BIRD USE AND NESTING IN CONVENTIONAL, MINIMUM-TILLAGE, AND ORGANIC CROPLAND

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Abstract: We examined seasonal bird use and nesting activity in fallow, sunflower, and wheat fields among conventional farms (using fall and spring tillage and pesticides), minimum-tillage farms (using reduced tillage), and organic farms (using zero synthetic pesticides) in southeast North Dakota. Observers recorded 18 species in crop fields in spring, 70 in summer, 40 in fall, and only 11 in winter. Birds counted in cropland in spring were mainly transient migrants. Spring bird densities were highest in minimum-tillage fallow fields that provided enhanced food and cover. There were no differences in bird densities among crops or field types in fall or winter, but mean densities in summer were highest in fallow fields (14–23/10 ha). Fallow fields also had the greatest mean number of nesting species (1.9/field) and the highest mean nest densities (15 nests/10 ha) probably due to increased amounts of plant litter cover. Compared to conventional fields, the mean number of nesting species (1.6 and 1.9/field) and mean nest densities (10–12 nest/10 ha) were higher in minimum-tillage and organic fields. Overall, hatching success was low for waterfowl (0%) and shorebirds (18%) and nest success was low for passerines (14%). Hatching success for shorebirds and passerines was not different among field types or crops when all loss factors were considered. Nest losses were caused primarily by predation and farming activities. When predation was not considered, hatching success was higher in minimum-tillage fields for passerines and in wheat fields for shorebirds. Although it would be difficult to reduce predation to increase nest success, mortality of nests and young might be lowered by reducing tillage frequency.

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Although most of the Prairie Pothole Region of North Dakota is cultivated (Stewart and Kantrud 1972), bird use of cropland is poorly known. The value of croplands as habitat for prairie birds is usually considered low in comparison to grasslands due to the soil-disturbance and possible negative effects from the application of chemicals (Graber and Graber 1963, Higgins 1977, Hill and Fleming 1982, Castrale 1985, Brewer et al. 1988). However, new cropping practices that use less tillage and less chemicals are being implemented on an increasing number of ha in North America. In 1991, North Dakota had more than 260,000 ha in minimum-tillage (Conserv. Tech. Inf. Cent. 1992) or organic farming (F. L. Kirschenmann, Farm Verified Organic, Medina, N.D., pers. commun.) primarily to reduce soil loss and minimize pesticide use.

There is some evidence that alternative cropping systems provide more food and cover for wildlife than conventional tillage methods in the form of crop residue, waste grain, and increased insects (Castrale 1985). Birds that use cropland during the migration, breeding, and winter seasons should be benefitted by these added food and cover resources. We hypothesized that alternative cropping practices would probably affect grassland passerines, upland-nesting shorebirds, and waterfowl, 3 avian groups that have shown declines in recent years (Robbins et al. 1986).

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The primary objectives of this study were: (1) to estimate and compare the number of species and density of birds using fallow, sunflower, and wheat in conventional, minimum-tillage, and organic fields during breeding, migration, and winter seasons, and (2) to estimate and compare the number of species and density of nesting birds in fallow, sunflower, and wheat in conventional, minimum-tillage, and organic fields.

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STUDY AREA

The study took place in the Prairie Pothole Region of southeastern North Dakota (Stewart and Kantrud 1974). The region is glaciated, gently-to-moderately rolling, and was interspersed with small wetlands, which occupied some 10% of the land. About 10–30% of the land was native grassland, and since 1990, an average of 5.6% of the cropland in these counties has been retired and planted to perennial grass under the Conservation Reserve Program (CRP; Kantrud 1993). Most of the land was cropland devoted to small grains (primarily wheat and barley), row crops (primarily sunflowers and corn), and fallow fields. Fallow fields normally were treated with tillage or herbicides to reduce plant growth and increase soil moisture and nutrients for crops planted the following year.

METHODS

Definitions and Field Selection Criteria

For the study, we defined 3 types of farming practices. Conventional farming included tillage in spring before seeding, fall tillage after harvest, and use of synthetic chemical herbicides and tillage to control weeds in crops and in fallow. Minimum-tillage farming included the placement of seed into plant residue that was untilled or moderately tilled. Fallow fields in minimum-tillage farming systems usually were small grain stubble, where weeds were controlled by herbicides. Organic farming excluded synthetic chemicals for weed and pest control, instead using cultivation and crop rotation. Yellow sweet clover (*Melilotus officinalis*), a legume, was tilled into the soil on organic fallow fields to add nitrogen.

Conventionally farmed fields were identified from information given in county offices of the U. S. Department of Agriculture. We obtained nearly complete lists of fields farmed by minimum-tillage and organic methods from the alternative farming organizations. We visited potential cooperators, and those who had one or more of the focal crops and who granted access, were included in the study. Each year we attempted to survey 32 ha of each crop on 10 fields of each type. Fields, not farms, were used as the experimental units because most North Dakota farms include land that is spatially separated. Fields were selected randomly within farms and new fields were selected each year.

We used the term "hatching success" to indicate the percentage of nests that hatched at least 1 egg and the term "fledging success" to indicate the percentage of nests with young that produced at least 1 fledgling. We used the term "nest success" for passerines to indicate the percentage of nests with eggs that produced at least 1 fledgling.

