Grassland bird habitat selection in Northwest Illinois

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Introduction

The regional and national population declines of grassland birds have attracted much attention. The primary cause of these declines is habitat loss mainly as a result of agricultural intensification. The Conservation Reserve Program (CRP), intended to take marginal land out of crop production, and a growing interest in prairie restoration has led to an expansion of grassland habitats in some areas. This study was designed to examine grassland bird use of various grassland habitats in northwestern Illinois in order to develop management recommendations to benefit grassland birds.

Most previous studies indicate that vegetation structure is far more important than species composition of the plant community for grassland birds (Herkert et al. 1993). This idea is certainly true when different plant species have the same growth form or when different management practices produce different vegetation structure from the same plant species. On the other hand, a common expectation in ecology is that diversity begets diversity. In other words, areas with differing plant species composition should also have different bird communities and, possibly, areas with greater plant diversity will support a greater diversity of birds. While several studies have examined grassland bird communities in native and non-native grasslands (Sutter and Brigham 1998, Davis and Duncan 1999, Washburn et al. 2000, Ludwig et al. 2001), none have examined the influence of plant species diversity on grassland bird diversity in detail.

The underlying expectation is that because grassland birds in central North America existed in prairie vegetation for at least 8,000 years, prairies, and by analogy prairie restorations, should provide optimal habitat for them. On the other hand, non-native cool season grasses have dominated grassland habitats east of the Mississippi river for the past 300 years after European settlers replaced forest with pastures, hayfields, and other agricultural lands. In this study we examined the relationship between grassland bird diversity and abundance and plant diversity and vegetation structure across a variety of grasslands in Jo Daviess and Carroll counties, Illinois. Because the structure of the landscape is also known to affect grassland bird habitat selection (Helzer and Jelinski 1999, Winter and Faaborg 1999, Haire et al. 2000, Soderstrom and Part 2000, Coppedge et al. 2001), we also incorporated landscape parameters that may confound effects of diversity and structure.

Study Sites

Grassland sites were located in Jo Daviess and Carroll Counties, Illinois. Virtually all of the 33 sites were within the Wisconsin Driftless region that has never been glaciated. Some characteristics of the study sites are listed in Table 1. We specifically selected sites that had not been burned in the previous year because of known effects of recent burning on grassland bird occurrence (Herkert 1994, Swengel 1996, Johnson 1997, Madden et al. 1999). Similarly, we avoided any grassland area with active grazing (Renken and Dinsmore 1987, Belanger and Picard 1999, Renfrew and Ribic 2001).

Methods

Bird surveys – Birds were counted at 32 variable-distance point counts. Points were located to maximize the area of grassland within 100-m radius and to include as few trees as possible. At each point all birds seen or heard were counted for 5 minutes. Birds seen only in flight were not counted. All counts were conducted between 5:00 AM and 10:30 AM local time. Three counts were conducted at each point: one in each of three time periods: May 25-June5, June 6 – June 20, and June 21-July 1. Each species was classified in terms of reliance on grassland habitat as either obligate grassland (OG), secondary grassland (G2), or non-grassland (NG) species as defined for this region (Herkert et al. 1993, Sample and Mossman 1997).

Vegetation measurements –Vegetation structure was measured at four points within a 100m-radius circle centered on the bird-count point. Each of the four points was placed by randomly selecting a compass direction and distance from the center of the circle. At each of these four points, structure was measured using a modified Robel pole method (Robel et al. 1970). Each Robel measurement is a combination of vegetation height and density obtained by recording two values from 1 m above ground and 4 m away from the pole. The first value recorded is the highest 10-cm interval in which more than 80% of the interval is obstructed by vegetation ("obstructed"). This value indicates the height of the most dense part of the vegetation. The second value recorded is the highest 10-cm interval in which any vegetation occurs ("highest"). This value indicates the maximum height of the vegetation. Robel measurements were made at four evenly spaced locations around each point (approximately in cardinal directions). Vegetation structure values reported for each site therefore are the mean or coefficient of variation (CV = standard deviation/mean) of 16 measurements (4 locations x 4 points). Leaf litter depth was measured at the same points as the Robel readings, so that litter depth values are also from 16 measurements. Vegetation composition was measured at all sites by visually estimating the percent of canopy area covered by each species of plant in ten 0.5 x 1 m plots. These plots were spaced at 20 m intervals along two randomly located, 100m-long transects within the 100m-radius circle centered at the bird-count point. Bare ground and litter cover were also estimated so that the total cover of each plot was at least 100%. In addition, any species occurring within 0.5 m of the transect lines were recorded in order to compile a more complete species list for each site.

Vegetation measurements were done three times during the 2002 growing season: late May-early June; mid July; and mid August. Vegetation variables reported here reflect the average over the entire growing season. Average cover of individual species, bare ground, and litter, and average height and litter depth were calculated from the three values. Vegetation data were summarized into the following parameters for each site: highest plant height, obstructed height, litter depth; total plant cover, bare ground cover, litter cover; total plant species richness (from transect species list over entire season), Shannon diversity index (H'), Shannon evenness index (E, as an inverse indicator of dominance); ratio of warm-season to cool-season graminoid cover, where graminoids include grasses, sedges, and rushes; and, ratio of graminoid to forb cover. Except for total plant species richness, both the mean and the CV of all vegetation parameters were calculated for each site. Standard formulae for the diversity and evenness indices were used (Magurran 1988).

Statistical analyses - Data were analyzed with the Systat 8.0 statistical package(SPSS 1998). Abundance (#birds/pt), richness (#spp/pt), diversity (H') and vegetation measurements were compared among grassland habitat types with analysis of variance tests (ANOVA). Points where no birds of a particular species were recorded within 100-m were listed as 0 in the data sets for abundance. Any significant ANOVA was followed by Tukey pairwise comparisons. Note that with only 5-6 replicates of each habitat type, power to detect differences among the habitats was relatively low. Although we used a significance level of 0.05 we mention tests that were close ($0.05 < P < 0.1$) because of the small sample sizes. These cases are referred to as marginally significant.

Bird-habitat associations were examined with backwards-stepwise linear regression. Terms were removed from the model one at a time until only significant variables remained. Site area, warm to cool season ratio, and graminoid to forb ratio were log-transformed for analyses in order to better fit the assumptions of ANOVA.

We also used principle components analysis (PCA) to assess the relationships of the plant diversity, vegetation structure, and landscape variables simultaneously. PCA uses all the independent variables and constructs new ones, each of which is a different combination of the independent variables. These new variables, called principle components or factors, can be used to depict the data. PCA gives the amount of variation in the data that is explained by each component as well as which independent variables are most important for each component. Because the data used in PCA are those collected at each study site, PCA generates for each site a component score for each of the principle components. These values can be used for a multivariate comparison of the study sites. We did PCA twice; first with a set of vegetation, diversity, and landscape variables and secondly with only vegetation and diversity variables. We also used PCA with bird abundances as variables.

Results

Study sites – The five grassland habitats differed for several of the landscape and vegetation variables (Figure 1, Table 2). Prairies tended to be larger than the other habitats and were significantly larger than restorations ($P = 0.047$). Similarly, restorations had higher perimeter/area ratios than prairies ($P = 0.039$) but none of the other habitats differed. Prairies also had a non-significant trend ($P = 0.08$) to have more grassland habitat within 1 km radius than other habitats (particularly oldfields; $P = 0.09$ and restorations; $P = 0.1$). The amount of grassland within 5 km radius did not differ among the sites.

