Bird Communities of Prairie Uplands and Wetlands in Relation to Farming Practices in Saskatchewan

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Abstract: *Modern farm practices can vary in their emphasis on tillage versus chemicals to control weeds, and researchers know little about which emphasis has greater ecological benefits. We compared avifaunas of uplands and wetlands in four treatments: conventional farms, conservation farms (contrasting those that minimized frequency of tillage [minimum tillage] with those that eliminated chemical inputs [organic]), and restored or natural (wild) sites in Saskatchewan, Canada. Of 37 different upland bird species encountered during surveys, one made greater use of farms, four made greater use of wild sites, and the remaining species showed no preference. When all upland species were combined, higher relative abundance occurred on wild than on farm sites, and on minimum tillage than on conventional farms. Wild upland sites also had more species than did conventional farms. Of 79 different species encountered during surveys of wetlands and their margins, most had similar encounter probabilities among treatments, although seven were more common on either organic farms or wild sites. Higher relative abundances were documented in wetland habitat of wild sites and organic farms than of minimum tillage or conventional farms. Wetlands of wild sites had more species than did minimum tillage or conventional farms. Overall, in terms of both avifaunal density and diversity, small treatment effects could be ascribed to differences between conventional and conservation farms, whereas larger effects were due to differences between farms and wild sites. Wetlands were heavily used by birds in all treatments, suggesting high conservation priority regardless of context.*

Comunidades de Aves de Praderas de Altiplano y Humedales en Relación con Prácticas de Labranza en Saskatchewan, Canadá

Resumen: *Las prácticas modernas de labranza pueden variar en su énfasis en el arado contrario al uso de químicos para controlar malezas. Los investigadores conocemos poco acerca de cuál de los énfasis tiene beneficios ecológicos mayores. Nosotros comparamos las avifaunas de altiplanos y de humedales en cuatro tratamientos: granjas convencionales, granjas de conservación (contrastando aquéllas que minimizaron la frecuencia del arado [arado mínimo] contra aquéllas que eliminaron el uso de químicos [orgánicas]), y sitios restaurados o naturales (silvestres) en Saskatchewan, Canadá. De las 37 especies de aves encontradas durante los reconocimientos, una mostró un uso mayor de las granjas, cuatro mostraron un mayor uso de los sitios silvestres y las especies restantes no mostraron preferencias. Cuando se combinaron todas las especies del altiplano, la abundancia relativa de los sitios silvestres fue más alta que la de las granjas y en los sitios de arado mínimo que en las granjas convencionales. Los sitios silvestres del altiplano tuvieron también más especies que las granjas convencionales. De 79 especies diferentes halladas durante los reconocimientos en los humedales y sus márgenes, la mayoría tuvo una probabilidad similar de ser hallada entre los tratamientos, sin embargo siete fueron más comunes en las granjas orgánicas o en los sitios silvestres. Las abundancias relativas documentadas fueron más altas en hábitats de humedales de sitios silvestres y granjas orgánicas que en los sitios de arado mínimo o las granjas convencionales. Los humedales de sitios silvestres tuvieron más especies que las granjas de arado mínimo o las granjas convencionales. En general, en términos de densidad y diversidad de avifauna, los efectos pequeños del tratamiento pueden ser*

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adjudicados a diferencias entre granjas convencionales y de conservación, mientras que los efectos mayores se debieron a diferencias entre granjas y sitios silvestres. Los humedales fueron altamente utilizados por aves en todos los tratamientos, lo que sugiere una alta prioridad de conservación independientemente del contexto.

Introduction

North American prairie is virtually gone, and ongoing anthropogenic perturbations continue to diminish the abundance of many of its wildlife species (Kantrud 1981; Bock & Bock 1988; McNicholl 1988; Samson & Knopf 1994). Although maintenance and restoration of native prairie are justifiable and necessary conservation strategies, farmlands also have conservation potential. Because of the large land area devoted to farms, practices that enhance habitat on farms could have significant benefits for wildlife (Milonski 1958; Elliott & Cole 1989; Jackson & Piper 1989; Paul & Robertson 1989; Rodenhouse et al. 1995; Folke et al. 1996; Vandermeer & Perfecto 1997). Farming practices are influenced by legislation, economics, and attitudes about their ecological effects (Altieri 1987; Turner et al. 1987; Goldstein 1988; Johnson & Schwartz 1993; Freemark 1995). Data on the ecological effects of farming practices are crucial to inform future legislation and current views on the most ecologically beneficial approaches (Burke et al. 1995; Freemark & Boutin 1995; Rodenhouse et al. 1995). We investigated the effects of different modern agricultural practices on bird communities.

