Avian Response to Meadow Restoration in the Central Great Plains

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AVIAN RESPONSE TO MEADOW RESTORATION IN THE CENTRAL GREAT PLAINS

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Abstract: Native grassland is one of the most heavily degraded of all North American ecosystems, and restoration of altered grasslands is a tool used to mitigate some of the biological ramifications of past land use practices. Providing habitat for grassland-dependent bird species often is one of the many goals of restoration. We evaluated the efficacy of meadow restoration for breeding birds in the Nebraska Platte River Valley by comparing the bird community and vegetation structure on 25 natural (original sod) and 25 restored meadows. We conducted principal components analyses on the vegetation structure and on the bird community, and modeled the densities of common bird species in relation to vegetation features. Vegetation structure of natural and restored meadows overlapped broadly, although some metrics differed between the 2 types of meadows. With the exception of Dickcissel (*Spiza americana*), natural meadows supported higher densities of upland bird species, whereas restored meadows supported generalist species associated with moister conditions and brushier vegetation. Models of bird density reflected some of the differences in bird communities and vegetation structure between the 2 types of meadows: species with higher densities on natural meadows were associated with less bare ground, less woody vegetation, and less litter, whereas species that were more common on restored meadows were associated with more bare ground, more woody vegetation, more litter, less grass, and greater vegetation height-density. Periodic burning and grazing may help restore planted meadows in the Platte River Valley while maintaining species diversity.

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The widespread introduction of agriculture associated with European settlement in the Platte River Valley, as well as elsewhere in the Great Plains, brought many changes. Agriculture has become a major land use in the valley (Sidle et al. 1989). Cultivation was most common in drier areas, and the wetter meadows often were grazed. Water-control projects and irrigation practices reduced water tables and drained wetlands (Currier et al. 1985). Increases in woody vegetation along the Platte River of Nebraska have been attributed to alterations in the flow regime in the river. Wet meadows adjacent to the river have been dramatically altered (Sidle et al. 1989). Between 1938 and 1983, 332,542 ha of wet meadows remaining since settlement were lost to roads, housing, sand and gravel pits, and conversion to agriculture (Sidle et al. 1989).

The effects of habitat loss on grassland birds dependent on wet meadows are difficult to assess.

However, the loss of meadows in the Platte River Valley has contributed to the overall decrease in grassland habitat, which has been linked to the decline of grassland birds (Herkert et al. 1996, Johnson 1996, Peterjohn and Sauer 1999).

Restoration of habitats is essential to maintaining biodiversity in general, as habitat preservation will be an inadequate policy for mitigating losses of habitats (Sinclair et al. 1995). Restoration of prairies, in particular, has been practiced for decades (Spooner and Yeager 1942). Most evaluations have focused on plant communities (e.g., Sluis 2002), but restoration is important to grassland bird management as well, especially in agriculture-intensive areas (Blankespoor 1980, Higgins et al. 1984, Gatti et al. 1994), and birds constitute 1 useful indicator of restoration success. However, there are few studies that actually compared bird communities on natural and restored grasslands (but see Fletcher and Koford 2002). Wet meadows have been recognized as a vital component of the Platte River Valley (Currier and Davis 2000), a river ecosystem that may be partially restored under the Platte River Cooperative Agreement, a basin-wide habitat and flow re-regulation plan (Derby and Strickland 2001). The ultimate goal of the cooperative agreement is, in part, to protect 11,700 ha of wet meadow and riverine habitat for Whooping Cranes (*Grus americana*), Least Terns (*Sterna antillarum*), and Piping Plovers (*Charadrius melodus*). Key to successful restoration is an evaluation of how well restored habitats perform their ecological functions in comparison to natural habitats.

To assess how closely restored meadows mimic natural meadows with respect to breeding bird communities that they support, we compared the bird communities and vegetation structure on restored versus natural meadows in the Platte River Valley. Grassland bird species in the valley that have exhibited local or continental-wide population declines include Upland Sandpiper (*Bartramia longicauda*), Grasshopper Sparrow (*Ammodramus savannarum*), Dickcissel (*Spiza americana*), Bobolink (*Dolichonyx oryzivorus*), and Western Meadowlark (*Sturnella neglecta*) (Sauer et al. 2006). We examined the null hypothesis that densities of these species do not differ between natural and restored meadows. Further, to understand their habitat associations in the Platte River Valley meadows, we modeled the densities of these species in relation to vegetation structure.

STUDY AREAS

We surveyed plots within each of 25 natural meadows (12 - 160 ha; 30 – 395 ac) and 25 restored meadows (14 – 140 ha; 35 – 346 ac) in Hall, Phelps, and Buffalo counties of central Nebraska in 2002. Locally referred to as wet meadows, they are characterized by high water tables, poor drainage, nutrient-rich soils, and an undulating topography reminiscent of the braided channels from which they were formed (Henszey et al. 2004). Water levels, especially the 10-day high levels, influence the composition of Platte River meadow vegetation (Henszey et al. 2004). Plots were 16.2 ha (40 ac) in size, except in the smallest meadows (1 12-ha [30-ac] natural and 1 14-ha [35-ac] restored meadow). Meadows were owned or managed by the Platte River Whooping Crane Maintenance Trust, The Nature Conservancy, the U.S. Fish and Wildlife Service, the National Audubon Society, or the Nebraska Public Power District.

