grassland birds have become a conservation priority, and concern over grassland birds has contributed to efforts to protect and restore tallgrass prairies kn8-18.1(v)6.28.1V] TJ1

Next, we asked whether the occurrence and density of birds was affected by the size and shape of prairie fragments and by the degree of urbanization surrounding them. There are a significant number of prairie remnants in and around urban areas and, although there are compelling reasons to maintain them for social and educational purposes (Miller and Hobbs 2002), the question remains whether small fragments of tallgrass prairie still retain their conservation value as surrounding landscapes become more urbanized (Shafer 1997).

ME HOD

, . We studied tallgrass prairie fragments in and around Omaha and Lincoln, Nebraska, and Council Bluffs, Iowa (Mount 2013). Prior to European settlement, the region was dominated by tallgrass prairie, but is now dominated by suburban and urban areas surrounded by row-crop agricultural fields. Sites included remnant tallgrass prairies that have been protected, as well as sites that have been restored from agriculture to tallgrass prairie. We included all accessible urban and suburban prairie remnants, whereas rural sites were selected from among available grasslands nearest to the urban areas. All sites are managed in a similar fashion by prescribed burning, grazing, or mowing. Prairies burned in the spring were not surveyed that season. In 2011, we surveyed 20 sites. Extreme flooding the summer of 2011 resulted in the loss of five rural grasslands located at DeSoto and Boyer Chute National Wildlife Refuges along the Missouri River. In addition, two sites used in 2011 were burned in the spring of 2012. In 2012, we retained 13 original sites and added eight new sites.

We quantified urbanization surrounding each study site based on 1-m-resolution digital orthoimagery acquired by the U.S. Farm Service Agency in 2010 and obtained from the Nebraska Department of Natural Resources (http://www.dnr.ne.gov/digital-imagery-1993-through-2012-1-2-meter). Imurbanization as a categorical variable in our analyses. We used ANOVA to test whether there were significant differences among the categories of urbanization in vegetation characteristics (forb density, shrub density, mean vegetation height, and total grass hits) and site characteristics (area and edge-to-interior ratio). We chose these vegetation characteristics because each describes a different aspect of vegetation in grassland habitats. Forb density and shrub density provide an indication of the structural diversity of the grassland, mean vegetation height provides an indication of vegetation height, weighted by vegetation density, and total grass hits indicate the overall density of grass (Fisher and Davis 2010). Summary descriptions of habitat variables are presented as means $\pm$ SE.

Although we recorded all species seen or heard during bird surveys, our analyses are limited to three obligate grassland bird species (Dickcissels [*Spiza americana*], Grasshopper Sparrow [*Ammodramus savannarum*], and Eastern Meadowlarks [*Sturnella magna*]) for which we recorded sufficient observations to analyze their densities and occurrence. Other obligate grassland bird species, including Henslow's

Table 1. Continued

	K[a]	AICc[b]	□ AIC[c]	w_i[d]
Grass Hits	3	140.77	4.87	0.04
Forb Density + Veg H	4	141.42	5.52	0.03
Null	2	141.49	5.59	0.02
Shrub Density + Forb Density + Grass Hits	5	142.27	6.37	0.02
Shrub Density + Veg H	4	142.61	6.71	0.01
Forb Density +				

Table 2. Model selection results of the effects of vegetation and patch covariates on densities of Dickcissels, Grasshopper Sparrows, and Eastern Meadowlarks. Models with $w_i < 0.01$ are not presented.