Comparisons among the plant composition variables are illustrated in Figure 2 and analyses summarized in Table 2. Prairies ($P = 0.033$) and restorations ($P = 0.02$) had higher

Shannon diversity than cool season fields but the other habitats did not differ in diversity. Prairies also showed a non-significant trend for higher species richness than cool season plantings (P = 0.08). Cool season fields tended to have lower evenness than the other habitats but the trend was not significant. Cool season fields had a significantly higher percentage of introduced species than prairies (P < 0.001), restorations (P = 0.004), and warm season plantings (P = 0.021) but did not differ from old fields (P = 0.69). Oldfields had higher percentage of introduced species than prairie (P = 0.012) but none of the other pairwise comparisons differed significantly. Not surprisingly, the warm/cool ratio differed among habitats and was lower in cool season plantings than in warm season plantings (P = 0.009), or restorations (P = 0.017).

Prairies had lower Robel values than restorations (P = 0.027) but none of the other pairwise comparisons among the habitats differed for Robel values (Figure 3, Table 2). Prairies had shorter vegetation than cool season plantings (P = 0.008). Maximum height did not differ significantly among the other habitats but was marginally taller in restorations than in prairies (P = 0.09). None of the other vegetation structure variables differed among the habitats.

Bird surveys – 27 grassland bird species were encountered during the point counts (Table 3). Red-winged blackbird was by far the most common species, occurring at 25 of 33 sites with an average of over 2.5 individuals per site. Song sparrow and common yellowthroat occurred at 21 and 25 sites, respectively, but with much lower abundance than red-winged blackbirds. Bobolink, eastern meadowlark, American goldfinch, and field sparrow occurred at 10 or more sites. Upland sandpiper, vesper sparrow, lark sparrow, and orchard oriole each occurred at only one site. Grassland species not observed during this study but known to occur in the area include horned lark, northern harrier, short-eared owl, common nighthawk, and killdeer. Considering the ten most abundant species in each habitat type it is clear that obligate grassland species occur in all habitats but that red-winged blackbird is the most or second-most abundant bird in all habitats (Table 4). Restorations and prairies supported different bird communities with restorations dominated by secondary or nongrassland species (Table 4).

Species richness, species diversity (H'), or species evenness in each category of birds (OG, G2, NG, Total) did not differ significantly among the habitat types (Figures 4-6, Table 5) except total evenness was higher in restorations than in cool season fields (P = 0.037). Eastern meadowlark abundance differed significantly among the habitats (Table 5) with trends for higher abundance in prairie than in oldfields (P = 0.054) or restorations (P = 0.06). Similarly, grasshopper sparrow abundance differed among the habitats (Table 5) with trends for higher abundance in prairie than in cool season plantings (P = 0.064) or restorations (P = 0.054). Among secondary grassland species, mourning dove tended to be more common (P = 0.07) and song sparrows tended to be less common (P = 0.06) in prairie than oldfields.

Bird-Habitat Relationships – Total species richness of birds was significantly correlated with species richness of plants (F = 4.44, P = 0.043). This relationship, however, was mainly a result of more secondary and non-grassland bird species at sites with higher plant species richness (Figure7, Table 6). The relationship between bird and plant diversity was similar when Shannon diversity indices were used (Figure 8), but the relationship was not significant (Table 6). Multiple regression analyses showed that plant species richness and site area were the most frequently significant predictors of bird richness and diversity (Table 6). Obligate grassland bird species richness and diversity were negatively related to plant species richness. In contrast, secondary grassland bird species richness and diversity tended to be positively related to plant species richness. Obligate grassland bird abundance and diversity were positively related to site area, while the reverse was true for secondary grassland species (Table 6).

The habitat variables important in predicting abundance of individual bird species varied greatly among the species. No two species had the same regression model (Table 7). Shannon diversity of plants and warm/cool ratio were the only variables not included in any models. The most common significant predictors included plant species richness and evenness, Robel (visual obstruction), maximum vegetation height, site area, and amount of grassland within 5 km (Table 7).

Principle Components Analyses - For the PCA including vegetation structure, plant diversity and landscape variables, the first three components explained 70% of the variation (Table 8). The first component was largely a combination of landscape and structural variables on one side of the axis and plant diversity variables on the other end (Table 8). The second component had high loadings for landscape and plant diversity variables on both ends of the axis. The third component was mostly landscape and structural variables. Graphical representation of this analysis shows a tendency for the cool season sites to cluster together but wide scatter among the other habitats (Figure 9). This analysis suggests an overriding importance of the landscape variables in explaining the variation among the study sites.

A second PCA including 4 structure and 4 diversity variables had over 75% of the variation explained by the first two components (Table 9). The first component had a combination of structure and diversity variables on both ends of the axis. The second component had high loadings of structure and diversity variables on one end of the axis and diversity variable on the other end (Table 9). The third component was relatively unimportant (Figure 10). The cool season sites tend to cluster together (with one exception) while restorations and warm season sites tended to cluster with prairie sites (Figure 11). Old field sites were evenly divided among these two groups (Figure 11).

PCA using bird abundance as variables had about 50% of the variation explained by the first three components (Table 10). The first two axes showed a tendency for species found in short grass areas to fall on one end and species typical of taller vegetation on the other (Table 10). Graphically most of the sites clustered together with the exception of a group of four sand prairies and one warm season planting adjacent to the sand prairies (Figure 12).

Discussion

The five grassland habitats clearly differed with respect to landscape, plant composition, and vegetation structure variables. Similarly, a mix of the landscape, composition and structure variables were useful in predicting bird abundance. Unfortunately the composition variables that differed most among the habitats (H', % of introduced species, warm/cool ratio) were relatively unimportant in predicting grassland bird abundances. Similarly, the clustering of sites based on plant-derived variables was different from that based on bird-derived variables (Figures 11 and 12), suggesting that bird and plant communities at these sites are structured in different ways.

This dilemma is partially explained by the importance of site area and autocorrelations among some of the composition and structure variables with area. The largest sites were sand prairie remnants, while the smallest sites tended to be the prairie restorations. Prairies and restorations had higher species richness than the other three habitats. Thus, any influence of species richness would be moderated by the effects of site area. Similarly, because most of the prairie sites were sand prairies but few of the other sites were on sand, differences in vegetation structure among habitats may be a result of the soil type more so than plant community. Similarly, sand prairies tended to have a different set of birds than the other sites (Figure 12, Table 4).

The importance of grassland area is known from previous studies. Several of the birds in our study are known to be area-sensitive (more likely to occur on larger sites) and most of our sites are at or below the suggested area requirements of 40 ha. Upland sandpiper, bobolink, Henslow's, grasshopper, and savannah sparrows, eastern and western meadowlarks, and sedge wren are all considered highly or moderately area-sensitive and all are obligate grassland species. In contrast, no secondary grassland species is considered dependent on large grasslands.

Thus, the main conclusion of this study is that large grasslands will likely benefit declining grassland birds regardless of the plant species composition. Consequently, the small size of prairie restorations in this part of the state seems to limit their ability to attract significant numbers of obligate grassland birds despite the development of similar plant composition and vegetation structure to prairie sites. A second conclusion is that because most prairie remnants are on sand and most restorations are not, restorations are likely to support different bird communities than sand prairies regardless of area.

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References

Belanger, L., and M. Picard. 1999. Cattle grazing and avian communities of the St. Lawrence River Islands. Journal of Range Management **52**:332-338.

Coppedge, B. R., D. M. Engle, R. E. Masters, and M. S. Gregory. 2001. Avian response to landscape change in fragmented southern Great Plains grasslands. Ecological Applications **11**:47-59.

Davis, S. K., and D. C. Duncan. 1999. Grassland songbird occurrence in native and crested wheatgrass pastures of southern Saskatchewan. Studies in Avian Biology **19**:211-218.

Haire, S. L., C. E. Bock, B. S. Cade, and B. C. Bennett. 2000. The role of landscape and habitat characteristics in limiting abundance of grassland nesting songbirds in an urban open space. Landscape and Urban Planning **48**:65-82.

Helzer, C. J., and D. E. Jelinski. 1999. Relative importance of patch area and perimeter-area ratio to grassland breeding birds. Ecological Applications **9**:1448-1458.