Restored meadows, formerly used as croplands, had been planted during spring or fall at various, but unspecified, occasions between 1981 and 2001. In some cases, hand-collected seeds from as many as 200 plant species were used for plantings; in other cases, less-diverse mixtures typical of early Conservation Reserve Program (CRP) plantings were used. Dominant graminoid species (names follow http://plants.usda.gov/) were big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), water sedge (*Carex aquatilis*), switchgrass (*Panicum virgatum*), and, to a lesser extent, little bluestem (*Schizachyrium scoparium*). Forbs included goldenrod (*Solidago* spp.), Illinois bundleflower (*Desmanthus illinoensis*), and Maximilian sunflower (*Helianthus maximilianii*) (William S. Whitney, Prairie Plains Resource Institute, pers. comm.). During the first 2 years after planting, weedy annuals dominated, including common sunflower (*Helianthus annuus*), Canadian horseweed (*Conyza canadensis*), sandbur (*Cenchrus* spp.), green bristlegrass (*Setaria viridis*), and cheatgrass (*Bromus tectorum*). Natural meadows contained smooth brome

(*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*), both of which are non-native, in addition to native tallgrass prairie species (W. S. Whitney, pers. comm.). The limited amount of woody vegetation in restored meadows consisted mainly of young cottonwoods (*Populus* spp.) in human-made sloughs that had been created to boost wetland habitat. Most of the woody vegetation in natural meadows was Woods' rose (*Rosa woodsii*) or desert false indigo (*Amorpha fruticosa*).

Natural meadows historically had been grazed by domestic livestock, but contemporary grazing occurred in 2002 on 8 natural and 7 restored meadows. One of the natural meadows and 3 of the restored meadows that were grazed also had been burned in the spring of 2002. Two additional natural meadows and 2 additional restored meadows also were burned in spring 2002. In 2001, 5 natural and 1 restored meadow were hayed and 2 natural meadows were grazed. Based subjectively on the extent of cropping by cattle, grazing was generally moderate to heavy, with the exception of 1 natural meadow that was lightly grazed. We refer to study sites that had been burned, hayed, or grazed in the previous 2 years as managed; otherwise they are called unmanaged.

The Platte River Valley experienced a severe drought during 2002, with higher temperatures and lower precipitation than average. Based on the National Climatic Data Center (2002) information from the eastern edge of the study area, total rainfall during May and June was 79% and 47% of average levels for those months. May was, on average, 1.0°C (1.8°F) cooler than long-term average temperatures, whereas June was 3.2°C (5.8°F) warmer than long-term average temperatures.

MATERIALS AND METHODS

Vegetation Methods

A single observer conducted all vegetation surveys between 11 and 29 June 2002. We randomly located 5 sampling locations in each plot. If the random point was located in an area where the vegetation was atypically trampled by cattle, we took measurements from a nearby untrampled area. We placed a Daubenmire (1968) frame at each sampling location. We estimated the percent cover within the Daubenmire frame to the nearest 5%—separately for grasses, forbs, woody plants, litter (lying: < 45º, and standing: 45-90º), and exposed (i.e., bare) soil. We counted the number of woody stems within the Daubenmire frame, distinguishing between short stems (≤ 30 cm [12 in] tall) and tall stems (> 30 cm [12 in] tall). We estimated litter depth and vegetation height approximately 3 cm (1.2 in) outside each corner of the Daubenmire frame, for a total of 4 measurements per sampling location. We recorded litter depth as the height at which a ruler was completely covered by horizontally lying dead plant material as it was viewed horizontally. If the ruler pressed the litter down, we placed a dry grass stem vertically through the vegetation to estimate litter depth. We measured maximum vegetation height as the highest point at which vegetation contacted a vertical bar. To measure vegetation height-density, we placed a Robel pole in the center of the Daubenmire frame (Robel et al. 1970). We estimated vegetation height-density as the nearest 0.5-dm (2-in) interval that was not completely covered by vegetation. We took this measurement from a distance of 4 m (13 ft) at a height of 1 m (3.3 ft) in each cardinal direction from the pole (4 measurements per sampling location).

In our analyses, we included the average of all measurements in the field. We also examined the coefficient of variation (standard deviation divided by mean) of each variable, which reflects the patchiness of the field with respect to that variable.

