Agroecology of Birds in Organic and Nonorganic Farmland

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Abstract: *Ecological relationships between wildlife conservation and farm management provide common ground for the enhancement of bird habitat and the natural suppression of pests on farmland. We compared bird populations in 15 paired organic and nonorganic sites (cornfields plus edges, 30 sites total) that were similar in environment and edge habitat but that differed in use of fertilizers, herbicides, cultivation, and crop rotations. At each site, we used one strip transect to sample birds and vegetation in the bordering edge and cornfield perimeter (0–25 m from the edge) and another to sample in the cornfield (50–150 m from the edge). During the 1995 and 1996 growing seasons, we recorded 54 bird species, 51 in organic and 39 in nonorganic sites. On average, bird abundance on organic sites was 2.6 times higher than on nonorganic sites, and mean species richness per visit was 2.0 times greater. When analyzed separately, organic edge, perimeter, and field transects supported higher bird abundance and greater richness than did their nonorganic counterparts. Abundance and richness were higher on organic sites for insectivores, omnivores, and granivores, and for each of three migratory groups. Twelve species were individually more abundant on organic sites, and one regularly observed species was observed only on organic sites. No species had greater abundance on nonorganic sites. More non-crop vegetation on organic cornfields, most likely a result of no herbicide use, may have provided better foraging opportunities for birds. The plant food, cover, and invertebrate prey in organic cornfields appeared to augment birds not only in the field but also in the uncropped edges. Organic fields appear to benefit birds, but reproductive success needs further study. Modifying farm-management practices, especially near field edges where bird activity is concentrated, may enhance the conservation of birds and their potential predation on crop pests.*

Agroecología de Aves en Granjas Orgánicas y No Orgánicas

Resumen: *Las relaciones ecológicas entre la conservación de vida silvestre y el manejo de granjas proporciona un eslabón natural para incrementar las aves y la supresión natural de plagas en los terrenos agrícolas. Comparamos las poblaciones de aves en 15 pares de sitios orgánicos y no orgánicos (campos de maíz más los bordes, en total 30 sitios) similares en ambiente y en hábitat de borde pero diferentes en el uso de fertilizantes, herbicidas, prácticas agrícolas y rotación de cultivos. En cada sitio, utilizamos un transecto lineal para muestrear aves y vegetación en el borde y en el perímetro del campo de maíz (0-25 m del borde) y otro para muestrear dentro del maizal 50 – 150 m del borde. Registramos 54 especies de aves en la temporada de crecimiento de 1995 y 1996, 51 en campos orgánicos y 39 en no orgánicos. En promedio, la abundancia de aves en sitios orgánicos fue 2.6 veces mayor que en no orgánicos, y la riqueza promedio de especies/visita fue 2.0 veces mayor. Analizados por separado, el borde orgánico, el perímetro y los transectos de campo soportaron mayor abundancia y riqueza que los no orgánicos. La abundancia y riqueza fueron mayores en sitios orgánicos para insectívoros, omnívoros y granívoros, y para cada uno de tres grupos migratorios. Doce espe-*

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cies fueron individualmente más abundantes en sitios orgánicos, y una especie observada regularmente fue registrada solo en sitios orgánicos. Ninguna especie fue más abundante en sitios no orgánicos. Una mayor vegetación no cultivada, muy probablemente consecuencia de la no utilización de herbicidas, pudo haber proporcionado a las aves mejores oportunidades de forrajeo. El alimento vegetal, la cobertura y los invertebrados presa en los campos orgánicos parecen aumentar a las aves no solo en el campo, sino también en los bordes no cultivados. Los campos orgánicos parecen ser benéficos para las aves pero el éxito reproductivo requiere de mayores estudios. La modificación de las prácticas de manejo de granjas, especialmente cerca del borde de los campos donde se concentra la actividad de las aves, puede incrementar la conservación de aves y su depredación potencial de plagas de los cultivos.

Introduction

Nearly one-fifth of the United States is covered by cropland that for almost two generations has been chemically managed to create uniform monocultures (National Research Council 1989; U.S. Resource Assessment Division 1997). Birds use cropland areas for breeding, foraging, migration stopover, and wintering activities, and, although most use is in uncultivated field edges, many edge-dependent birds also forage in crop fields (Johnson & Beck 1988; Gerard 1995; Boutin et al. 1999*a*). Pesticide use, along with other farming practices, affects the potential quality of fields as a foraging resource and is coming under greater scrutiny because of a variety of unforeseen negative effects (Biswas 1994; Boutin et al. 1999*b*; Krebs et al. 1999). One response has been an increased interest in how the fields themselves contribute to conservation of birds or other biota in agricultural systems (Jules and Dietsch 1997; Lokemoen & Beiser 1997). Similarly, agricultural interest has begun to shift away from chemical management and toward alternative practices, creating an increased need for management options that are environmentally friendly yet economically viable (Rogers & Freemark 1991; Bignal & McCracken 1996). Various alternative farming approaches offer management options that seek to retain both short- and long-term profitability while using ecologically sound methods (National Research Council 1989). Compared with conventional farming, alternative agriculture "sustains and enhances rather than reduces and simplifies the biological interactions" (National Research Council 1989:4).

One such system is organic farming, which excludes synthetic fertilizers and pesticides and relies on mechanical and cultural practices, organic on-farm inputs, and natural processes (U.S. Department of Agriculture Study Team on Organic Farming 1980). Research has demonstrated greater richness and abundance of birds on whole organic farms than on conventional farms (Dahlgren 1984; Chamberlain et al. 1999), and some research has begun to elucidate how components of organic versus conventional farm management affect birds (Braae et al. 1988; Rogers & Freemark 1991; Christensen et al. 1996). Because organic farms typically have smaller fields and more uncultivated edge habitats than conventional farms, the effects of farming practices on birds are confounded with habitat variability. A few studies have compared bird communities in organic and nonorganic farmland, but none in the United States has separated the effects of field-edge habitats from those of farm management and none have focused on cornfields, which cover 30 million ha in the United States and 141 million ha worldwide (U.S. Department of Agriculture National Agricultural Statistics Service 1998). We examined bird communities in paired organic and nonorganic cornfields, with each pair matched to control habitat variation and isolate farm-management differences. Our objectives were to compare bird abundance, species richness, and composition between organic and nonorganic farmland and to evaluate differences in relation to farm management, biological control of crop pests, and bird conservation.