Avifaunal declines have been reported for many nongrassland species (Wilcove 1985; Robbins et al. 1989; Robinson & Wilcove 1994), but globally, avifauna of grasslands have been declining more rapidly as modern agriculture has intensified (Beintema & Muskens 1987; Goriup 1988; Askins 1993; Warner 1994; Herkert 1995). Concerns about so-called "conventional" farming and its reliance on agrochemicals and its tendency to promote soil erosion have motivated conservation farming, which includes "organic" and "minimum tillage" farming. Modern organic farming arose because agrochemicals are expensive and because they have detrimental effects on nontarget organisms (Rands 1985; Martin et al. 1991; McLaughlin & Mineau 1995; Howe et al. 1996; Boutin et al. 1999), but organic farmers suffer from increased weed incursions because they do not use herbicides. Thus, they can either tolerate higher weed densities or compensate with more frequent tillage, the latter leading to increased soil erosion. Concerns about erosion and loss of soil fertility have motivated reduced tillage and direct seeding into the previous year's crop stubble; we refer collectively to these practices as minimum tillage. Although minimum tillage turns the soil fewer times than in other farming practices, it also allows weeds more time to proliferate. Hence, minimum tillage farmers tend to use more herbicides than other farmers. In controlling weeds, therefore, conservation farming can face a tradeoff between herbicide use and erosion (Wooley et al. 1985).

Previous studies have found that conservation farms support richer avifaunas than do conventional farms (reviewed in Rodenhouse et al. 1995; Kirk et al. 1996), but few studies have compared the avifaunas of organic and minimum tillage farms. One of these few studies (Lokemoen & Beiser 1997) found that minimum tillage tends to support higher density and diversity in uplands than does organic farming. To further test how avifauna respond to the tradeoff between erosion and herbicide use, we surveyed bird communities on both uplands and wetlands of conventional, minimum tillage, and organic farms (farm treatments) and of wild areas in Saskatchewan. Based on previous research, we expected that wild areas would have richer avifaunas than farms and that conservation farms would have a richer avifauna than conventional farms. There were too few published data to provide expectations regarding the avifauna of organic versus minimum tillage farms or of wetlands among these treatments.

Methods

Study Area

Our study area occupied the dark soils region of Saskatchewan (Richards & Fung 1969; Fig. 1); over 90% of this area is devoted to crop farming. To put our study area in context, of 26.6 million ha of land devoted to agriculture in Saskatchewan in 1996, 54% was occupied by crops, 17% was in summer fallow, 5% was in tame or seeded pasture, 19% was in natural pasture, and the remaining 5% was in other land uses. Of cropland, 45% is farmed conventionally, 55% is subject to direct seeding or minimum tillage, and <1% is farmed organically (Statistics Canada 1997).

Our choice of study area was determined by studies initiated by Agriculture and Agricultural Foods Canada (AAFC) to investigate the effects of conservation farming on crop production, soils, and water and by the availability of organic farmers willing to cooperate in our study. We selected farms from the AAFC studies that were no further than 200 km from Saskatoon; our total study area encompassed over 60,000 km^2 (Fig. 1). Organic farms are uncommon, so to minimize geographic bias we located sites for the three other treatments (conventional and mini-