Herkert, J. R. 1994. Breeding bird communities of midwestern prairie fragments the effects of prescribed burning and habitat area. Natural Areas Journal **14**:128-135.

Herkert, J. R., R. E. Szafoni, V. Kleen, M., and J. E. Schwegman. 1993. Habitat establishment enhancement and management for forest and grassland birds in Illinois. Natural Heritage Technical Publication 1, Illinois Department of Natural Resources, Springfield, IL.

Johnson, D. H. 1997. Effects of fire on bird populations in mixed-grass prairie. Pages 181-206 *in* F. L. Knopf and F. B. Samson, editors. Ecology and conservation of Great Plains vertebrates. Springer-Verlag, New York.

Ludwig, D. R., S. N. Kobal, J. Suchecki, and R. A. Reklau. 2001. Grassland bird use and vegetative characteristics of planted cool season and warm season fields in northeastern Illinois. Pages 42-54 *in* Proceedings of 12th Northern Illinois Prairie Workshop. Forest Preserve District of DuPage County, College of DuPage, Illinois.

Madden, E. M., A. J. Hansen, and R. K. Murphy. 1999. Influence of prescribed fire history on habitat and abundance of passerine birds in northern mixed-grass prairie. Canadian Field-Naturalist **113**:627-640.

Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, NJ.

Renfrew, R. B., and C. A. Ribic. 2001. Grassland birds associated with agricultural riparian practices in southwestern Wisconsin. Journal of Range Management **54**:546-552.

Renken, R., B., and J. Dinsmore, J. 1987. Nongame bird communities on managed grasslands in North Dakota. Canadian Field-Naturalist **101**:551-557.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual and obstruction measurements and weight of grassland vegetation. Journal of Range Management **23**:295-297.

Sample, D. W., and M. J. Mossman. 1997. Managing habitat for grassland birds: A guide for Wisconsin. Wisconsin Department of Natural Resources, Madison, WI.

Soderstrom, B., and T. Part. 2000. Influence of landscape scale on farmland birds breeding in semi-natural pastures. Conservation Biology **14**:522-533.

SPSS. 1998. SYSTAT 8.0 Statistics. SPSS, Inc., Chicago.

Sutter, G. C., and R. M. Brigham. 1998. Avifaunal and habitat changes resulting from conversion of native prairie to crested wheat grass: patterns at songbird community and species levels. Canadian Journal of Zoology **76**:869-875.

Swengel, S. R. 1996. Management responses of three species of declining sparrows in tallgrass prairie. Bird Conservation International **6**:241-353.

Washburn, B. E., T. G. Barnes, and J. D. Sole. 2000. Improving northern bobwhite habitat by converting tall fescue fields to native warm-season grasses. Wildlife Society Bulletin 2000 **28**:97-104.

Winter, M., and J. Faaborg. 1999. Patterns of area sensitivity in grassland-nesting birds. Conservation Biology **13**:1424-1436.

Table 1. Study sites

Site #	Site Name	Type	Age (years)	Previous Use	Area (ha)
1	Rachuy Mountain Prairie	prairie	13	row crop	7
2	Rachuy Christmas Prairie	restoration	8	row crop	4
3	Rachuy Lyle's Mound	old field	26	pasture	5
4	Downing Bluebird Prairie	restoration	6	row crop	2
5	TPE Elmoville Prairie	prairie	N.A.	never plowed	1
6	Winter	cool season	20	row crop	12
7	Burns	old field	N.A.	never plowed	16
8	Burns	warm season	9	row crop	8
9	IDNR Schapville Savanna	old field	8	pasture	4
10	IDNR AMCO East	old field	3	row crop	4
11	IDNR AMCO West	old field	4	row crop	5
12	IDNR Thompson Prairie	restoration	2	row crop	8
13	Rutherford Twin Bridges	old field	25	pasture	2
14	Storch	cool season	5	row crop	21
15	Storch	cool season	5	row crop	21
16	Harmet	restoration	6	row crop	8
17	GTA Vincent Farm West	cool season	15	row crop	27
18	GTA Vincent Farm East	cool season	15	row crop	6
19	IDNR Beatty Hollow Prairie	restoration	9	row crop	5
20	IDNR Witkowsky Prairie	restoration	8	row crop	2
21	Schwerdtfeger	cool season	23	row crop	26
22	Schwerdtfeger	warm season	7	row crop	7
23	Schwerdtfeger	warm season	9	row crop	3
24	Loberg	old field	4	pasture	15
25	FWS Lost Mound B	prairie	2	pasture	121
26	FWS Lost Mound F	old field	2	pasture	77
27	FWS Lost Mound E	prairie	2	pasture	695
28	Camp Creek South	cool season	N.A.	N.A.	10
29	Camp Creek North	cool season	N.A.	N.A.	21
30	IDNR Thompson-Fulton NP	prairie	N.A.	never plowed	31
31	IDNR Ayers NP	prairie	>20	never plowed	48
32	FWS Thomson 5	prairie	N.A.	never plowed	41
33	FWS Thomson 8	warm season	21	row crop	24

Table 2. Summary of ANOVA tests of landscape and plant variables among the 5 grassland habitats (cool season, warm season, restorations, prairie remnants, and oldfields). Statistically significant P-values are shown in bold.

Variable	F-ratio	P
Landscape		
Area (log-ha)	2.615	0.056
Shape (perimeter/area)	2.774	**0.046**
Grassland within 5 k radius	0.163	0.956
Plant diversity		
Species richness	2.663	0.053
H'	3.584	**0.018**
Evenness	2.297	0.084
% Introduced species	8.229	**0.000**
Graminoid/forb ratio	0.750	0.567
Warm/cool ratio	4.831	**0.004**
Vegetation Structure		
Bare ground	0.470	0.757
Litter depth	1.898	0.139
Total plant cover	1.310	0.290
Robel (visual obstruction)	3.064	**0.033**
Max. height	3.617	**0.017**

Table 3. Distribution (number of sites observed), relative abundance (average #birds within 100m radius) and standard deviation of relative abundance of grassland birds observed during the point counts. Species codes used in other tables are also listed.

Species code	Common Name	Sites	Relative abundance	Standard deviation
Obligate grassland species				
BOBO	Bobolink	10	0.26	0.53
DICK	Dickcissel	9	0.12	0.42
EAME	Eastern Meadowlark	17	0.30	0.54
GRSP	Grasshopper Sparrow	9	0.77	1.51
HESP	Henslow's Sparrow	5	0.10	0.29
SAVS	Savannah Sparrow	2	0.05	0.21
SEWR	Sedge Wren	15	0.38	0.62
UPSA	Upland Sandpiper	1	0.00	0.00
VESP	Vesper Sparrow	1	0.01	0.06
WEME	Western Meadwolark	3	0.06	0.29
Secondary grassland species				
AMGO	American Goldfinch	10	0.16	0.29
BHCO	Brown-headed Cowbird	9	0.15	0.40
COGR	Common Grackle	3	0.21	1.10
COYE	Common Yellowthroat	25	0.72	0.76
EABL	Eastern Bluebird	3	0.02	0.08
EAKI	Eastern Kingbird	8	0.12	0.34
FISP	Field Sparrow	18	0.24	0.42
LASP	Lark Sparrow	1	0.01	0.06
MODO	Mourning Dove	8	0.09	0.25
NOBO	Northern Bobwhite	6	0.06	0.21
OROR	Orchard Oriole	1	0.01	0.06
RHWO	Red-headed Woodpecker	2	0.04	0.18
RNPH	Ring-necked Pheasant	4	0.03	0.13
RTHA	Red-tailed Hawk	2	0.03	0.17
RWBL	Red-winged Blackbird	25	2.68	3.15
SOSP	Song Sparrow	21	0.54	0.71
WIFL	Willow Flycatcher	1	0.02	0.12

Table 4. The 10 most common bird species in each habitat type. Obligate grassland species shown in bold. Values are the summed abundance within each habitat.