Study Areas

Research sites were located on privately owned farms in east-central Nebraska (U.S.A.) at the western edge of the dryland corn belt in the central Great Plains. Of the 30 sites, 26 had rolling hills and 4 were in the high plains. The sites spanned seven counties that averaged approximately 74% cropland, 42% of which was planted in corn (U.S. Bureau of the Census 1994). Each year farmers completed questionnaires about their management of the studied cornfields (Beecher 1998).

We selected paired sites, each pair consisting of one organic and one nonorganic cornfield 0.8–8 km apart. Edge vegetation bordering the cornfields differed between pairs and years, but was matched within paired sites (coniferous windbreaks, deciduous windbreaks, deciduous riparian corridors, herbaceous fencerows, grassed roadsides, alfalfa, and soybean crops). Field sizes in 1995 averaged 9 ha (range: 4–16 ha) for organic fields and 21 ha (7–39 ha) for nonorganic fields. In 1996 organic fields averaged 13 ha (9–16) and nonorganic averaged 16 ha (5–26). We studied 16 sites (8 pairs) in early summer of 1995 and repeated 12 of them (6 pairs) in late summer of that year. In 1996, because crops were rotated annually, we selected 14 different sites (7 pairs) and studied them in both early and late summer.

Nonorganic cornfields in our study received modified conventional management, which included sustainable practices such as crop rotation and reduced pesticide application. All fields were rotated annually between corn and soybeans except for two that were planted in corn both years. All nonorganic cornfields received both synthetic fertilizer and herbicide applications, but four of eight fields in 1995 and four of seven in 1996 received herbicide applications at one-third to one-half the rates suggested by the label. Synthetic insecticides were applied on two of the nonorganic cornfields in 1995 and on one in 1996.

Organic cornfields were certified by private certifying agents (U.S. Organic Foods Production Act of 1990), with the exception of one 1996 site in its second year of organic management. For certification, farmers followed written organic farming plans, including abstaining from synthetic fertilizer and pesticide applications for ≥3 consecutive years. Although the organically certified insecticidal bacterium *Bacillus thuringiensis* (Bt) was allowed, only one organic cornfield each year received this treatment. Farmers in our study had been farming organically for a mean of 15.8 years. Three study sites in 1995 and four in 1996 had been managed organically for ≥25 years.

Methods

We surveyed birds on the paired sites each year during the early and late summer seasons. Early summer seasons (6 June to 9 July 1995, 12 June to 18 July 1996) began after all cornfields were planted. Late summer seasons (4 August to 4 September 1995, 31 July to 7 September 1996) followed early summer seasons after an interim of about 2 weeks. To avoid observer variability, one observer, the first author, conducted all bird surveys.

In early summer, each research site had two strip-transect lines, one bordering the cornfield edge (edge transect to survey the edge and cornfield perimeter) and the other 100 m into the cornfield running parallel to the edge (field transect). The first author recorded birds within 50 m of either side of the field-transect line, such that observations spanned 50–150 m from the sampled edge. When field pairs were small, however, field transects spanned only 50–100 m to avoid confounding edge effects. From the edge-transect line, the observer surveyed edge vegetation immediately adjacent to the field and in the first 25 m (perimeter) of the cornfield. If the bordering edge vegetation consisted of an adjacent crop (crop against crop, 1995, two pairs; 1996, one pair), the edge transect width was 25 m. If the edge consisted of uncropped vegetation (1995 and 1996, six pairs), the edge transect spanned the entire width of edge habitat unless confined by a steep bank. Edge habitat type, vertical and horizontal structure, and topography were the primary criteria for pair selections. Among pairs, uncropped edge transects ranged from 1.4 to 17.6 m wide (mean = 9.2 m). Transects were as long as field conditions allowed, with a mean transect length of 226 m. Within pairs, the lengths of edge and field transects were identical, except for three 1996 field transects that differed by 25, 50, or 75 m, respectively, because of nonlinear field shapes. Total transect area for both organic and nonorganic fields was 21.5 ha in 1995 and 19.6 ha for organic sites and 20.9 ha for nonorganic sites in 1996. We placed transects ≥50 m from any other herbaceous edge and ≥100 m from any other woody edge.

In late summer, corn height interfered with strip-transect surveys, so we used modified fixed-distance point counts. We divided each transect into contiguous rectangular or square point counts that covered the same transect areas as in early summer, and a 2.4-m stepladder served as the point-count center along transect lines. We used one point-count center for each 100 m or part of 100 m of transect. In each point count, ≥78% of the area was ≤50 m from the center and all was ≤70 m from the center. The observer could avoid double counting among contiguous point counts because of low farmland bird densities. We assumed equal detection ability between farm types. We later averaged observations over all point counts within each transect. With this technique, we could compare relative bird abundance between organic and nonorganic edge, perimeter, and field-transect areas in both seasons.

We rotated surveys among research sites (three to six visits per site per season) between sunrise and 4 hours later, with paired sites always visited on the same day. Transects were walked at an approximate pace of 100 m/10 minutes (Ralph et al. 1993), and point counts lasted 5 minutes (Johnson 1995). Bird species and abundance were mapped within strip-transect and point-count areas. Birds in the sampling area, entering and leaving the area, and foraging immediately above the transect or canopy (aerial foragers) were mapped where first detected; birds flying by without stopping or foraging were ignored.

