 (9)	34.3 (12)	35
FOOD	Om	17.2 (5)	33.3 (13)	16.7 (6)	13.3 (4)	19.2 (5)	23.8 (10)	11.9 (5)	12.9 (4)	43.9 (18)	0.0 (0)	24
FOOD SUBSTRATE	Air	4.8 (1)	14.3 (5)	0.0 (0)	0.0 (0)	5.6 (1)	5.3 (2)	34.6 (9)				12
FOOD SUBSTRATE	Grd	15.4 (6)	18.9 (10)	35.9 (14)	18.4 (7)	7.7 (3)	50.0 (21)	7.4 (4)				35
FOOD SUBSTRATE	Loca	16.7 (3)	25.8 (8)	3.6 (1)	5.0 (1)	20.0 (3)	5.4 (2)	17.2 (5)				11
Grd Omnivores		12.0 (3)	21.1 (8)	16.1 (5)	16.7 (4)	13.6 (3)	24.3 (9)	5.1 (2)	0.0 (0)	51.4 (18)	0.0 (0)	18
Loca Omnivores		16.7 (2)	10.3 (3)	4.8 (1)	0.0 (0)	22.2 (2)	3.2 (1)	3.8 (1)	36.4 (4)	0.0 (0)	0.0 (0)	4
MIGRATORY STATUS	Nt	10.0 (3)	41.7 (15)	7.9 (3)								23
MIGRATORY STATUS	SD2	15.2 (5)	14.3 (7)	39.4 (13)								28
MIGRATORY STATUS	SD1	13.3 (2)	9.4 (3)	4.2 (1)								7
MIGRATORY STATUS	Res	0.0 (0)	8.6 (3)	3.7 (1)								10
NESTING STRATUM	Ground	33.3 (7)										18
NESTING STRATUM	Above Grd	5.6 (2)										28
No. species		10	28	18	10	7	28	23	11	35	12	68[a]

Table 3: Summary statistics for habitat and agricultural practices at bird survey sites and surrounding landscapes in Ontario. Averages and ranges are based on the number of sites at which variable occurred. Min. and max. are the minimum and maximum values for variables at n sites. Categ. represents categorical variables. * denotes significant ($p<0.05$) t-tests on organic versus chemical values per site. n/a = not applicable or data not available. Variables in bold were included in statistical analyses.

A. Local habitat at survey sites (based on 200m-radius semicircle along field edge facing into surveyed field; approximately 6.3 ha)

				Total			Organic			Conventional		
Variable	measure	min.	max.	n	$\bar{X}n$	sd	no	$\bar{X}no$	sd	nc	$\bar{X}nc$	sd
CROP												
Rowcrop	ha/ha	0.01	1.00	36	0.57	0.32	15	0.53	0.32	21	0.60	0.32
-Corn	ha/ha	0.01	1.00	16	0.49	0.37	3	0.56	0.51	13	0.47	0.35
-Soybean	ha/ha	0.00	0.98	26	0.49	0.32	13	0.48	0.32	13	0.50	0.33
Spring grain	ha/ha	0.01	1.00	41	0.53	0.34	25	0.50	0.33	16	0.58	0.37
Winter grain	ha/ha	0.06	0.88	13	0.47	0.23	9	0.39	0.20	4	0.65	0.22
Hay	ha/ha	0.02	1.00	26	0.51	0.36	11	0.49	0.34	15	0.53	0.38
Pasture	ha/ha	0.01	0.71	12	0.17	0.20	8	0.15	0.24	4	0.21	0.13
Farmstead	ha/ha	<0.01	0.28	17	0.08	0.08	8	0.07	0.09	9	0.09	0.08
NONCROP												
Hedgerow	m/ha	2.5	187.0	32	45.1	39.3	18	48.0	33.9	14	41.4	47.5
Woodland	ha/ha	<0.01	0.59	44	0.15	0.13	22	0.15	0.14	22	0.14	0.13
-Upland	ha/ha	<0.01	0.30	24	0.09	0.80	11	0.08	0.06	13	0.09	0.09
-Riparian	ha/ha	<0.01	0.02	4	0.01	0.01	1	0.02	---	3	0.01	0.01
-Isolated trees	ha/ha	0.00	<0.01	30	<0.01	<0.01	16	<0.01	<0.01	14	<0.01	<0.01
Stream	m/ha	2.5	62.9	16	29.4	18.0	8	29.8	21.0	8	29.0	16.0
-Stream	m/ha	3.7	52.9	13	26.3	16.9	5	22.0	19.2	8	29.0	16.0
-Ditch	m/ha	2.5	57.3	4	32.1	22.4	4	32.1	22.4	0	----	----
Road	m/ha	3.5	120.6	42	49.0	26.5	18	43.7	18.8	24	53.0	30.8
-Road	m/ha	3.5	120.6	39	48.1	27.6	16	43.0	19.7	23	51.6	31.9
-Railway line	m/ha	21.3	64.1	2	42.7	30.3	2	42.7	30.3	0	----	----
-Transmission corridor	m/ha	27.9	58.4	4	39.1	13.9	3	32.6	6.3	1	58.4	----
Fenceline (herbaceous)	m/ha	4.8	80.6	18	46.1	24.0	9	42.2	23.1	9	50.1	25.7
Habitat heterogeneity	H'	0.00	0.69	72	0.24	0.17	36	0.26	0.17	36	0.22	0.18

Table 3 continued: Summary statistics for habitat and agricultural practices at bird survey sites and surrounding landscapes in Ontario. Averages and ranges are based on the number of sites at which variable occurred. Min. and max. are the minimum and maximum values for variables at n sites. Categ. represents categorical variables. * denotes significant ($p<0.05$) t-tests on organic versus chemical values/site. n/a = not applicable or data not available. Variables in bold were included in statistical analyses.

B. Agricultural practices at survey sites (based on 200m-radius semicircle along field edge facing into surveyed field; approximately 6.3 ha). See Appendix 5 for a list of agrichemicals used.

				Total			Organic			Conventional		
Variable	**measure**	**min.**	**max.**	**n**	**$\bar{X}$n**	**sd**	**no**	**$\bar{X}$no**	**sd**	**nc**	**$\bar{X}$nc**	**sd**
Field size	ha	1.9	61.2	72	16.1	13.8	36	13.4	9.8	36	22.8	15.7*
Proportional field size	ha/ha	0.31	9.65	72	2.96	2.78	36	2.18	1.57	36	3.75	2.61*
# Tillages	#	1.0	3.0	46	1.4	0.7	24	1.5	0.6	22	1.4	0.7
# Passes	#	1.0	6.0	65	2.9	1.4	32	2.8	1.2	33	3.0	1.5
Insecticide	categ.	0	1	2	n/a	n/a	0	n/a	n/a	2	n/a	n/a
Herbicide	categ.	0	1	22	n/a	n/a	0	n/a	n/a	22	n/a	n/a
Chemical fertilizer	categ.	0	1	22	n/a	n/a	0	n/a	n/a	22	n/a	n/a
Manure	categ.	0	1	17	n/a	n/a	10	n/a	n/a	7	n/a	n/a
-green	categ.	0	1	7	n/a	n/a	6	n/a	n/a	1	n/a	n/a
-solid/semi-solid	categ.	0	1	5	n/a	n/a	1	n/a	n/a	4	n/a	n/a
-liquid	categ.	0	1	8	n/a	n/a	4	n/a	n/a	4	n/a	n/a
Biodynamic spray	categ.	0	1	13	n/a	n/a	13	n/a	n/a	0	n/a	n/a
Farm type	categ.	0(org)	1(conv)	72	n/a	n/a	36	n/a	n/a	36	n/a	n/a
Accumulated biomass	cm-day	32.5	3362.5	72	791.8	783.4	36	830.3	947.5	36	753.3	586.8
Δ Growth 2	cm/day	-0.6	2.9	72	0.5	0.6	36	0.4	0.6	36	0.5	0.6
Δ Growth 3	cm/day	0.0	5.8	72	0.9	1.0	36	1.0	1.3	36	0.8	0.7
Δ Growth 4	cm/day	-0.4	5.0	72	1.3	1.0	36	1.3	1.1	36	1.3	0.9
1st tillage date	julian day	91.0	157.0	46	126.2	15.2	24	128.7	12.2	22	123.5	17.8
Planting date	julian day	110.0	161.0	50	131.9	13.4	26	132.8	12.4	24	130.9	14.6
Haying date	julian day	149.0	176.0	7	166.6	9.5	1	176.0	-----	6	165.0	9.3
Stubble	categ.	0	1	7	n/a	n/a	2	n/a	n/a	5	n/a	n/a

Table 3 continued: Summary statistics for habitat and agricultural practices at bird survey sites and surrounding landscapes in Ontario. Averages and ranges are based on the number of sites at which variable occurred. Min. and max. are the minimum and maximum values for variables at n sites. Categ. represents categorical variables. * denotes significant (p<0.05) t-tests on organic versus chemical values/site. n/a = not applicable or data not available. Variables in bold were included in statistical analyses.

C. Landscapes surrounding survey sites (based on approximately 400 ha)

				Total			Organic			Conventional		
Variables	measure	min.	max.	n	$\bar{X}n$	sd	no	$\bar{X}no$	sd	nc	$\bar{X}nc$	sd
BY SITE (n=72)												
# Cultivated Fields	#/ha	0.03	0.18	72	0.08	0.04	36	0.09	0.04	36	0.07	0.03
# Uncultivated Fields	#/ha	<0.01	0.03	66	0.01	0.01	31	0.01	0.01	35	0.01	0.01
Farmstead	ha/ha	0.01	0.07	72	0.03	0.01	36	0.03	0.01	36	0.02	0.01
Woodland	ha/ha	0.01	0.40	71	0.14	0.08	36	0.12	0.06	35	0.16	0.09
-Upland	ha/ha	0.01	0.37	71	0.11	0.07	36	0.12	0.06	35	0.11	0.09
-Riparian	ha/ha	<0.01	0.23	56	0.03	0.05	25	0.01	0.01	31	0.05	0.06*
Woodland edge	m/ha	5.0	78.8	71	26.1	12.5	36	25.1	11.1	35	27.2	13.8
-Upland	m/ha	4.0	60.7	71	19.5	10.8	36	20.8	11.1	35	18.2	10.4
-Riparian	m/ha	0.5	26.5	56	8.4	6.7	25	6.1	4.8	31	10.2	7.5*
Hedgerow	m/ha	0.7	33.6	71	7.5	7.0	36	8.7	8.7	35	6.2	4.5
Stream	m/ha	0.7	27.3	72	14.7	6.1	36	14.2	6.8	36	15.1	5.3
Sand quarry	ha/ha	<0.01	0.01	14	<0.01	<0.01	13	<0.01	<0.01	1	<0.01	----
Railway	m/ha	1.5	7.4	11	5.2	1.5	4	5.2	0.8	7	5.2	1.8
Habitat heterogeneity	H'	0.12	0.62	72	0.33	0.10	36	0.32	0.08	36	0.34	0.12
BY SPATIALLY-INDEPENDENT REGION (n=16)												
# Cultivated Fields	#/ha	0.04	0 .17	16	0.08	0.04	8	0.09	0.04	8	0.07	0.03
# Uncultivated Fields	#/ha	0.00	0.02	16	0.01	0.01	7	0.01	0.01	8	0.01	0.01
Farmstead	ha/ha	0.01	0.05	16	0.03	0.01	8	0.03	0.01	8	0.02	0.01*
Woodland	ha/ha	0.03	0.36	16	0.14	0.08	8	0.12	0.05	8	0.15	0.11
-Upland	ha/ha	0.01	0.33	16	0.10	0.08	8	0.11	0.06	8	0.10	0.10
-Riparian	ha/ha	0.00	0.23	15	0.03	0.06	7	0.01	0.01	8	0.05	0.08
Woodland edge	m/ha	11.7	40.8	16	24.4	8.8	8	24.3	9.7	8	24.4	8.4
-Upland	m/ha	5.1	33.1	16	17.4	8.2	8	19.5	9.1	8	15.3	7.1
-Riparian	m/ha	0.3	26.5	15	7.4	6.9	7	5.4	3.2	8	9.2	8.9
Hedgerow	m/ha	0.7	30.5	16	6.8	7.2	8	8.9	9.7	8	4.7	2.8
Streams	m/ha	4.6	24.7	16	14.4	5.7	8	14.7	7.2	8	14.2	4.2
Sand quarry	ha/ha	<0.01	0.01	5	<0.01	<0.01	5	<0.01	<0.01	0	----	----
Railway	m/ha	0.9	5.8	3	3.9	2.6	2	3.0	3.0	1	5.8	----
Habitat heterogeneity	H'	0.16	0.44	16	0.32	0.08	8	0.34	0.07	8	0.31	0.10

Table 4: Regression models on species richness and abundance by bird class for Ontario farms. Models are listed in order of best overall fit. % Hab = sum of % partial R^2 for habitat variables (hedgerow, woodland, utility corridors, fenceline, stream, habitat heterogeneity, winter grain, hay, spring grain, rowcrop, pasture, farmstead); % Pr = sum of % partial R^2 for practice variables (herbicides, # tillages, # passes, chemical fertilizer, biodynamic spray, field size, o/farm type). Models may include variables that are marginally significant ($.05 \leq p < .10$). Models including variables with $p \geq .10$ are shown only to document robustness of other models. Spp = number of species. Ab = estimated abundance.

Class	% Adj. R^2/ % R^2	% R^2 Hab	% R^2 Pr	Regression model (% partial R^2)
Total				
√Spp	42/44	39	5	3.5 + 0.01 hedgerow (31) + 1.14 woodland (8) - 0.27 herbicide (5)
(n=68)	40/42	39	3	3.5 + 0.01 hedgerow (31) + 1.12 woodland (8) + 0.19 o/farm* (3)
	39/42	39	3	3.5 + 0.01 hedgerow (31) + 1.17 woodland (8) - 0.06 # passes* (3)
	39/42	39	3	3.4 + 0.01 hedgerow (31) + 1.23 woodland (8) - 0.19 chemical fertilizer* (3)
	44/47	39	8	3.5 + 0.01 hedgerow (31) + 1.13 woodland (8) - 0.34 herbicide (5) - 0.25 biodyn. spray* (3)
√Ab	33/38	14	23	3.8 - 0.39 herbicide (14) + 0.25 # tillages (9) + 5.62 pasture (8) + 0.43 hay (6)
(n=67)	33/37	17	20	4.0 - 0.47 herbicide (14) - 0.59 winter grain (9) + 5.80 pasture (8) + 0.15 # tillages (6)
	36/41	21	20	3.9 - 0.41 herb. (14) - 0.48 w.grain* (9) + 5.88 pasture (8) + 0.21 # till. (6) + 0.36 hay (4)
Omnivore				
Spp	45/48	48	0	7.6 + 0.05 hedgerow (37) + 4.38 woodland (6) - 2.64 winter grain (5)
(n=70)	47/49	49	0	7.3 + 0.04 hedgerow (37) + 3.92 H′ (7) - 3.67 winter grain (5)
	42/45	45	0	8.0 + 0.05 hedgerow (37) - 2.74 winter grain (5) + 3.95 pasture* (3)
	48/51	51	0	7.3 + 0.04 hedgerow (37) + 3.72 H′ (7) + 3.58 winter grain (5) + 3.37 pasture ** (2)
Ab	28/29	0	29	13.1 - 3.43 herbicide (29)
(n=72)	20/21	0	21	13.4 + 2.69 o/farm (21)
	33/35	14	21	12.9 + 2.94 o/farm (21) + 3.44 hay (14)
	30/32	0	32	12.6 - 3.72 herbicide (29) + 0.65 # tillages* (3)

Table 4 continued ...