Cool		Oldfield		Warm		Restoration		Prairie	
RWBL	36.3	RWBL	28.0	RWBL	7.7	COYE	6.3	**GRSP**	**15.3**
COYE	7.0	SOSP	8.3	COYE	4.3	RWBL	5.3	RWBL	11.0
SEWR	5.0	COGR	6.3	**SEWR**	3.7	SOSP	4.3	**EAME**	**5.3**
EAME	2.7	**GRSP**	4.7	**GRSP**	3.7	BHCO	3.3	FISP	3.0
HESP	2.7	COYE	4.3	SOSP	2.3	FISP	2.7	**DICK**	2.3
BOBO	2.3	**BOBO**	2.7	**BOBO**	2.0	AMGO	1.7	AMGO	2.3
SOSP	2.0	**SEWR**	2.3	**EAME**	1.7	**BOBO**	1.7	MODO	2.3
GRSP	1.7	**DICK**	1.7	MODO	0.3	**SEWR**	1.3	EAKI	2.0
FISP	1.3	AMGO	1.3			NOBO	1.0	**WEME**	1.7
RHWO	1.0	FISP	1.0			**SAVS**	1.0	COYE	1.7

Table 5. Summary of ANOVA tests of bird variables among the 5 grassland habitats (cool season, warm season, restorations, prairie remnants, and oldfields).

Variable	F-ratio	P
OG species richness	0.705	0.595
OG H'	0.743	0.571
OG Evenness	1.503	0.228
G2 species richness	1.106	0.373
G2 H'	1.326	0.285
G2 Evenness	1.989	0.124
NG species richness	0.592	0.671
NG H'	0.473	0.755
NG Evenness	0.716	0.588
Total species richness	0.785	0.545
H' total	1.067	0.391
Total Evenness	2.376	0.076
Obligate grassland species (OG)		
Bobolink	0.655	0.628
Dickcissel	0.919	0.467
Eastern Meadowlark	2.806	**0.045**
Grasshopper Sparrow	2.747	**0.048**
Henslow's Sparrow	2.041	0.116
Sedge Wren	1.902	0.138
Secondary grassland species (G2)		
American Goldfinch	2.010	0.120
Brown-headed Cowbird	2.010	0.120
Common Yellowthroat	1.531	0.220
Eastern Kingbird	0.549	0.701
Field Sparrow	1.298	0.295
Mourning Dove	2.528	0.063
Northern Bobwhite	1.058	0.396
Red-winged Blackbird	1.746	0.168
Song Sparrow	2.557	0.061

Table 6. Summary of multiple regression analyses for grassland bird categories. Each column lists the P values for variables in the final model of backwards stepwise regressions. A minus sign before the P value indicates a negative correlation between the variable and abundance of that species.

	Species Richness			Relative Abundance			Shannon Diversity (H')			Shannon Evenness		
Variable	**OG**	**G2**	**Total**	**OG**	**G2**	**Total**	**OG**	**G2**	**Total**	**OG**	**G2**	**Total**
Landscape												
Area (log)		-0.000	-0.002	0.000			-0.002	-0.000	-0.001	-0.004	-0.000	-0.001
Shape	-0.000		-0.003						-0.001			
Grassland w/in 5K			0.006						0.017	-0.035	0.004	
Composition												
Species richness	-0.034		0.042	-0.007			-0.032	0.029	0.003	-0.018	0.008	0.001
H'												
Evenness						-0.001						
% Introduced Spp					-0.017				0.043			
Warm/Cool (log)											0.048	
Gram/forb (log)												
Structure												
Bare Ground			0.017						0.032			
Litter Depth		-0.004	-0.009					-0.048	-0.005			-0.007
Plant cover			0.004						0.037		-0.017	
Robel									0.029			
Max Height				-0.007	0.003				-0.038			
Woody stems												

Table 7. Summary of multiple regression analyses for grassland species that occurred at 5 or more sites. Each column lists the P values for variables in the final model of backwards stepwise regressions. A minus sign before the P value indicates a negative correlation between the variable and abundance of that species.

	Obligate Grassland Species						**Secondary Grassland Species**							
Variable	BOBO	DICK	EAME	GRSP	HESP	SEWR	AMGO	COYE	EAKI	FISP	MODO	NOBO	RWBL	SOSP
Landscape														
Area		0.000	0.002	0.000										-0.010
Shape		0.006												
Grassland within 5K			-0.018				-0.004					-0.042		
Composition														
Species richness	-0.022			-0.000						0.002				
H’														
Evenness					-0.003			-0.022					-0.023	
% Introduced Spp				-0.003										
Warm/Cool ratio														
Graminoid/forb						0.018		-0.036						
Structure														
Bare Ground									0.000					
Litter Depth							-0.002			-0.006				
Plant cover										0.012				
Robel							0.039	0.003			-0.024			
Max Height				-0.000		0.002							0.000	
Woody stems									-0.054					

Table 8. Results of Principle Component Analysis including plant diversity, vegetation structure, and landscape variables. The columns list the importance of each independent variable for the four principle components. A higher absolute value indicates higher importance. The last row lists the amount of variation in the data explained by each principle component.

Variable	**1**	**2**	**3**	**4**
Bare Ground	-0.233	-0.371	-0.614	-0.139
Species Richness	-0.688	-0.144	0.217	-0.096
Plant Diversity	-0.683	-0.551	0.218	0.299
Max. Height	0.762	-0.138	0.548	0.024
Robel	0.654	-0.361	0.587	-0.132
Litter Depth	0.579	0.328	0.534	0.226
% Introduced Spp.	0.624	0.516	0.121	0.125
Shape	0.362	-0.756	0.125	-0.294
Log Area	-0.584	0.689	0.053	0.150
Grass w/in 5 K	-0.416	0.366	0.607	-0.218
% Cool spp.	0.430	0.753	-0.330	-0.253
% Gramminoid	0.421	0.726	-0.359	-0.239
Forest w/in 5K	-0.176	0.265	0.740	-0.016
Urban w/in 5K	0.268	0.087	-0.224	0.811
# Buildings	0.834	-0.317	-0.246	0.017
Roads (K)	0.638	-0.385	-0.164	0.068
% of Variance	30.872	22.410	17.040	7.145

Table 9. Results of Principle Component Analysis including plant diversity and vegetation structure variables. Columns as in Table 8.

Variable	**1**	**2**	**3**	**4**
Bare Ground	-0.513	-0.379	-0.698	0.108
Robel	0.509	0.719	-0.397	-0.182
Max. Height	0.704	0.596	-0.333	0.074
Litter Depth	0.742	0.465	0.263	-0.098
Diversity	-0.825	0.463	0.186	0.140
Evenness	-0.592	0.687	0.145	0.106
% Cool spp.	0.803	-0.146	0.059	0.571
% Gramminoid	0.628	-0.668	0.120	-0.177
% of Variance	45.460	29.813	11.239	5.597

Table 10. Results of Principle Component Analysis including bird abundance variables. Columns as in Table 8.