During every bird survey, we visually ranked non-crop vegetation (weed) cover in the cornfields based on seven described levels of weed coverage (Beecher 1998). Once a year (1995, October 7–15; 1996, September 4–10), we measured groundcover in the edge, perimeter, and field transects and tree dispersion in the woody edges. We described groundcover types using a Daubenmire frame with stratified, random sampling (Daubenmire 1959). Transects of ≤199 m had three edge, two perimeter, and two field sampling points and transects of ≥200 m had six edge, four perimeter, and four field sampling points. We divided transects into equal sections for each sampling point and randomly dropped a frame within each section. In each frame we recorded percentage of live cover (grasses and forbs), bare ground, litter, and corn (if in the perimeter or field transects), totaling 100% cover per frame. We used a point-quarter technique with stratified, random sampling (Noon 1981) to measure tree dispersion (density and evenness) along woody edges, and we used one sampling point for each 100 m or part of 100 m of transect. We divided transects into equal sections for each sampling point and randomly selected a tree as the point-quarter center within each section. From this center tree, we used lines parallel and perpendicular to the edge boundary to create four quadrants and, within each quadrant, recorded the distance to the nearest tree.

Statistical Analysis

Our experimental design was a split plot with repeated measures through time. Main units were farm types (organic and nonorganic) and subunits were transects (edge, perimeter, and field). Because there were no treatment-by-year interactions that affected results or conclusions, data from the 2 years were combined for analysis. We analyzed early and late-summer seasons separately because of temporal changes in avian composition and behavior and because of different estimation capabilities of the strip-transect and point-count sampling techniques.

We assigned birds to foraging and migratory guilds to examine the potential for avian biological control of agricultural pests and bird conservation in farmland. Foraging guild classification was based on that of De Graaf et al. (1985) except for the American Robin (scientific names are given in Table 1), the only early summer vermivore, which we classified instead as an insectivore. Migratory guild classification (permanent residents, short-distance migrants, and Neotropical migrants) was based on that of Peterjohn and Sauer (1993) except for the American Crow (*Corvus brachyrhynchos*), American Goldfinch, Blue Jay, European Starling, and House Finch, which we classified as permanent residents.

We compared mean abundance (expressed as birds per 10 ha of transect) and species richness (mean species per survey) between organic and nonorganic systems for birds overall and for foraging and migratory guilds, and we used restricted maximum-likelihood estimation to fit the linear mixed models (PROC MIXED, SAS Institute 1997). For birds overall, the variables of farm type (organic, nonorganic), transect (edge, perimeter, field), and year (1995, 1996) were fixed effects. The variable pair (1–8) and its interactions were declared random. To account for non-normal distributions, we transformed data prior to analysis using the natural logarithm of the observed abundance plus one (Zar 1999). For foraging and migratory guilds, analysis was the same except that guilds were not analyzed by transect because sample sizes were small.

Because of low abundance of most individual species, we used a two-tailed binomial paired *t* test to test for differences in abundance between the organic and nonorganic sites (Snedecor & Cochran 1989). The observed proportion ($\hat{p}$) of visits in which abundance was higher in the organic than in the nonorganic site was computed for each pair. If abundance was the same on average for both sites, then it should be greater on the organic site about half the time and on the nonorganic site about half the time. The hypothesis of interest was $H_o{:}p = 0.5$, where p is the true proportion of the time abundance is greater on organic than on nonorganic sites. We tested only species with a mean abundance of ≥0.1 bird/10 ha in at least one farm type within any season. Because there were no treatment-by-season interactions that affected results or conclusions, we analyzed early and late-summer seasons together and separately. Because the *t* tests were performed on estimated proportions and not observed abundances, different estimation capabilities of the two sampling techniques (early summer strip transects and late-summer point counts) did not interfere with our combined-seasons comparisons.

We compared groundcover from the Daubenmire frame measurements using chi-square tests for two-way contingency tables. To ensure expected frequencies of ≥5, we grouped data by cover type based on expected frequencies (SAS Institute 1988). We analyzed visual cornfield vegetation ranks, tree dispersion, and corn height with linear mixed models in which the variable pair and its interactions were declared random.

Results

Organic sites had consistently higher mean bird abundance and greater species richness than nonorganic sites in both early ($F_{1,13} \geq 32.6, p \leq 0.0001$) and late ($F_{1,11} \geq 26.6, p \leq 0.0003$) summers. There were no transect-by-farm interactions with these comparisons (early summer: $F_{2,394} \leq 2.03$, $p \geq 0.13$; late summer: $F_{2,260} \leq 1.29, p \geq 0.28$), indicating that this response pattern was consistent across edge, perimeter, and field transects. On average, abundance was 2.6 times greater and richness per survey 2.0 times greater on organic study sites. Over the 2 years, we recorded 54 bird species, 51 in organic sites and 39 in nonorganic sites. Of the 54 species, 10 were seldom observed (0.1–0.29 bird/10 ha) and 15 rarely observed (<0.1 bird/10 ha), and these are listed elsewhere (Beecher 1998). To ensure that results were not influenced by chance occurrences, we temporarily excluded from the analysis species with a mean abundance of <1 bird/10 ha. Abundance and richness remained greater on the organic sites (early summer: $F_{1,6} \geq 17.6, p \leq 0.006$; late summer: $F_{1,5} \geq 24.2, p \leq 0.010$).