Bird Census Methods

We censused birds using the area search method (Stewart and Kantrud 1972, Igl and Johnson 1997). One observer surveyed birds once on each plot between 11 and 26 June 2002 by following a zigzag course within each plot, making an effort to avoid duplication in counts. This survey period covers the active breeding period of both earlier (e.g., Grasshopper Sparrow) and later breeders (e.g., Sedge Wren [*Cistothorus platensis*] and Dickcissel) in Nebraska. Plots were surveyed between 0545 and 1000 CDT. We conducted surveys when there was no precipitation or only light drizzle and when wind speeds were < 15 km/h (9 mi/h). The observer counted birds by walking slowly for 23 minutes and then stopping for 5 minutes to observe territorial behavior (Bond

1957). For Brown-headed Cowbirds (*Molothrus ater*), the breeding population (number of indicated pairs) was based on number of females. For other species, the breeding population was based on males or pairs detected. Polygamous species such as Red-winged Blackbirds (*Agelaius phoeniceus*) were estimated based on counts of territorial males and thus represent minimum estimates.

Data Analysis

To determine if there were differences in the bird community and in vegetation structure between natural and restored meadows, as well as between meadows that had undergone management (burning, haying, or grazing) within 2 years of the study versus those that had not, we used principal components analysis (PCA) with a correlation structure in SAS (SAS Institute Inc. 2000). In the PCA of birds we included only those species that were found on at least 4 plots. For all vegetation structure variables measured we included their mean and coefficient of variation in PCA. We used 95% confidence intervals to compare the densities of the 12 most abundant bird species and to compare vegetation structure on natural versus restored meadows.

We modeled the densities of the 7 most common bird species in relation to a subset of vegetation variables in a generalized linear model framework with a Gaussian error distribution (McCullagh and Nelder 1989). To select the vegetation structure measurements to use as explanatory variables in the regression, we evaluated a correlation matrix of all of the variables. For pairs of highly correlated variables ($r > 0.50$), we included only the variable that had the higher correlation coefficient with the response variable. We log-transformed (bird density + 1) to

Table 1. Eigenvectors associated with vegetation structure variables from principal component analysis on Platte River Valley, Nebraska, meadows. Primary positive loadings are in bold and underlined, and variables loading negatively are in bold.

Variable	VPC1	VPC2	VPC3	VPC4
Grass cover	-0.198	-0.187	**<u>0.420</u>**	0.209
Forb cover	0.184	0.142	**-0.398**	0.108
Woody cover	**<u>0.312</u>**	0.213	0.233	-0.009
Woody cover ≤ 30 cm (12 in)	**<u>0.235</u>**	0.174	0.068	0.222
Woody cover > 30 cm (12 in)	**<u>0.295</u>**	0.133	0.224	-0.107
Standing litter cover	-0.216	0.297	-0.071	-0.186
Lying litter cover	0.082	-0.096	-0.219	-0.043
Exposed soil	0.260	-0.140	-0.086	-0.277
Litter depth	-0.241	**<u>0.345</u>**	0.090	0.019
Maximum height	-0.185	**<u>0.374</u>**	0.142	0.150
Height-density	-0.070	**<u>0.362</u>**	-0.232	0.283
Grass cover patchiness	0.229	0.138	**-0.451**	-0.075
Forb cover patchiness	-0.215	0.138	0.140	0.068
Woody cover patchiness	**<u>0.325</u>**	0.155	0.207	0.040
Woody cover ≤ 30 cm (12 in) patchiness	**<u>0.301</u>**	0.224	0.227	0.039
Woody cover > 30 cm (12 in) patchiness	**<u>0.337</u>**	0.147	0.109	-0.101
Standing litter cover patchiness	0.097	-0.104	-0.053	0.179
Lying litter cover patchiness	0.091	0.046	0.143	0.278
Litter depth patchiness	0.073	-0.058	-0.144	**<u>0.556</u>**
Exposed soil patchiness	0.053	-0.171	-0.116	**<u>0.408</u>**
Maximum height patchiness	0.118	-0.197	0.052	0.243
Height-density patchiness	0.143	**-0.353**	0.155	-0.014

Table 2. Means and standard deviations of the first four principal components of the vegetation variables (VPC1-VPC4) and bird densities (BPC1-BPC4) on natural and restored meadows in the Platte River Valley, Nebraska. Managed meadows (M) have been burned, hayed, or grazed within 2 years of the study and unmanaged meadows (U) have not been managed within 2 years of the study.

		Mean				Standard deviation			
		Natural		Restored		Natural		Restored	
		M	U	M	U	M	U	M	U
Vegetation	VPC1	-0.16	-1.17	1.04	0.44	2.23	1.10	2.58	3.00
	VPC2	-0.27	-0.58	-0.78	1.41	1.52	1.96	1.51	1.48
	VPC3	0.79	0.19	0.09	-1.32	1.65	0.96	0.97	1.55
	VPC4	0.16	-0.13	-0.47	0.27	1.06	0.82	1.99	1.46
Birds	BPC1	-0.67	-0.51	0.47	0.87	0.84	0.54	0.67	0.75
	BPC2	0.25	-0.18	0.39	-0.42	1.07	0.60	1.43	0.65
	BPC3	0.34	-0.39	-0.15	0.00	1.33	0.34	1.15	0.68
	BPC4	-0.01	-0.09	-0.30	0.29	0.51	0.31	0.79	1.67

meet more closely the assumption of normality and multiplied the result by 10 for ease of interpretation. We used the Akaike Information Criterion for small sample sizes (AIC_c) to select the best model for each species (Burnham and Anderson 2002). A priori models included all possible combinations of 2 vegetation variables, with and without their interaction, and all possible single-variable models. To determine if more-complex models would better describe the data, we further ran a stepwise procedure with 1 or 2 variables entered or removed at a time ($P \leq 0.10$ to enter or be removed from model). To evaluate whether grassland patch size influenced bird density, we also ran the best model for each species with the natural log of grassland size included in the model.