Bird Counting Techniques

Birds were counted on fields once or twice each season, beginning in April 1991 and ending in July 1993. We selected the dates of the bird surveys to portray the spring and fall migration, breeding, and wintering periods in North Dakota. Spring surveys extended from 1 March to 20 April, summer surveys from 21 April to 2 July, fall surveys from 15 August through 30 November, and winter surveys from 2 December to 2 February. Each field survey was separated by a period of at least 30 days.

Birds were surveyed by individuals walking truncated line-transects (Burnham et al. 1980). Crop rows or furrows were used as transect lines. Birds were counted within 50 m on each side of the transect line. Surveys were conducted from sunrise to 1300 hours (Dawson 1981). Summer surveys were not conducted when it was raining, the temperature was less than 0 C or higher than 32 C, or the wind speed exceeded 30 km/hour (Dawson 1981). Spring, fall, and winter surveys were not conducted if it was raining or snowing, the temperature was less than −12 C or more than 32 C, or the wind speed exceeded 30 km/hour.

Only birds observed on the ground in the field were counted. Birds flying over fields or those using other habitats, such as wetlands or fencerows, were not counted. Also, we estimated snow depth on the fields during the bird surveys.

Estimating Bird Densities

We attempted to use techniques described by Buckland et al. (1993) to estimate the undetected proportion of birds in fields. Due to small sample sizes and large flock sizes we were not able to employ distance sampling methods. Instead we used the observed bird density to test for differences among the years, crops, and field types.

Nest Searching Techniques

Each field was searched for bird nests 3 times during the nesting season. Two complete searches were made with a 40-m chain flushing device pulled between 2 all-terrain vehicles (Klett et al. 1986). The first nest search was initiated mainly before plant growth in late April and early May. The second search was conducted mainly after plants were growing from mid-May to early July. A third visual, walking search was made in late July to locate nests of late-nesting red-winged blackbird (*Agelaius phoeniceus*). The location of each nest was plotted on a map, and a marker flag was set 4 m north of the nest.

The number of host eggs, number of parasitic eggs, and the incubation or nestling stage was recorded during each nest visit. To determine incubation stage, we developed a technique to estimate days of incubation by examining the eggs with candlers (Lokemoen and Koford 1996). Fledging stage (days since hatching) was estimated from information published on the development of mourning doves (*Zenaida macroura*, Hanson and Kossack 1963) and chestnut-collared longspurs (*Calcarius ornatus*, Bent 1968). Nests were monitored every 7 days and hatching success was calculated by the Mayfield method (Mayfield 1975), with modifications described by Johnson (1979).

Daily Survival Rates

We used daily survival rate (DSR) calculations to estimate hatching success, fledging success, and nest success for passerines, and hatching success for shorebirds and waterfowl. To increase the number of exposure days, nests were pooled for all years to form a single DSR for all combinations of crop and field type. Comparisons among the field types, crops, and the crop-field type interaction were made with the Chi-square test described by Sauer and Williams (1989) and implemented by the Interactive Matrix Language (IML) procedure (SAS Inst. Inc. 1989*b*). Testing was done sequentially. First, we tested the interaction between the field type and crop. If the interaction was not significant, we tested separately for crop and field type effects. A nonsignificant field type-crop interaction implies that the effect of one main effect (crop or field type) on DSR is the same regardless of the level of the other main effect (field type or crop).

Plant Cover and Field Treatment Measurements

Two assessments of vegetative cover were made at each field in the spring. Visual obstruction readings of plant density were estimated from 4 readings of a calibrated pole made at 25 stations distributed across each field (Kirsch et al. 1978). Plant canopy cover, percent dead litter, and plant height were also evaluated at each station as the means of 4 estimates from each quarter of the station with a Daubenmire (1959) frame.

We recorded the number and time of tillages performed on each field each year because these treatments physically altered vegetative cover used by birds. We subsequently examined the relation between the number of tillage treatments on fields with nest densities and nest success using Pearson product-moment correlations.

Statistical Analyses

We used 3-way analysis of variance (ANOVA) techniques (Milliken and Johnson 1984) to assess the effects of years, crops, field types, and all interactions on bird densities (no./ha) by season, nest densities (no./ha), plant cover, and litter cover. Sample sizes varied because several fields had missing data. Unless noted, all analyses were conducted with General Linear Models (GLM) procedure (SAS Inst. Inc. 1989*a*).

Table 1. The percent frequency of species that occurred on ≤5% of ≤1 seasonal surveys and the total number of individuals recorded in cropland fields during spring, summer, fall, and winter in southeast North Dakota, 1991–93.