Variable	**1**	**2**	**3**	**4**
AMGO	0.393	0.662	-0.216	-0.080
BHCO	0.039	0.434	0.379	0.366
BOBO	-0.391	-0.066	0.042	0.783
COYE	-0.609	0.241	-0.145	-0.117
DICK	0.385	-0.429	0.077	0.370
EAKI	0.492	0.360	-0.628	0.156
EAME	0.278	-0.654	0.206	-0.324
FISP	0.279	0.337	0.383	-0.105
GRSP	0.729	-0.591	0.068	0.054
HESP	-0.389	-0.230	-0.436	-0.266
MODO	0.585	0.063	-0.715	0.106
RWBL	-0.599	-0.205	-0.283	0.310
SEWR	-0.605	-0.293	-0.272	-0.186
SOSP	-0.112	0.674	0.191	-0.190
% of Variance	21.337	18.084	12.123	9.256

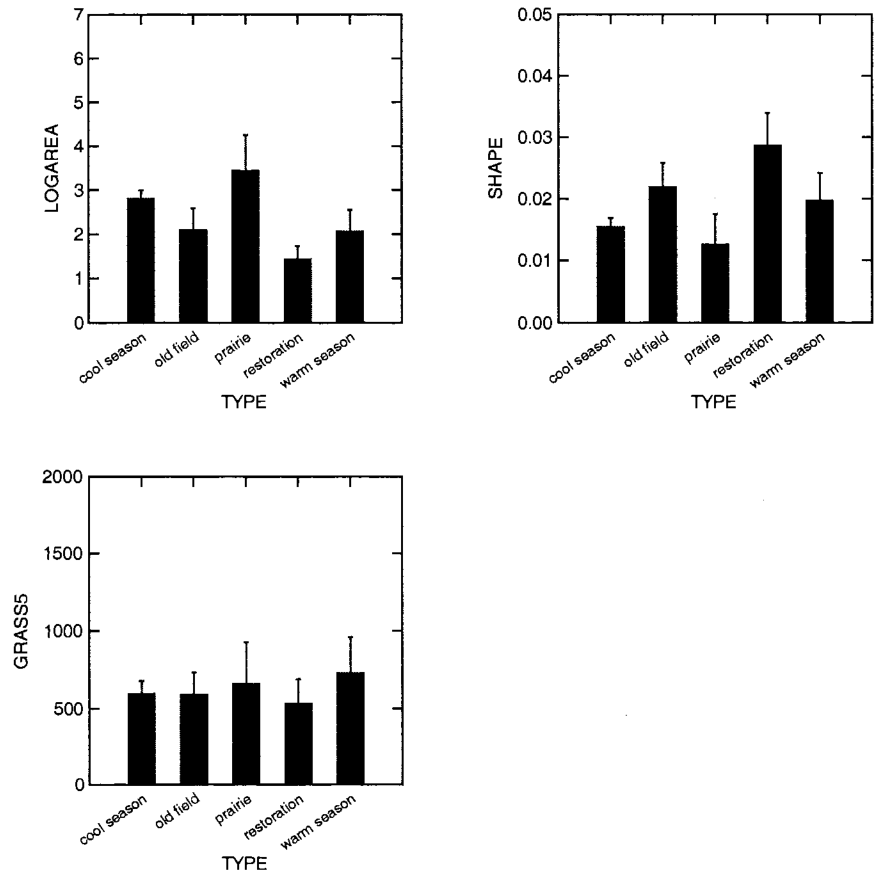

Figure 1. Landscape variables (mean + standard error) of the 5 grassland habitats. Variables include site area (log transformed), shape (perimeter/area), and grassland area (ha) within 5 km radius.

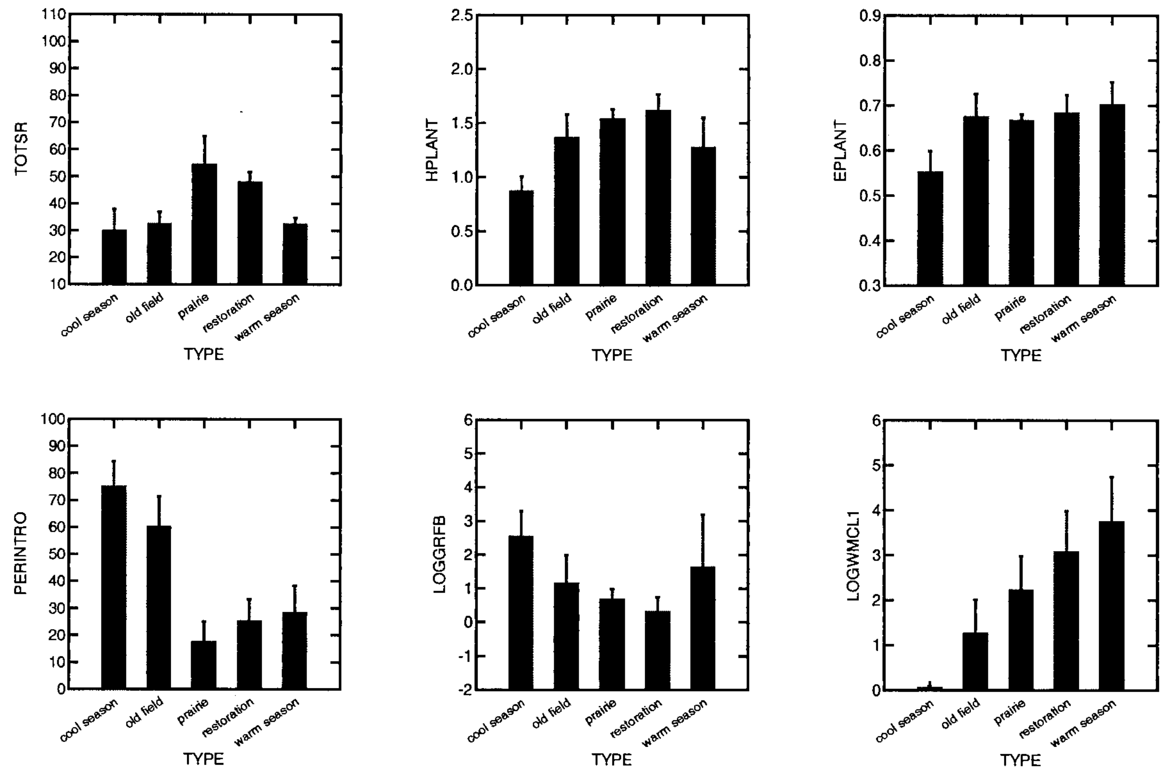

Figure 2. Plant composition variables (mean + se) at the five grassland habitats. Variables include species richness (TOTSR), Shannon diversity index (HPLANT), Shannon evenness (EPLANT), percentage of introduced species (PERINTRO), graminoid/forb ratio (LOGGRFB), and warm/cool season plant ratio (LOGWMCL1).