Foraging guilds, mostly represented by insectivores and omnivores, and migratory guilds exhibited similar trends. Within the insectivorous, omnivorous, and granivorous guilds, greater abundance and richness were observed on organic sites than on nonorganic sites in both early ($F_{1,6} \geq 6.4$, $p \leq 0.045$) and late ($F_{1,5} \geq 4.1$, $p \leq 0.099$) summers (Fig. 1). Similarly, short-distance and Neotropical migrant guilds had greater abundance and richness on organic sites in both early ($F_{1,6} \geq 4.3, p \leq 0.083$) and late ($F_{1,5} \geq 5.8$, $p < 0.062$) summers (Fig. 1). For permanent residents, however, abundance and richness did not differ between organic and nonorganic sites in early ($F_{1,6} \leq 2.8$,

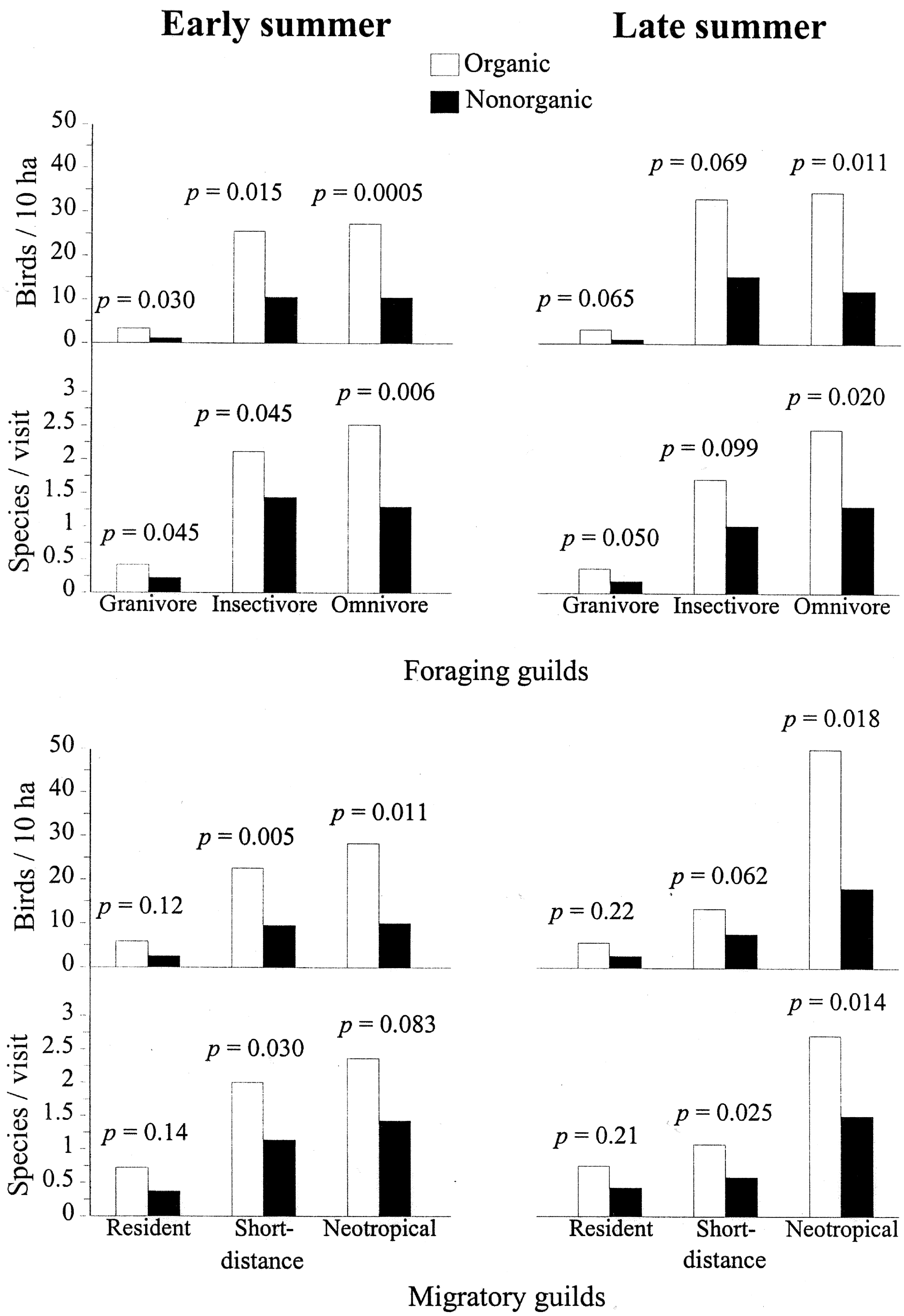

Figure 1. Mean bird abundance ($\bar{x}$/10 ha) and mean species richness ($\bar{x}$/visit) within foraging and migratory guilds in paired organic and nonorganic cornfield sites (bordering edge, cornfield perimeter, and field transects combined) in early and late summer of 1995 and 1996 in east-central Nebraska. Number of bird surveys: early summer, n *= 144 (72 each of organic and nonorganic farm types); late summer,* n *= 98 (49 each). Probability values are above bars.*

Table 1. Mean abundance ($\bar{x}$/10 ha) of bird species observed on paired organic (O) and nonorganic (N) cornfield sites (bordering edge, field perimeter, and field transects combined) in early, late, and combined summer seasons (east-central Nebraska, 1995, 1996).[a]