RESULTS

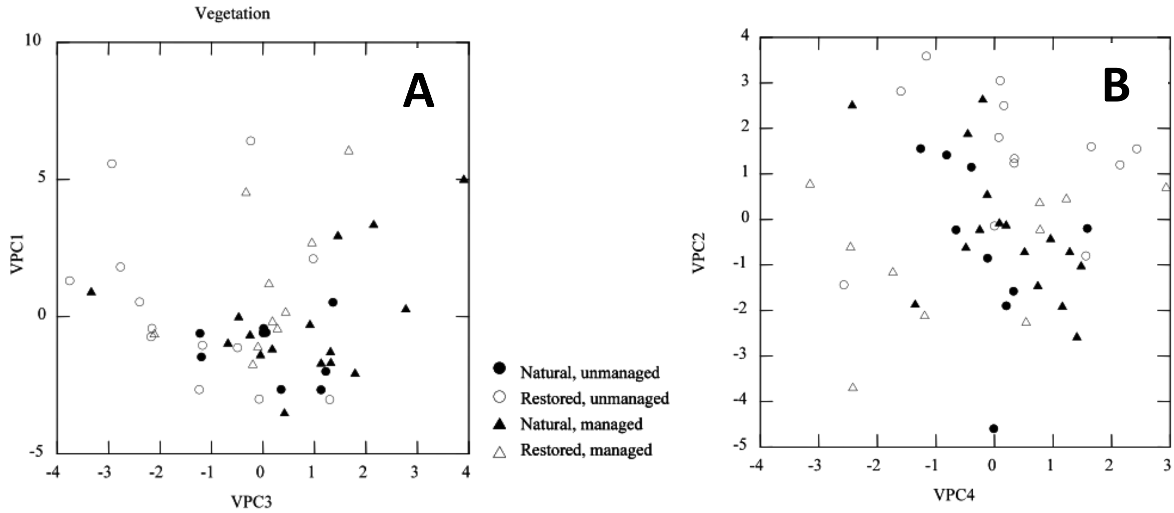
Vegetation Structure

Of the principal components based on vegetation variables, the first 4 — VPC1, VPC2, VPC3, and VPC4 — explained 26, 14, 11, and 8% of the variance in the 22 original variables, respectively (Table 1). VPC1 distinguished study plots on the basis of woody cover and its patchiness. VPC2 separated plots with greater values of height-density patchiness from those with greater litter depth, maximum height, and mean height-density. With VPC3, plots with greater grass cover patchiness and forb cover were separated from plots with higher values of grass cover. VPC4 reflects patchiness in litter depth and exposed soil.

Vegetation structure differed somewhat between natural and restored meadows along VPC1 and VPC3 but not VPC2 or VPC4 (Figures 1a,b; Table 2). Plots that were outliers in the PCA included both those that had been grazed or burned and those that had not been managed, although there was some separation between managed and unmanaged meadows along VPC3 (Fig. 1a). Restored meadows had substantially more forb cover, much more exposed soil, and less grass cover than natural meadows (Table 3). Sample sizes were inadequate to compare effects of the various kinds of management activities on vegetation.

Bird Communities

We found 22 and 29 bird species on natural and restored meadows, respectively (Table 4). Mean species richness was similar on natural (mean = 6.84, SD = 2.69, 95% CI = 5.79 - 7.89) and restored meadows (mean = 7.12, SD = 2.17, 95% CI = 6.27 – 7.97). Wild Turkey (*Meleagris gallopavo*), Swamp Sparrow (*Melospiza georgiana*), and Eastern Meadowlark (*Sturnella magna*) occurred on 1 natural meadow each but on no restored meadows. Spotted Sandpiper (*Actitis macularia*), American Woodcock (*Scolopax minor*), Willow Flycatcher (*Empidonax traillii*),



Figs. 1a and b. Vegetation principal components for natural and restored meadows that were managed (burned, grazed, or hayed within two years of the study) and unmanaged in the Platte River Valley, Nebraska. VPC1 reflects woody cover and its patchiness. VPC2 separated plots with greater values of height-density patchiness (negative values of VPC2) from those with greater litter depth, maximum height, and height-density (positive values). In VPC3, plots with greater grass cover patchiness and forb cover (negative values of VPC3) were separated from plots with higher values of grass cover (positive values). VPC4 reflects patchiness in litter depth and exposed soil.