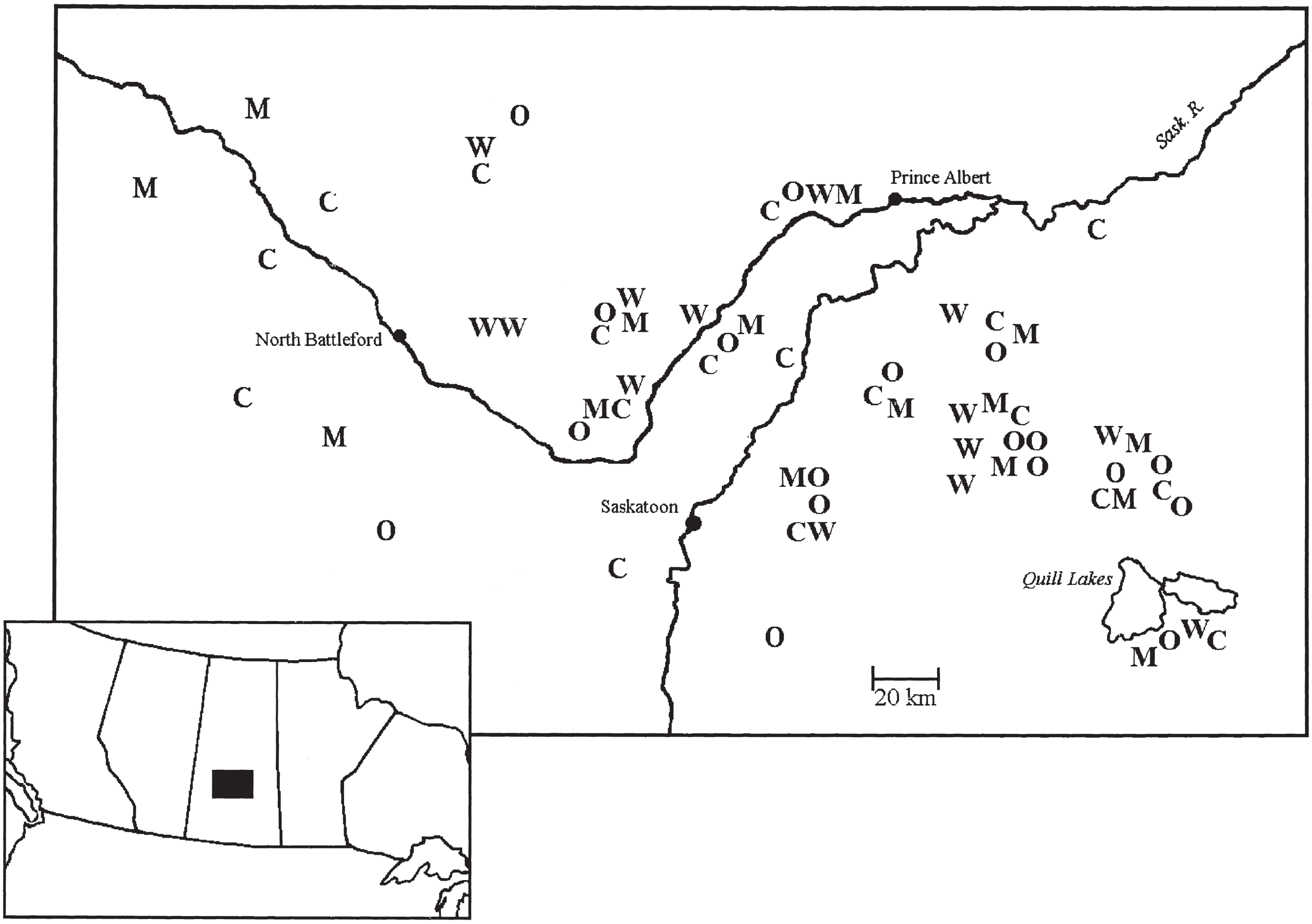

Figure 1. Study sites used in surveys of bird communities on uplands and wetlands in Saskatchewan, Canada. Letters indicate location of landscape treatments: C, conventional; M, minimum tillage; O, organic; W, wild.

mum tillage farms and wild sites) within 25 km of organic farms (we call groups of four treatments clusters). We conducted ground surveys to find ecologically homogeneous sites for bird surveys. In some cases, suitable sites for some treatments were not found in some clusters; in other clusters, multiple sites were selected. Nonetheless, the experimental design was approximately balanced (Table 1), with minimal geographic bias (Fig. 1).

The organic farms we selected were government-certified as not having used agrochemicals for at least 4 years.

Table 1. Number of plots surveyed for birds in Saskatchewan, Canada, by landscape treatment.*

Treatment	*Uplands*	*Wetlands*
Conventional farm	21 (2)	17 (1)
Minimum tillage farm	20 (3)	17 (4)
Organic farm	21	19 (2)
Wild site	14 (5)	17 (8)
Total	76 (10)	70 (15)

**See Fig. 1. for locations. Numbers in parentheses denote the number of cases where plots were surveyed for birds less than four times.*

Preliminary studies by AAFC found overlap in tillage frequency between farmers that called their practices minimum tillage or conventional. On farms that were tilled less than three times per year, however, there was usually stubble on the fields in spring, and this definition was associated with visibly distinct differences in soil properties. Hence, we defined minimum tillage farms as those for which farmers stated that they regularly tilled their soil less than three times per year and conventional farmers as those that tilled three or more times per year. Wild sites were mostly lands that Ducks Unlimited or governments (federal or provincial) had purchased or leased to take out of crop production. These lands were sometimes seeded to provide nesting cover for ducks or hay, but they were not tilled and they had no or lower chemical inputs than did conventional or minimum tillage farms.

Bird Surveys

We used a fixed-radius, point-count method (Hutto et al. 1986) to survey birds. In the first year of the study, upland sites were chosen in the middle of cereal fields (usually wheat) that were large enough to contain bird survey plots. Survey plots were circles with radii of 100 m and were our upland experimental units. Where possible, we tried to allow an additional 100 m of cereal outside the circle to serve as a buffer zone from other habitats. Also, in the first year of the study, we chose wetland sites that were the drainage sites for a cereal field that had no direct link to basins outside the cereal field. On smaller wetlands, plots consisted of the entire wetland, including noncrop margins. On large wetlands, plots were semicircular with a fixed radius of 100 m and included noncrop margins within that radius. We controlled for variation in wetland size in analyses. Birds flying over plots were considered outside survey areas, except in the case of swallows flying <2 m above wetlands. Swallows were often seen feeding on insects that probably originated from wetlands (Hussell & Quinney 1987).

We conducted surveys between 12 June and 19 July 1996 and between 2 June and 4 July 1997, when it was not windy or raining, beginning just after sunrise at 0430 hours and ending by 0930 hours. For uplands, all birds seen or heard during 5 minutes were recorded, providing that they were on the crop within the plot. For wetlands, all birds occupying the wetland or the noncrop margin were recorded, and an extra 5 minutes was spent with a playback tape to get responses from Pied-billed Grebes (bird common names follow American Ornithologists' Union [1983]; species names appear in Tables 2 and 3), American Bitterns (*Botaurus lentiginosus*), Virginia Rails (*Rallus limicola*, which were never heard), and Soras.

Most plots were surveyed two times each in 1996 and 1997 (Table 1), but some were visited less than four times because permission to visit a plot was withdrawn or was granted after some surveys had been completed. Treatments within a cluster were surveyed on the same day, except when weather or temporal constraints intervened (10 of 48 times). To reduce time-of-day bias, the order of plot visits was reversed between first and second surveys. For over 80% of surveys, the same observer (three observers in 1996, two in 1997) was not used twice on the same plot within a year.