Abundance category, bird species	*Farm*	*Early summer*		*Late summer*		*Combined seasons*	
		mean	*SE*	*mean*	*SE*	*mean*	*SE*
Abundant (≥3 birds/10 ha)							
American Robin	O	4.2	0.9*	2.3	0.7	3.4	0.6**
Turdus migratorius	N	2.1	0.6	0.7	0.3	1.5	0.4
Barn Swallow	O	8.3	1.7**	17.7	3.9	12.1	1.9**
Hirundo rustica	N	3.2	0.6	9.5	1.9	5.7	0.9
Cliff Swallow	O	0	0.0	10.6	4.1	4.3	1.7
Hirundo pyrrhonota	N	0	0.0	4.0	2.3	1.6	0.9
Dickcissel	O	4.3	1.1	15.0	4.2***	8.6	1.9**
Spiza americana	N	2.6	0.7	1.7	0.5	2.2	0.5
Red-winged Blackbird	O	4.4	1.1	1.0	0.6	3.0	0.7
Agelaius phoeniceus	N	2.3	0.8	4.8	2.9	3.3	1.3
Common (1–2.9 birds/10 ha)							
Baltimore Oriole	O	2.9	0.6***	0.7	0.5	2.0	0.4***
Icterus galbula	N	0.8	0.3	0.1	0.3	0.5	0.2
Blue Jay	O	1.7	0.6**	0.7	0.3	1.3	0.4**
Cyanocitta cristata	N	0.2	0.1	0.6	0.5	0.4	0.2
Brown-headed Cowbird	O	1.5	0.6	2.8	2.8	2.0	1.2
Molothrus ater	N	0.5	0.3	0.1	0.1	0.3	0.2
Chipping Sparrow	O	2.2	0.6	0.8	0.4	1.6	0.4
Spizella passerina	N	0.9	0.3	0.6	0.3	0.8	0.2
Common Grackle	O	2.6	0.8***	0.02	0.0	1.6	0.5***
Quiscalus quiscula	N	0.6	0.4	0	0.0	0.4	0.2
Eastern Kingbird	O	2.5	0.6*	1.8	0.5	2.3	0.4**
Tyrannus tyrannus	N	0.8	0.3	1.0	0.5	0.8	0.2
House Sparrow	O	1.5	0.6	0.8	0.5	1.2	0.4
Passer domesticus	N	0	0.0	0.8	0.4	0.3	0.2
Indigo Bunting	O	1.0	0.4	2.3	0.9[b]	1.5	0.4**
Passerina cyanea	N	0.7	0.3	0.2	0.2	0.5	0.2
Killdeer	O	2.7	1.1	0.5	0.3	1.8	0.6
Charadrius vociferus	N	1.6	0.8	0	0.0	0.9	0.5
Lark Sparrow	O	1.5	0.6*	0.4	0.3	1.1	0.4*
Chondestes grammacus	N	0.1	0.1	0.02	0.0	0.05	0.0
Mourning Dove	O	2.6	0.6***	3.1	1.1	2.8	0.6**
Zenaida macroura	N	0.5	0.2	1.0	0.3	0.7	0.2
N. Rough-winged Swallow	O	2.1	1.0	1.0	0.5	1.7	0.6*
Stelgidopteryx serripennis	N	0.6	0.3	0.5	0.1	0.6	0.2
Red-headed Woodpecker	O	1.2	0.4	1.5	0.7	1.3	0.4
Melanerpes erythrocephalus	N	1.0	0.3	0.7	0.3	0.9	0.2
Occasional (0.3–0.9 bird/10 ha)							
American Goldfinch	O	0.4	0.3	0.7	0.3	0.6	0.2
Carduelis tristis	N	0.2	0.1	0.2	0.1	0.2	0.1
Brown Thrasher	O	1.4	0.6	0.4	0.3	1.0	0.4
Toxostoma rufum	N	0.1	0.1	0.02	0.0	0.1	0.0
European Starling	O	0	0.0	1.3	1.2	0.5	0.5
Sturnus vulgaris	N	0	0.0	0	0.0	0	0.0
Horned Lark	O	0.6	0.2	0.7	0.6	0.6	0.3
Eremophila alpestris	N	0.8	0.5	0	0.0	0.5	0.3
House Finch	O	0.7	0.3	0.1	0.1	0.5	0.2
Carpodacus mexicanus	N	0.5	0.2	0	0.0	0.3	0.1
House Wren	O	0.5	0.2	0.4	0.2	0.5	0.2
Troglodytes aedon	N	0.2	0.1	0.3	0.2	0.3	0.1
Meadowlark	O	0.6	0.2	0.5	0.4	0.6	0.2
Sturnella spp.	N	0.7	0.4	0.3	0.3	0.6	0.3

continued

$p \geq 0.12$) or late ($F_{1,5} \leq 1.9$, $p \geq 0.21$) summers. Although we did not analyze guilds by transect because observed abundances were small, observed mean numbers of species and individuals within the six guild subgroups were consistently higher in the organic than in the nonorganic sites in all edge, perimeter, and field-transect comparisons, with the exception of two, where mean species richness was equal.

Table 1. (continued)

Abundance category, bird species	*Farm*	*Early summer* mean	*Early summer* SE	*Late summer* mean	*Late summer* SE	*Combined seasons* mean	*Combined seasons* SE
Northern Cardinal	O	0.4	0.2	0.5	0.2	0.4	0.1
Cardinalis cardinalis	N	0.1	0.0	0.6	0.3	0.3	0.1
Turkey Vulture	O	0.5	0.4	0	0.0	0.3	0.2
Cathartes aura	N	0	0.0	0.1	0.1	0.1	0.1
Upland Sandpiper	O	1.6	0.7[b]	0	0.0	1.0	0.4
Bartramia longicauda	N	0	0.0	0.1	0.1	0.05	0.0
Vesper Sparrow	O	0.5	0.2	1.2	0.8[b]	0.8	0.3
Pooecetes gramineus	N	0	0.0	0	0.0	0	0.0

[a] *Number of bird surveys: early summer,* n = *144 (72 each farm type, O, N); late summer,* n = *98 (49 each); combined summer seasons,* n = *242 (121 each). Asterisks indicate abundance in organic differed from that in nonorganic:* *p ≤ *0.1;* **p ≤ *0.05;* ***p ≤ *0.01.*
[b] *Organic > nonorganic, based on greater abundance in organic sites for every field pair and every visit, which, with the binomial paired* t *test, gave SE = 0 and an incalculable* p *value.*