Class	% Adj. R^2/ % R^2	% R^2 Hab	% R^2 Pr	Regression model (% partial R^2)
Insectivore				
√Spp	22/24	0	24	2.5 - 0.09 field size (15) - 0.10 # passes (9)
(n=71)	24/27	3	24	2.6 - 0.09 field size (15) - 0.10 # passes (9) - 0.003 road** (3)
Ground feeders				
Spp	44/48	42	6	9.2 + 0.04 hedgerow (29) - 3.70 winter grain (7) - 2.37 hay (6) - 1.29 herbicide (6)
(n=69)	44/48	39	8	6.8 + 0.04 hedgerow (29) - 1.63 herbicide (8) + 2.56 spring grain (6) + 3.07 rowcrop (4)
	42/46	42	4	9.1 + 0.04 hedgerow (29) - 3.44 winter grain (7) - 1.66 hay (6) + 0.91 o/farm (4)
log(Ab)	30/32	0	32	2.5 - 0.37 herbicide (21) + 0.13 # tillages (11)
(n=69)	24/26	0	26	2.4 - 0.40 herbicide (21) + 0.05 # passes (5)
	32/35	3	32	2.5 - 0.40 herbicide (21) + 0.13 # tillages (11) - 0.002 hedgerow* (3)
Aerial feeders				
Spp	32/34	0	34	2.9 - 0.20 field size (22) - 0.22 # passes (12)
(n=70)	27/29	0	29	2.7 - 0.22 field size (22) - 0.314 # tillages (7)
	33/36	0	37	3.0 - 0.18 field size (22) - 0.22 # passes (12) + 0.35 o/farm* (3)
Lower canopy feeders				
Spp	20/23	23	0	1.8 + 0.02 hedgerow (12) + 3.45 woodland (6) + 1.09 hay (5)
(n=72)	18/22	18	4	2.5 + 0.02 hedgerow (12) + 3.06 woodland (6) - 0.19 # passes* (4)
	21/25	23	2	1.9 + 0.16 hedgerow (12) + 3.45 woodland (6) + 1.13 hay (5) - 0.56 biodyn. spray** (2)
	20/25	25	0	1.5 + 0.01 hedgerow (12) + 2.61 woodland (6) + 1.23 hay (5) + 1.37 H′*** (2)
√Ab	23/26	22	4	1.3 + 0.01 hedgerow (12) + 1.62 woodland (10) - 1.15 # tillages (4)
(n=71)	22/26	22	3	1.4 + 0.01 hedgerow (12) + 1.59 woodland (10) - 0.08 # passes* (3)
	21/24	24	0	1.1 + 0.01 hedgerow (12) + 1.70 woodland (10) + 0.30 hay* (2)
	25/29	25	4	1.4 + 0.01 hedgerow (12) + 1.57 wood. (10) - 0.18 # tillages (4) - 0.51 winter grain ** (3)

Table 4 continued ...

Class	% Adj. R^2/ % R^2	% R^2 Hab	% R^2 Pr	Regression model (% partial R^2)
Ground-feeding omnivores				
Spp	54/57	58	0	5.0 + 0.03 hedgerow (36) + 3.53 H′ (8) - 2.81 winter grain (8) + 1.17 spring grain (6)
(n=70)	51/54	51	3	5.8 + 0.03 hedgerow (36) + 3.00 H′ (8) - 3.18 winter grain (8) + 0.61 o/farm (3)
	56/59	58	2	5.3 + 0.03 hedge.(36) + 3.48 H′ (8) - 2.90 w.grain (8) + 1.08 s.grain (6) + 0.50 o/farm* (2)
Lower-canopy feeding omnivores				
√Ab	25/27	27	0	1.1 + 0.08 √hedgerow (19) + 1.29 woodland (8)
(n=72)	26/29	27	2	1.2 + 0.08 √hedgerow (19) + 1.32 woodland (8) - 0.10 # tillages** (2)
	26/29	29	0	1.1 + 0.08 √hedgerow (19) + 1.25 woodland (8) - 0.38 winter grain** (2)
Neotropical migrants				
√Spp	29/32	11	21	1.9 - 0.14 # passes (21) - 0.40 rowcrop (6) + 1.09 woodland (5)
(n=71)	28/31	5	26	1.9 - 0.13 # passes (21) + 1.01 woodland (5) - 0.30 herbicide (5)
	32/36	11	25	1.9 - 0.10 # passes (21) - 0.36 rowcrop (6) + 1.10 woodland (5) - 0.26 herbicide* (4)
√Ab	45/49	35	13	1.7 + 0.60 hay (31) - 0.31 herbicide (8) - 0.10 # passes (5) - 0.004 hedgerow (4)
(n=69)	47/50	36	13	1.7 + 0.73 hay (31) - 0.12 # passes (8) - 0.004 hedgerow (5) - 0.29 o/farm (5)
SD2 migrants (Can-USA-C.Am-S.Am)				
Spp	23/25	26	0	7.0 + 0.03 hedgerow (20) - 2.31 winter grain (6)
(n=70)	22/24	20	4	7.4 + 0.03 hedgerow (20) - 0.19 field size* (4)
	28/31	20	11	7.9 + 0.02 hedgerow (20) - 1.32 biodynamic sprays (7) - 0.25 field size (4)
√Ab	31/34	4	30	3.4 + 0.42 o/farm (25) + 0.11 # tillages (5) - 0.52 H′ (4)
(n=69)	30/33	3	30	3.2 + 0.42 o/farm (25) + 0.16 # tillages (5) + 0.24 hay** (3)
	30/33	5	28	3.4 + 0.44 o/farm (25) - 0.53 H′ (5) + 0.05 # passes** (3)
	34/38	7	30	3.5 + 0.44 o/farm (25) + 0.16 # tillages (5) - 0.59 H′ (4) - 0.25 spring grain* (3)
	33/37	4	33	3.4 + 0.28 o/farm (25) + 0.15 # tillages (5) - 0.53 H′ (4) - 0.22 herbicide* (3)

Table 4 continued ...

Class	% Adj. R^2/ % R^2	% R^2 Hab	% R^2 Pr	Regression model (% partial R^2)
SD1 migrants (Can-USA)				
Spp	34/37	37	0	1.4 + 0.02 hedgerow (25) - 1.45 winter grain (7) + 2.47 woodland (5)
(n=70)	33/36	36	0	1.3 + 0.02 hedgerow (25) - 1.88 winter grain (7) + 1.61 H′ (4)
	33/36	36	0	1.5 + 0.02 hedgerow (25) - 1.32 winter grain (7) + 0.02 streams (4)
	36/40	41	0	1.4 + 0.02 hedgerow (25) - 1.55 winter grain (7) + 2.74 woodland (5) - 4.58 farmstead* (4)
√Ab	22/25	25	0	1.0 + 0.01 hedgerow (16) + 1.40 woodland (9)
(n=70)	19/21	21	0	1.2 + 0.01 hedgerow (16) - 0.01 fenceline (5)
	25/28	29	0	1.0 + 0.01 hedgerow (16) + 1.28 woodland (9) - 0.01 fenceline* (4)
Permanent Residents				
√Ab	24/26	13	12	0.8 + 6.30 farmstead (13) + 0.32 # tillages (12)
(n=71)	20/22	12	10	0.9 + 2.83 pasture (12) + 0.29 # tillages (10)
	19/21	21	0	1.2 + 5.06 farmstead (13) - 1.06 winter grain (8)
	26/30	17	12	1.0 + 5.88 farmstead (13) + 0.27 # tillages (12) - 0.78 winter grain* (4)
Ground nesters				
log(Ab)	47/50	39	12	2.6 - 1.41 woodland (16) - 0.01 hedgerow (14) - 0.30 herbicide (12) - 0.004 road (9)
(n=70)	45/48	40	9	2.6 - 1.29 woodland (16) - 0.01 hedgerow (14) - 0.01 road (10) - 0.27 chem. fert. (9)
	43/47	36	11	2.6 - 1.45 woodland (16) - 0.01 hedgerow (14) + 0.23 o/farm (11) - 0.003 road (6)
	50/53	43	11	2.5 - 1.33 woodland(16) - 0.01 hedgerow(14) - 0.004 road(6) + 0.25 o/farm(11) + 0.33 hay(7)

Table 4 continued ...

Class	% Adj. R^2/ % R^2	% R^2 Hab	% R^2 Pr	Regression model (% partial R^2)
Above-ground nesters				
√Spp	24/26	26	0	1.6 + 2.26 woodland (14) + 0.01 hedgerow (12)
(n=69)	25/28	28	0	1.6 + 2.21 woodland (14) + 0.01 hedgerow (12) - 0.48 winter grain*** (2)
	24/28	27	0	1.6 + 2.69 woodland (14) + 0.01 hedgerow (12) - 0.62 H´*** (1)
√Ab	29/31	31	0	1.2 + 2.38 woodland (20) + 0.01 hedgerow (11)
(n=68)	31/33	32	0	1.1 + 2.33 woodland (18) + 0.01 hedgerow (12) + 0.003 road** (2)
	30/32	30	1	1.1 + 2.18 woodland (18) + 0.01 hedgerow (12) + 0.01 farm i.d.*** (1)
Grassland species of concern				
Spp	34/38	14	23	5.6 - 0.78 herbicide (18) - 0.02 road (8) + 1.64 hay (6) - 0.16 field size (5)
(n=72)	34/38	19	19	5.6 - 0.75 chem. fertilizer (14) - 0.02 road (10) + 1.69 hay (9) - 0.16 field size (5)
	36/41	17	24	5.5 - 0.85 herb.(19) - 0.02 road (8) + 1.61 hay(6) - 0.16 field size(5) + 0.01 fenceline* (3)
Ab	62/65	55	9	7.5 + 6.04 hay (42) - 0.03 road (13) + 1.57 biodyn. spray (6) - 1.24 herbicide (3)
(n=71)	62/64	58	6	8.3 + 5.47 hay (42) - 0.03 road (13) - 1.50 herbicide (6) - 1.55 rowcrops (3)
	61/64	59	5	8.4 + 5.49 hay (42) - 0.03 road (13) - 1.43 chemical fertilizer (5) - 1.79 rowcrop (4)
	61/64	57	6	6.7 + 6.58 hay (42) - 0.03 road (13) + 1.89 biodyn. spray (6) + 2.12 winter grain* (2)
	61/64	55	8	7.5 + 6.20 hay (42) - 0.03 road (13) + 1.64 biodyn. spr. (6) - 1.00 chem. fert.* (2)
	64/66	56	9	7.8 + 5.65 hay (42) - 0.03 road (13) + 1.27 biodyn.(6) - 1.20 herbic.(3) - 1.14 rcrop**(1)

* $.05 \le p < .10$

** $.10 \le p < .20$

*** $.20 \le p < .30$

Table 5: Summary of regression models (except those including variables with $p \geq .10$) for bird classes on Ontario farms. "Total" column averaged across all models in a class. Other columns averaged only across models in a class in which variable significant ($p < .10$). "Overall" row averaged across all classes.

	MEAN % PARTIAL R^2							
	HABITAT			PRACTICES			TOTAL	
	Noncrop[1]	Crop[2]	Total	Herbicides	Other[3]	Total	% R^2	No. Models
NO. SPECIES								
Total	39	0	39	5	3	4	43	5
Omnivores	41	6	47	0	0	0	47	3
Insectivores	0	0	0	0	24	24	24	1
Ground feeders	29	12	41	7	4	6	47	3
Aerial feeders	0	0	0	0	33	33	33	3
Lower canopy feeders	18	5	21	0	4	2	23	2
Ground-feeding omnivores	44	12	56	0	3	2	57	3
Neotropical migrants	5	6	9	5	21	24	33	3
SD2 migrants	20	6	22	0	8	5	27	3
SD1 migrants	30	8	38	0	0	0	37	4
Above-ground nesters	26	0	26	0	0	0	26	1
Grassland spp.	10	7	17	19	10	22	39	3
Overall	22	5	26	3	9	10	36	n/a
ABUNDANCE								
Total	0	17	17	14	7	21	39	3
Omnivores	0	14	4	29	15	26	29	4
Ground feeders	3	0	1	21	9	30	31	3
Lower canopy feeders	22	2	23	0	4	2	25	3
Lower-canopy-feeding omnivores	27	0	27	0	0	0	27	1
Neotropical migrants	5	31	36	8	9	13	50	2
SD2 migrants	4	3	5	3	30	31	36	3
SD1 migrants	25	0	25	0	0	0	25	3
Residents	0	16	16	0	11	9	25	4
Ground nesters	38	7	40	12	10	11	50	4
Above-ground nesters	31	0	31	0	0	0	31	1
Grassland spp.	13	44	57	5	6	7	64	5
Overall	14	11	24	8	8	13	36	n/a

[1] Noncrop = hedgerow,woodland,road,fenceline,stream,habitat heterogeneity [2] Crop = winter grain, hay, spring grain, rowcrop, pasture, farmstead
[3] Other practices = # tillages, # passes, chemical fertilizer, biodynamic spray, field size, o/farm type

Table 6: Summary of regression models (except those including variables with p≥.10) for bird classes on Ontario farms. % partial R^2 averaged only across models in a class in which each variable was significant (p<.10). * indicates statistics that were calculated only across classes with significant models.