Tree Swallow (*Tachycineta bicolor*), Eastern Bluebird (*Sialia sialus*), Lark Bunting (*Calamospiza melanocorys*), and Henslow's Sparrow (*Ammodramus henslowii*) were found only on restored meadows, but only on a single plot each. Sedge Wren and Song Sparrow (*Melospiza melodia*) occurred on 4 and 2 restored meadows, respectively, but on no natural meadows.

The percentages of variance in the bird community explained by principal components on bird density BPC1, BPC2, BPC3, and BPC4 were 22, 16, 13, and 9%, respectively. BPC1 separated Grasshopper Sparrows, Western Meadowlarks, and Bobolinks from Common Yellowthroats, Dickcissels, Red-winged Blackbirds, and American Goldfinches (*Carduelis tristas*) (Table 5). BPC2 was strongly associated with Eastern Kingbirds (*Tyrannus tyrannus*) and Mourning Doves (*Zenaida macroura*), and moderately associated with Upland Sandpipers and Brown-headed Cowbirds. Brown-headed Cowbirds, Red-winged Blackbirds, Upland Sandpipers, and Bobolinks were positively associated with BPC3 (Table 5). We found a distinct separation between natural and restored meadows along BPC1 of the bird community but no clear distinction along other axes (Fig. 2, Table 2).

Of the more common bird species, most that have been experiencing declines, such as Upland Sandpiper, Grasshopper Sparrow, Bobolink, and Western Meadowlark, occurred at higher densities on natural meadows than on restored meadows (Fig. 3). However, Dickcissel density was higher on restored meadows, and Sedge Wren occurred only on restored meadows (Fig. 3). In general, densities of species that prefer or can tolerate more woody vegetation or wetter conditions, such as American Goldfinch, Common Yellowthroat, Red-winged Blackbird, and Sedge Wren, were higher on restored meadows (Fig. 3). The densities of Mourning Doves, Brown-headed Cowbirds, and

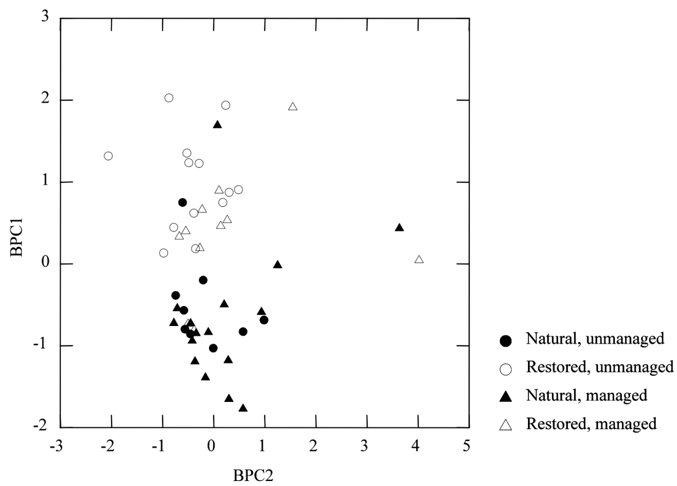


Fig. 2. Bird principal components 1 and 2 in natural and restored meadows that were managed (burned, grazed, or hayed within two years of the study) and unmanaged in the Platte River Valley, Nebraska. Positive values of BPC1 reflect more Common Yellowthroats, Dickcissels, Red-winged Blackbirds, and American Goldfinches and fewer Grasshopper Sparrows, Western Meadowlarks, and Bobolinks. BPC2 was strongly associated with Eastern Kingbirds and Mourning Doves and moderately associated with Upland Sandpipers and Brown-headed Cowbirds.

Table 3. Means and standard deviations of vegetation variables measured on natural and restored meadows in the Platte River Valley, Nebraska.

	Mean		Standard deviation	
Vegetation Variable	Natural	Restored	Natural	Restored
Grass cover (%)	64.3	40.3	20.1	21.9
Forb cover (%)	14.1	24.8	10.4	17.1
Woody cover (%)	1.0	1.16	3.2	2.3
Standing litter (%)	12.2	12.8	15.9	15.8
Lying litter (%)	6.5	5.3	14.9	5.9
Exposed soil (%)	2.0	15.1	2.7	16.8
Woody cover ≤ 30 cm (12 in) (%)	0.02	0.2	0.1	0.5
Woody cover > 30 cm (12 in) (%)	0.09	0.09	0.30	0.22
Litter depth (cm)	0.27	0.26	0.20	0.30
Maximum height (cm)	39.8	42.7	14.1	16.2
Height-density (cm)	19.3	29.9	9.6	17.5

Eastern Kingbirds (all associated with high values of BPC2) differed little between natural and restored meadows (Fig. 3).

Table 4. Number of plots on which bird species were observed on natural (n = 25) and restored (n = 25) meadows in the Platte River Valley, Nebraska.