Of the 39 bird species analyzed separately with binomial *t* tests, 13 had higher counts on organic sites and 26 showed no difference in abundance between farm types (Table 1). The 13 species, which are often found in farmland, included 5 common native species (American Robin, Barn Swallow, Eastern Kingbird, Mourning Dove, and Northern Rough-winged Swallow; Johnsgard 1979); 2 nest predators (Blue Jay and Common Grackle; Martin et al. 1951; Gates & Gysel 1978); 2 species that have adapted to agriculture, relatively stabilizing their numbers (Baltimore Oriole and Upland Sandpiper; Johnsgard 1979; Sauer et al. 2001); and 4 species of conservation concern (Dickcissel, Indigo Bunting, Lark Sparrow, and Vesper Sparrow; Robinson 1997; Sauer et al. 2001). Of the 26 species that showed no difference, 19 had few observations (mean abundance of <1 bird/10 ha). Of the remaining 7, the Brown-headed Cowbird and Cliff Swallow were observed sporadically in flocks, the Red-headed Woodpecker was observed primarily at sites with large dead trees, House Sparrows at sites with nearby buildings, and Red-winged Blackbirds at sites with telephone lines for perching or ditches with water. The Killdeer and Chipping Sparrow showed no significant differences between organic and nonorganic sites but did have consistently higher numbers on organic sites.

In edge vegetation bordering the cornfields, percent live groundcover (grasses and forbs) and tree dispersion did not differ between organic and nonorganic edges, and no differences were found for corn height ($p \geq 0.3$; Beecher 1998). Live groundcover did differ, however, in cornfields (perimeter and field transects combined). Non-crop live grasses and forbs (weeds) constituted 16% of groundcover in organic cornfields and 6% in nonorganic fields ($\chi^2 = 36.01$, df = 6, $p < 0.0001$) (Fig. 2). Visual rankings of non-crop vegetation density made during each bird survey supported these results (organic > nonorganic: early summer $t = 4.44$, df = 6, $p = 0.004$; late summer $t = 2.23$, df = 5, $p = 0.077$). The most common non-crop plants were foxtail (*Setaria* spp.), pigweed (*Amaranthus* spp.), and smartweed (*Polygonum* spp.) in organic cornfields and foxtail and pigweed in nonorganic fields.

The most distinguishing difference between organic and nonorganic farm management was use of synthetic inputs (Table 2). Unlike organic cornfields, all nonorganic fields received both synthetic fertilizers (forms of nitrogen or nitrogen plus phosphorus) and herbicides. Organic farmers used more types of mechanical weed control and repeated tillage practices more often. Furthermore, they designed extensive crop rotations ($x = 5.3$ crops) to help minimize pest problems and improve soil quality.

Discussion

Our findings suggest that organic cropland, compared with nonorganic cropland, sustains a greater abundance and species richness of birds across foraging and migratory guilds and that these differences hold true across edge, perimeter, and field transects. Previously, habitat fragments such as crop edges have been shown to be important for bird dispersal, migration, and cropland use (Best et al. 1990; Moore et al. 1993). Recently, Jules and Dietsch (1997) discussed the importance of the landscape between these fragments. Our results suggest that organically farmed fields offer a larger resource base for birds and demonstrate that birds in uncropped edges and in cropped fields are influenced by farm management of the agricultural landscape. We believe that our conclusions about organic fields are conservative because our nonorganic fields had limited herbicide applications and only one (1996) or two (1995) fields had synthetic insecticides applied. Differences might have been greater had our organic fields been compared with conventional agricultural fields that typically rely more on synthetic inputs.

The most likely reason our organically managed fields supported larger bird communities is the better foraging opportunities associated with vegetation diversity. In our organic cornfields, a larger percentage of ground was covered with grasses and forbs (weeds), a difference most likely attributed to a lack of herbicides. Herbicide use, which removes broad-leaved plants, is listed as

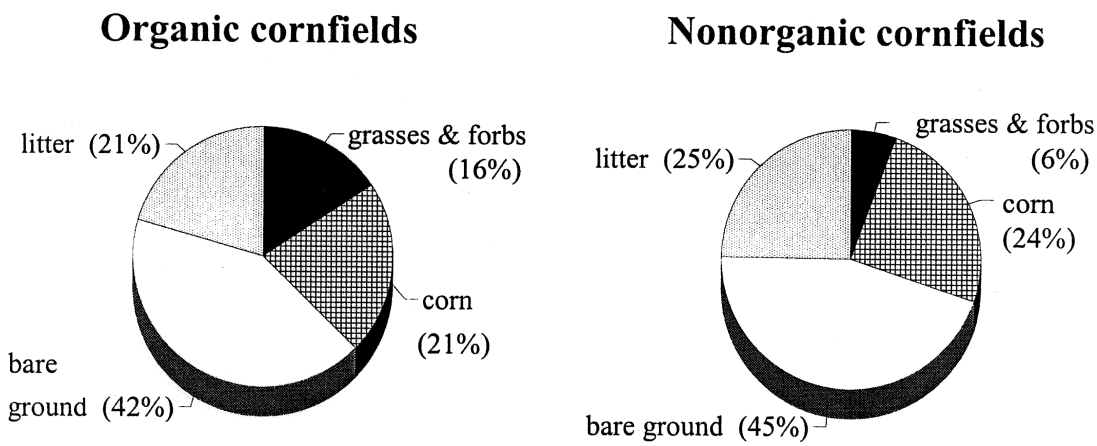

Figure 2. Mean percent vegetation cover ($\bar{x}$/Daubenmire frame) in paired organic and nonorganic cornfields (cornfield perimeter and field transects combined) in east-central Nebraska, October 1995 and September 1996. Number of Daubenmire frames: n *= 220 (110 organic and 110 nonorganic farm types). For grasses and forbs, df = 6,* $\chi^2 = 36.012$, $p < 0.0001$.

a cause of population decline in some farmland birds in Europe (Newton 1998). Non-crop plants support non-damaging arthropods eaten by birds and provide plant food and cover for birds (Altieri 1987, 1992; Freemark & Boutin 1995). Moreover, vegetation diversity supports beneficial pollinating species and predatory and parasitic arthropods that act as natural controls of crop pests (Altieri 1992; Freemark & Boutin 1995). To explore differences in our study, we collected arthropod samples from the organic and nonorganic perimeter and field-transect areas in 1996. The organic cornfields supported higher arthropod abundance, more taxonomic orders (primarily nonpest organisms), and more predator and parasitic species (Beecher 1998).