Species	Spring		Summer		Fall		Winter	
	% Freq.	Total	% Freq.	Total	% Freq.	Total	% Freq.	Total
Sharp-tailed grouse	2	13	<1	19	5	327	9	173
Gray partridge	4	40	1	69	5	517	14	201
Ring-necked pheasant	0	0	0	1	2	346	10	357
Killdeer	3	24	6	373	2	146	0	0
Mourning dove	<1	2	5	388	18	471	0	0
Horned lark	66	712	30	1,939	25	991	38	886
Brown-headed cowbird	0	0	7	939	0	0	0	0
Yellow-headed blackbird	0	0	2	757	<1	93	0	0
Red-winged blackbird	3	277	7	1,104	6	7,534	0	0
Western meadowlark	3	15	2	124	7	166	0	0
Snow bunting	<1	1	0	0	2	262	15	367
Lapland longspur	8	1,997	1	965	2	172	10	575
Chestnut-coll. longspur	8	1,049	2	165	2	31	0	0
Vesper sparrow	0	0	10	582	11	260	0	0
Grasshopper sparrow	<1	1	5	240	5	58	0	0
Other species	3	53	22	1,775	9	795	4	92
Totals	100	4,184	100	9,440	100	12,169	100	2,651

The population marginal means (or least squares means, LSM) are reported for all analyses. We used $\alpha \leq 0.05$ to indicate significance.

There were no conventional fallow, minimum-tillage fallow, or minimum-tillage sunflower fields surveyed in the 1991 field season. Therefore, the year-crop-field type (3-way) interaction could not be tested for all 3 years. The 3-way interaction was partially tested by analyzing the data as an expanded 1-way model (Milliken and Johnson 1984:177) and with a contrast statement to test the interaction in 1992 and 1993. If this 3-way interaction was not significant, we tested for main effects (field type, crop, and year [YR]) and 2-way interactions (YR-crop, YR-field type, and field type-crop) using all 3 years of data with ANOVA. The nonsignificance of 2-way and 3-way interactions indicates that the differences in a main effect are consistent among all levels of the other main effects. If interactions are significant, differences in a main effect must be interpreted within the levels of the other effect. If significant effects were found, we used Fisher's least significant differences (LSD) procedure to isolate the differences (Milliken and Johnson 1984).

The number of species observed in summer and the number of nesting species were analyzed with analysis of covariance (ANCOVA; Milliken 1984). The natural logarithm of the size of the field was used as the covariate. Because there were 3 missing combinations of crop and field type in 1991 and only 1 fallow field was surveyed in 1991, only 1992 and 1993 data were used in these analyses. The LSM are reported as the average value of the covariate (27 ha).

For the analysis of the bird densities in fall, winter, and spring we had data for only 2 years. We tested for crop, field type, and the crop-field type interaction with an expanded 1-way model (Milliken and Johnson 1984:177) and used contrast statements to test for interactions and main effects in 1992 (1993 for spring). To stabilize variances bird densities were logarithmically transformed with $\ln(y + 1)$.

Birds have different preferences for the amount of vegetative cover (Stewart 1975). Recognizing these species differences, we separated the birds into 2 groups for correlations between density (bird or nest) and cover (plant or litter). One group included those species that prefer sparse cover, and the other included those that prefer dense cover.

RESULTS

Bird Use by Season

During the study, birds were counted on 153 fields totaling 4,570 ha (range 6–96, $\bar{x}$ = 30 ha). Horned larks (*Eremophila alpestris*) were the most frequently observed species in all seasons, but the most common species was red-winged blackbirds seen mainly in fall (Table 1). The frequency and number of other species varied considerably among seasons.

In spring, we counted 18 species and 4,184 birds on 86 fields. Migrating chestnut-collared longspurs and lapland longspurs (*Calcarius lapponicus*) were the second and third most frequently encountered species, but they were the most numerous because they occurred in large flocks. No other species exceeded 10% of the sightings during the spring.

In summer, we counted 70 bird species and 9,440 birds on 153 fields. The vesper sparrow (*Pooecetes gramineus*) was the second most frequently observed species after horned lark. However, vesper sparrows were less numerous than yellow-headed blackbirds (*Xanthocephalus xanthocephalus*), red-winged blackbirds, brown-headed cowbirds, and lapland longspurs, which typically occur in large flocks.

There were insufficient data to test differences in the number of species among crops, field types, and years for spring, fall, and winter, but there were sufficient data for summer counts. The rate of increase between the number of species and the natural logarithm of the size of the field was consistent among all combinations of years, crops, and field types ($F = 0.71$; 17, 93 df; $P = 0.781$). Thus, the regression lines were parallel and differences among the treatments would be the same at any value of covariate. The 2-way and 3-way interactions were not significant ($P > 0.05$), which makes differences in the main effects interpretable. No differences in the mean number of species were found among field types ($F = 0.19$; 2, 110 df; $P = 0.827$) or between years ($F = 2.89$; 1, 110 df; $P = 0.092$). However, there were differences among the crops ($F = 11.09$; 2, 110 df; $P < 0.001$). The LSD tests indicated that the number of species ($\bar{x} = 7.3$, SE = 0.472) on fallow fields was larger ($P < 0.001$) than the number of species on sunflower fields ($\bar{x} = 4.6$, SE = 0.400) and wheat fields ($\bar{x} = 4.8$, SE = 0.340). No difference was found between sunflower and wheat fields ($P = 0.726$).