Species	Natural	Restored
Mallard (*Anas platyrhynchos*)	1	1
Ring-necked Pheasant (*Phasianus colchicus*)	3	9
Wild Turkey (*Meleagris gallopavo*)	1	0
Northern Bobwhite (*Colinus virginianus*)	2	5
Killdeer (*Charadrius vociferous*)	4	4
Spotted Sandpiper (*Actitis macularia*)	0	1
Upland Sandpiper (*Bartramia longicauda*)	11	3
American Woodcock (*Scolopax minor*)	0	1
Mourning Dove (*Zenaida macroura*)	8	13
Willow Flycatcher (*Empidonax traillii*)	0	1
Eastern Kingbird (*Tyrannus tyrannus*)	6	3
Tree Swallow (*Tachycineta bicolor*)	0	1
Sedge Wren (*Cistothorus platensis*)	0	4
Eastern Bluebird (*Sialia sialis*)	0	1
American Robin (*Turdus migratorius*)	1	1
Gray Catbird (*Dumetella carolinensis*)	1	1
Yellow Warbler (*Dendroica petechia*)	2	1
Common Yellowthroat (*Geothlypis trichas*)	4	16
Field Sparrow (*Spizella pusilla*)	2	1
Lark Bunting (*Calamospiza melanocorys*)	0	1
Grasshopper Sparrow (*Ammodramus savannarum*)	24	12
Henslow's Sparrow (*Ammodramus henslowii*)	0	1
Song Sparrow (*Melospiza melodia*)	0	2
Swamp Sparrow (*Melospiza georgiana*)	1	0
Dickcissel (*Spiza americana*)	23	25
Bobolink (*Dolichonyx oryzivorus*)	20	9
Red-winged Blackbird (*Agelaius phoeniceus*)	8	17
Eastern Meadowlark (*Sturnella magna*)	1	0
Western Meadowlark (*Sturnella neglecta*)	23	16
Brown-headed Cowbird (*Molothrus ater*)	18	18
Orchard Oriole (*Icterus spurius*)	0	1
American Goldfinch (*Carduelis tristas*)	6	10

Associations between Bird Density and Vegetation Structure

For most species evaluated, vegetation models explained from one-third to three-fourths of the variance in bird density (Table 6). For the Upland Sandpiper, however, the null model, with no explanatory variables, had the lowest AIC_c value and therefore was the best model. Grasshopper Sparrows strongly avoided woody cover and preferred less exposed soil and less lying litter (Table 6). The interaction between litter depth and vegetation height-density was important because at low height-density values, Grasshopper Sparrow density was higher where litter depth was higher; however, at high height-density values, litter depth was not important. Western Meadowlark density was explained by the same interaction, in addition to responding negatively to exposed soil and higher litter cover (Table 6).

Dickcissel density was influenced by several interacting vegetation variables (Table 6). Given that forb cover was negatively correlated with grass cover (and therefore the latter was not included in models), interactions indicated that when grass was plentiful, Dickcissel density showed a weak positive relationship with height-density and no relationship with lying litter cover. However, when there was little grass cover, Dickcissel density increased with greater height-density and more lying litter cover. The interaction between exposed soil and woody cover was due to a positive

Table 5. Coefficients of principal components of bird densities on natural and restored meadows in the Platte River Valley, Nebraska. Primary positive loadings are bold and underlined, and variables loading negatively are in bold.

Species	BPC1	BPC2	BPC3	BPC4
Upland Sandpiper	-0.199	**<u>0.285</u>**	**<u>0.335</u>**	0.068
Mourning Dove	0.061	**<u>0.430</u>**	-0.098	0.184
Eastern Kingbird	0.037	**<u>0.542</u>**	-0.199	0.024
Sedge Wren	0.145	-0.145	0.004	**<u>0.590</u>**
Common Yellowthroat	**<u>0.418</u>**	-0.068	0.127	0.143
Grasshopper Sparrow	**-0.443**	0.068	-0.030	0.072
Dickcissel	**<u>0.310</u>**	-0.048	0.070	**<u>0.211</u>**
Bobolink	**-0.311**	-0.057	**<u>0.251</u>**	0.014
Red-winged Blackbird	**<u>0.286</u>**	-0.041	**<u>0.447</u>**	**-0.225**
Western Meadowlark	**-0.359**	0.140	0.190	-0.059
Brown-headed Cowbird	-0.006	**<u>0.233</u>**	**<u>0.562</u>**	0.011
American Goldfinch	**<u>0.280</u>**	0.122	-0.180	**-0.401**