Ecological Covariates

Apart from differences in tillage and chemical usage among treatments, additional ecological variables in farmlands could influence avifauna. Hence, a series of covariates was characterized during ground visits between late July and early August 1996. Except where noted, covariates were measured both on the ground and from digitized measures of air photos (Easydij Digitiser, Version 6.1). Most (75%) of the upland sites on conventional and minimum tillage farms were seeded entirely to wheat, whereas this was the case on only 41% of organic farms (mixed crops are more common on organic farms). By definition, wild sites had various native or planted vegetation, or less often hay, as substitutes for cereal. Because we detected no effect of crop type on birds, we do not discuss this further.

Because it was not always possible to find survey plots with 100 m–wide buffer zones, we recorded whether buffer zones contained wetlands (wetland in buffer) or trees and hedgerows (wooded habitat in buffer). Birds could spill in from adjacent habitats onto crops. Therefore, on quartersections (a section is 1 square mile or 2.6 km^2) on which survey plots were located, we counted the number of wetlands (number of wetlands nearby) and measured the area of wetland basins plus their noncrop margins (area of wetlands nearby) and area of woody vegetation (area woody nearby).

Wetland plots met minimum criteria if the wetland was at least 0.5 m deep in June 1996 and occupied a basin of <10 ha. Within these limits, each of the former variables was quantified as a covariate. "Late July depth" was measured by walking out into wetlands. Depths of >1 m (measured with a meter stick) were scored as 1.5 m on 12 basins (18%) because 1 m was the limit of chest waders. "Area of basin + margin" included the noncrop area around the wetland. Because there were no clear distinctions between upland and crop on wild plots, margins were arbitrarily defined as 10 m wide. "Area of basin" included open water, wet meadow, and emergent vegetation. "Area of water" was area of open water estimated on the ground in July. "Percent margin woody" was area occupied by trees and shrubs. Finally, "complexity" was a subjective score that rated wetlands according to the variety of habitats they offered (Appendix). With practice, complexity was highly repeatable among observers on randomly selected wetlands (A. M., unpublished data).

Analyses

We analyzed upland and wetland bird data separately with SAS Institute (1990). To determine factors influencing individual species' use of plots, we used general linear models (PROC GLM) with the proportion of times a species was encountered on a plot as a response variable, treatment as the variable of interest, and the appropriate (upland or wetland) covariates. The least significant covariate was removed iteratively to produce final models that contained treatment and significant covariates only (Alisauskas & Ankney 1994). To assess the proportion of variation explained by treatment in GLMs, we divided their type III mean squares by the total mean squares in final models and multiplied this by the model R^2 (Hatcher & Stepnaski 1994).

At the level of bird community, relative abundance was the number of birds per survey, and number of species was based on cumulative bird communities from four surveys. Shannon diversity (Pielou 1969) showed trends similar to those for number of species, so we included only the latter. Because new species are added even after hundreds of surveys (K. Hobson, E. Bayne, and D. S., unpublished data), we could not predict precisely the number of species that would be recorded for a given plot. Hence, for species number analyses, we used only plots that had been surveyed four times (Table 1). We compared relative abundance and number of species separately among treatments in the same way as for individual species.

Results

Because of limits to statistical power, we tested for species-specific treatment effects, providing that a species was detected on ≥3% of 280 upland surveys (8 of 37 species; Table 2). On uplands, Horned Larks were more numerous on farms, whereas Sedge Wrens and Le Conte's, Savannah, and Clay-colored Sparrows were more numerous on wild sites (Tukey tests; Table 2). Either because of small samples or because of genuine random distributions, treatment effects were not detected for the remaining three species. Number of wetlands nearby and area of wetlands nearby negatively influenced four species, and area woody nearby affected three species either positively or negatively (Table 2).

On uplands, relative abundance was higher on wild than on farm treatments and higher on minimum tillage than on conventional farms (Fig. 2; $F = 18.1, p < 0.001$). Treatment accounted for 61% of explained variation in relative abundance; the remainder was accounted for by positive effects of wetlands in buffer ($F = 6.2, p = 0.02$) and of area woody nearby ($F = 5.3, p = 0.02$). More species were found on wild than on conventional treatments, and treatment accounted for 35% of explained variation in the number of species (Fig. 2; $F = 3.1, p = 0.03$); remaining variation was explained by the positive effects of wetlands in buffer ($F = 5.7, p = 0.02$).

Using the same criterion described above for uplands, we tested for species-specific treatment effects on 39 of 79 different species detected during 245 surveys of wetlands and their margins (Table 3). Relative abundance was higher for Blue-winged Teal, Tree Swallows, and Yellow-headed Blackbirds on wild than on farm sites; higher for Black-billed Magpies on organic than on other treatments; higher for American Robins on organic than on minimum tillage or wild treatments and on conventional than on wild treatments; higher for Le Conte's Sparrows on organic than on conventional or minimum tillage treatments; higher for Vesper Sparrows on minimum tillage and organic than on wild treatments; and higher for Song Sparrows on farms than on wild sites (Tukey tests; Table 3). Either because of small samples or because of genuine random distributions, treatment effects were not detected for the remaining 32 species (Table 3). Size and depth of the wetland had both significant negative and positive effects on 20 different species, and percent margin woody and complexity had (usually positive) effects on 31 different species (Table 3).