	K[a]	AICc[b]	□ AICc[c]	w_i[d]
Dickcissel ($N = 752$, 26 m, 182 m)[e]				
Density Models: Vegetation Characteristics + Year				
Vegetation Height + Year ($P = 0.59$)[f]	6	1255.85	0.00	0.40
Vegetation Height + Shrub Density + Year	7	1257.24	1.39	0.20
Vegetation Height + Forb Density + Year	7	1258.09	2.24	0.13
Vegetation Height _ Shrub Density + Grass Hits + Year	8	1259.22	3.37	0.07
Vegetation Height + Shrub Density + Forb Density + Year	8	1259.52	3.67	0.06
Vegetation Height + Grass Hits + Year	6	1259.73	3.88	0.06
Vegetation Height + Forb Density + Grass Hits + Year	8	1260.14	4.29	0.05
Veg. Height + Shrub Density +Forb Density + Grass Hits + Year	9	1261.49	5.63	0.02
Density Models: Patch + Vegetation Characteristics + Year				
Urban + Edge + Vegetation Height + Year ($P = 0.66$)	9	1234.45	0.00	0.97
Edge + Vegetation Height + Year	7	1241.46	7.01	0.03
Grasshopper Sparrow ($N = 200$; 19 m, 95 m)				
Density Models: Vegetation Characteristics				
Vegetation Height + Shrub Density ($P = 0.44$)	6	681.63	0.00	0.32
Vegetation Height	5	682.58	0.95	0.20
Vegetation Height + Shrub Density + Forb Density	7	683.85	2.22	0.10
Vegetation Height + Shrub Density + Grass Hits	7	683.86	2.23	0.10
Vegetation Height + Grass Hits	6	684.70	3.07	0.07
Vegetation Height + Forb Density	6	684.76	3.13	0.07
Shrub Density	5	685.88	4.25	0.04
Veg. Height +Shrub Density + Forb Density + Grass Hits	8	686.09	4.46	0.03
Vegetation Height + Forb Density + Grass Hits	7	686.87	5.23	0.02
Shrub Density + Forb Density	6	686.91	5.28	0.02
Shrub Density + Forb Density + Grass Hits	7	688.75	7.12	0.01
No covariates (null)	4	689.50	7.87	0.01
Forb Density	5	689.87	8.23	0.01
Density Models: Patch + Vegetation Characteristics				
Urban + Vegetation Height + Shrub Density ($P = 0.40$)	8	677.79	0.00	0.68
Edge + Vegetation Height + Shrub Density	7	680.09	2.30	0.22
Vegetation Height + Shrub Density	6	681.63	3.84	0.10
Eastern Meadowlark ($N = 82$; 86 m, 258 m)				
Density Models: Vegetation Characteristics				
Vegetation Height + Grass Hits ($P = 0.52$)	6	409.78	0.00	0.34
Vegetation Height + Grass Hits + Shrub Density	7	410.40	0.62	0.25
Vegetation Height + Grass Hits + Forb Density	7	410.60	0.82	0.23
Vegetation Height + Grass Hits + Shrub Density + Forb Density	8	411.40	1.62	0.15
Density Models: Patch + Vegetation Characteristics				
Urban + Grass Hits + Vegetation Height ($P = 0.55$)	8	394.02	0.00	0.73
Urban + Edge + Grass Hits + Vegetation Height	9	396.03	2.01	0.27

[a]Number of parameters.
[b]Akaike's information criterion corrected for small sample sizes.
[c]The difference in AICc values between the current and top-ranked model's AICc value.
[d]Weight of evidence supporting the model.
[e]Number of birds detected, distance bin size, and the maximum distance included in each analysis.
[f]*P*-values from Freeman-Tukey goodness of fit test, with values >0.05 indicating adequate fit.

Study sites ranged in area from 0.9 ha to 55.6 ha, and had edge-to-interior ratios ranging from 0.044 to 0.006. We studied 28 sites across the 2 yr, and found no systematic differences among sites with low, moderate, and high levels of surrounding urbanization in either total area (low = 15.5 ± 3.5 ha, moderate = 21.1 ± 5.5 ha, high = 15.6 ± 5.1 ha; $F_{2,25} = 0.4$, $P = 0.67$) or edge-to-interior ratio (low = 0.013 ± 0.002 m/m^2, moderate = 0.014 ± 0.003

m/m^2, high $= 0.018 \pm 0.003$ m/m^2; $F_{2,25} = 0.9$, $P = 0.41$). There was a significant negative correlation between the edge-to-interior ratio and area among sites ($r = -0.68$, $N = 28$, $P < 0.001$).

O In 2011, we recorded 293 Dickcissels, 121 Grasshopper Sparrows, and 44 Eastern Meadowlarks. Numbers of these same species recorded in 2012 were 463, 79, and 49, respectively. We used all sampling periods for analysis of occurrence.

Including year as a factor explained the occurrence of Dickcissels better than the null model (□ AICc$_{Null\text{-}Year}$ = 3.4). The model with mean vegetation height and year was the best model among those including vegetation characteristics (Table 1). However, the model including only year as a covariate had a ΔAICc = 0.51 and the AICc weights of the two models were similar ($w_{Veg\ Ht + Year} = 0.22$, $w_{Year} = 0.17$). Therefore, we concluded that the addition of vegetation variables did not improve the explanatory power of the models.