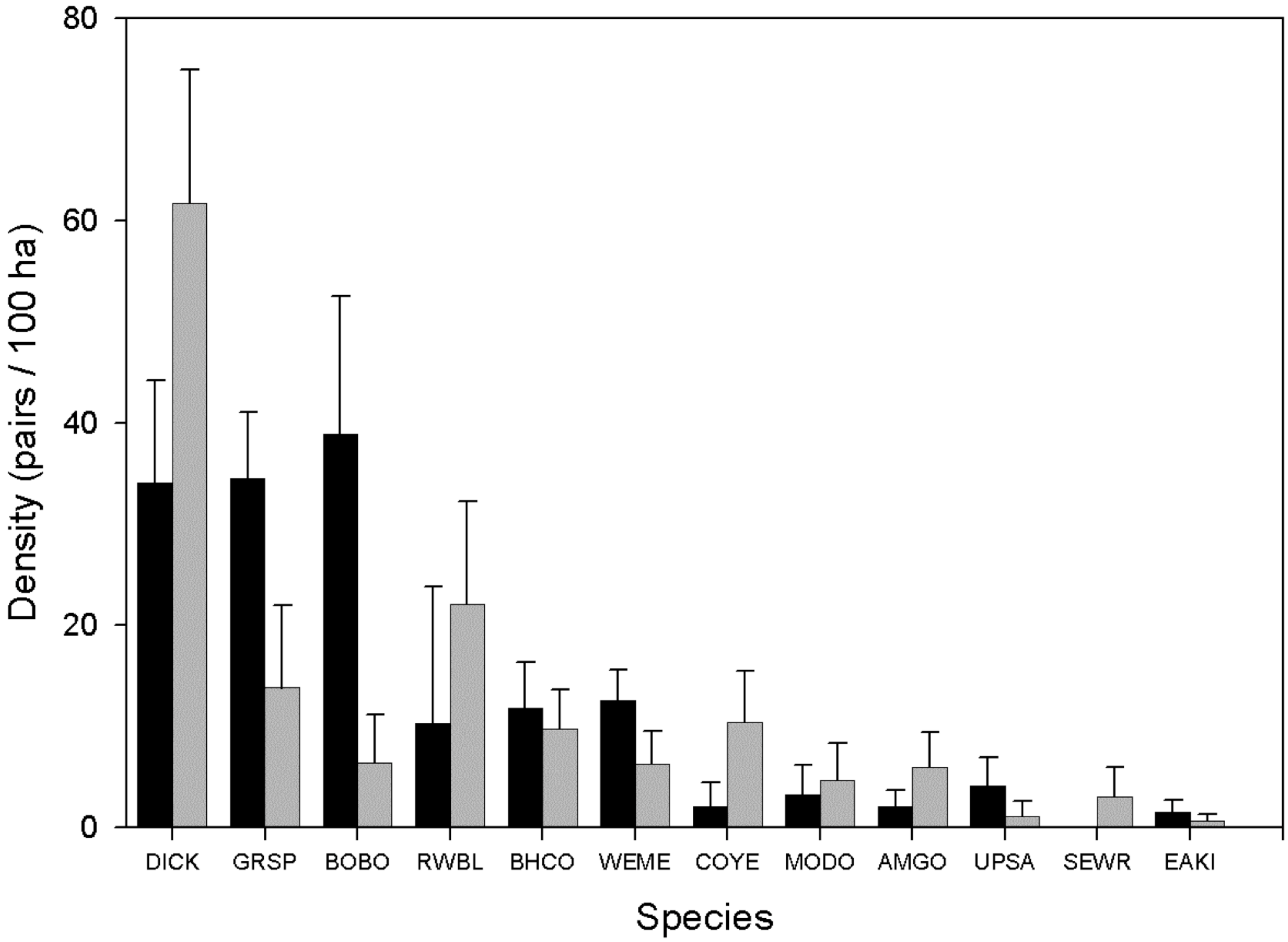


Fig. 3. Mean density (number of pairs/100 ha) and 95% confidence interval of most abundant bird species on natural (black shading) and restored (gray shading) meadows in the Platte River Valley, Nebraska. Codes: DICK = Dickcissel, RWBL = Red-winged Blackbird, BOBO = Bobolink, BHCO = Brown-headed Cowbird, WEME = Western Meadowlark, COYE = Common Yellowthroat, MODO = Mourning Dove, AMGO = American Goldfinch, UPSA = Upland Sandpiper, SEWR = Sedge Wren, EAKI = Eastern Kingbird.

Table 6. Best models based on AICc from generalized linear regression relating densities of the seven most common bird species to vegetation variables and patch size of natural (*n* = 25) and restored (*n* = 25) meadows in the Platte River Valley, Nebraska.

Species	Variables in model (and sign of coefficient)	R^2_{adj}
Upland Sandpiper	Null model	—
Grasshopper Sparrow	Woody cover (-), Soil (-), Lying litter cover (-), Height-density*Litter depth	0.758
Dickcissel	Forb cover*Height-density, Forb cover*Lying litter cover, Woody cover*Soil, Lying litter cover*Soil	0.425
Bobolink	Height-density (-), Soil (-), Lying litter cover (-)	0.336
Red-winged Blackbird	Woody cover (+), Height-density (+), Soil (+)	0.316
Western Meadowlark	Soil (-), Lying litter cover (-), Height-density*Litter depth	0.421
Brown-headed Cowbird	Forb cover (+), log (Patch size) (+)	0.188

relationship between Dickcissel density and woody cover only at the highest levels of exposed soil. The interaction between exposed soil and lying litter cover was driven by only a few influential plots.