On wetlands and their margins, wild and organic treatments had higher relative abundance than did minimum tillage or conventional farms (Fig. 3; $F = 3.6, p = 0.02$, 6% of explained variation). Higher relative abundance was observed with larger area of basin ($F = 4.1, p = 0.05$), greater percent margin woody ($F = 13.3, p = 0.001$), and greater complexity ($F = 34.7, p < 0.001$). Wild sites had more species than did conventional or minimum tillage farms (Fig. 3; $F = 3.0, p = 0.04$, 9% of explained variation). More species were detected on sites with larger area of basin ($F = 6.8, p = 0.01$) and greater complexity ($F = 23.0, p < 0.001$).

Discussion

Land use clearly affected avifauna. In general, wild sites had the most individuals and the highest diversity. Among farm uplands, minimum tillage had more individuals and

Table 2. Percentage of surveys by landscape treatment where upland bird species were present (including only those species detected in ≥3% of surveys) on plots in Saskatchewan, Canada, and magnitude of the influence of ecological covariates and treatments on species presence.

	Surveys present (%)[a]				*Significance of variables in final model*[b]			
Species	*conv*	*min till*	*org*	*wild*	*no. wetlands nearby*	*area of wetlands nearby*	*area woody nearby*	*treatment*
Killdeer, *Charadrius vociferus*	3	4	4	2				
Horned Lark, *Eremophila alpestris*	29	37	40	2	<0.05−		<0.01−	<0.01
Sedge Wren, *Cistothorus platensis*			1	17				<0.001
Le Conte's Sparrow, *Ammodramus leconteii*			2	15				<0.001
Vesper Sparrow, *Pooecetes gramineus*	5	7	4	9	<0.05−			
Savannah Sparrow, *Passerculus sandwichensis*	46	54	42	75			<0.05−	<0.01
Song Sparrow, *Melospiza melodia*	4		2	11		<0.01−	<0.01+	
Clay-colored Sparrow, *Spizella pallida*	1	1	2	19	<0.05−			<0.001

[a] *Conv, min till, org, and wild denote conventional, minimum tillage, organic, and wild plots, respectively.*
[b] *Signs indicate whether effects of ecological covariates on a species were negative or positive.*