MEAN % PARTIAL R^2

	NONCROP					CROP						PRACTICES						
	Hedge	**Woods**	**Road**	**Fence**	**Stream**	**H′**	**W.grain**	**Hay**	**S.Grain**	**Rcrop**	**Pasture**	**Farmstd**	**Herbic.**	**Tills**	**Passes**	**Chem.Fert.**	**Biodyn.**	**Field size**	**O/farm**
NO. SPECIES																			
Total	+ 31	+ 8											- 5		- 3	- 3	- 3		+ 3
Omnivores	+ 37	+ 6				+ 7	- 5				+ 3								
Insectivores															- 9			- 15	
Ground feeders	+ 29						- 7	- 6	+ 6	+ 4			- 7						+ 4
Aerial feeders														- 7	- 12			- 22	+ 3
Lower canopy feeders	+ 12	+ 6						+ 5							- 4				
Ground omnivores	+ 36					+ 8	- 8		+ 6										+ 3
Neotropical migrants		+ 5								- 6			- 5		- 21				
SD2 migrants	+ 20						- 6										- 7	- 4	
SD1 migrants	+ 25	+ 5			+ 4	+ 4	- 7					- 4							
Above-ground nesters	+ 12	+ 14																	
Grassland spp.			- 9	+ 3				+ 7					- 19			- 14		- 5	
% of classes	67	50	8	8	8	25	42	25	17	17	8	8	33	8	42	17	17	33	33
% positive*	100	100	0	100	100	100	0	67	100	50	100	0	0	0	0	0	0	0	100
Mean of partial R^2* +	23	7	n/a	3	4	6	n/a	6	6	4	3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3
-	n/a	n/a	9	n/a	n/a	n/a	7	6	n/a	6	n/a	4	9	7	10	9	5	12	n/a
ABUNDANCE																			
Total							- 9	+ 5			+ 8		- 14	+ 7					
Omnivores								+ 14					- 29	+ 3					+ 21
Ground feeders	- 3												- 21	+ 11	+ 5				
Lower canopy feeders	+ 12	+ 10						+ 2						- 4	- 3				
Lower canopy omnivores	+ 19	+ 8																	
Neotropical migrants	- 5							+ 31					- 8		- 7				- 5
SD2 migrants						- 4			- 3				- 3	+ 5					+ 25
SD1 migrants	+ 16	+ 9		- 4															
Residents							- 6				+ 12	+ 13		+ 11					
Ground nesters	- 14	- 16	- 8					+ 7					- 12			- 9			+ 11
Above-ground nesters	+ 11	+ 20																	
Grassland spp.			- 13				+ 2	+ 42		- 3			- 5			- 4	+ 6		
% of classes	58	42	17	8	0	8	17	50	8	8	17	8	58	50	25	17	8	0	33
% positive*	57	80	0	0	n/a	0	50	100	0	0	100	100	0	83	33	0	100	n/a	75
Mean of partial R^2* +	15	12	n/a	n/a	n/a	n/a	2	17	n/a	n/a	10	13	n/a	7	5	n/a	6	n/a	19
-	7	16	11	4	n/a	4	8	n/a	3	3	n/a	n/a	13	4	5	7	n/a	n/a	5

Table 7: Summary of significant (p<.05; p<.10 in parenthesis) Spearman correlations between abundance of selected bird species and habitat and practices at survey sites on Ontario farms. Species (abbreviation) as follows: American Robin (AMRO), Barn Swallow (BASW), Brown-headed Cowbird (BHCO), Horned Lark (HOLA), Killdeer (KILL), Red-winged Blackbird (RWBL), Savannah Sparrow (SASP), Song Sparrow (SOSP) and Vesper Sparrow (VESP). See Appendix 7 for details.

VARIABLE	% of spp.	% +ve	EFFECT ON ABUNDANCE								
			AMRO	BASW	BHCO	HOLA	KILL	RWBL	SASP	SOSP	VESP
NONCROP											
Hedgerow	56	60	(+)		(+)	-			-	+	
Woodland	22	0							(-)		(-)
Road	33	33						+	(-)		-
Fenceline	44	50	(-)	+					+	(-)	
Stream	22	50					(+)		-		
H′	22	50							-	(+)	
CROP											
Winter grain	33	33	(-)					-	+		
Hay	33	33				-	-		+		
Spring grain	11	100				(+)					
Rowcrop	44	75	(+)				+	(+)	-		
Pasture	22	50	+								(-)
Farmstead	44	50	+	+					-		-
PRACTICES											
Herbicides	11	0							(-)		
# Tillages	44	100			+	+	+	+			
# Passes	22	100				+		(+)			
Chemical fertilizer	0	n/a									
Manure	33	66	(+)				(+)		(-)		
Biodynamic spray	11	100							+		
Field size	56	60	(-)			+	-		+		(+)
Organic farmtype	11	100			+						
Farm i.d.	56	60	+			-		+	-	+	

Table 8: Summary of significant (p<.05, p<.10 in parenthesis) Spearman correlations between species richness and abundance for bird classes and landscape characteristics around survey sites on Ontario farms. See Appendix 9 for details.

	EFFECT N = 72 sites N = 16 regions								
NO. SPECIES	**Hedgerow**	**Woodland**	**Woodland edge**	**Stream**	**H´**	**Farmstead**	**# Cultivated fields**	**# Uncultivated fields**	**O/farm type**
Total	+	+	+		(+)		+		+
	+		(+)		(+)		(+)		
Insectivores	+						(+)		(+)
	+								(+)
Omnivores	+	+	+	(-)	(+)		+		(+)
	+	+	+		+		(+)		
Aerial feeders	(+)						(+)		+
	+						(+)		+
Ground feeders	+		+				+		+
	(+)				(+)		(+)		
Lower canopy feeders	+	+	+		+				
	+	+	+						
Ground omnivores	+		+				+		+
	+			(-)			(+)		
Lower-canopy omnivores	+	(+)	+		(+)		(+)		
	+	+	+						
Neotropical migrants									+
	+								
SD2 migrants	+	+	+		+		+	(+)	
	+	+	+		+		+		
SD1 migrants	+	+	+	(-)	(+)		+		(+)
	+	+	+		+				
Residents	+						+		
	+						+		
Ground nesters									+
Above-ground nesters	+	+	+		(+)		+		
	+	(+)	(+)						
Grassland species									+
									(+)
% of classes	87	47	60	20	47	0	73	7	67
% positive	100	100	100	0	100	n/a	100	100	100

Table 8 continued ...

ABUNDANCE	Hedgerow	Woodland	Woodland edge	Stream	H´	Farmstead	# Cultivated fields	# Uncultivated fields	O/farm type
					EFFECT N = 72 sites N = 16 regions				
Total									+
									+
Insectivores									
Omnivores									+
						+			+
Aerial feeders									
	+								
Ground feeders									+
						(+)			+
Lower canopy feeders	+			-			+		
	+		(+)						
Ground omnivores	(-)								+
						(+)			
Lower-canopy omnivores	+			-			+		
	+			(-)			(+)		
Neotropical migrants				+			(-)		
				+					
SD2 migrants						+			+
						+			+
SD1 migrants	+			-	(+)		+	(+)	
	+			(-)			(+)		
Residents	+						+		
Ground nesters	-			+			-		+
	-			(+)					
Above-ground nesters	+		(+)	(-)			+		
	+		(+)				(+)		
Grassland species	-						-		+
	(-)			(+)					
% of classes	60	0	13	53	7	27	53	7	47
% positive	67	n/a	100	38	100	100	63	100	100

Table 9: Summary of significant (p<.05, p<.10 in parenthesis) Spearman correlations between abundance of selected bird species and landscape characteristics around survey sites on Ontario farms. See Appendix 9 for details.

EFFECT ON ABUNDANCE
N = 72 sites
N = 16 regions

SPECIES	Hedgerow	Woodland	Woodland edge	Stream	H′	Farmstead	# Cultivated fields	Uncultivated fields	Organic farm type
American Robin	+						(+)		
	+								
Barn Swallow			(-)	(+)					
				+					
Brown-headed Cowbird									+
									(+)
Horned Lark	(-)					-			
Killdeer							+		
		-					+		
Red-winged Blackbird	(+)			-		+	+	(+)	
							(+)		
Savannah Sparrow	-			+			-		
	-						(-)		
Song Sparrow	+			(-)			+		
							+		
Vesper Sparrow				-			(+)		
				-					
% of species	56	11	11	56	0	22	67	11	11
% positive	60	0	0	40	n/a	50	83	100	100

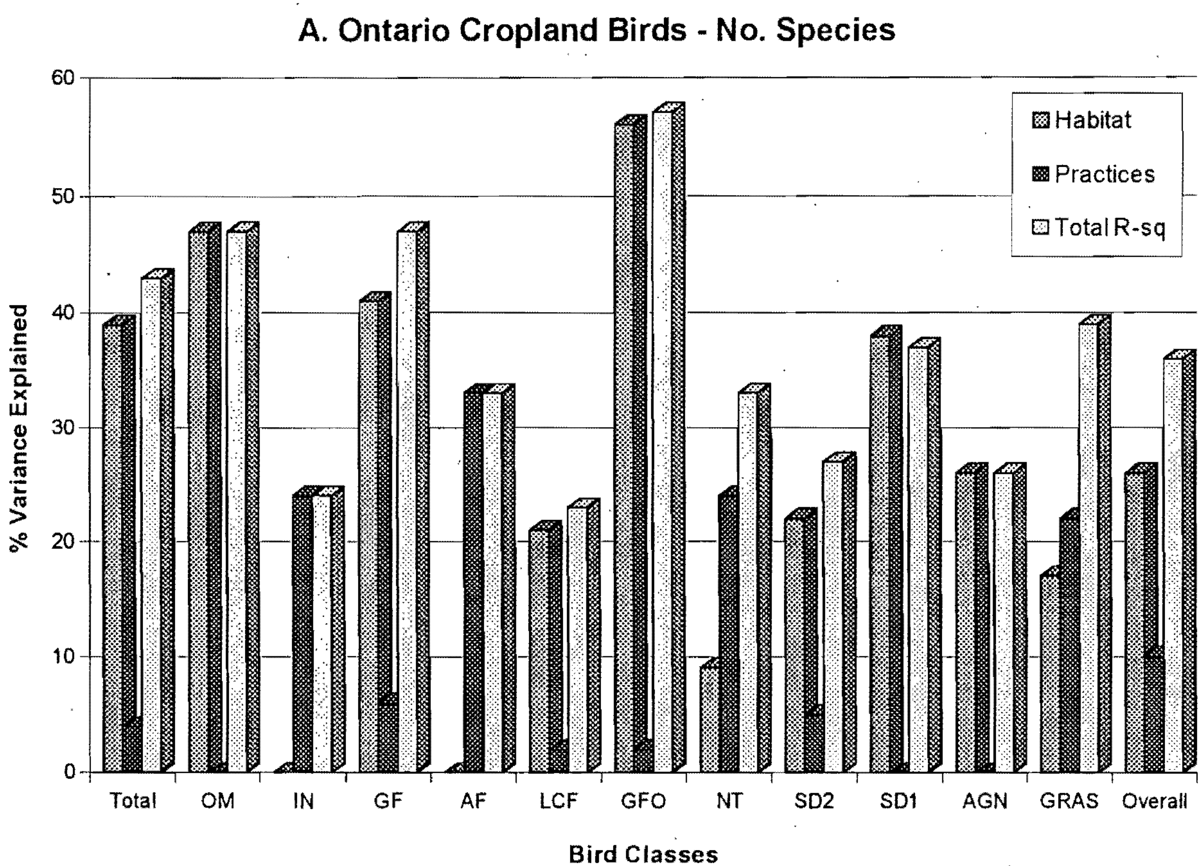


Figure 1: Summary of regression models for bird classes on Ontario farms for local A. species richness, B. abundance and C. richness and abundance. "Overall" averaged across all classes. See Table 5 for details.

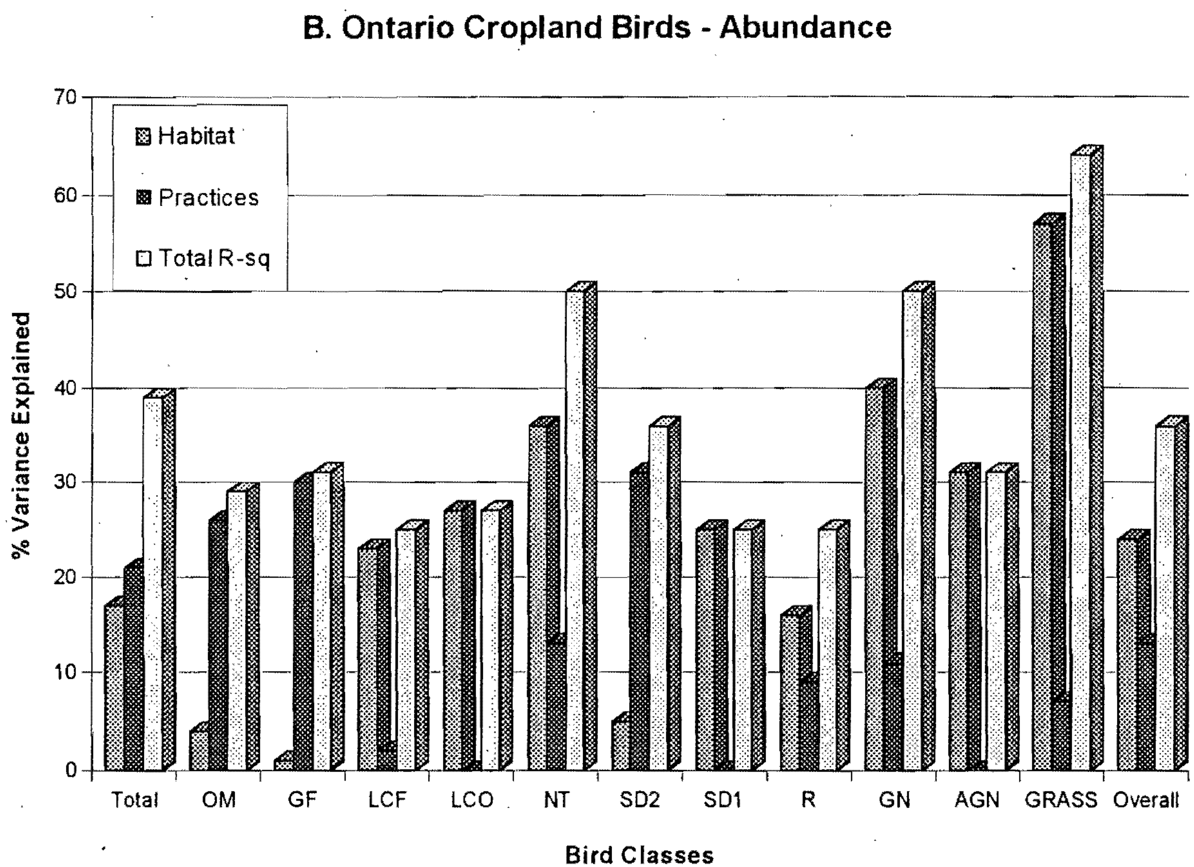


Figure 1: Summary of regression models for bird classes on Ontario farms for local A. species richness, B. abundance and C. richness and abundance. "Overall" averaged across all classes. See Table 5 for details.