During the 2 fall surveys, we observed 40 species totaling 12,169 birds on 88 fields. Vesper sparrows were again second to horned larks in frequency, but both species were less numerous than red-winged and yellow-headed blackbirds, which composed 63% of all birds observed in fall. Eighty-three percent of the blackbirds seen in fall were observed in conventional sunflower fields.

In winter, we observed 11 species and 2,651 birds on 85 fields. The most common species were horned larks, snow buntings (*Plectrophenax nivalis*), and lapland longspurs. These 3 species commonly remained on our fields until snow depths exceeded 15–25 cm. Also present in the fields in the winter were resident game birds, including sharp-tailed grouse (*Tympanuchus phasianellus*), gray partridge (*Perdix perdix*), and ring-necked pheasant (*Phasianus colchicus*). These 6 species included 96% of all birds seen in winter.

Table 2. Back-transformed mean density of birds/10 ha on conventional, minimum-tillage, and organic fields in fallow, sunflower, and wheat during spring, fall, and winter in southeastern North Dakota, 1991–93.

Season Crop	Conventional	Min-till	Organic	Mean
Spring[a]				
Fallow	12	22ABC	2A	12
Sunflower	15	1B	15	1
Wheat	3	3C	4	3
Mean	1	9	7	
Fall				
Fallow	11	17	13	14
Sunflower	42	11	12	22
Wheat	4	5	11	7
Mean	19	11	12	
Winter				
Fallow	3	3	3	3
Sunflower	2	1	6	3
Wheat	1	2	2	2
Mean	2	2	4	

[a] Numbers in a row or a column followed by the same letter differ within season ($P \leq 0.05$).

Bird Density by Season

Because there was a crop-field type interaction ($F = 2.66$; 4, 71 df; $P = 0.039$) in the spring, we tested for crop differences within field types and field type differences within crops. Bird densities in minimum-tillage fallow were higher than those in organic fallow. Bird densities in minimum-tillage fallow fields were higher than densities in minimum-tillage sunflower or wheat fields (Table 2).

In summer, there was a significant ($F = 2.71$; 4, 134 df; $P = 0.033$) year-crop interaction so differences among crops were interpreted within years. In 1992, fallow fields had higher bird densities than sunflower and wheat fields (Table 3). In 1993, fallow and wheat fields had higher bird densities than sunflower fields. Bird densities in fallow fields were enhanced mainly by breeding birds, not transient migrants.

In fall, there were no differences among field types ($F = 0.32$; 2, 73 df; $P = 0.725$) or among

Table 3. Back-transformed mean density of birds/10 ha in summer on conventional, minimum-tillage, and organic fields in fallow, sunflower, and wheat in southeastern North Dakota during 1991–93.[a]

Year	Conventional	Minimum-till	Organic
1991	11	20	10
1992	11	11	12
1993	11	10	9
Mean	11	11	10
Year	Fallow	Sunflower	Wheat
1991	14	16EF	10
1992	23AB	7AE	6B
1993	15C	6CDF	10D
Mean	17	9	9

[a] Numbers in a row or a column followed by the same letter differ ($P \leq 0.05$).

crops ($F = 2.66$; 2, 73 df; $P = 0.077$). Sunflower fields were attractive to birds, mainly blackbirds, but counts were variable and no differences were detected (Table 2).

Similarly, in winter there was large variation in bird counts and no effects due to crops ($F = 0.77$; 2, 70 df; $P = 0.469$) or field types ($F = 1.06$; 2, 70 df; $P = 0.353$) were detected.

Nesting Species and Nesting Period

Nineteen species nested in the crop fields, and brown-headed cowbirds (*Molothrus ater*) laid parasitic eggs in 39% of the passerine nests. Horned lark, vesper sparrow, and killdeer (*Charadrius vociferus*) initiated 66% of all nests located (Table 4). Passerines initiated 75% of all nests, shorebirds 17%, waterfowl 5%, doves 3%, and upland game 1%.

Nesting started in mid-April and extended into early August (Fig. 1). The peak period for active nests was late May and early June. Most wheat was seeded by late May, most sunflowers were planted by mid-June, but the cultivating and spraying of fallow fields occurred during the entire period.

We compared the number of nesting species per field for 1992 and 1993. The rate of increase between the number of species and the natural logarithm of the size of the field was consistent for all combinations of years, crops, and field types ($F = 0.90$; 17, 93 df; $P = 0.578$). Therefore, the regression lines were parallel and the differences in the years, crops, and field types were tested at the average value of the covariate. The 2-way and 3-way interactions were not significant ($P > 0.05$), making differences in the main effects interpretable. There was a differ-

Table 4. Nesting species on conventional, minimum-tillage, and organic fields in fallow, sunflower, and wheat in North Dakota, 1991–93.