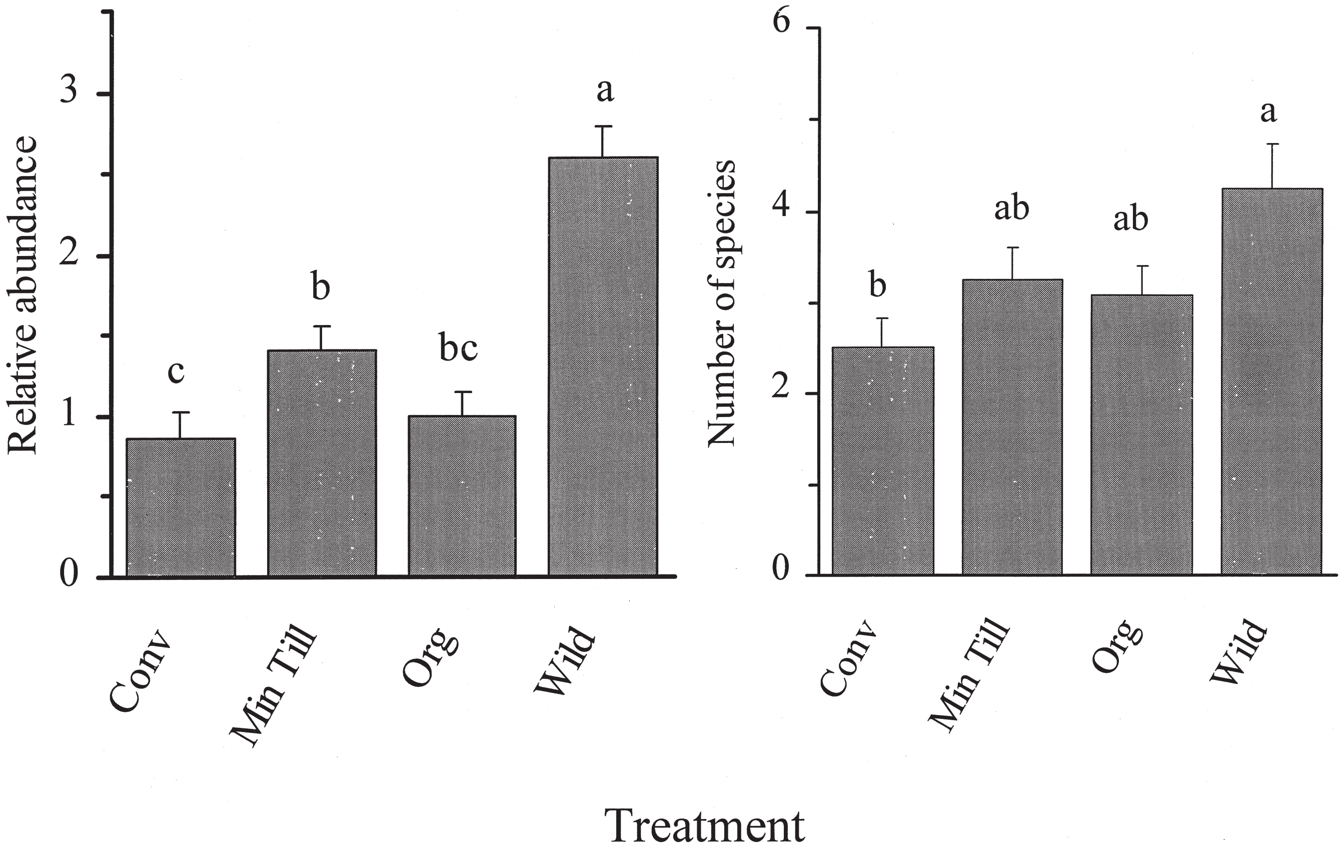

Figure 2. Comparison relative to landscape treatment (Conv, conventional farms; Min till, minimum tillage farms; Org, organic farms; Wild, wild plots) of upland bird communities in Saskatchewan, Canada. Bars are least-square means (±SE, controlling for covariates described in text) of relative abundance (average number of individuals per survey) and the cumulative number of species recorded from four surveys. Bars sharing the same letters are not significantly different (Tukey-Kramer tests).

species than did organic or conventional farms. Among farm wetlands and their margins, organic had higher relative abundance than did minimum tillage or conventional farms. In addition, noncrop habitats were important. Upland birds were more numerous and diverse where wetlands were nearby, and wetland birds were similarly influenced by diversity in habitat types (also see Rodenhouse et al. 1995; Jobin et al. 1996; Freemark & Csizy 1997).

As was the case here, other studies have also found that wildlife makes greater use of uplands of minimum tillage than conventional farms, for both feeding and nesting (Higgins 1977; Cowan 1982; Warburton & Klimstra 1984; Castrale 1985; Basore et al. 1986; Lokemoen & Beiser 1997). Higher use has been ascribed to cover provided by stubble and to richer food resources resulting from decomposition of stubble (Edwards & Lofty 1982; Blumberg & Crossley 1983; Gregory & Musick 1976; Reganold et al. 1987; but see Basore et al. 1987; Rodenhouse & Best 1994). Nonetheless, habitat use is not necessarily indicative of habitat quality or breeding activity (Wiens & Rotenberry 1981; Van Horne 1983; Pulliam 1988; Best et al. 1995). For example, minimum tillage may provide attractive nest cover, but nests are often destroyed once agricultural equipment moves through (Rodenhouse & Best 1983; Best 1986; Baines 1990; Bollinger et al. 1990); equivalent or higher nest success has been found in minimum tillage (Cowan 1982; Lokemoen & Beiser 1997). In any case, a better indication of habitat quality is breeding success. We are not aware of any studies of the effects of minimum tillage on wetlands; our results indicate that minimum tillage wetlands had similar avifaunas to those of conventional farms.

Organic farms on uplands had slightly more individuals and species of birds than did conventional farms (also see Rogers & Freemark 1991), and wetlands of organic farms had more abundant and richer avifaunas than both conventional and minimum tillage farms. Within farm uplands, differences in bird communities between organic and conventional farms may arise because many organic farmers plant hedgerows to mitigate erosion. These can create corridors for dispersal and provide habitat for species that normally would not be found in fields (Wegner & Merriam 1979; Fahrig & Merriam 1985; Best et al. 1990; Haas 1995). Hedgerows, however, are subject to edge effects that can

Table 3. Percentage of surveys by landscape treatment where bird species were present (including only those species detected in ≥3% of surveys) on wetlands and their margins in Saskatchewan, Canada, and magnitude of the influence of ecological covariates and treatments on species presence.