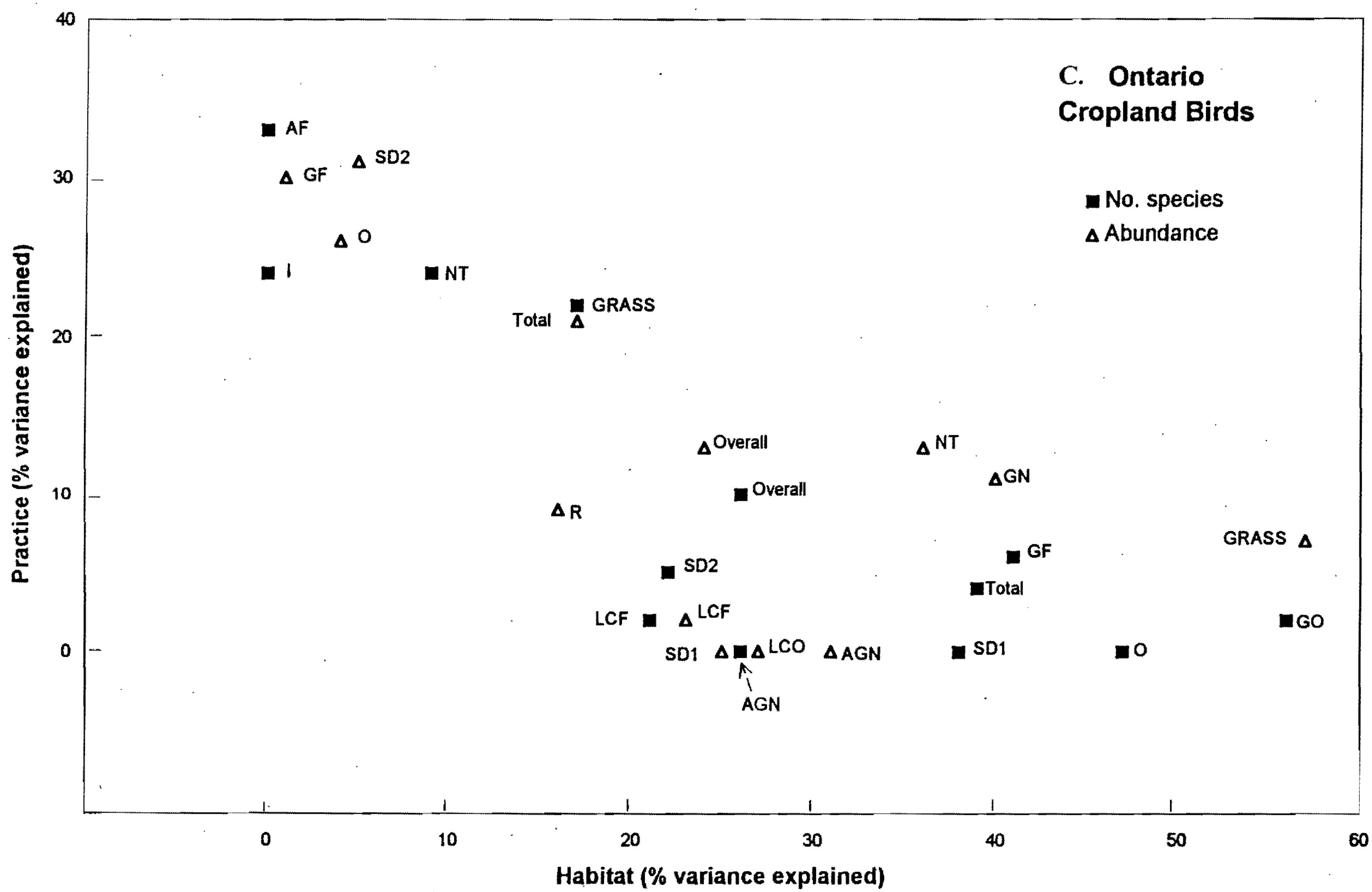


Figure 1: Summary of regression models for bird classes on Ontario farms for local A. species richness, B. abundance and C. richness and abundance. "Overall" averaged across all classes. See Table 5 for details.

Appendix 1: Species list for bird surveys on Ontario farms, 1990. Percent of sites at which species occurred (100n/72), mean species abundance (unlimited distance survey) and standard deviation (sd) for sites at which species occurred (n) are listed.

CODE	SPECIES COMMON NAME	SCIENTIFIC NAME	n	% sites	$\bar{X}n$	sd
AMBI	American Bittern	*Botaurus lentiginosus*	1	1.4	0.5	---
MALL	Mallard	*Anas platyrhynchos*	2	2.8	1.0	0.7
TUVU	Turkey Vulture	*Cathartes aura*	1	1.4	0.2	---
NOHA	Northern Harrier	*Circus cyaneus*	7	9.7	0.3	0.1
RTHA	Red-tailed Hawk	*Buteo jamaicensis*	7	9.7	0.6	0.7
AMKE	American Kestrel	*Falco sparverius*	1	1.4	0.5	---
KILL	Killdeer	*Charadrius vociferus*	46	63.9	1.0	0.8
SPSA	Spotted Sandpiper	*Actitis macularia*	3	4.2	0.5	0.0
UPSA	Upland Sandpiper	*Bartramia longicauda*	6	8.3	0.6	0.2
COSN	Common Snipe	*Gallinago gallinago*	6	8.3	0.5	0.0
RBGU	Ring-billed Gull	*Larus delawarensis*	16	22.2	4.2	3.9
RODO	Rock Dove	*Columba livia*	19	26.4	1.4	1.3
MODO	Mourning Dove	*Zenaida macroura*	20	27.8	0.9	0.8
BBCU	Black-billed Cuckoo	*Coccyzus erythropthalamus*	1	1.4	0.5	---
YBCU	Yellow-billed Cuckoo	*Coccyzus americanus*	1	1.4	0.5	---
CHSW	Chimney Swift	*Chaetura pelagica*	2	2.8	0.2	---
DOWO	Downy Woodpecker	*Picoides pubescens*	2	2.8	0.2	0.0
NOFL	Northern Flicker	*Colaptes auratus*	11	15.3	0.4	0.2
EWPE	Eastern Wood-Pewee	*Contopus virens*	8	11.1	0.5	0.2
ALFL	Alder Flycatcher	*Empidonax aldorum*	2	2.8	0.5	0.0
LEFL	Least Flycatcher	*Empidonax minimus*	1	1.4	0.5	---
EAPH	Eastern Phoebe	*Sayornis phoebe*	1	1.4	0.5	---
GCFL	Great-crested Flycatcher	*Myiarchus crinitus*	5	6.9	0.5	0.0
EAKI	Eastern Kingbird	*Tyrannus tyrannus*	22	30.6	0.5	0.2
HOLA	Horned Lark	*Eremophila alpestris*	42	58.3	2.4	3.7
TRSW	Tree Swallow	*Tachycineta bicolor*	22	30.6	0.7	0.9
BANS	Bank Swallow	*Riparia riparia*	8	11.1	1.3	1.2
CLSW	Cliff Swallow	*Hirundo pyrrhonota*	4	5.6	0.3	0.1
BARS	Barn Swallow	*Hirundo rustica*	42	58.3	0.8	0.8
BLJA	Blue Jay	*Cyanocitta cristata*	21	29.2	0.5	0.3
AMCR	American Crow	*Corvus brachyrhynchos*	37	51.4	0.5	0.3
BCCH	Black-capped Chickadee	*Parus atricapillus*	8	11.1	0.6	0.4
WBNU	White-breasted Nuthatch	*Sitta carolinensis*	2	2.8	0.4	0.2
HOWR	House Wren	*Troglodytes aedon*	3	4.2	0.8	0.3
WOTH	Wood Thrush	*Hylocichla mustelina*	3	4.2	0.5	0.0
AMRO	American Robin	*Turdus americanus*	52	72.2	0.8	0.5
GRCA	Gray Catbird	*Dumetella carolinensis*	1	1.4	0.5	---
BRTH	Brown Thrasher	*Toxostoma rufum*	10	13.9	0.6	0.2
WAPI	Water Pipit	*Anthus spinoletta*	1	1.4	0.8	---
CEWA	Cedar Waxwing	*Bombycilla cedrorum*	10	13.9	0.7	0.5
EUST	European Starling	*Sturnus vulgaris*	34	47.2	0.7	0.6
WAVI	Warbling Vireo	*Vireo gilvus*	4	5.6	0.5	0.0
REVI	Red-eyed Vireo	*Vireo olivaceus*	5	6.9	0.4	0.1
YEWA	Yellow Warbler	*Dendroica petechia*	18	25.0	0.6	0.2
CSWA	Chestnut-sided Warbler	*Dendroica pensylvanica*	2	2.8	0.5	0.0

Appendix 1 continued ...

CODE	SPECIES COMMON NAME	SCIENTIFIC NAME	n	% sites	$\bar{X}n$	sd
BWWA	Black-and-white Warbler	*Mniotilta varia*	4	5.6	0.5	0.0
OVEN	Ovenbird	*Seiurus aurocapillus*	2	2.8	0.5	0.0
MOWA	Mourning Warbler	*Oporornis philadelphia*	2	2.8	0.8	0.4
COYE	Common Yellowthroat	*Geothlypis trichas*	10	13.9	0.7	0.4
SCTA	Scarlet Tanager	*Piranga olivacea*	1	1.4	0.2	---
CARD	Northern Cardinal	*Cardinalis cardinalis*	2	2.8	0.5	0.0
RBGR	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	4	5.6	0.6	0.3
INBU	Indigo Bunting	*Passerina cyanea*	5	6.9	0.6	0.2
CHSP	Chipping Sparrow	*Spizella passerina*	5	6.9	1.4	1.0
VESP	Vesper Sparrow	*Pooecetes gramineus*	53	73.6	1.1	0.7
SASP	Savannah Sparrow	*Passerculus sandwichensis*	70	97.2	3.3	2.2
SOSP	Song Sparrow	*Melospiza melodia*	57	79.2	1.7	1.0
WTSP	White-throated Sparrow	*Zonotrichia albicollis*	3	4.2	0.4	0.1
WCSP	White-crowned Sparrow	*Zonotrichia leucophrys*	7	9.7	0.4	0.3
LALO	Lapland Longspur	*Calcarius lapponicus*	1	1.4	0.5	---
BOBO	Bobolink	*Dolichonyx oryzivorus*	40	55.6	1.6	1.4
RWBL	Red-winged Blackbird	*Agelaius tricolor*	57	79.2	1.9	1.4
EAME	Eastern Meadowlark	*Sturnella magna*	24	33.3	1.0	0.7
COGR	Common Grackle	*Quiscalus quiscula*	25	34.7	0.8	1.2
BHCO	Brown-headed Cowbird	*Molothrus ater*	50	69.4	1.1	0.8
NOOR	Northern Oriole	*Icterus galbula*	13	18.1	0.6	0.3
AMGO	American Goldfinch	*Carduelis tristis*	31	43.1	0.6	0.4
HOSP	House Sparrow	*Passer domesticus*	21	29.2	1.0	1.2

Appendix 2: Summary of primary food source and feeding substrate, migratory status, and nesting stratum for bird species observed on Ontario farms, 1990. See footnote for definition of abbreviations.

Species	-----------Food----------- Type	Substrate	Migratory Status	Nesting Stratum
American Bittern	IN	FRSH	SD2	GROUND
Mallard	GR	GRD	SD2	GROUND
Turkey Vulture	CA	GRD	SD2	NONE
Northern Harrier*	CA	GRD	SD2	GROUND
Red-tailed Hawk	CA	GRD	SD2	ABOVE GRD
American Kestrel	IN	GRD	SD2	CAVITY
Killdeer	IN	GRD	SD2	GROUND
Spotted Sandpiper	IN	GRD	SD2	GROUND
Upland Sandpiper*	IN	GRD	NT	GROUND
Common Snipe	VE	FRSH	SD2	GROUND
Ring-billed Gull	IN	GRD	RESIDENT	GROUND
Rock Dove	GR	GRD	RESIDENT	OTHER
Mourning Dove	GR	GRD	SD2	ABOVE GRD
Black-billed Cuckoo	IN	LOCA	NT	ABOVE GRD
Yellow-billed Cuckoo	IN	LOCA	NT	ABOVE GRD
Chimney Swift	IN	AIR	NT	OTHER
Downy Woodpecker	IN	BARK	RESIDENT	CAVITY
Northern Flicker	IN	GRD	SD2	CAVITY
Eastern Wood-Pewee	IN	AIR	NT	ABOVE GRD
Alder Flycatcher	IN	AIR	NT	ABOVE GRD
Least Flycatcher	IN	AIR	NT	ABOVE GRD
Eastern Phoebe	IN	AIR	SD1	OTHER
Great-crested Flycatcher	IN	AIR	NT	CAVITY
Eastern Kingbird	IN	AIR	NT	ABOVE GRD
Horned Lark	OM	GRD	SD2	GROUND
Tree Swallow	IN	AIR	SD2	CAVITY
Bank Swallow	IN	AIR	NT	OTHER
Cliff Swallow	IN	AIR	NT	OTHER
Barn Swallow*	IN	AIR	NT	OTHER
Blue Jay	OM	GRD	RESIDENT	ABOVE GRD
American Crow	OM	GRD	RESIDENT	ABOVE GRD
Black-capped Chickadee	IN	LOCA	RESIDENT	CAVITY
White-breasted Nuthatch	IN	BARK	RESIDENT	CAVITY
House Wren	IN	LOCA	SD1	CAVITY
Wood Thrush	OM	GRD	NT	ABOVE GRD
American Robin	OM	LOCA	SD2	ABOVE GRD
Gray Catbird	OM	GRD	SD2	ABOVE GRD
Brown Thrasher	OM	GRD	SD1	ABOVE GRD
Water Pipit	IN	GRD	SD2	N/A
Cedar Waxwing	IN	AIR	SD2	ABOVE GRD
European Starling	OM	GRD	RESIDENT	CAVITY
Warbling Vireo	IN	UPCA	NT	ABOVE GRD
Red-eyed Vireo	IN	UPCA	NT	ABOVE GRD
Yellow Warbler	IN	LOCA	NT	ABOVE GRD
Chestnut-sided Warbler	IN	LOCA	NT	ABOVE GRD
Black-and-white Warbler	IN	BARK	SD2	GROUND
Ovenbird	MO	GRD	SD2	GROUND
Mourning Warbler	IN	GRD	NT	GROUND
Common Yellowthroat*	IN	LOCA	SD2	ABOVE GRD
Scarlet Tanager	IN	UPCA	NT	ABOVE GRD
Northern Cardinal	OM	GRD	RESIDENT	ABOVE GRD
Rose-breasted Grosbeak	OM	UPCA	NT	ABOVE GRD
Indigo Bunting	OM	LOCA	NT	ABOVE GRD
Chipping Sparrow	OM	GRD	SD2	ABOVE GRD
Vesper Sparrow*	OM	GRD	SD2	GROUND

Appendix 2 continued ...