Species	No. of nests	%
Mallard	2	1
Northern pintail	14	4
Blue-winged teal	2	1
Sharp-tailed grouse	3	1
Killdeer	44	12
Willet	5	1
Upland sandpiper	10	3
Marbled godwit	2	1
Wilson's phalarope	1	<1
Mourning dove	10	3
Horned lark	110	29
Vesper sparrow	93	25
Lark bunting	25	7
Savannah sparrow	4	1
Grasshopper sparrow	20	5
Chestnut-collared longspur	2	1
Red-winged blackbird	20	5
Western meadowlark	5	1
Brewer's blackbird	2	1
Totals	374	102

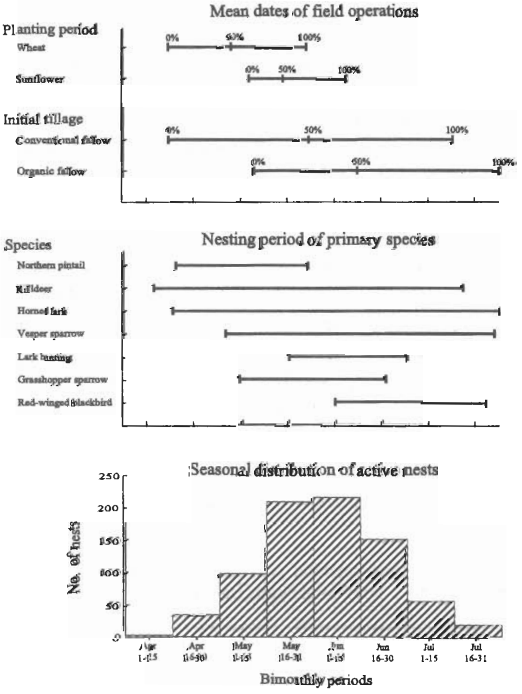

Fig. 1. Chronology of active nests and the length of the nesting period of the primary species compared to the normal planting period for wheat and sunflowers and the normal fallow tillage dates in southeastern North Dakota, 1991–93.

Table 5. A comparison of the number of nesting species per field on conventional, minimum-tillage, and organic fields in fallow, sunflower, and wheat in North Dakota, 1992–93.

	Mean no. of species/field[a]	SE
Field type		
Conventional	0.9BC	0.18
Minimum-tillage	1.9B	0.22
Organic	1.6C	0.18
Crop type		
Fallow	1.9A	0.23
Sunflower	1.2A	0.19
Wheat	1.3	0.17

[a] Numbers in the column followed by the same letter differ ($P \leq 0.05$)

Table 6. Density of nests/10 ha on conventional, minimum-tillage, and organic fields in fallow, sunflower, and wheat in southeast North Dakota, 1992–93.

	Nest density[a]	SE
Field type		
Conventional	0.5AB	0.02
Minimum-tillage	1.2A	0.03
Organic	1.0B	0.02
Crop type		
Fallow	1.5CD	0.04
Sunflower	0.5C	0.02
Wheat	0.6D	0.01

[a] Numbers in a column followed by the same letter differ ($P \leq 0.05$).

ence between years ($F = 4.07$; 1, 110 df; $P = 0.046$). The number of species in 1993 ($\bar{x} = 1.69$, SE = 0.168) was larger than the number of species in 1992 ($\bar{x} = 1.24$, SE = 0.150). There were differences ($F = 7.01$; 1, 110 df; $P = 0.001$) in the number of species among field types (Table 5). Minimum-tillage and organic fields had a wider variety of nesting species, including upland sandpipers (*Bartramia longicauda*), red-winged blackbirds, grasshopper sparrows (*Ammodramus savannarum*), and lark buntings (*Calamospiza melanocorys*) than conventional fields. Conventional fields were used mainly by the killdeer, horned lark, and vesper sparrow. There was no difference in the number of nesting species between minimum-tillage and organic fields.

There was a marginal difference ($F = 2.83$; 2, 110 df; $P = 0.063$) in the number of species per field among crops. Fallow fields had significantly more species than sunflower fields, but no differences were detected between fallow fields and wheat fields or between sunflower fields and wheat fields. Overall, 16 species nested in fallow fields compared to 12 for wheat fields, and 10 for sunflower fields.

Nest Densities

There were no significant 2-way and 3-way interactions between year, field type, and crop when comparing nest densities. Thus, differences in the years, crops, and field types could be interpreted. We did find significant differences in nest densities among field types ($F = 4.01$; 2, 134 df; $P = 0.02$) and among crops ($F = 3.07$; 2, 134 df; $P = 0.049$). Among field types, minimum-tillage and organic fields had significantly more nests than conventional fields (Table 6). There was no difference between minimum-tillage and organic fields. Fallow fields had more nests than sunflower fields and wheat fields, but there was no difference between sunflower and wheat fields.

Hatching Success and Fledging Success

We found no significant interactions for passerine nest loss between field type and crops ($\chi^2 = 3.91$, 4 df, $P = 0.419$). Also, there were no differences in DSR among field types ($\chi^2 = 2.26$, 2 df, $P = 0.324$) or crops ($\chi^2 = 2.50$, 2 df, $P = 0.287$; Table 7). For passerine nestling survival, we found no interaction between field type and crop ($\chi^2 = 4.44$, 4 df, $P = 0.349$). Also, there were no differences among the crops ($\chi^2 = 1.99$, 2 df, $P = 0.369$) or among the field types ($\chi^2 = 1.10$, 2 df, $P = 0.576$). Although hatching success of passerine nests was higher than that of shorebirds, nest success for passerine nests was low: 13% for conventional fields, 18% for minimum-tillage fields, 11% for organic fields, and 14% overall. For shorebird nests

Table 7. Percent hatching success of breeding waterfowl, shorebirds, and passerines on conventional, minimum-tillage, and organic fields in southeast North Dakota, 1991–93.