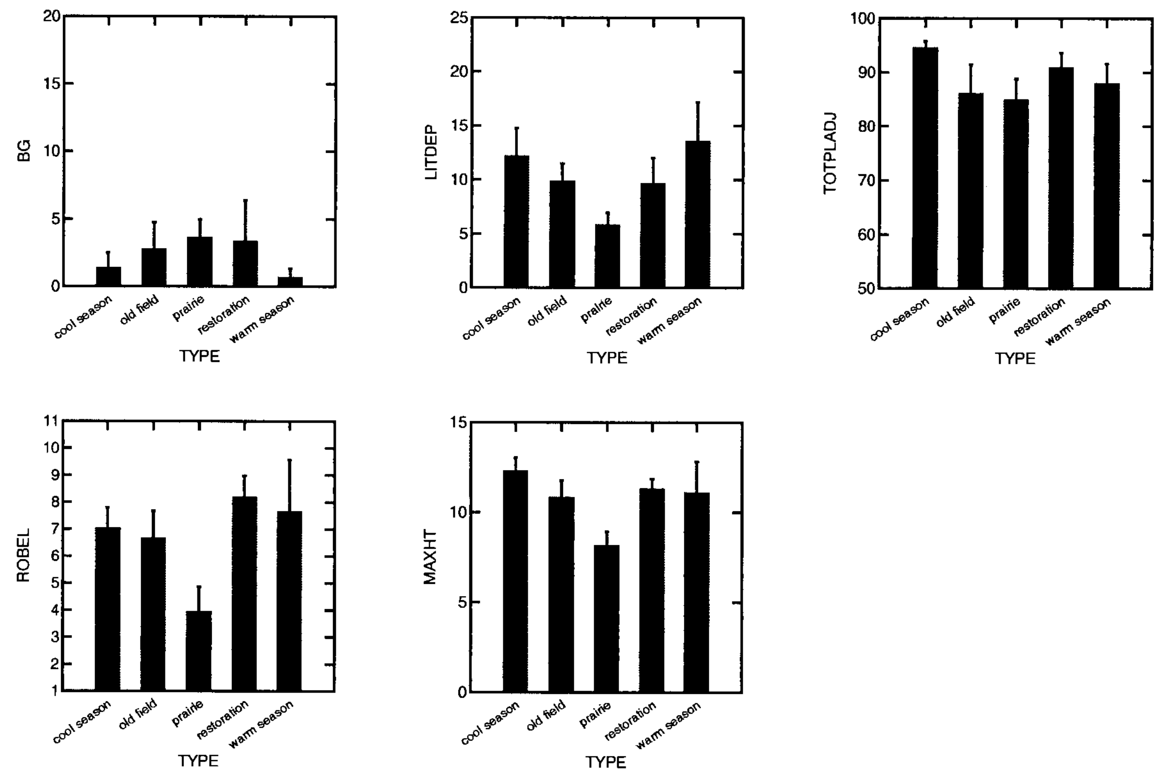

Figure 3. Vegetation structure variables (mean + se) of the five grassland habitats. Variables include bare ground (BG), litter depth (LITDEP), total plant cover (TOTPLADJ), visual obstruction (ROBEL), and maximum height (MAXHT).

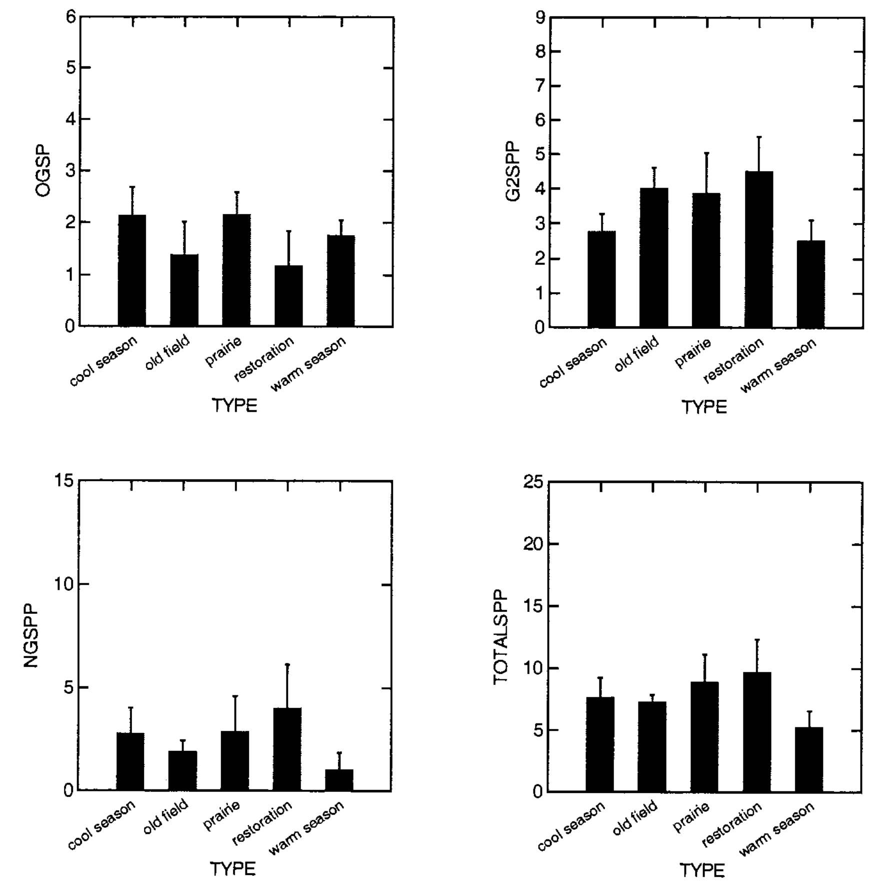

Figure 4. Species richness of obligate grassland birds (OGSP), secondary grassland birds (G2SPP), non-grassland birds (NGSPP) and all birds (TOTALSPP) among the five habitats. Values are mean + standard error.

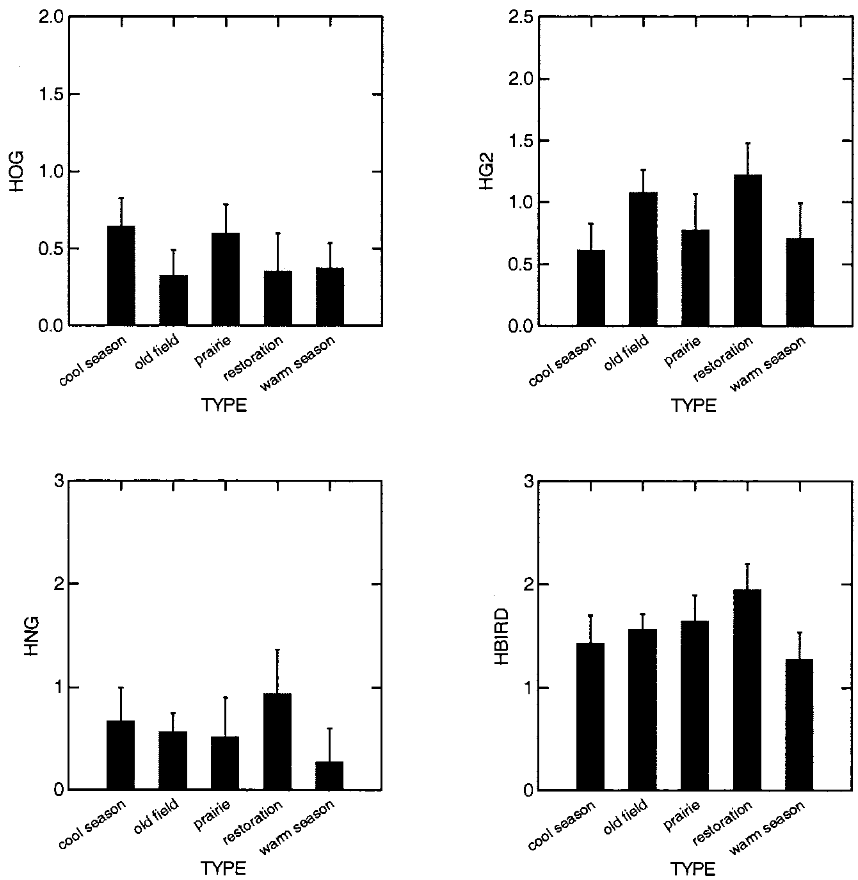

Figure 5. Shannon diversity indices of obligate grassland birds (HOG), secondary grassland birds (HG2), non-grassland birds (HNG) and all birds (HBIRD) among the five habitats. Values are mean + standard error.