Species	-----------Food------------ Type	Substrate	Migratory Status	Nesting Stratum
Savannah Sparrow*	OM	GRD	SD2	GROUND
Song Sparrow*	OM	LOCA	SD1	GROUND
White-throated Sparrow	OM	GRD	SD2	GROUND
White-crowned Sparrow	OM	GRD	SD2	N/A
Lapland Longspur	OM	GRD	SD1	N/A
Bobolink*	OM	GRD	NT	GROUND
Red-winged Blackbird	OM	GRD	SD2	OTHER
Eastern Meadowlark*	IN	GRD	SD2	GROUND
Common Grackle	OM	GRD	SD1	ABOVE GRD
Brown-headed Cowbird	OM	GRD	SD2	NONE
Northern Oriole	OM	UPCA	NT	ABOVE GRD
American Goldfinch*	OM	LOCA	SD1	ABOVE GRD
House Sparrow	GR	GRD	RESIDENT	OTHER

Abbreviations:

Food Type: CA = Carnivore; GR = Granivore; IN = Insectivore; MO = Molluscivore; OM = Omnivore; VE = Vermivore

Food Substrate: FRSH = Fresh water shoreline; GRD = Ground; LOCA = Lower canopy; UPCA = Upper canopy

Migratory Status: NT = Neotropical migrant (winters in C/S America); SD1 = Short distance migrant (winters in Canada-USA-Mexico); SD2 = Short distance migrant (winters in USA-Mexico-C/S America); RESIDENT = Permanent resident

Nesting Stratum: ABOVE GRD = Tree/Shrub Nesters; OTHER = Man-made Structures or other non-agricultural habitat; N/A = Not local breeder

* Grassland species of conservation concern in the Midwest, USA and/or Ontario, Canada. See Appendix 3 for details.

Appendix 3: Grassland species of conservation concern in the Midwest, USA and/or in Ontario, Canada.[3]

Grassland species	% Population Decline[1] Ontario	Illinois	Midwest[2]
Northern Harrier[E]	N/A	N/A	N/A
Upland Sandpiper[E]	?	16.8	0
Barn Swallow	1-3/yr.	N/A	-
Common Yellowthroat	1-3/yr.	8.8	-
Vesper Sparrow	3/yr.	12.1*	-
Savannah Sparrow[V]	1-3/yr.	58.9	0
Song Sparrow	3/yr.	29.3	+
Bobolink	0/yr.	90.4	-
Eastern Meadowlark	3/yr.	67.0	0
American Goldfinch	0/yr.	42.8	0

1 Percent decline for Ontario taken from Bird Trends (Dunn 1991) and based on BBS surveys for 1966-89

Percent decline for Illinois taken from USFWS estimated population change between 1967-89 as reported in Herkert (1991)

? = decline suspected but undetermined as reported in Morrison et al. (1993/94)

* = an increase in local estimated population

2 Breeding bird survey trend data 1980-1994 for the region encompassing Iowa, Minnesota, Missouri, Wisconsin, Illinois, Indiana and Ohio (reported in Best et al. 1996):
+ = significant positive trend
- = significant negative trend
0 = no significant trend

3 The Common Grackle, European Starling, Brown-headed Cowbird and Red-winged Blackbird, all considered declining grassland species in either Illinois or Ontario, were not included because of their relatively high abundances and because they are not of conservation concern.

E = species designation of endangered largely due to prairie habitat loss in Illinois

V = COSEWIC species status designation of vulnerable in Ontario (Dunn 1991)

N/A = data not available.

Appendix 4: Summary of literature review for important habitat features for birds in farmland for A. area surveyed/censused = 5 to 6.3 ha, and B. area surveyed/censused > 100 ha. + or - denote positive or negative correlation/effect (where specified) on the following:

sp = correlation/effect on overall species number
ab = correlation/effect on overall density/abundance
S = correlation/effect on particular species
D = correlation/effect on species diversity

A. Area surveyed/censused = 5 to 6.3 ha

HABITAT FEATURE	VARIABLE TYPE	UNIT OF MEASURE	EFFECT ON BIRDS	SOURCE
CROPLAND	area	%	- D	Yahner (1983)
	distance to	m	- S	Yahner (1983)
GRASS	area	ha	+ sp	Arnold (1983)
HAY	distance to	m	- S	Gremaud (1983)
PASTURE	area	%	- sp	Yahner (1983)
	distance to	m	- S	Gremaud (1983)
MEADOW	area	ha/ha	+ sp	Møller (1984)
ABANDONNED FIELD	distance to	m	+ S	Yahner (1983)
FARMSTEAD	area	ha/ha	+ sp	Møller (1984)
Buildings:	area	ha/ha	+ sp	Møller (1984)
	distance to	m	-ab;+sp;+D	Yahner (1983)
Village:	area	ha/ha	+ sp	Møller (1984)
Lawn:	distance to	m	+ D	Yahner (1983)
Permanent Food:	distance to	m	+ D	Yahner (1983)
WOODLAND	distance to	m	+sp;+ab;+D;+S	Yahner (1983) Gremaud (1983)
	length linear	m	+ sp	Arnold (1983)
Brush:	distance to	m	+ S	Gremaud (1983)
Conifer Plant'n:	area	ha/ha	+ sp	Møller (1984)
HEDGEROWS	length	m	- sp	Arnold (1983)
	height	m	+ sp	Arnold (1983)
	cover at 1m	%	+ sp	Arnold (1983)
	# shrub spp.	#	± S	Arnold (1983)
	herbaceous spp.	#	± S	Arnold (1983)
	shrub spp hedge and ditch	mean #	± S	Arnold (1983)
	shrub spp.	mean # $10m^{-1}$	- S	Arnold (1983)
	herbaceous spp.	mean # $10m^{-1}$	- S	Arnold (1983)
	distance to	m	± S	Gremaud (1983)
Field w/hedgerow:	area	ha/ha	+ sp	Møller (1984)

Appendix 4A continued ...

HABITAT FEATURE	VARIABLE TYPE	UNIT OF MEASURE	EFFECT ON BIRDS	SOURCE
SHELTERBELTS	length	m	+ sp	Yahner (1983)
	perimeter	m	+ sp	Yahner (1983)
	area	ha	- sp	Yahner (1983)
DITCH	width	m	+ sp	Arnold (1983)
	depth	m	- sp	Arnold (1983)
	volume	m^3	+ S(nests)	Arnold (1983)
	cover	0-5	+ S	Arnold (1983)
WATER				
Peat bog:	area	ha/ha	+ sp	Møller (1984)
TREES	trees	#	+ sp	Arnold (1983)
	dead trees	#	+ sp	Arnold (1983)
HABITAT HETEROGENEITY	habitat diversity index (Shannon-Weaver)	H'	+ sp	Møller (1984)

Appendix 4 continued: Summary of literature review for important habitat features for birds in farmland for A. area surveyed/censused = 5 to 6.3 ha, and B. area surveyed/censused > 100 ha. + or - denote positive or negative correlation/effect (where specified) on the following:

sp = correlation/effect on overall species number
ab = correlation/effect on overall density/abundance
S = correlation/effect on particular species
D = correlation/effect on species diversity

B. Area surveyed/censused > 100 ha

HABITAT FEATURE	VARIABLE TYPE	UNIT OF MEASURE	EFFECT ON BIRDS	SOURCE
FARMSTEAD	density	#/ha	+ S	O'Connor and Shrubb (1986)
Buildings & Gardens:	area	ha	+ sp	Robertson et al. (1990)
Gardens:	area	ha/ha	± S	Arnold (1983)
WOODLAND	area	ha/ha	- sp	Arnold (1983)
Edges:	length	m	+sp;+ab	Best et al. (1990)
Scrub:	area	ha	+ sp	Robertson et al. (1990)
Deciduous:	area	ha	+ sp	Robertson et al. (1990)
Coniferous:	area	ha	- sp	Roberston et al. (1990)
Clearcut	area	ha	- sp	Robertson et al. (1990)
HEDGEROW	density	m/ha	± S	O'Connor and Shrubb (1986)
With trees:	density	m/ha	+ S	O'Connor and Shrubb (1986)
Without trees:	density	m/ha	+ S	O'Connor and Shrubb (1986)
Tall hedge:	length	m	+ S	Arnold (1983)
Short hedge:	length	m	+ S	Arnold (1983)
TREES				
Treeline:	length	m	- sp	Arnold (1983)
	density	m/ha	+ S	O'Connor and Shrubb (1986)
WATER				
Ponds:	density	#/ha	+ S	O'Connor and Shrubb (1986)
Linear water:	length/area	m/ha	+ S	O'Connor and Shrubb (1986)
Reeds:	area	ha	+ sp	Robertson et al. (1990)
MEADOW	area	ha	+ sp	Robertson et al. (1990)
FIELDS	size	#/ha	+ S	O'Connor and Shrubb (1986)
Arable Fraction:	area	ha/ha	+ S	O'Connor and Shrubb (1986)
Edges (shape):	area:perimeter	m^2/m	- ab	Best et al. (1990)
OPENNESS	index	% area (dots)	+ S	O'Connor and Shrubb (1986)
ALTITUDE		m/m	± S	O'Connor and Shrubb (1986)
SLOPE		m/m	+ S	O'Connor and Shrubb (1986)

Appendix 5: Agrichemicals applied on Ontario farms in 1990 listed by crop. A. Herbicide and insecticide compound names, recommended application rates; B. Chemical fertilizer compositions, actual application rates. The number of sites affected per crop type is listed for each compound. Sites may be treated with more than one compound. See footnotes for other details.

A. Herbicides and Insecticides (I)

CROP	# SITES	COMPOUND TRADE NAME	COMMON NAME	FORM	RECOMMENDE D RATE
Barley and/or Oat	4	Target; Estemine-MCPA	MCPA	L	0.07-1.5 l/ha
	2	Embutox	2,4 DB	L	1.75-2.25* l/ha
	2	2,4 D	2,4 D	L	1 l/ac
	1	2,4 D amine	2,4 D amine	L	n/a
	2	MCPA amine 500	MCPA amine 500	L	0.5-0.70 l/ac
Corn	3	Target; Estemine-MCPA	MCPA	L	0.25-0.50 l/ac
	2	Counter(I)	Terbufos	GR	5 lb/ac
	2	Pardner	Bromoxynil-octanoate	ES	1-1.2 l/ha
	2	Bladex	Cyanozine	wd	1.75-5.0 kg/ha
	1	Banvel	Dicamba	L	0.7-1.5* l/ha

Appendix 5A continued ...

A. Herbicides and Insecticides (I)

CROP	# SITES	COMPOUND TRADE NAME	COMMON NAME	FORM	RECOMMENDE D RATE
Soybean	1	Edge	Ethalfluralin	DF	1.4-2.2* kg/ha
	2	Sencor	Metribuzin	DF	0.55-1.5* kg/ha
	1	Roundup	Glyphosate	L	2.5-12* l/ha
	1	Treflan	Trifluralin	L	1.5-2.6 l/ha
	2	Dual	Metolachlor	EC	2-2.75* l/ha
	1	Lorox	Linuron	DF	2.25-4.5* kg/ha
Winter wheat	1	MCPA amine 500	MCPA amine 500	L	0.7-1.75* l/ac

Footnotes:

Recommended rates are given in litres per acre (l/ac), litres per hectare (l/ha), and kilograms per hectare (kg/ha).

n/a = data not available.

I = insecticide; all remaining compounds are herbicides.

FORM (Formulation): DF=dry flowable; L=liquid; E, EC or ES=emulsifiable compound or solution; GR=granular; wd=wettable dry.

* Application rate used by farmers was lower than recommended rate given in table.

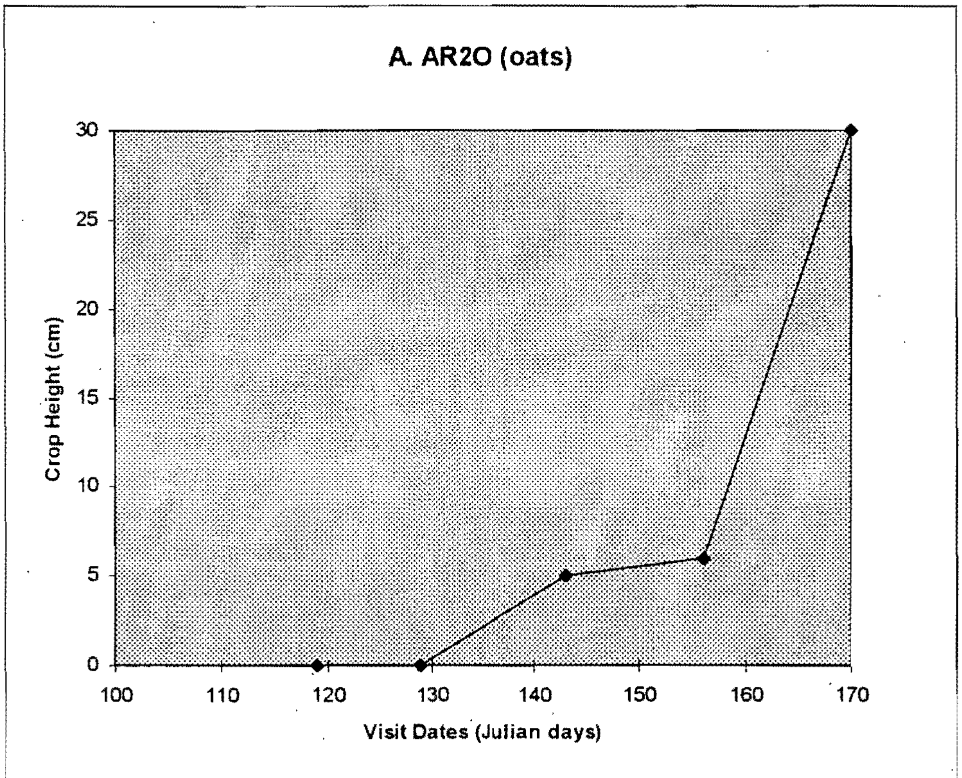
Appendix 5 continued: Agrichemicals applied on Ontario farms in 1990 listed by crop. A. Herbicide and insecticide compound names, recommended application rates; B. Chemical fertilizer compositions, actual application rates. The number of sites affected per crop type is listed for each compound. Sites may be treated with more than one compound. See footnote for other details.