	Conventional		Minimum-till		Organic		Total	
	Success	95% CI	Success	95% CI	Success	95% CI	Success	95% CI
Waterfowl	0	0–100	0	0–39	0	0–14	0	0–5
Shorebirds	17	4–63	33	14–76	11	4–30	18	10–32
Passerines	29	16–51	31	21–45	21	15–30	25	20–32

there was no field type-crop interaction (χ^2 = 4.55, 4 df, P = 0.337), no differences among the crops (χ^2 = 2.58, 2 df, P = 0.275), or among field types (χ^2 = 2.81, 2 df, P = 0.245).

Passerine clutches that were unsuccessful (n = 173) were lost to predators (62%), farming activities (22%), abandonment (9%), and other (7%). Losses of shorebird nests (n = 47) were attributed to predators (47%), farming activities (41%), abandonment (9%), and other (3%). Unsuccessful waterfowl nests (n = 16) were destroyed by a combination of predators (50%), farming activities (44%), and abandonment (6%).

We also examined the DSR of passerine eggs when losses were due to factors other than predators, mainly farming activities and weather. There was no interaction between crop and field type (χ^2 = 3.31, 4 df, P = 0.508) and no differences among field types (χ^2 = 2.13, 2 df, P = 0.344). However, there were differences among the crops (χ^2 = 11.81, 2 df, P = 0.003). The DSR (0.985, SE = 0.004) for wheat fields was significantly larger than the DSR (0.962, SE = 0.008) for fallow fields (P = 0.014) and the DSR (0.939, SE = 0.017) for sunflower fields (P = 0.008). No differences were found between fallow fields and sunflower fields (P = 0.221).

For shorebird egg losses due to factors other than predators, there was no field type-crop interaction (χ^2 = 1.93, 4 df, P = 0.758) and no difference among crops (χ^2 = 3.50, 2 df, P = 0.174). However, there were differences among field types (χ^2 = 10.24, 2 df, P = 0.006). The DSR (0.9947, SE = 0.005) for minimum-tillage fields was significantly larger than the DSR (0.9516, SE = 0.014) for organic fields (P = 0.002). There was no difference between the DSR (0.9744, SE = 0.015) for conventional fields and minimum-tillage fields (P = 0.188) or between conventional fields and organic fields (P = 0.242).

Bird and Nest Density Associations with Vegetative Cover

Plant cover and litter cover were used to compare the relation between vegetation in the fields and bird populations and nest density. Plant height was not used because it was highly correlated with plant cover (r = 0.893), and visual obstruction values were not used because they were correlated with litter cover (r = 0.436).

In summer, no relation was found between percent plant cover and species of birds that prefer dense cover (r = −0.072, n = 151, P = 0.378) or species that prefer sparse cover (r = −0.061, n = 151, P = 0.456). Also, we found no significant correlations between litter cover and species that prefer sparse cover (r = 0.035, n = 151, P = 0.668) but there was a significant association between species that prefer dense cover and percent litter cover (r = 0.304, n = 151, P = 0.001).

There also were significant correlations between percent litter cover and the nesting densities of species that prefer dense cover (r = 0.231, n = 151, P = 0.004) and the nesting densities of species that prefer sparse cover (r = 0.162, n = 151, P = 0.047). However, the correlation coefficients (r) for the associations were small, suggesting that other factors affect this relation. There were no correlations between nest densities and plant cover ($P > 0.05$).

Plant cover did not differ among field types (F = 2.39; 2, 134 df; P = 0.095), but litter cover did vary (F = 7.55; 2, 134 df; P = 0.008). Minimum-tillage fields had a higher ($P < 0.001$) litter cover ($\bar{x}$ = 39.216, SE = 4.678) than conventional fields ($\bar{x}$ = 22.125, SE = 3.373) or organic fields ($\bar{x}$ = 20.732, SE = 2.918).

There were differences between crops for both plant cover and litter cover, but tests were made within years due to the year-crop interaction. In 1991, percent plant cover for wheat ($\bar{x}$ = 41.842, SE = 3.359) was significantly higher ($P < 0.001$) than sunflower ($\bar{x}$ = 16.777, SE = 5.539). In 1992, percent plant cover for wheat ($\bar{x}$ = 51.847, SE = 2.487) was higher ($P < 0.001$) than fallow ($\bar{x}$ = 26.181, SE = 2.867) and (P = 0.022) sunflower ($\bar{x}$ = 16.495, SE = 3.061).

In 1992, percent litter cover in fallow ($\bar{x}$ = 43.930, SE = 3.861) was higher ($P < 0.001$) than litter cover in sunflower ($\bar{x}$ = 24.024, SE = 4.121) and wheat ($\bar{x}$ = 12.614, SE = 3.348). In 1993, percent litter cover for fallow ($\bar{x}$ = 38.400, SE = 4.565) was marginally higher (P = 0.063) than wheat ($\bar{x}$ = 27.892, SE = 3.292), and percent litter cover for sunflower ($\bar{x}$ = 38.193, SE = 4.040) was significantly larger (P = 0.050) than wheat.