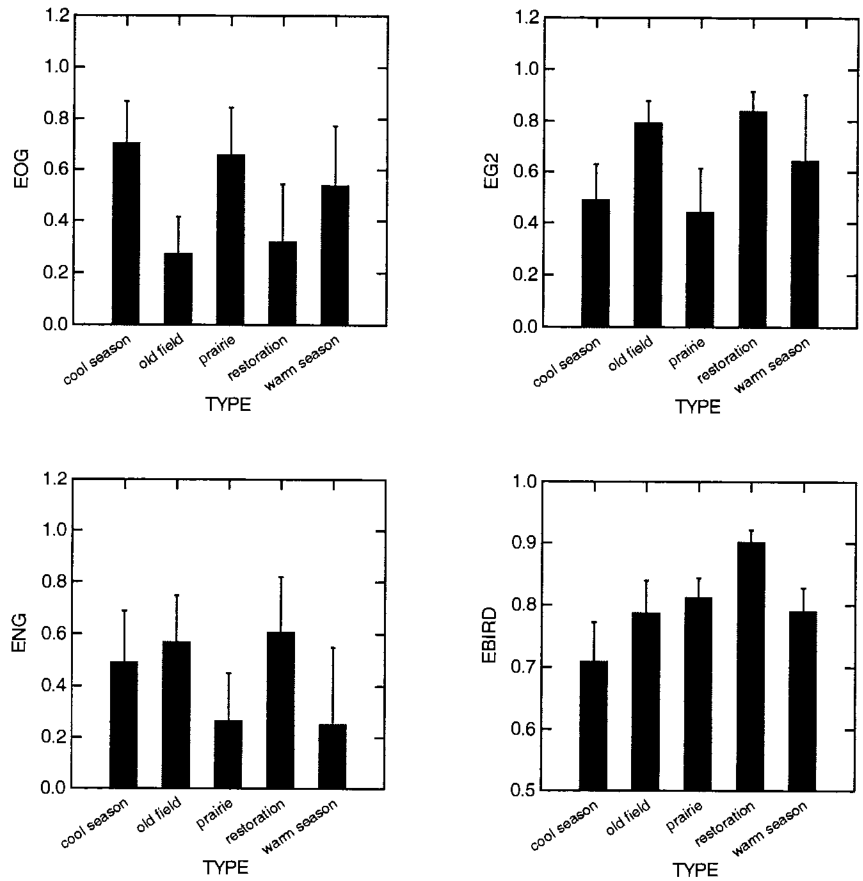

Figure 6. Shannon evenness of obligate grassland birds (EOG), secondary grassland birds (EG2), non-grassland birds (ENG) and all birds (EBIRD) among the five habitats. Values are mean + standard error.

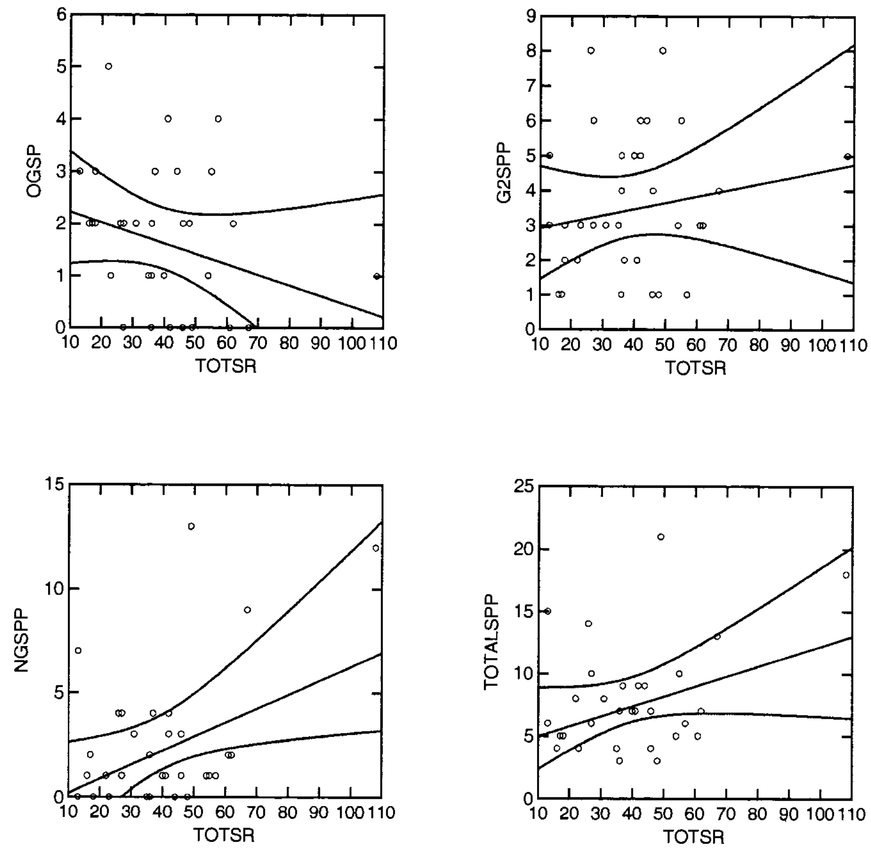

Figure 7. Total species richness (number of species) of obligate grassland birds (OGSP), secondary grassland birds (G2SPP), non-grassland birds (NGSPP) and all birds (TOTALSPP) as functions of plant species richness (TOTSR). 95% confidence intervals are shown.

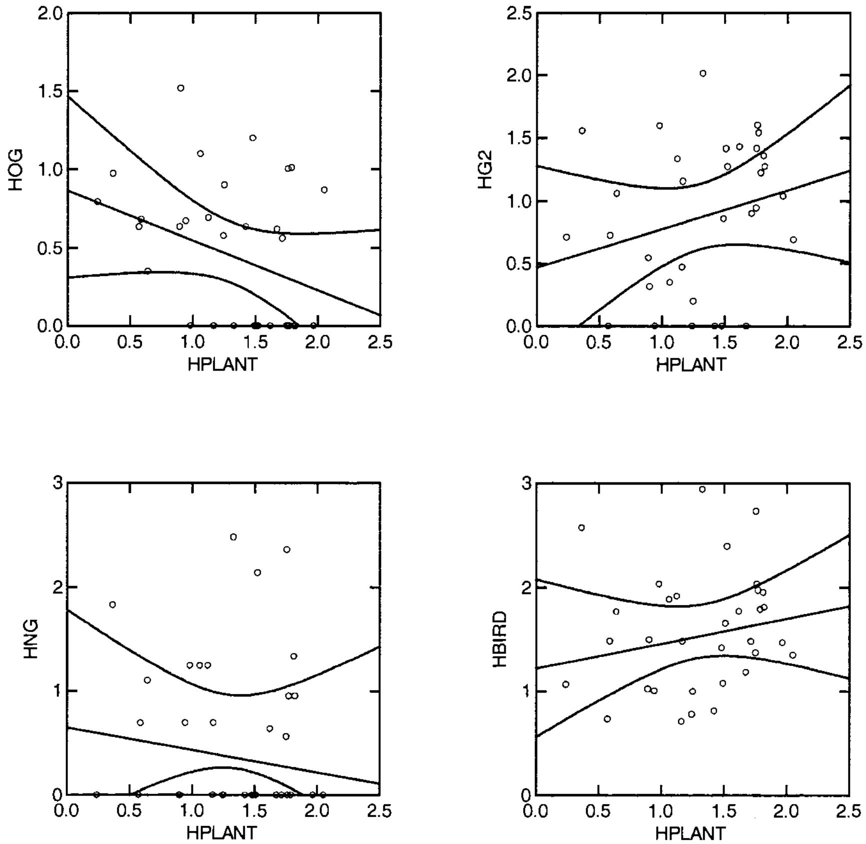

Figure 8. Shannon diversity of obligate grassland birds (top left), secondary grassland birds (top right), non-grassland birds (bottom left) and all birds as functions of Shannon diversity of plants.