B. Chemical fertilizers

CROP	# SITES	COMPOSITION	RATE APPLIED
Barley and/or oat	2	Urea	100 lb/ac
	3	19-19-19	175-200 lb/ac
	1	8-32-16	102 kg/ac
	3	18-18-18	150-200 lb/ac
	4	6-24-24	100-175 lb/ac
	1	UAN	28%
	1	16-16-16	150 lb/ac
Corn	6	Urea	100-200 lb/ac
	4	Potash	50 lb/ac
	1	19-19-19	150 lb/ac
	2	6-16-6	100-170 lb/ac
	2	8-35-9	150 lb/ac
	1	14-46-0	125 lb/ac
	2	18-46-0	125 lb/ac
Soybean	1	6-16-6	100 lb/ac

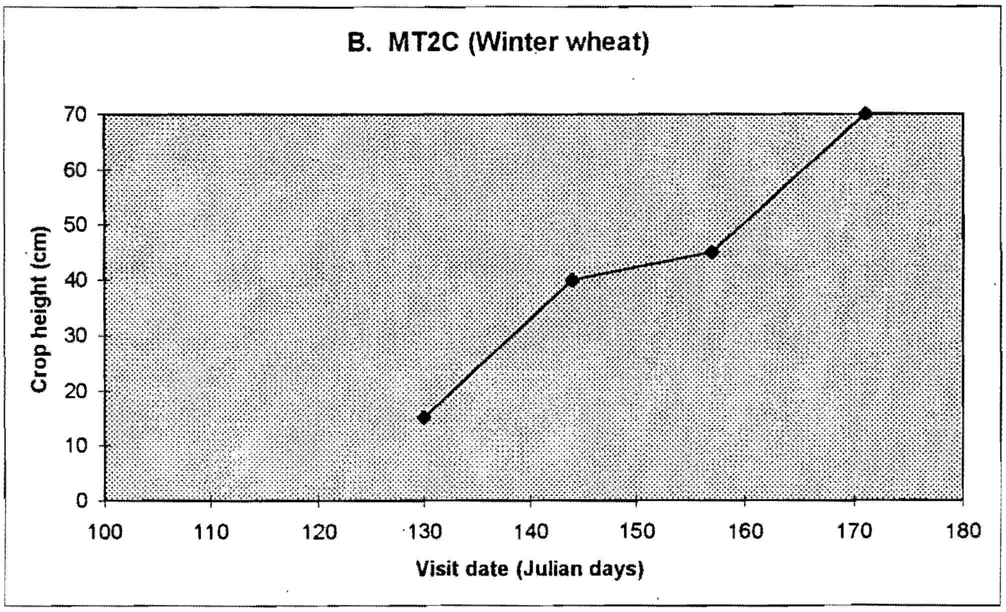
Footnote:

Appendix 6: Crop growth profiles for two study sites with sample calculations for accumulated biomass and growth rates.



Interval	Start		End		Duration (Days)	Growth (cm)	Accumulated Biomass (cm-days)	Growth Rate (cm/day)
	Date (Julian days)	Crop Height (cm)	Date (Julian days)	Crop Height (cm)				
1	119	0	129	0	10	0	0	0.00
2	129	0	143	5	14	5	35	0.36
3	143	5	156	6	13	1	71.5	0.08
4	156	6	170	30	14	24	252	1.71
						Total:	358.5	

Appendix 6 continued ...



Interval	Start		End		Duration (Days)	Growth (cm)	Accumulated Biomass (cm-days)	Growth Rate (cm/day)
	Date (Julian days)	Crop Height (cm)	Date (Julian days)	Crop Height (cm)				
1	130	0	130	15	0	15	0	n/a
2	130	15	144	40	14	25	385	1.79
3	144	40	157	45	13	5	552.5	0.38
4	157	45	171	70	14	25	805	1.79
						Total:	1742.5	

Appendix 7: Spearman correlation of local habitat and farming practices with species abundance for 72 sample sites. Spearman correlation coefficients (Rho) and the probability > |R| under Ho: Rho = 0. * denotes a significant correlation, $p \leq 0.05$.

	Farm type	Rowcrop	Spring Grain	Winter Grain	Hay	Pasture	Farmstead
SPECIES							
American Robin	0.1764	0.1972	-0.1146	-0.2155	-0.1725	0.2433	0.3007
	0.1382	0.0968	0.3378	0.0690	0.1473	0.0394*	0.0103*
Brown-headed Cowbird	-0.2769	-0.0044	0.1819	-0.0255	-0.0966	0.1095	0.0971
	0.0185*	0.9704	0.1262	0.8316	0.4196	0.3599	0.4170
Red-winged Blackbird	-0.1252	0.2284	0.1933	-0.2902	-0.0697	-0.0788	0.0569
	0.2949	0.0536	0.1038	0.0134*	0.5609	0.5108	0.6351
Savannah Sparrow	-0.0686	-0.4807	-0.0963	0.3796	0.3433	-0.0636	-0.4121
	0.5686	0.0001*	0.4210	0.0010*	0.0032*	0.5956	0.0003*
Song Sparrow	-0.1074	0.0496	-0.0592	-0.1147	0.1029	0.0495	0.1176
	0.3690	0.6788	0.6210	0.3373	0.3899	0.6796	0.3250
Vesper Sparrow	-0.1786	0.0735	0.1773	-0.1348	-0.1398	-0.2124	-0.2629
	0.1333	0.5397	0.1363	0.2590	0.2414	0.0733	0.0257*

Appendix 7 continued: Spearman correlation of local habitat and farming practices with species abundance for 72 sample sites. Spearman correlation coefficients (Rho) and the probability > |R| under Ho: Rho = 0. * denotes a significant correlation, $p \leq 0.05$.

	Farm type	Rowcrop	Spring Grain	Winter Grain	Hay	Pasture	Farmstead
SPECIES							
Barn Swallow	0.1829	0.1006	-0.1782	0.0394	-0.0687	-0.0099	0.2619
	0.1241	0.4005	0.1343	0.7422	0.5662	0.9345	0.0262*
Horned Lark	-0.0674	0.1893	0.2035	-0.0424	-0.2626	-0.1618	-0.1788
	0.5739	0.1113	0.0864	0.7239	0.0258*	0.1744	0.1329
Killdeer	-0.1147	0.4443	-0.0497	-0.0803	-0.3580	-0.1694	0.1472
	0.3372	0.0001*	0.6785	0.5026	0.0020*	0.1549	0.2173

Appendix 7 continued: Spearman correlation of local habitat and farming practices with species abundance for 72 sample sites. Spearman correlation coefficients (Rho) and the probability > |R| under Ho: Rho = 0. * denotes a significant correlation, $p \leq 0.05$.

	Hedgerow	Woodland	Stream	Road	Herbaceous Fenceline	Habitat Heterogeneity	# Tillages
SPECIES							
American Robin	0.1966	0.1596	0.0702	0.1718	-0.2233	0.0741	0.0332
	0.0980	0.1805	0.5581	0.1490	0.0593	0.5360	0.7819
Brown-headed Cowbird	0.2250	-0.0048	0.0658	-0.0640	-0.0271	0.1713	0.2996
	0.0574	0.9677	0.5827	0.5930	0.8214	0.1501	0.0106*
Red-winged Blackbird	0.0715	0.0947	0.1680	0.2790	-0.1920	0.1630	0.3092
	0.5504	0.4288	0.1585	0.0176*	0.1061	0.1714	0.0082*
Savannah Sparrow	-0.3484	-0.2057	-0.3572	-0.2257	0.2860	-0.2565	-0.1238
	0.0027*	0.0830	0.0021*	0.0567	0.0149*	0.0297*	0.3002
Song Sparrow	0.3435	0.1834	0.0503	-0.0411	-0.2008	0.1966	-0.1693
	0.0031*	0.1230	0.6749	0.7318	0.0908	0.0978	0.1551
Vesper Sparrow	0.1661	-0.2258	0.0813	-0.2494	-0.0123	-0.0702	0.0425
	0.1631	0.0565	0.4972	0.0346*	0.9185	0.5579	0.7227

Appendix 7 continued: Spearman correlation of local habitat and farming practices with species abundance for 72 sample sites. Spearman correlation coefficients (Rho) and the probability > |R| under Ho: Rho = 0. * denotes a significant correlation, $p \leq 0.05$.

	Hedgerow	Woodland	Stream	Road	Herba-ceous Fenceline	Habitat Hetero-geneity	# Tillages
SPECIES							
Barn Swallow	0.0400	-0.1924	-0.0396	0.0975	0.2777	0.0202	-0.0301
	0.7385	0.1055	0.7410	0.4152	0.0182*	0.8663	0.8016
Horned Lark	-0.2774	-0.1932	-0.0082	-0.1852	0.1417	-0.0840	0.3027
	0.0183*	0.1040	0.9458	0.1193	0.2351	0.4832	0.0098*
Killdeer	0.0474	-0.0224	0.2079	0.1663	-0.0816	-0.0695	0.2385
	0.6929	0.8521	0.0796	0.4955	0.1626	0.5618	0.0436*

Appendix 7 continued: Spearman correlation of local habitat and farming practices with species abundance for 72 sample sites. Spearman correlation coefficients (Rho) and the probability > |R| under Ho: Rho = 0. * denotes a significant correlation, p ≤ 0.05.

	# Passes	Herbicide	Chemical Fertil-izer	Manure	Biodyn-amic Sprays	Field Size	Farm ID
SPECIES							
American Robin	0.0250	0.0954	0.0678	0.2061	-0.1696	-0.2105	0.3270
	0.8352	0.4255	0.5714	0.0824	0.1545	0.0759	0.0050*
Brown-headed Cowbird	0.1138	-0.0569	-0.0613	0.0472	0.0194	-0.1173	0.0448
	0.3412	0.6352	0.6090	0.6935	0.8711	0.3266	0.7090
Red-winged Blackbird	0.2214	0.0197	-0.0665	-0.0618	-0.0997	-0.1406	0.3469
	0.0616	0.8694	0.5791	0.6061	0.4046	0.2389	0.0028*
Savannah Sparrow	-0.1914	-0.2261	-0.1134	-0.2200	0.2794	0.3236	-0.5010
	0.1072	0.0562	0.3429	0.0634	0.0174*	0.0056*	0.0001*
Song Sparrow	-0.1928	-0.1313	-0.0756	0.0088	-0.0984	-0.1913	0.3796
	0.1046	0.2716	0.5282	0.9418	0.4110	0.1074	0.0010*
Vesper Sparrow	0.0192	-0.1122	-0.1471	0.0862	-0.1166	0.2066	0.0828
	0.8726	0.3481	0.2176	0.4714	0.3296	0.0817	0.4894

Appendix 7 continued: Spearman correlation of local habitat and farming practices with species abundance for 72 sample sites. Spearman correlation coefficients (Rho) and the probability > |R| under Ho: Rho = 0. * denotes a significant correlation, $p \leq 0.05$.

	# Passes	Herbicide	Chemical Fertil-izer	Manure	Biodyn-amic Sprays	Field Size	Farm ID
SPECIES							
Barn Swallow	-0.0307	0.1622	0.0780	-0.0271	-0.0490	-0.1019	-0.0804
	0.7980	0.1736	0.5146	0.8211	0.6827	0.3945	0.5018
Horned Lark	0.4442	0.0573	0.0075	0.1538	0.0731	0.2686	-0.4524
	0.0001*	0.6326	0.9499	0.1973	0.5415	0.0225*	0.0001*
Killdeer	0.1462	-0.0015	-0.0563	0.2124	-0.0305	-0.2384	-0.0402
	0.2205	0.9900	0.6388	0.0733	0.7989	0.0438*	0.7374

Appendix 8: Estimating risk to mean species richness and abundance for A. omnivores and B. grassland species of concern from potential changes in local habitat and agricultural practices at sites.

A. Calculation of 95% confidence intervals around predicted mean species richness for omnivores. Test values for **winter grain (wgrai) = 0.2; wooded hedgerow (lhedg1) = 100; woodland (woods) = 0.3.**

Model: MODEL1
Dependent Variable: ULDSP
(n=70): pts. MT2O and HH4C removed.

a)

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	4	270.28136	67.57034	20.534	0.0001
Error	**66**	**217.18343**	**3.29066**		
C Total	70	487.46479			

Root MSE	1.81402	R-square	0.5545
Dep Mean	8.56338	Adj R-sq	0.5275
C.V.	21.18342		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	7.591391	0.32785378	23.155	0.0001
WGRAI	1	-2.642198	1.09532737	-2.412	0.0186
LHEDG1	1	0.053073	0.00790483	6.714	0.0001
WOODS	1	4.379762	1.71853313	2.549	0.0132
Z1	**1**	**13.684170**	**1.99935564**	**6.844**	**0.0001**

b) 95% prediction intervals for omnivore species richness:

$t_{[.05,66]} SE\hat{Y} = 2.00(1.9994) = 3.9988.$

Lower limit = $\hat{Y}$ - 3.9988 = 13.6842 - 3.9988 = 9.6854.

Upper limit = $\hat{Y}$ + 3.9988 = 13.6842 + 3.9988 = 17.6830.

Appendix 8 continued ...

A. Calculation of 95% confidence intervals around predicted mean species richness for omnivores. Test values for **winter grain (wgrai) = 0.6; wooded hedgerow (lhedg1) = 20; woodland (woods) = 0.1.**

Model: MODEL2
Dependent Variable: ULDSP
(n=70): pts. MT2O and HH4C removed.

a)

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	4	270.28136	67.57034	20.534	0.0001
Error	**66**	**217.18343**	**3.29066**		
C Total	70	487.46479			

Root MSE	1.81402	R-square	0.5545
Dep Mean	8.56338	Adj R-sq	0.5275
C.V.	21.18342		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	7.591391	0.32785378	23.155	0.0001
WGRAI	1	-2.642198	1.09532737	-2.412	0.0186
LHEDG1	1	0.053073	0.00790483	6.714	0.0001
WOODS	1	4.379762	1.71853313	2.549	0.0132
Z1	**1**	**7.505507**	**1.91515966**	**3.919**	**0.0002**

b) 95% prediction intervals on omnivore species richness:

$t_{[.05,66]}SE\hat{Y} \approx 2.00(1.9152) = 3.8304.$

Lower limit $= \hat{Y} - 3.8304 = 7.5055 - 3.8304 = 3.6751.$

Upper limit $= \hat{Y} + 3.8304 = 7.5055 + 3.8304 = 11.3359.$

Appendix 8 continued ...

A. Calculation of 95% confidence intervals around predicted mean abundance for omnivores. Test value for **herbicide (herbic90) = 0**.

Model: MODEL3
Dependent Variable: ULDAB
(n=72)

a)

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	322.95684	161.47842	25.484	0.0001
Error	**70**	**443.54830**	**6.33640**		
C Total	72	766.50514			

Root MSE	2.51722	R-square	0.4213
Dep Mean	11.88699	Adj R-sq	0.4048
C.V.	21.17628		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	13.100000	0.35598888	36.799	0.0001
HERBIC90	1	-3.429545	0.64400812	-5.325	0.0001
Z1	**1**	**13.100000**	**2.54226913**	**5.153**	**0.0001**

b) 95% prediction limits for omnivore abundance:

$t_{[.05,70]}SE\hat{Y} \approx 2.00(2.5423) = 5.0846.$

Lower limit $= \hat{Y} - 5.0846 = 13.1000 - 5.0846 = 8.0154.$

Upper limit $= \hat{Y} + 5.0846 = 13.1000 + 5.8046 = 18.1846.$

Appendix 8 continued ...