Tillage Treatments

The number of tillages averaged 1.1/year for minimum-tillage fields compared to 2.8/year for conventional fields and 4.0/year for organic fields. Overall, the fewest tillage treatments were applied to fallow fields (0.5/yr for minimum-tillage, 2.3/yr for conventional, and 3.6/yr for organic) and the most to sunflower fields (2.0/yr for minimum-tillage, 3.8/yr for conventional, and 5.4/yr for organic). The mean number of tillage treatments was not related to DSR ($r = -0.423$, $n = 9$, $P = 0.257$), but it was related to nest density ($r = -0.176$, $n = 129$, $P = 0.045$).

We found a negative correlation ($r = -0.292$, $n = 49$, $P = 0.041$) between tillage treatments and nest density for organic fields, but a non-significant correlation for conventional ($r = -0.022$, $n = 24$, $P = 0.889$) or minimum-tillage fields ($r = -0.179$, $n = 36$, $P = 0.296$). For crops there was a similar negative relation ($r = -0.319$, $n = 38$, $P = 0.050$) between tillage treatments and nest density for sunflowers. However, there was a non-significant relation between tillage treatments and nest density for fallow fields ($r = -0.127$, $n = 38$, $P = 0.446$) and wheat fields ($r = -0.101$, $n = 53$, $P = 0.472$).

DISCUSSION

Seasonal Use of Cropland

The weather of the northern plains in spring can be harsh, and bird numbers and species increased only moderately over winter populations. The principal birds present were horned larks and transient species migrating to northern breeding grounds.

Minimum-tillage fallow fields may have been more attractive to birds in spring because these fields were usually unplowed and provided enhanced resources in the form of food and cover. Organic and conventional fallow and wheat fields in general had reduced value to birds in spring because seeds and plant cover was reduced the previous fall by tillage.

In summer, a wide variety of species occurred in crop fields, including species nesting in fields and species nesting elsewhere but foraging in fields. Although we used different survey techniques, the 70 species and 6–23 birds/10 ha that we observed in cropland in summer were similar to the 73 species and 12 pairs/10 ha counted in CRP fields in the northern Great Plains (Johnson and Schwartz 1993). Bird densities we observed in cropland were only one-third the density counted in nearby CRP fields in a study using similar survey techniques (R. R. Koford, Natl. Biol. Serv., Ames, Ia, unpubl. data).

Birds were probably attracted to fallow fields in summer because the fields contained the best plant cover and the greatest plant variety, primarily from crop residue of the previous year plus new plant growth. Fallow fields in our study area were treated with tillage, mowing, and chemicals to reduce weed populations and store moisture and nutrients. However, fallow field alterations often were not initiated until late May or June, after the peak period for nesting. In contrast, wheat fields and sunflower fields usually had little plant residue in early summer when birds began nesting due to prior fall and spring tillage to control weeds and to prepare the ground for the new crop. In Texas, Flickinger and Pendleton (1994) noted greater bird species diversity in summer in fields with reduced tillage.

Populations were highest in the cropland in fall, bolstered mainly by migrant blackbirds feeding in sunflower fields. We could not determine field and crop preferences in fall because birds were concentrated in large flocks. A few species, such as horned larks, snow buntings, and upland game birds were present in winters when there was little snow. However, when snow accumulated in fields, small passerines departed and resident game birds either perished or moved to farm yards and wooded areas.

Nesting Aspects

Four of the 9 most numerous nesting species (killdeer, mourning dove, horned lark, and vesper sparrow) in cropland were responsible for 69% of all nests (Table 4). All of these 4 species are either abundant in North America or have increasing populations. These species are probably doing well because they are adapted to nesting on bare or nearly bare soil that is abundant in many crop fields. Another 3 of the 9 most numerous nesting species (northern pintail [*Anas acuta*], grasshopper sparrow, and lark bunting), initiating 16% of all nests, are breeding species of special concern to Midwestern managers due to declining populations (Peterjohn and Sauer 1993). These 3 species generally require moderate cover for nesting and are not attracted to bare crop fields. Nests of these 3 species occurred primarily in organic fallow, secondarily in minimum-tillage wheat stubble, and were nearly absent in other fields. The other 2 of the 9 most numerous nesting species (upland sandpiper and red-winged blackbird) were responsible for 8% of all nests. Upland sandpipers nested mainly in growing wheat when its growth form was similar to open grassland and red-winged blackbirds nested only in weeds in unsprayed organic wheat.

A density of about 8 nests/10 ha was found in CRP fields, in the same general area during the same period as our study (R. R. Koford, unpubl. data). This density is 6 times larger than minimum-tillage stubble and organic fallow in our study and 11 times larger than densities in the other field types and crops. In Iowa, Basore et al. (1986) found nest densities of 36 nests/10 ha in no-tillage crop fields and observed that adjacent grass strip cover had 6–100 times more nests than cropland. Other authors concluded that birds in cropland benefitted from permanent edge covers, and populations were higher at field perimeters (Rodenhouse and Best 1983, Best et al. 1990). Our bird population densities may have been low as we did not survey birds in field-borders, and our fields were large with a small ratio of edge/area. Also, drought conditions present during our study most likely reduced bird populations, particularly waterfowl and shorebirds.