Although herbicide use in nonorganic cornfields probably led to decreased foraging opportunities, direct effects on birds appear unlikely to be factors contributing to our results. Of the seven herbicides used, five are classified as practically nontoxic to slightly toxic to birds (acetochlor, alachlor, atrazine, dicamba, and metolachlor: LD50 > 2000 mg/kg) and two as slightly to moderately toxic to birds (cyanazine and 2,4-D: LD50 ≥ 272 mg/kg) (EXTOXNET 1996). Furthermore, we have no evidence that these herbicides are directly repellent to birds, and most were applied 2–5 weeks before early summer observations began. Generally, herbicides commonly used in agriculture have a low risk of exposure to birds at levels that are acutely toxic, but they may have direct effects harmful to some insects (Freemark & Boutin 1995). During 1995, one nonorganic site used the insecticide fonofos, which is classified as highly toxic to birds and, each year, one site used methyl parathion, which is classified as highly to very highly toxic (EXTOXNET 1996) and thus potentially harmful to birds if ingested. We saw no evidence of direct effects on birds at these sites, however; this, along with limited use (2 sites), prevented us from altering our conclusions. As with any pesticide use, we could not rule out all potential sublethal or unobserved effects and conclude that use of our fields by birds was curbed primarily through indirect herbicide effects on vegetation and associated insect diversity, rather than by direct pesticide influence.

Successful bird conservation in farmland also requires consideration of farmers' concerns. One possible negative consequence of use of cropland by birds is damage to crops by certain flocking birds (Dolbeer 1994); although we did not specifically sample for this, bird damage was not reported by the farmers and none was observed. Moreover, factors that relate to the potential for such crop damage, such as proximity to large roosts, crop timing, and thickness and length of corn husks (Dolbeer 1994), appear unrelated to whether management is organic or nonorganic. Conversely, reduction of pest insects by birds and other pest-insect predators or parasites is an area receiving increased attention (Dix et al. 1995; Barbosa 1998). The insectivorous and omnivorous guilds, which encompassed 50 of our 54 bird species, were more abundant on organically farmed land. Moreover, of the 13 individual species found more commonly on organic sites, 12 are known to include pest insects in their diet (Martin et al. 1951).

The few studies that have compared birds on organic and conventional farmland reported results similar to ours. A 1-year pilot study in Canada found more birds and more bird species on organic cropland and attributed the difference primarily to herbicides (Rogers & Freemark 1991). In a larger 4-year Danish study, Braae et al. (1988) and Christensen et al. (1996) investigated birds and Hald and Reddersen (1990) sampled weeds and arthropods on the same crop fields. Mean bird abundance in conventional sites was 38–52% that of organic sites, and the

Table 2. Cornfield management in eight (1995) and seven (1996) cornfield pairs, each pair consisting of one organic (O) and one nonorganic (N) cornfield with similar environment and bordering edge habitat (east-central Nebraska, 1995, 1996).

Management	*Farm*	*1995*	*1996*[a]
Herbicides	O	none used	none used
	N	4 recommended rate, 4 1/2–1/3 rate	2 recommended rate, 4 1/2–1/3 rate
Fertilizers	O	2 organic fertilizers,[b] 6 fields had none	3 organic fertilizers, 4 fields had none
	N	5 used NH_3, 3 used NH_3 + P	3 used NH_3, 3 used NH_3 + P
Weed management[c]	O	$\bar{x}$ = 3.8 practices/field	$\bar{x}$ = 3.4 practices/field
	N	$\bar{x}$ = 2.5 practices/field	$\bar{x}$ = 1.8 practices/field
Crop rotation[d]	O	multiple crops rotated	multiple crops rotated
	N	6 corn-bean, 2 corn-corn	4 corn-bean, 2 corn-corn
Average cornfield size (ha)[e]	O	8.98	13.03
	N	20.70	16.33
Planting dates	O	5 May–12 June	1 May–22 May
	N	28 April–28 May	23 April–20 May
Irrigation	O	1 irrigated, 7 not irrigated	1 irrigated, 6 not irrigated
	N	4 irrigated, 4 not irrigated	3 irrigated, 4 not irrigated
Surveyed edge management[f]	O	3 mow, 3 none	5 mow, 1 till
	N	3 mow, 1 rogue, 1 2,4-D, 1 none	2 mow, 1 rogue, 1 2,4-D, 2 none
Insecticides	O	1 organic insecticide, 7 none	1 organic insecticide, 6 none
	N	2 insecticides, 6 none	1 insecticide, 5 none

[a] *Different cornfields were studied in 1996 because of annual crop rotations. One questionnaire was not returned in 1996.*
[b] *Organic fertilizers: composted manure (1 field each year), fish and kelp emulsion (1 field 1995), or manure plus emulsion (2 fields 1996).*
[c] *Weed management practices often used by both organic and nonorganic farmers: field and rolling cultivation and disking. Additional practices often used by organic farmers: row cultivation, ridge till, rotary hoe, and hand roguing (weeding).*
[d] *Average number of crops in rotation: 5.3 organic, 1.7 nonorganic.*
[e] *Size of entire cornfield, not just transect areas.*
[f] *Edge-management methods included mowing, roguing (hand weeding), 2,4-D [(2,4-dichlorophenoxy)acetic acid] herbicide application, and none. Cropped edges (alfalfa and soybean) not included.*

number of breeding species on conventionally farmed fields averaged only 83% of the number on organically farmed fields. Plant species diversity, abundance of plant species known to benefit herbivorous insects, invertebrate species diversity, and abundance of both herbivorous and nonherbivorous insects (many of which are considered important sources of bird food) were also greater on organic sites. The most consistent difference between organic and conventional management techniques was herbicide and insecticide use. As in our study, Braae et al. (1988) and Christensen et al. (1996) proposed that the organic sites had a greater carrying capacity for birds, probably because of a greater amount and quality of plant and animal food. They concluded that the decrease of certain Danish farmland bird species was probably linked to modern intensive farming practices.