A. Calculation of 95% confidence intervals around predicted mean abundance for omnivores. Test value for **herbicide (herbic90) = 1.**

Model: MODEL4
Dependent Variable: ULDAB
(n=72)

a)

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	322.95684	161.47842	25.484	0.0001
Error	**70**	**443.54830**	**6.33640**		
C Total	72	766.50514			

Root MSE	2.51722	R-square	0.4213
Dep Mean	11.88699	Adj R-sq	0.4048
C.V.	21.17628		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	13.100000	0.35598888	36.799	0.0001
HERBIC90	1	-3.429545	0.64400812	-5.325	0.0001
Z1	**1**	**9.670455**	**2.57379537**	**3.757**	**0.0004**

b) 95% prediction limits for omnivore abundance:

$t_{[.05,70]}SE\hat{Y} \approx 2.00(2.5738) = 5.1476.$

Lower limit $= \hat{Y} - 5.1476 = 9.6704 - 5.1476 = 4.5228.$

Upper limit $= \hat{Y} + 5.1476 = 9.6704 + 5.1476 = 14.8180.$

Appendix 8 continued ...

B. Calculation of 95% confidence intervals around a predicted mean species richness of grassland species of concern surveyed on Ontario farms, 1990. Test values: corridor (utility corridors) = 49.01; hay = 0.51; field (field size) = 2.96; **herbic90 (herbicides) = 0.**

Model: MODEL1
Dependent Variable: ULDSP
(n=72)

a) Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	80.61313	16.12263	11.273	0.0001
Error	**67**	**95.82522**	**1.43023**		
C Total	72	176.43836			

Root MSE	1.19592	R-square	0.4569
Dep Mean	4.65753	Adj R-sq	0.4164
C.V.	25.67713		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	5.593623	0.29367209	19.047	0.0001
HERBIC90	1	-0.777976	0.33787140	-2.303	0.0244
HAY	1	1.643345	0.47502100	3.460	0.0009
CORRIDOR	1	-0.016180	0.00470002	-3.443	0.0010
FIELD	1	-0.160277	0.06718408	-2.386	0.0199
Z1	**1**	**5.164321**	**1.21651534**	**4.245**	**0.0001**

b) 95% prediction intervals for grassland species of concern species richness:

$t_{[0.05,\ 67]}$ = 2.00(1.2165) = 2.4330.

Lower limit = $\hat{Y}$ - 2.4330 = 5.1643 - 2.4330 = 2.7313.

Upper limit = $\hat{Y}$ + 2.4330 = 5.1643 + 2.4330 = 7.5973.

Appendix 8 continued ...

B. Calculation of 95% confidence intervals around a predicted mean species richness of grassland species of concern surveyed on Ontario farms, 1990. Test values: corridor (utility corridors) = 49.01; hay = 0.51; field (field size) = 2.96; **herbic90 (herbicides) = 1.**

Model: MODEL1
Dependent Variable: ULDSP
(n=72)

a) Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	80.61313	16.12263	11.273	0.0001
Error	**67**	**95.82522**	**1.43023**		
C Total	72	176.43836			

Root MSE	1.19592	R-square	0.4569
Dep Mean	4.65753	Adj R-sq	0.4164
C.V.	25.67713		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	5.593623	0.29367209	19.047	0.0001
HERBIC90	1	-0.777976	0.33787140	-2.303	0.0244
HAY	1	1.643345	0.47502100	3.460	0.0009
CORRIDOR	1	-0.016180	0.00470002	-3.443	0.0010
FIELD	1	-0.160277	0.06718408	-2.386	0.0199
Z1	**1**	**4.386345**	**1.24540562**	**3.522**	**0.0008**

b) 95% prediction intervals for grassland species of concern species richness:

$t_{[0.05,\ 67]}$ = 2.00(1.2454) = 2.4908.

Lower limit = $\hat{Y}$ - 2.4908 = 4.3863 - 2.4908 = 1.8955.

Upper limit = $\hat{Y}$ + 2.4908 = 4.3863 + 2.4908 = 6.8771.

Appendix 8 continued ...

B. Calculation of 95% confidence intervals around a predicted mean abundance of grassland species of concern surveyed on Ontario farms, 1990. Test values: corridor (utility corridors) = 49.01; hay = 0.51; biodyn (biodynamic sprays) = 1; **herbic90 (herbicides) = 0.**

Model: MODEL2
Dependent Variable: ULDAB
(n=71) point HH4C removed

a) Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	473.18440	94.63688	27.451	0.0001
Error	**66**	**227.53435**	**3.44749**		
C Total	71	700.71875			

Root MSE	1.85674	R-square	0.6753
Dep Mean	7.43750	Adj R-sq	0.6507
C.V.	24.96460		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	7.489375	0.39949624	18.747	0.0001
HERBIC90	1	-1.244210	0.52710116	-2.360	0.0212
HAY	1	6.034640	0.74657433	8.083	0.0001
CORRIDOR	1	-0.031228	0.00712871	-4.381	0.0001
BIODYN	1	1.572067	0.60228521	2.610	0.0112
Z1	**1**	**10.608612**	**1.94451029**	**5.456**	**0.0001**

b) 95% prediction intervals for grassland species of concern abundance:

$t_{[0.05,\ 66]}$ = 2.00(1.9445) = 3.8890.

Lower limit = $\hat{Y}$ - 3.8890 = 10.6086 - 3.8890 = 6.7196.

Upper limit = $\hat{Y}$ + 3.8890 = 10.6086 + 3.8890 = 14.4976.

Appendix 8 continued ...

B. Calculation of 95% confidence intervals around a predicted mean abundance of grassland species of concern surveyed on Ontario farms, 1990. Test values: corridor (utility corridors) = 49.01; hay = 0.51; biodyn (biodynamic sprays) = 1; **herbic90 (herbicides) = 1.**

Model: MODEL1
Dependent Variable: ULDAB
(n=71) point HH4C removed

a) Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	473.18440	94.63688	27.451	0.0001
Error	**66**	**227.53435**	**3.44749**		
C Total	71	700.71875			

Root MSE	1.85674	R-square	0.6753
Dep Mean	7.43750	Adj R-sq	0.6507
C.V.	24.96460		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	7.489375	0.39949624	18.747	0.0001
HERBIC90	1	-1.244210	0.52710116	-2.360	0.0212
HAY	1	6.034640	0.74657433	8.083	0.0001
CORRIDOR	1	-0.031228	0.00712871	-4.381	0.0001
BIODYN	1	1.572067	0.60228521	2.610	0.0112
Z1	**1**	**9.364402**	**2.02806762**	**4.617**	**0.0001**

b) 95% prediction intervals for grassland species of concern abundance:

$t_{(0.05,\ 66)}$ = 2.00(2.0281) = 4.0562.

Lower limit = $\hat{Y}$ - 4.0562 = 9.3644 - 4.0562 = 5.3082.

Upper limit = $\hat{Y}$ + 4.0562 = 9.3644 + 4.0562 = 13.4206.

Appendix 9: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, $p \leq 0.05$.

A. Species richness (n=72)

	FARM TYPE	# CULTIVATED FIELDS	# UNCULTIVATED FIELDS	FARMSTEAD	HEDGEROW	WOODLAND	WOODLAND EDGE	STREAM	HABITAT HETEROGENEITY
CLASS									
Total	-0.251	0.421	0.142	0.054	0.553	0.268	0.297	-0.071	0.214
	0.034*	0.0002*	0.235	0.652	0.0001*	0.023*	0.011*	0.552	0.070
Insectivores	-0.223	0.209	0.098	-0.029	0.251	0.162	0.083	0.128	0.140
	0.059	0.078	0.411	0.808	0.034*	0.175	0.486	0.282	0.241
Omnivores	-0.225	0.392	0.106	0.033	0.519	0.259	0.337	-0.198	0.214
	0.057	0.001*	0.374	0.784	0.0001*	0.028*	0.004*	0.096	0.071
Aerial Feeders	-0.308	0.207	-0.046	-0.049	0.204	0.086	0.089	0.129	0.104
	0.008*	0.082	0.703	0.683	0.086	0.471	0.455	0.282	0.385
Ground Feeders	-0.235	0.436	0.124	0.046	0.488	0.165	0.246	-0.090	0.119
	0.047*	0.0001*	0.301	0.700	0.0001*	0.165	0.037	0.450	0.319
Lower Canopy Feeders	0.092	0.195	0.125	-0.052	0.359	0.273	0.235	-0.125	0.247
	0.443	0.101	0.295	0.662	0.002*	0.020*	0.047*	0.296	0.037*

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, p ≤ 0.05.

A. Species richness (n=72)

	FARM TYPE	# CULTIVATED FIELDS	# UNCULTIVATED FIELDS	FARMSTEAD	WOODED HEDGEROW	WOODLAND	WOODLAND EDGE	STREAMS	HABITAT HETEROGENEITY
CLASS									
Ground Omnivores	-0.263	0.426	0.119	0.016	0.456	0.184	0.275	-0.267	0.164
	0.026*	0.0002*	0.320	0.896	0.0001*	0.121	0.019*	0.024*	0.170
Lower Canopy Omnivores	0.016	0.215	0.036	0.004	0.387	0.200	0.263	-0.071	0.214
	0.892	0.070	0.766	0.971	0.001*	0.092	0.025*	0.552	0.071
Neotropical Migrants	-0.232	-0.102	-0.147	-0.059	0.170	-0.027	-0.023	0.114	0.150
	0.049*	0.392	0.217	0.621	0.154	0.820	0.849	0.340	0.209
Short Distance 1 Migrants	-0.209	0.330	0.162	0.183	0.530	0.285	0.329	-0.206	0.218
	0.079	0.005*	0.174	0.124	0.0001*	0.015*	0.005*	0.082	0.066
Short Distance 2 Migrants	-0.172	0.383	0.217	0.033	0.421	0.384	0.402	-0.028	0.300
	0.147	0.001*	0.067	0.781	0.0002*	0.001*	0.0005*	0.817	0.010*
Winter Residents	0.018	0.401	0.136	0.031	0.464	0.084	0.146	-0.117	0.040
	0.882	0.0005*	0.254	0.797	0.0001*	0.482	0.220	0.327	0.736

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, $p \leq 0.05$.

A. Species richness (n=72)

	FARM TYPE	# CULTIVATED FIELDS	# UNCULTIVATED FIELDS	FARMSTEAD	HEDGEROW	WOODLAND	WOODLAND EDGE	STREAM	HABITAT HETEROGENEITY
CLASS									
Ground Nesters	-0.270	0.078	0.153	0.111	0.062	0.175	0.137	0.192	0.083
	0.022*	0.513	0.199	0.353	0.605	0.141	0.253	0.106	0.487
Above Ground Nesters	-0.090	0.291	0.088	-0.006	0.504	0.274	0.303	-0.180	0.226
	0.450	0.013*	0.461	0.958	0.0001*	0.020*	0.010*	0.130	0.056
Declining Grassland Species	-0.263	0.089	0.117	0.141	0.170	0.192	0.083	0.052	0.159
	0.026*	0.459	0.327	0.237	0.153	0.106	0.488	0.666	0.182

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, p ≤ 0.05.

B. Abundance (n=72)

	FARM TYPE	# CULTIVATED FIELDS	# UNCULTIVATED FIELDS	FARMSTEAD	HEDGEROW	WOODLAND	WOODLAND EDGE	STREAM	HABITAT HETEROGENEITY
CLASS									
Total	-0.327	0.142	0.128	0.127	0.173	0.037	-0.071	0.003	-0.015
	0.005*	0.234	0.282	0.288	0.147	0.755	0.552	0.982	0.902
Insectivores	-0.082	0.044	0.058	-0.070	0.056	-0.047	-0.180	0.045	-0.055
	0.492	0.710	0.626	0.558	0.641	0.694	0.130	0.708	0.647
Omnivores	-0.472	0.095	0.090	0.181	0.024	0.036	0.049	-0.050	0.050
	0.0001*	0.429	0.450	0.128	0.844	0.762	0.683	0.677	0.676
Aerial Feeders	-0.127	0.140	0.021	-0.127	0.114	0.045	-0.025	0.168	0.109
	0.287	0.240	0.862	0.287	0.338	0.708	0.836	0.157	0.360
Ground Feeders	-0.384	0.020	0.010	0.190	-0.046	-0.120	-0.168	0.117	-0.100
	0.001*	0.867	0.931	0.109	0.700	0.315	0.158	0.327	0.401
Lower Canopy Feeders	0.023	0.317	0.167	0.003	0.372	0.137	0.138	-0.250	0.101
	0.845	0.007*	0.160	0.981	0.001*	0.251	0.248	0.034*	0.397

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, p ≤ 0.05.

B. Abundance (n=72)

	FARM TYPE	# CULT-IVATED FIELDS	# UN-CULT-IVATED FIELDS	FARM-STEAD	HEDGE-ROW	WOOD-LAND	WOOD-LAND EDGE	STREAM	HABITAT HETERO-GENEITY
CLASS									
Ground Omnivores	-0.405	-0.093	0.039	0.141	-0.197	-0.004	-0.0222	0.108	0.030
	0.0004*	0.436	0.747	0.238	0.098	0.976	0.856	0.368	0.805
Lower Canopy Omnivores	-0.036	0.371	0.154	0.0.61	0.409	0.077	0.136	-0.252	0.075
	0.763	0.001*	0.197	0.610	0.0004*	0.520	0.254	0.033*	0.532
Neotropical Migrants	-0.162	-0.197	-0.138	-0.089	-0.005	-0.089	-0.066	0.250	0.041
	0.174	0.098	0.249	0.459	0.966	0.456	0.584	0.034*	0.731
Short Distance 1 Migrants	-0.131	0.404	0.196	0.095	0.396	0.126	0.193	-0.328	0.061
	0.272	0.0004*	0.099	0.428	0.001*	0.291	0.104	0.005*	0.066
Short Distance 2 Migrants	-0.451	0.055	0.068	0.243	-0.013	-0.038	-0.004	0.150	0.015
	0.0001*	0.648	0.567	0.040*	0.915	0.749	0.976	0.208	0.897
Winter Residents	0.006	0.271	0.084	0.018	0.313	-0.025	-0.072	-0.110	-0.121
	0.960	0.021*	0.482	0.878	0.007*	0.834	0.546	0.358	0.312

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, p ≤ 0.05.