Although alternative cropping practices provided more plant cover on cropland and enhanced breeding populations, hatching and fledging success was low and not different among field types or crops. Both eggs and young suffered high losses due primarily to predation, secondarily to farming activities, and lastly to other causes such as nest abandonment or weather. There is concern that more birds might be attracted to nest in fields with reduced tillage and enhanced cover, but many nests would be lost during delayed seeding and tillage operations (Best 1986). However, low success for passerine nests seems to be a common problem in a variety of study areas and an assortment of cover types in cropland habitats. In nearby CRP fields, the nest success rate of 18% (R. R. Koford, unpubl. data) was similar to the 14% we found in cropland. The 22% fledging success reported by Basore et al. (1986) for nests in cropland was similar to 17% fledging success for nests in adjacent grassy strips. If the nest success rates in grassland are really higher than cropland, the small difference would be important to overall population success.

By changing the frequency and timing of the tillage operations it may be possible to moderately enhance hatching success. When we examined hatching success without predator losses in the equation, nests were more successful in wheat and minimum-tillage fields where there were fewer tillage treatments. Hatching success might be improved in cropland if tillage operations can be delayed. In winter wheat in North Dakota, Duebbert (1987) found relatively "good" nest success of 26 and 29% for ducks. He indicated that nesting birds in winter wheat had adequate time to lay eggs and complete incubation without being disturbed by farming activities. Winter wheat probably provides better nesting cover for birds than spring wheat because winter wheat growth starts several weeks earlier.

Vegetative values of crop fields in spring are difficult to characterize accurately because plants are growing rapidly and are being altered by mechanical treatments. Generally, there was increased bird and nest densities in fields with increased cover, particularly litter cover. Other studies of wildlife in cropland found similar preferences for plant cover, particularly plant residue and inter-row cover (Warburton and Klimstra 1984, Castrale 1985). Work in Iowa found birds selecting nest sites in fields with more cover residue, but not necessarily increased cover height (Basore et al. 1986). Plant litter may be critical to birds in crop fields because litter provides cover, food for birds, and food for insects eaten by birds. Litter is continually diminished in crop fields by herbicides, cultivation, and harvest operations.

MANAGEMENT IMPLICATIONS

Minimum-tillage and organic fields in our study had a greater variety and density of birds than did conventional crop fields, particularly on fallow fields. Minimum-tillage and organic fields appeared to be more attractive to birds because more vegetation, particularly residual cover, was maintained on the land.

Although wildlife populations were higher on minimum-tillage and organic fields, success of eggs and young was low due to predation and mechanical activities. Reducing predation of eggs and young in crop fields would be difficult, but mechanical activities might be reduced in certain field types. The largest benefits for reducing nest loss would accrue on minimum-tillage wheat and organic fallow fields because they contained the highest nest densities.

In minimum-tillage fields, hatching success might be raised by limiting spring field activities. Minimum-tillage growers are attempting to farm without tillage, but some tillage was applied on most minimum-tillage fields during our study due to weed problems. Refinements in minimum-tillage practices could result in zero-tillage systems that could increase cover on cropland and success of nesting. On organic fallow fields, destruction of nests would be reduced by delaying tillage until late June or early July. Delayed tillage of organic fallow fields could occur if growers were able to use a legume that matured later in the growing season. Later-maturing legumes could be tilled or hayed later because soil water use is delayed and forage quality is extended. Several new late-maturing legume varieties are being developed by agricultural experiment stations (J. C. Gardner, N. D. State Univ., Carrington, pers. commun.). Field trials of later maturing legumes would be appropriate to assess the value of the practice to nesting birds and the use to farmers.

In addition to bird use in alternative farm types, we were interested in determining the effectiveness of alternative farming in reducing soil erosion and synthetic chemical use and in maintaining crop yields. Thus, we measured soil loss on each field and estimated grain yields and synthetic chemical use by querying farm cooperators (Lokemoen and Beiser 1995).

Both minimum-tillage and organic farmers were successful in achieving respective goals of zero soil erosion or zero synthetic chemical use. However, both groups also had associated limitations because of their altered farming practices. Organic farmers reduced their synthetic chemical use to zero, but thereby reduced their grain yields, probably due to increased weed populations. The reduction in grain yields by organic farmers was partly recovered because they receive premium prices for their product. Organic farmers used more tillage to reduce problem weed growth than did minimum-tillage or conventional farmers and this procedure negatively influenced nesting and increased soil erosion.

Minimum-tillage farmers were able to maintain good crop yields with reduced tillage, but they used more synthetic chemicals compared to organic and conventional farmers. Use of synthetic chemicals is of concern because some have toxic effects on prairie wildlife (Forsyth 1989). Compared to organic and conventional farmers, minimum-tillage growers had reduced soil losses from water erosion. There also was reduced water erosion on wheat fields compared to sunflower and fallow fields, but this was true for all farm types.

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