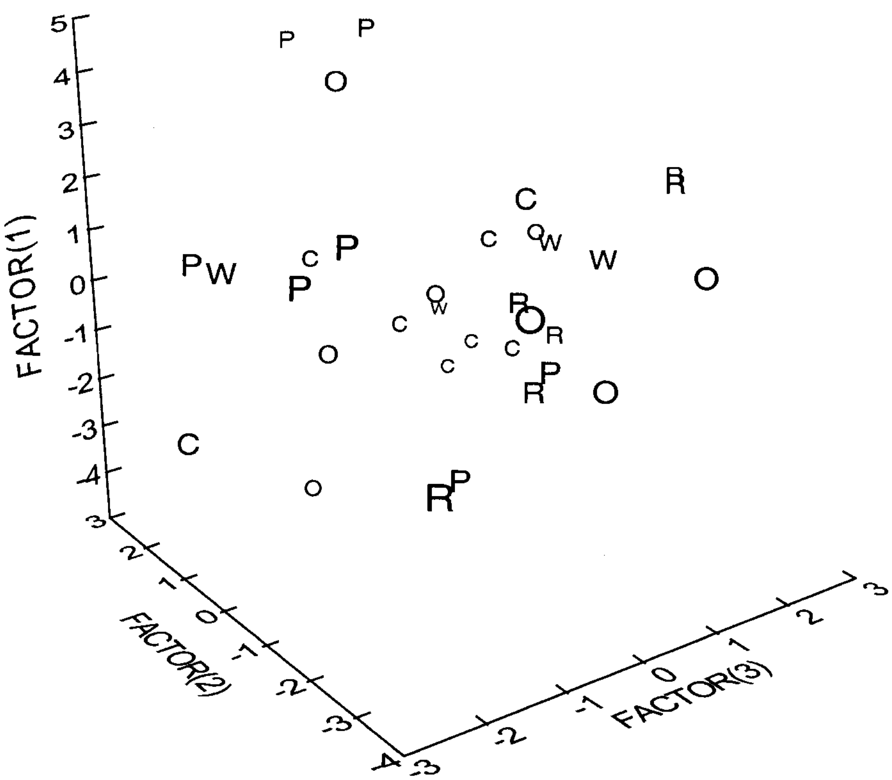

Figure 9. Graphical depiction of the PCA summarized in Table 8. Each study site is plotted against the first 3 principle components. Larger symbols are closer to the front of the three-dimensional figure.

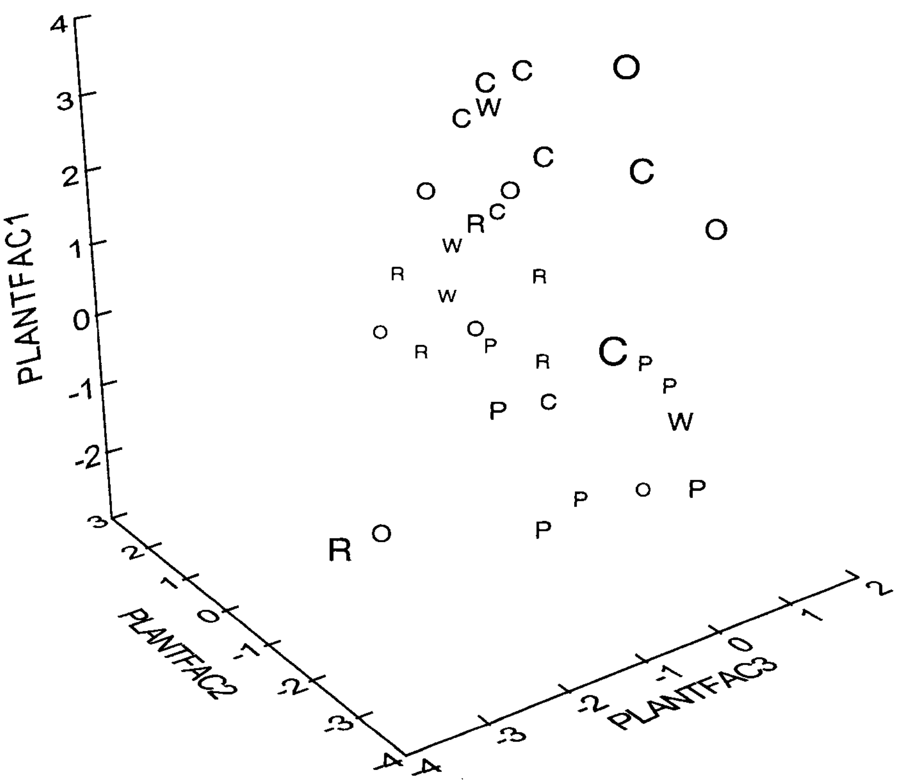

Figure 10. Graphical depiction of the PCA summarized in Table 9. Each study site is plotted against the first 3 principle components. Larger symbols are closer to the front of the three-dimensional figure. Note that Factor 3 explains relatively little of the variation because most points are towards one side of that axis (the positive side).

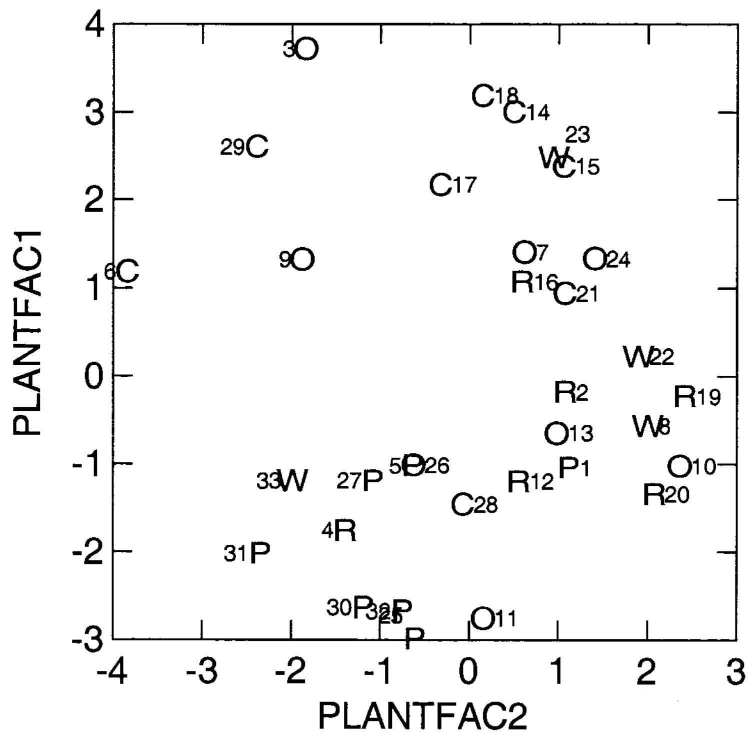

Figure 11. Two-dimensional plot of the data shown in Figure 10. Each study site is plotted against the first 2 principle components. Letters denote habitat (C=cool season, O = old field, P = prairie, R=restoration, W = warm season) and numbers indicate site number (see Table 1).

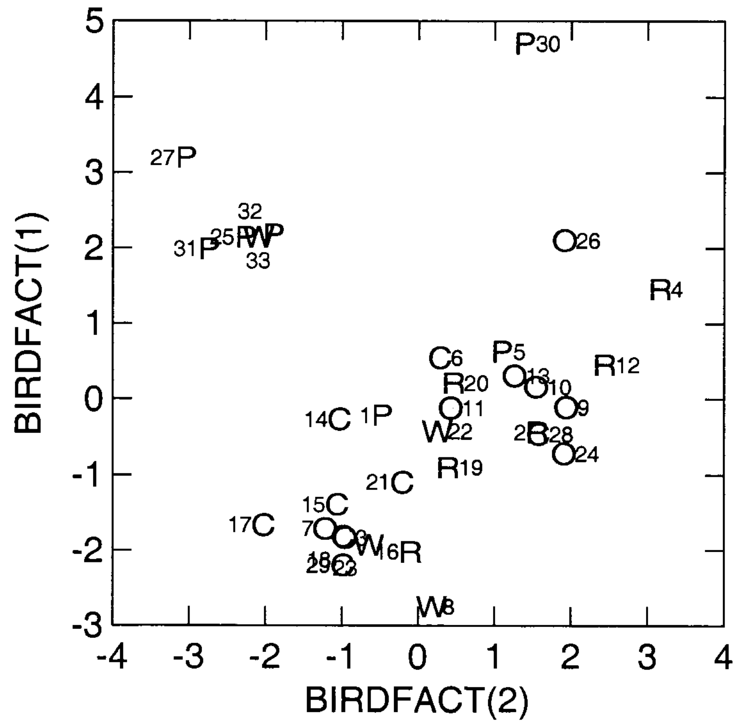

Figure 12. Two-dimensional plot of the data shown in Table 10. Each study site is plotted against the first 2 principle components. Letters denote habitat (C=cool season, O = old field, P = prairie, R=restoration, W = warm season) and numbers indicate site number (see Table 1).