	Surveys present (%)[a]				*Significance of variables in final model*[b]						
Species	*conv*	*min till*	*org*	*wild*	*area basin + margin*	*area of basin*	*area of water*	*late July depth*	*margin woody (%)*	*complexity*	*treatment*
Horned Grebe, *Podiceps auritus*	13	9	14	24				<0.05+			
Pied-billed Grebe, *Podilymbus podiceps*	9	7	5	15	<0.001+					<0.01+	
Mallard, *Anas platyrhynchos*	31	31	28	23				<0.05+			
Gadwall, *Anas strepera*	12	17	12	23						<0.001+	
Green-winged Teal, *Anas crecca*	8	15	18	21	<0.05+					<0.01+	
American Wigeon, *Anas americana*	5	5	4	17						<0.01+	
Northern Pintail, *Anas acuta*	5	7	4	2							
Northern Shoveler, *Anas clypeata*	16	15	16	34							
Blue-winged Teal, *Anas discors*	34	46	38	70					<0.05-	<0.01+	<0.01
Ruddy Duck, *Oxyura jamaicensis*	19	9	10	32						<0.05+	
Redhead, *Aythya americana*	10	5	8	13		<0.01+	<0.001-	<0.001+		<0.05+	
Lesser Scaup, *Aythya affinis*	13	3	5	15							
Sora, *Porzana carolina*	60	56	49	49	<0.01+	<0.05+	<0.05-				
American Soot, *Fulicula americana*	57	37	47	55				<0.05+	<0.01-	<0.001+	
Killdeer, *Charadrius vociferus*	6	5	1								
Black Tern, *Chlidonias niger*	8	2	8	6					<0.05-		
Eastern Kingbird, *Tyrannus tyrannus*	18	10	12	26					<0.01+		
Least Flycatcher, *Empidonax minimus*	22	17	30	40	<0.05-				<0.001+	<0.01+	
Alder Flycatcher, *Empidonax alnorum*	6	2	10	6			<0.001+	<0.05-			
Tree Swallow, *Tachycineta bicolor*	3	9		28				<0.05+			<0.001
Barn Swallow, *Hirundo rustica*	25	10	12	9					<0.05-	<0.05+	
Black-billed Magpie, *Pica pica*	2	5	15						<0.001+		
American Crow, *Corvus brachyrhynchos*	5	2	5	8					<0.01+		
House Wren, *Troglodytes aedon*	9	5	14	17					<0.001+		
American Robin, *Turdus migratorius*	12	3	15	2	<0.01-	<0.05+			<0.001+		<0.01
Gray Catbird, *Dumetella carolinensis*	12	10	8	13						<0.05+	
Warbling Vireo, *Vireo gilvus*	15	5	19	23					<0.05+	<0.05+	
Yellow Warbler, *Dendroica petechia*	37	39	49	53					<0.001+	+ <0.05	
Common Yellowthroat, *Geothlypis trichas*	2		7	9							
Le Conte's Sparrow, *Ammodramus leconteii*	2		10	6							<0.05
Vesper Sparrow, *Pooecetes gramineus*	9	7	16	4					<0.05+		
Savannah Sparrow, *Passerculus sandwichensis*	28	42	31	30			<0.05+	<0.05-	<0.05-	<0.05-	
Song Sparrow, *Melospiza melodia*	48	49	55	36	<0.05-				<0.01+	<0.05+	<0.05
Clay-colored Sparrow, *Spizella pallida*	45	44	62	59							
Red-winged Blackbird, *Aegelaius phoeniceus*	72	71	58	76				<0.01+			
Yellow-headed Blackbird, *X. xanthocephalus*	12	10	8	28				<0.01+			<0.01
Northern Oriole, *Icterus galbula*	6	3	7	8					<0.001+		
Brown-headed Cowbird, *Molothrus ater*	18	31	22	17			<0.05-		<0.001+		
American Goldfinch, *Carduelis tristis*	3	12	14	15							

[a] *Conv, min till, org, and wild denote conventional, minimum tillage, organic, and wild plots, respectively.*
[b] *Signs indicate whether effects of ecological covariates on a species were negative or positive.*