In England and Wales, Chamberlain et al. (1999) compared overall bird populations in organic and conventional fields and field boundaries. Their organic farms tended to have higher diversity and numbers of birds than did conventional farms, although several comparisons showed no differences. They attributed the results mainly to differences in hedgerow structure and cropping regimes, but they recognized the difficulty of isolating causal factors.

On a broader scale, Dahlgren (1984) studied birds in organic and conventional farms in Iowa (U.S.A.) and their associated crop and land-management practices. He found seven to eight times more birds on organic farms and attributed it to management associated with greater vegetation cover and diversity in the landscape. Although we did not analyze the landscape outside our transect areas, we did select our sites by matching geographical locations and surrounding habitats. Furthermore, even though each year two of our organic fields were completely surrounded by conventional farmland and two nonorganic fields were bordered by pasture or alfalfa, bird abundance and species richness were still greater on all organic sites. Therefore, we believe that our data reflect smaller-scale influences at the field level.

It appears that farm management of crop fields may affect bird communities not only in the fields but also in the uncropped edges. Better foraging opportunities and groundcover in the cornfields appeared to augment bird abundance and species richness in and near the uncropped edges. In fact, birds in the nonorganic edges may have been limited by farm practices out in the cornfield. A larger, more diverse, and more accessible resource base would allow birds to acquire proper nourishment with less energy expenditure (Kaspari & Joern 1993), an important factor in agroecosystems where the majority of landcover is row crops such as corn.

In spite of the apparent benefits of organic fields to birds, we caution that bird use of the organic sites does not necessarily mean greater reproductive success (Van Horne 1983). Within crop fields, tillage practices can disturb or destroy nests; our organic sites had more tillage passes, increasing the likelihood that nests within the crop field would be disrupted. Best (1986) reported four bird species

(Killdeer, Mourning Dove, Horned Lark, and Vesper Sparrow) plus the Brown-headed Cowbird, a brood parasite, as the major species nesting in tilled cornfields. These species were detected in our study; of these, the Vesper Sparrow, because of nest timing and ecology, would probably be affected most by nest disturbance or destruction from tillage (Rodenhouse & Best 1983; Best 1986). If Vesper Sparrows are attracted preferentially to organic fields, and tillage destroys their nests, the organic fields could be functioning as an ecological trap. Best (1986) noted that Vesper Sparrows nesting in cornfields place nests primarily within rows, so some within-row nests may survive tillage operations.

A similar question about application of our results is whether birds nesting in the uncropped field edges might have a low probability of reproductive success because of nest predation and brood parasitism associated with these linear edge habitats (Rodenhouse et al. 1995). Organic field edges could function as an ecological trap if birds that might have nested successfully elsewhere were attracted to these edges and were unsuccessful. The reproductive success of birds nesting in field edges appears to vary, however, depending on predation or parasitism levels, and there is uncertainty about associated relationships between predators, habitat, and food supply (Rodenhouse et al. 1995; Newton 1998). Haas (1997) and Friesen et al. (1999) report successful reproduction of birds in habitat fragments in agricultural systems, possibly because of factors such as isolation, landscape context, and the type of predators present. Overall, organic fields appear to benefit birds, but reproductive success in relation to frequent tillage within fields and the potential for predation or parasitism in uncropped edges are concerns that need further study.

Although most farmers do not grow their crops organically, some organic and sustainable practices might be integrated into conventional management plans to enhance bird conservation. Birds are most abundant in uncropped edges and adjacent crop perimeters (Best et al. 1990; Fitzmaurice 1995; Sunderman 1995; Boutin et al. 1999*b*) and therefore could benefit from the reduction or elimination of agrochemical applications near the edge. Farmers in environmentally sensitive areas in Britain use a conservation headlands program in which pesticide applications are avoided in the uncropped edges and adjacent 6 m of the crop fields, to the benefit of wildlife (Rands 1986; Sotherton 1991). Because farm management in fields affects birds and other natural enemies of crop pests, informed decisions about the application of pesticides and fertilizers could further the goals of conservation and farming (Rodenhouse et al. 1995; Letourneau 1998; Ruberson et al. 1998), as might incorporating other management practices such as crop rotation, trap crops, alteration of planting dates, host-plant resistance, and a variety of biological controls (Pimentel et al. 1992; Barbosa 1998).

Many of the practices we suggest foster biological diversity in cropping systems, which is the opposite of conventional management goals for monocultures (National Research Council 1989). Research to weigh the benefits of non-crop vegetation against the disadvantages of weed competition, in order to identify optimal and threshold vegetation levels and species in crop fields, could provide guidelines and new options for farmers. Further research and understanding of endemic natural enemies of crop pests (Dix et al. 1995; Simberloff & Stiling 1996; Barbosa 1998) could also decrease reliance on pesticide use.

The expanse of agricultural land and broad concerns about habitat loss and biodiversity conservation dictate that we find ways to more successfully integrate wildlife and agriculture (Johnson 1994; Letourneau 1998). There is a need to combine the objectives of conservation biology with those of agroecology to benefit both biodiversity and agriculture (Jules & Dietsch 1997; Vandermeer & Perfecto 1997). Our study considered both these objectives. We found that organically farmed land supports more abundant and diverse bird populations, including species of conservation concern and insect-eating species that may help buffer crops from insect-pest damage. Incorporating these findings, especially near field edges where bird activity is concentrated, may enhance conservation of birds and their potential predation of crop pests.

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