When comparing models of patch characteristics, those including edge-to-interior ratio had the lowest ΔAICc values and a cumulative AICc weight of 0.82 (Table 1). Model averaging

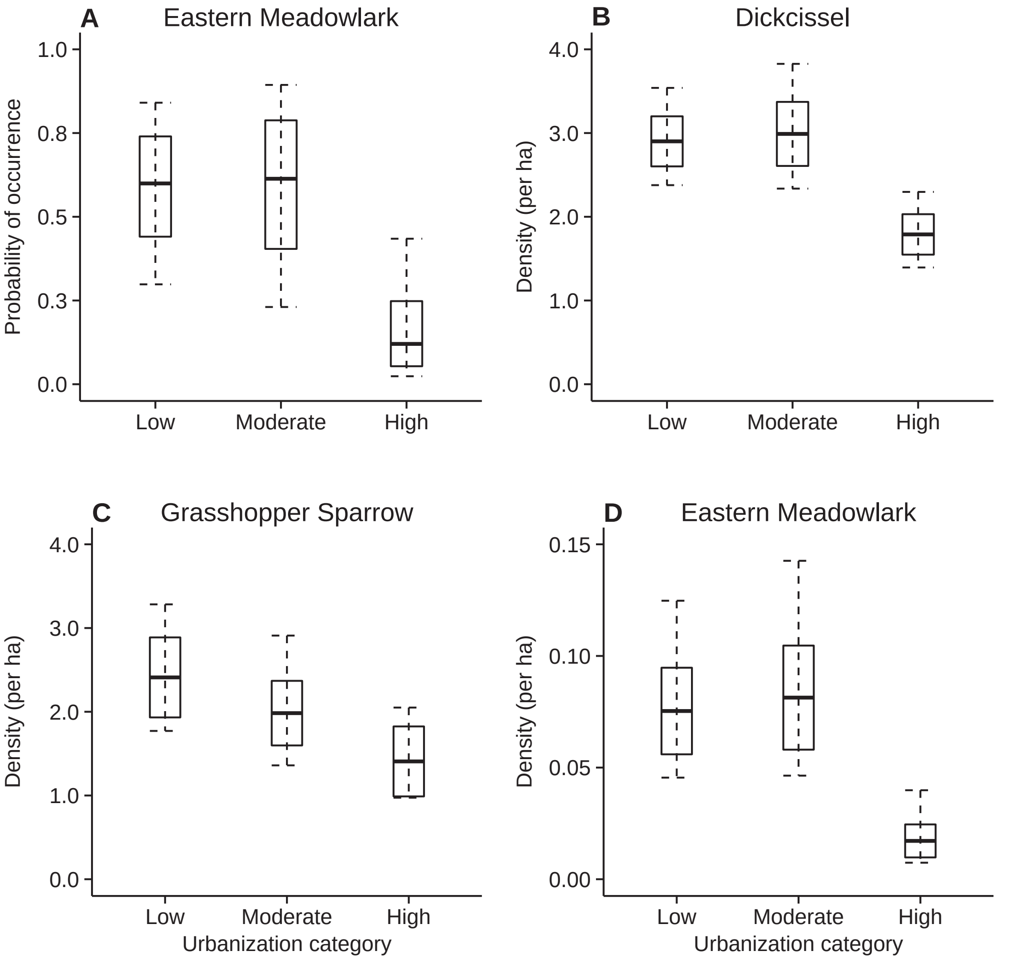

Fig. 2. The influence of urbanization on the probability of occurrence of (A) Eastern Meadowlarks and the density of (B) Dickcissels, (C) Grasshopper Sparrows, and (D) Eastern Meadowlarks. Bold crossbars indicate the predicted probability of occurrence and density produced from the most informative models, boxes encompass ± SE of the predicted value, and dashed lines represent upper and lower 95% confidence bounds for the predictions.

affected Grasshopper Sparrow density ($\beta = 0.19 \pm 0.09$; Fig. 1G).

Among models addressing hypotheses about patch characteristics, the most likely model included urbanization, and was three times more likely than the model including edge-to-interior ratio, and nearly seven times more likely than the null vegetation model with vegetation height and shrub density (Table 2). Sites with the highest levels of surrounding urbanization had the lowest densities of Grasshopper Sparrows ($\beta_{moderate} = 0.51 \pm 0.30$, $\beta_{low} = 0.77 \pm 0.26$; Fig. 2C).

For Eastern Meadowlarks, the minimum

from perceived risks associated with fire and from smoke production (Bock and Bock 1998). Given the scarcity of opportunities to conserve prairies, maintaining the quality of management at these sites to also maximize their contribution to conservation of native grassland species is important.