Density of Bobolinks was higher on sites with less exposed soil, lower vegetation height-density, and less lying litter cover. Red-winged Blackbird density was higher on meadows with more exposed soil, greater vegetation height-density, and more woody cover. The best model of Brown-headed Cowbird density explained little variation in the data (Table 6). This was the only species for which the addition of grassland size improved the best vegetation model, and the R^2 value increased by less than 0.10.

DISCUSSION

We were able to conduct this study in only 1 year, so we must be cautious in drawing broad generalizations. Further, as noted earlier, it was a drier-than-average year, although precipitation prior to our surveys was within the normal range of variation. Nonetheless, it is recognized that bird populations can vary dramatically from year to year, especially in response to varying precipitation. Accordingly, results from this study should be viewed as 1 component of a more comprehensive meta-replication (*sensu* Johnson 2002).

Vegetation structure differed somewhat between natural and restored meadows. Principal components separated meadows with more woody cover, exposed soil, and more forb cover from those with more litter and grass cover and taller vegetation. Based on means, 3 of these distinguishing characteristics were reflected in differences between natural and restored meadows: forb cover and exposed soil were greater on restored meadows whereas natural meadows had greater grass cover. Historical grazing or herbicide applications in natural meadows may have contributed to these differences by reducing the concentration of forbs and the height and density of vegetation.

The avian communities we found were similar to those reported by Helzer and Jelinski (1999) in native wet meadows in the same region during 1995-96. The breeding bird communities in our study differed between restored and natural meadows. Densities of Upland Sandpipers, Grasshopper Sparrows, Bobolinks, and Western Meadowlarks were greater in natural meadows; in contrast, densities of American Goldfinches, Sedge Wrens, Common Yellowthroats, Dickcissels, and Red-winged Blackbirds, were greater in restored meadows. In general, the bird community in natural meadows was characterized by species that prefer more open grassland, and restored meadows harbored species that are more tolerant of some woody vegetation.

Models of bird density reflected some of the differences in the bird communities and vegetation structure between natural and restored meadows. Densities of Dickcissels and Red-winged Blackbirds were higher on meadows with more exposed soil, more litter, greater height-density of vegetation, and more woody cover; these are similar to most of the characteristics of restored meadows, which had higher densities of these species than did natural meadows. Higher densities of Grasshopper Sparrows, Bobolinks, and Western Meadowlarks were associated with less woody cover, lesser amounts of exposed soil, less litter cover, and lower vegetation height-density. Most of these characteristics were typical of natural meadows, where these species occurred at higher densities.

Bird communities differed more than vegetation structure between natural and restored meadows. Variation in historical and current management practices such as burning, haying, and grazing within types of meadows may obscure differences in vegetation structure between the 2 types. In addition, the age of the restored meadows (time since planting) varied by as much as 20 years, which can cause considerable variation in the successional stage of a meadow. In general, however, succession within these meadows is repeatedly set back by frequent management actions such as burning, haying, or grazing. Importantly, our sample is in fact representative of meadows in the Platte River Valley.

Restoration of wet meadows has the potential to provide valuable habitat for grassland birds that have experienced population declines. Our results indicate that, compared with natural meadows, restored sites supported more Dickcissels, Common Yellowthroats, and Sedge Wrens, but fewer Grasshopper Sparrows and Bobolinks. It will be worthwhile to re-evaluate these restored sites through time to assess how vegetation structure and bird communities respond to natural succession and to management practices.

MANAGEMENT IMPLICATIONS

The goal of prairie restoration for birds should be to provide habitat for grassland specialists appropriate for the region rather than simply to maximize bird diversity (Byre 1997). Restoration efforts that include the creation of wetlands to provide waterfowl habitat may also consider habitat needs of grassland passerines. However, given that meadows in the Platte River Valley were historically saturated with areas of standing water, the goals of restoration efforts will be important in guiding management decisions.

Assuming the management goal is to maximize densities of grassland breeding birds that have experienced population declines, we recommend additional management on restored meadows to better mimic natural meadows. Prescribed burning and light to moderate grazing or mowing to diversify vegetation structure and reduce woody vegetation would likely improve restored meadows (Byre 1997). Burning currently is practiced on some meadows in this study and should be used where there is woody encroachment. However, these practices should be limited enough to encourage a diversity in grassy vegetation structure that will continue to support species that require tall, dense vegetation as well as encouraging settlement by species that prefer short to medium-height grass. Based on our results, reducing the amount of exposed soil, possibly through multiple plantings, will likely provide more habitat for Grasshopper Sparrows, Bobolinks, and Western Meadowlarks. Finally, restoration efforts should focus on larger meadows, or meadows adjoining other grasslands, to better support area-sensitive species of grassland birds.

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