B. Abundance (n=72)

	FARM TYPE	# CULT-IVATED FIELDS	# UN-CULT-IVATED FIELDS	FARM-STEAD	HEDGE-ROW	WOOD-LAND	WOOD-LAND EDGE	STREAM	HABITAT HETERO-GENEITY
CLASS									
Ground Nesters	-0.247	-0.301	-0.100	0.059	-0.342	-0.153	-0.190	0.275	-0.083
	0.037*	0.010*	0.405	0.620	0.003*	0.199	0.111	0.019*	0.115
Above Ground Nesters	-0.125	0.337	0.086	0.047	0.470	0.152	0.198	-0.198	0.193
	0.295	0.004*	0.473	0.694	0.0001*	0.201	0.095	0.094	0.104
Declining Grassland Species	-0.292	-0.238	-0.035	0.044	-0.278	-0.055	-0.174	0.145	-0.094
	0.013*	0.044*	0.768	0.714	0.018*	0.644	0.144	0.226	0.433

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, p ≤ 0.05.

C. Species richness (n=16)

	FARM TYPE	# CULTIVATED FIELDS	# UNCULTIVATED FIELDS	FARMSTEAD	HEDGEROW	WOODLAND	WOODLAND EDGE	STREAM	HABITAT HETEROGENEITY
CLASS									
Total	-0.393	0.483	0.082	0.190	0.759	0.421	0.428	0.026	0.427
	0.132	0.058	0.762	0.481	0.001*	0.104	0.098	0.922	0.099
Insectivores	-0.488	0.359	0.109	0.244	0.520	0.235	0.174	0.235	0.394
	0.055	0.172	0.688	0.362	0.039*	0.380	0.520	0.380	0.131
Omnivores	-0.122	0.437	0.074	0.062	0.776	0.585	0.602	-0.330	0.501
	0.652	0.090	0.786	0.820	0.0004*	0.017*	0.014*	0.212	0.048*
Aerial Feeders	-0.614	0.447	-0.021	0.326	0.582	0.033	-0.002	0.162	0.227
	0.011*	0.083	0.938	0.218	0.018*	0.902	0.996	0.549	0.397
Ground Feeders	-0.326	0.462	0.215	0.028	0.492	0.402	0.312	-0.100	0.468
	0.218	0.071	0.424	0.918	0.053	0.123	0.239	0.712	0.067
Lower Canopy Feeders	0.054	0.257	-0.056	0.065	0.608	0.505	0.639	-0.164	0.372
	0.841	0.337	0.836	0.811	0.012*	0.046*	0.008*	0.544	0.156

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, p ≤ 0.05.

C. Species richness (n=16)

	FARM TYPE	# CULTIVATED FIELDS	# UNCULTIVATED FIELDS	FARMSTEAD	HEDGEROW	WOODLAND	WOODLAND EDGE	STREAM	HABITAT HETEROGENEITY
CLASS									
Ground Omnivores	-0.302	0.464	0.040	-0.031	0.626	0.402	0.315	-0.492	0.406
	0.256	0.070	0.883	0.909	0.010*	0.123	0.234	0.053	0.119
Lower Canopy Omnivores	0.083	0.257	-0.052	0.138	0.605	0.516	0.640	-0.138	0.371
	0.761	0.336	0.847	0.612	0.013*	0.041*	0.008*	0.612	0.158
Neotropical Migrants	-0.422	0.047	-0.064	0.035	0.504	0.247	0.234	0.151	0.344
	0.103	0.862	0.815	0.896	0.045*	0.357	0.384	0.577	0.191
Short Distance 1 Migrants	-0.163	0.273	0.176	0.133	0.643	0.696	0.684	-0.224	0.622
	0.546	0.307	0.516	0.624	0.007*	0.003*	0.004*	0.404	0.010*
Short Distance 2 Migrants	-0.299	0.516	0.223	0.227	0.661	0.540	0.543	-0.013	0.516
	0.260	0.041*	0.407	0.398	0.005*	0.031*	0.030*	0.961	0.041*
Winter Residents	0.055	0.521	0.067	0.143	0.602	0.175	0.192	-0.328	0.097
	0.840	0.038*	0.805	0.596	0.014*	0.518	0.475	0.214	0.721

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, $p \leq 0.05$.

C. Species richness (n=16)

	FARM TYPE	# CULT-IVATED FIELDS	# UN-CULT-IVATED FIELDS	FARM-STEAD	HEDGE-ROW	WOOD-LAND	WOOD-LAND EDGE	STREAM	HABITAT HETERO-GENEITY
CLASS									
Ground Nesters	-0.339	-0.028	0.191	0.121	-0.015	0.205	0.140	0.250	0.193
	0.198	0.918	0.478	0.656	0.957	0.447	0.605	0.350	0.474
Above Ground Nesters	-0.095	0.282	-0.004	0.115	0.713	0.445	0.483	-0.228	0.332
	0.726	0.291	0.987	0.672	0.002*	0.084	0.058	0.395	0.210
Declining Grassland Species	-0.462	0.248	0.021	0.292	0.189	0.246	0.346	0.293	0.224
	0.072	0.355	0.940	0.273	0.484	0.358	0.189	0.270	0.404

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, $p \leq 0.05$.

D. Abundance (n=16)

	FARM TYPE	# CULT-IVATED FIELDS	# UN-CULT-IVATED FIELDS	FARM-STEAD	HEDGE-ROW	WOOD-LAND	WOOD-LAND EDGE	STREAM	HABITAT HETERO-GENEITY
CLASS									
Total	-0.542	0.188	-0.056	0.412	0.109	0.041	0.012	0.218	-0.065
	0.030*	0.485	0.837	0.113	0.688	0.880	0.966	0.418	0.812
Insectivores	-0.380	0.035	-0.054	0.110	0.211	0.019	-0.191	0.097	0.053
	0.146	0.897	0.841	0.684	0.434	0.944	0.478	0.720	0.845
Omnivores	-0.596	0.259	-0.041	0.624	-0.015	0.068	0.176	0.197	-0.047
	0.015*	0.333	0.880	0.010*	0.957	0.803	0.513	0.464	0.863
Aerial Feeders	-0.394	0.284	0.034	0.141	0.501	0.124	0.050	0.293	0.174
	0.131	0.286	0.901	0.601	0.048*	0.648	0.854	0.270	0.520
Ground Feeders	-0.515	0.056	-0.162	0.453	-0.206	-0.112	-0.044	0.341	-0.179
	0.041*	0.837	0.550	0.078	0.444	0.680	0.871	0.196	0.506
Lower Canopy Feeders	0.081	0.374	-0.043	0.043	0.630	0.383	0.434	-0.415	0.302
	0.764	0.154	0.875	0.875	0.009*	0.144	0.093	0.110	0.256

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, p ≤ 0.05.

D. Abundance (n=16)

	FARM TYPE	# CULT-IVATED FIELDS	# UN-CULT-IVATED FIELDS	FARM-STEAD	HEDGE-ROW	WOOD-LAND	WOOD-LAND EDGE	STREAM	HABITAT HETERO-GENEITY
CLASS									
Ground Omnivores	-0.488	-0.026	-0.085	0.485	-0.335	-0.115	0.029	0.412	-0.185
	0.55	0.922	0.754	0.057	0.204	0.672	0.914	0.113	0.492
Lower Canopy Omnivores	0.095	0.428	0.022	0.056	0.531	0.274	0.312	-0.478	0.202
	0.726	0.098	0.935	0.837	0.034*	0.305	0.239	0.061	0.454
Neotropical Migrants	-0.312	-0.165	0.004	0.069	0.125	0.160	0.193	0.543	0.128
	0.239	0.542	0.987	0.799	0.644	0.553	0.474	0.030*	0.636
Short Distance 1 Migrants	0.068	0.458	0.209	0.150	0.553	0.406	0.362	-0.440	0.349
	0.803	0.075	0.437	0.579	0.026*	0.118	0.168	0.088	0.186
Short Distance 2 Migrants	-0.638	0.096	0.124	0.530	-0.155	0.024	0.087	0.390	0.082
	0.008*	0.724	0.648	0.035*	0.567	0.931	0.749	0.135	0.761
Winter Residents	0.054	0.088	-0.147	-0.165	0.288	0.129	-0.159	-0.515	-0.118
	0.841	0.754	0.587	0.542	0.279	0.633	0.557	0.041*	0.664

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, p ≤ 0.05.

D. Abundance (n=16)

	FARM TYPE	# CULTIVATED FIELDS	# UNCULTIVATED FIELDS	FARMSTEAD	HEDGEROW	WOODLAND	WOODLAND EDGE	STREAM	HABITAT HETEROGENEITY
CLASS									
Ground Nesters	-0.244	-0.300	-0.038	0.194	-0.544	-0.229	-0.206	0.465	-0.285
	0.362	0.259	0.888	0.471	0.029*	0.393	0.444	0.070	0.284
Above Ground Nesters	-0.217	0.411	-0.094	0.244	0.753	0.344	0.468	-0.115	0.276
	0.420	0.087	0.729	0.362	0.001*	0.192	0.068	0.672	0.300
Declining Grassland Species	-0.271	-0.243	-0.106	0.258	-0.474	-0.190	-0.084	0.438	-0.293
	0.309	0.365	0.696	0.336	0.064	0.481	0.757	0.089	0.271

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, $p \leq 0.05$.

E. Species Abundance (n=72)

	FARM TYPE	# CULT-IVATED FIELDS	# UN-CULT-IVATED FIELDS	FARM-STEAD	HEDGE-ROW	WOOD-LAND	WOOD-LAND EDGE	STREAM	HABITAT HETERO-GENEITY
SPECIES									
American Robin	0.176	0.230	-0.005	-0.042	0.356	0.018	0.068	-0.137	0.172
	0.138	0.052	0.969	0.726	0.002*	0.882	0.573	0.252	0.148
Brown-headed Cowbird	-0.277	0.136	-0.012	-0.037	0.107	0.011	0.041	-0.191	0.071
	0.018*	0.256	0.918	0.757	0.369	0.926	0.734	0.108	0.553
Red-winged Blackbird	-0.125	0.435	0.207	0.242	0.232	0.016	0.089	-0.314	0.095
	0.250	0.0001*	0.080	0.040*	0.050*	0.892	0.458	0.007*	0.426
Savannah Sparrow	-0.068	-0.460	-0.179	0.039	-0.439	-0.043	-0.151	0.315	-0.054
	0.569	0.0001*	0.133	0.748	0.0001*	0.718	0.207	0.007*	0.652
Song Sparrow	-0.107	0.410	0.182	0.124	0.257	0.049	0.119	-0.199	-0.077
	0.369	0.0003*	0.126	0.298	0.029*	0.680	0.321	0.093	0.520
Vesper Sparrow	-0.179	0.215	0.031	-0.127	-0.049	-0.074	0.066	-0.237	-0.099
	0.133	0.070	0.795	0.287	0.685	0.538	0.579	0.045*	0.408

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, $p \leq 0.05$.

E. Species Abundance (n=72)

	FARM TYPE	# CULT-IVATED FIELDS	# UN-CULT-IVATED FIELDS	FARM-STEAD	HEDGE-ROW	WOOD-LAND	WOOD-LAND EDGE	STREAM	HABITAT HETERO-GENEITY
SPECIES									
Barn Swallow	0.1829	0.0498	0.0888	-0.0276	-0.1326	-0.1348	-0.2219	0.2156	-0.0599
	0.1241	0.6778	0.4584	0.8182	0.2670	0.2589	0.0611	0.0689	0.6170
Horned Lark	-0.0674	-0.1626	-0.0300	-0.2456	-0.2293	-0.0781	-0.0432	0.1347	0.0963
	0.5739	0.1725	0.8023	0.0375*	0.0527	0.5145	0.7185	0.2594	0.4209
Killdeer	-0.1147	0.2445	-0.0677	0.1388	0.0783	-0.16112	-0.0487	0.1115	-0.1009
	0.3372	0.0385*	0.5718	0.2450	0.5132	0.1761	0.6846	0.3512	0.3992

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, p ≤ 0.05.

F. Species abundance (n=16)

	FARM TYPE	# CULTIVATED FIELDS	# UNCULTIVATED FIELDS	FARMSTEAD	HEDGEROW	WOODLAND	WOODLAND EDGE	STREAM	HABITAT HETEROGENEITY
SPECIES									
American Robin	-0.041	0.285	-0.111	0.066	0.721	0.259	0.269	-0.223	0.281
	0.880	0.284	0.683	0.806	0.002*	0.333	0.314	0.406	0.292
Brown-headed Cowbird	-0.476	0.144	-0.294	-0.018	0.422	0.152	0.270	-0.218	0.178
	0.062	0.593	0.270	0.948	0.104	0.574	0.312	0.417	0.508
Red-winged Blackbird	-0.190	0.480	-0.140	0.336	0.375	0.072	0.056	-0.291	0.150
	0.481	0.060	0.606	0.204	0.152	0.791	0.837	0.274	0.579
Savannah Sparrow	-0.095	-0.450	-0.134	0.154	-0.584	-0.193	-0.087	0.358	-0.290
	0.726	0.080	0.621	0.568	0.018*	0.474	0.749	0.174	0.276
Song Sparrow	-0.177	0.710	0.004	0.304	0.413	-0.069	0.054	-0.408	-0.081
	0.513	0.002*	0.987	0.253	0.112	0.799	0.841	0.116	0.795
Vesper Sparrow	-0.068	0.356	-0.013	-0.117	-0.034	-0.208	-0.196	-0.521	-0.204
	0.802	0.176	0.961	0.667	0.901	0.439	0.466	0.038*	0.449

Appendix 9 continued: Spearman correlation of landscape habitat and farming practices with A. species richness and B. abundance for 72 sites, C. species richness and D. abundance for 16 spatially-independent sampling regions by bird class and abundance by species for E. 72 sites and F. 16 spatially independent sampling regions. Spearman correlation coefficient (Rho) and probability > |Rho| under Ho: Rho = 0 are listed for each class/species in the first and second rows, respectively. * denotes a significant correlation, $p \leq 0.05$.

F. Species abundance (n=16)

	FARM TYPE	# CULTIVATED FIELDS	# UNCULTIVATED FIELDS	FARMSTEAD	HEDGEROW	WOODLAND	WOODLAND EDGE	STREAM	HABITAT HETEROGENEITY
SPECIES									
Barn Swallow	0.1222	0.0162	0.3579	-0.0604	-0.2563	-0.1694	-0.3520	0.5847	-0.1075
	0.6521	0.9525	0.1735	0.8242	0.3381	0.5306	0.1812	0.0174*	0.6919
Horned Lark	0.0000	-0.1463	0.0806	-0.3672	-0.2418	-0.1015	-0.1881	0.1224	0.0388
	1.0000	0.5888	0.7667	0.1618	0.3669	0.7048	0.4855	0.6516	0.8865
Killdeer	-0.3261	0.5203	-0.4038	0.3434	0.1769	-0.5262	-0.3508	0.1592	-0.3670
	0.2177	0.0388*	0.1208	0.1928	0.5123	0.0363*	0.1828	0.5560	0.1620