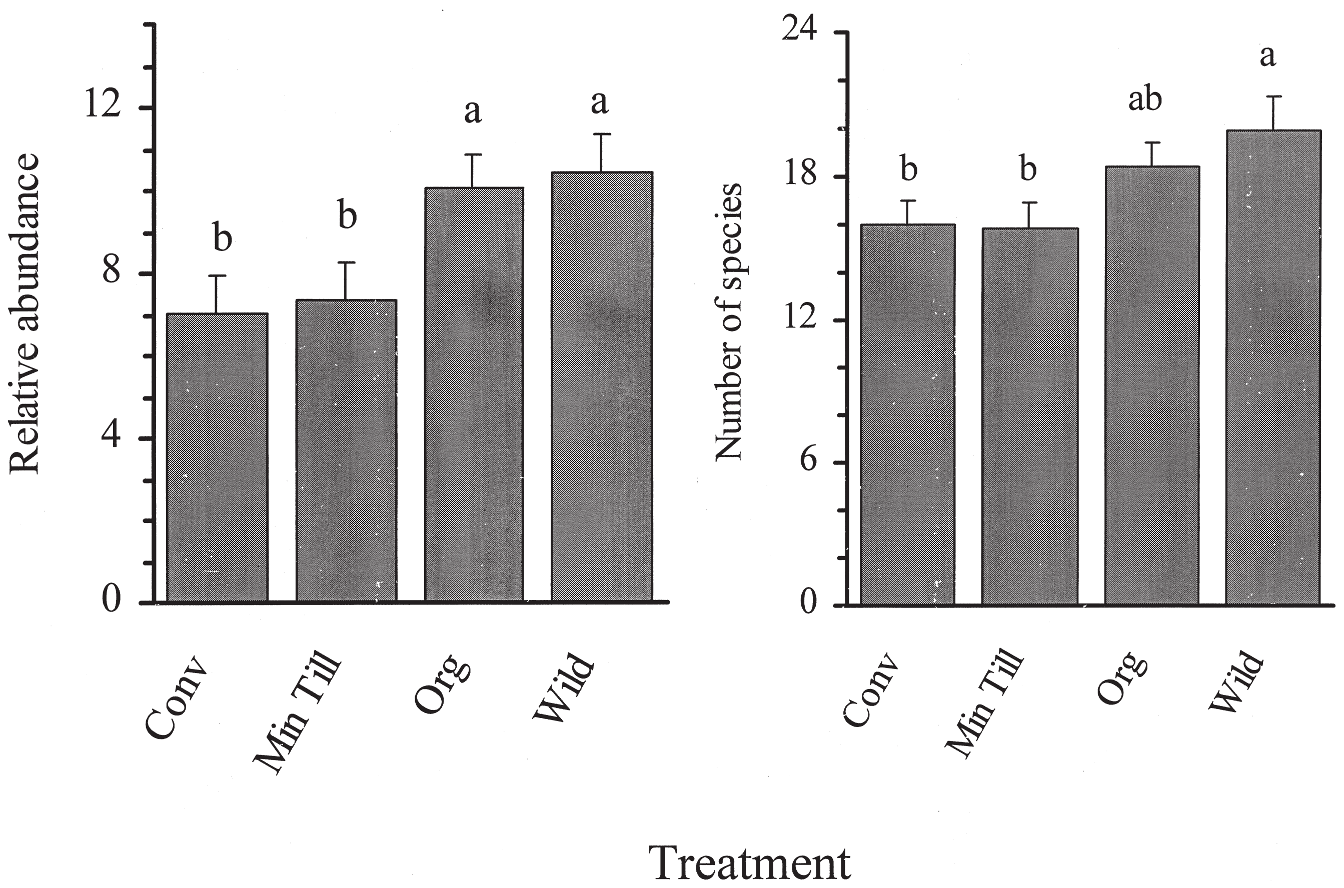

Figure 3. Comparison relative to landscape treatment (Conv, conventional farms; Min till, minimum tillage farms; Org, organic farms; Wild, wild plots) of bird communities of wetlands and their margins in Saskatchewan. Bars are least-square means (±SE, controlling for covariates described in text) of relative abundance (average number of individuals per survey) and the cumulative number of species recorded from four surveys. Bars sharing the same letters are not significantly different (Tukey-Kramer tests).

increase the risk of brood parasitism by Brown-headed Cowbirds or of predation (Rodenhouse & Best 1983). Another potential advantage of organic farms may be abrogation of chemical use, which leads to healthier invertebrate faunas (Madsen & Madsen 1982; Drinkwater et al. 1995; Freemark & Boutin 1995). Some of the latter benefits may be lost because of soil erosion or because wind causes some agrochemical drift from adjoining farms (e.g., Marrs et al. 1989). Nonetheless, our organic farms had higher relative abundance and more species-rich avifaunas than did conventional farms. This result requires further investigation, particularly with respect to potential chemical explanations.

Sedge Wrens and Savannah, Le Conte's, and Clay-colored Sparrows were more abundant on wild than on farm uplands, likely because these species nest in taller vegetation than is found on croplands during the nesting season. In contrast, Horned Larks were more abundant on farm than wild uplands, which is not surprising given this species' preference for short vegetation and bare soil (Godfrey 1986). At the community level, wild uplands and wetlands had higher relative abundance and diversity than did farms. These results, and the presence of species not found on farms, should encourage agencies that set aside wildlife areas. Also, because prairie bird species are more specialized than is generally appreciated (Askins 1993), not all can survive on agricultural lands. Hence, even conservation farming will be an insufficient strategy to retain healthy populations of some species (Rodenhouse et al. 1995), so acquisition and restoration of native habitats remains a critical conservation strategy.

Uplands had higher relative abundance and diversity if wetlands were nearby, and a similar effect of habitat complexity was observed on wetland avifauna (also see Arnold 1983; Best et al. 1995; Rodenhouse et al. 1995; Jobin et al. 1996; Freemark & Csizy 1997). This provides an ecological rationale for encouraging farmers to retain wetlands and a variety of habitats around them. The argument to maintain a variety of habitats needs to be weighed against the objective of restoring natural habitat.

We found some evidence that conservation farms were beneficial to prairie birds. Birds may make use of fields on several different farm types (reviewed by Kirk et al. 1996), however, so the scale of our study needs to be considered (Kotliar & Wiens 1990). Unfortunately, the agricultural landscape is a patchwork in continual flux, and treatments seldom occupy tracts of land sufficiently large to be independent of one another, at least for the way that birds make use of this habitat (Rodenhouse et al. 1995). Thus, although bird populations may be influenced by specific farming practices, it can be difficult to identify the magnitude of influences attributable to specific practices. To address this problem, one option is to find large, contiguous sections of land that are managed in the same way. Another is to incorporate surrounding land-use types in the analysis, which would necessitate substantially more data than we had to control for the enormous variation this would introduce. Despite these constraints, given the significant potential, it would be unwise to ignore the possible ecological benefits of conservation farming.

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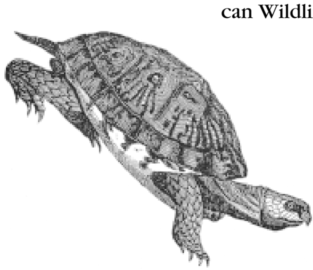

Appendix

Scoring guidelines for habitat "complexity" on wetlands in Saskatchewan, Canada.

Score	*Interpretation*
10	Subdivided basins with irregular shoreline that may or may not share water but are joined by natural vegetation and are only a short distance apart. Total area of basins is large, with emergent vegetation, willows, and trees all present in roughly equal amounts.
7.5	One or more subdivided basins with or without irregular shoreline. Emergents, willows, and trees all present.
5	One undivided basin, elongated or round, medium-sized. Emergents, willows, and trees all present.
2.5	One undivided basin, elongated or round, small to medium-sized. Some vegetation types missing or in short supply.
0	One undivided basin, round, small. Margin consists only of a thin strip of grass or crops.