ACKNO LEDGMEN

This project was supported by grants from the University of Nebraska Omaha, including the Department of Biology, Graduate Research and Creative Activity (GRACA), University Committee on Research and Creative Activity (UCRCA), the Nelle Boyer and Mary Ellen Patterson Phi Delta Gamma Scholarship, and the Bouteloua Scholarship. Other support included a Grant-in-Aid of Research from the National Academy of Sciences, administered by Sigma Xi, the Scientific Research Society, and the University of Nebraska Lincoln, Center for Great Plains Studies Grant-in-Aid. We would like to thank J. Janes, J. Andersen, A. Zigler, L. Brown, and M. Egan for assistance in the field and G. Pollock for his assistance in locating urban prairie fragments and helping to arrange access. Finally, this project would not have been possible without the cooperation and hospitality of the landowners and managers who provided access to their prairies. We thank the editors and anonymous reviewers for improving the manuscript by providing useful comments and suggestions.

LI E A E CI ED

ADAMS, H. L., L. BURGER, AND S. RIFFELL. 2013. Disturbance and landscape effects on avian nests in agricultural conservation buffers. Journal of Wildlife Management 77: 1213–1220.

ALBERTI, M., J. M. MARZLUFF, E. SHULENBERGER, G. BRADLEY, C. RYAN, AND C. ZUMBRUNNEN. 2003. Integrating humans into ecology: opportunities and challenges for studying urban ecosystems. BioScience 53: 1169–1179.

AUSPREY, I. J., AND A. D. RODEWALD. 2011. Postfledging survivorship and habitat selection across a rural-to-urban landscape gradient. Auk 128: 293–302.

AYCRIGG, J. L., A. DAVIDSON, L. K. SVANCARA, K. J. GERGELY, A. MCKERROW, AND J. M. SCOTT. 2013. Representation of ecological systems within the protected areas network of the continental United States. PLoS ONE 8: e54689.

BATES, D., M. MAECHLER, AND B. BOLKER. [online]. 2012. lme4: Linear mixed effects models using S4 classes. R package version 0.999999–0. <http://CRAN.R-project.org/package=lme4> (Accessed 11 June 2013).

BOCK, C. E., J. H. BOCK, AND B. C. BENNETT. 1999. Songbird abundance in grasslands at a suburban interface on the Colorado High Plains. Studies in Avian Biology 19: 131–136.

BOCK, J. H., AND C. E. BOCK. 1998. Tallgrass prairie: remnants and relicts. Great Plains Research 8: 213–230.

BRIGGS, J. M., A. K. KNAPP, J. M. BLAIR, J. L. HEISLER, G. A. HOCH, M. S. LETT, AND J. K. MCCARRON. 2005. An ecosystem in transition: causes and consequences of the conversion of mesic grassland to shrubland. BioScience 55: 243–254.

BUCKLAND, S. T., D. R. ANDERSON

———, ———, ———, ———, ———, A. L. ZIMMERMAN, AND B. R. EULISS [online]. 2003b. Effects of management practices on grassland birds: Dickcissel. USGS, Northern Prairie Wildlife Research Center, Jamestown, ND. <http://www.npwrc.usgs.gov/resource/literatr/grasbird/dick/dick.htm> (Accessed 5 January 2014).

ESRI (ENVIRONMENTAL SYSTEMS RESOURCE INSTITUTE). 2010. ArcMap 10.1. ESRI, Redlands, CA.

FISHER, R. J., AND S. K. DAVIS. 2010. Wiens to Robel: a review of grassland-bird habitat selection. Journal of Wildlife Management 74: 267–273.

FISKE, I., AND R. B. CHANDLER. 2011. unmarked: an R package for fitting hierarchical models of wildlife occurrence and abundance. Journal of Statistical Software 43: 1–23.

FITZGERALD, J. A., AND D. N. PASHLEY [online]. 2000. Partners in Flight bird conservation plan for dissected till plains. American Bird Conservancy. Brentwood, MO. <http://www.

and R. Donnelly, eds.), pp. 19–47. Kluwer Academic Publishers, Norwell, MA.
———, AND K. EWING. 2001. Restoration of fragmented

———, ———, AND J. A. SHAFFER. 2005. Variability in vegetation effect on density and nesting success of grassland birds. Journal of Wildlife Management 69: 185–197.

———, ———, T. M. DONOVAN, AND W. D. SVEDARSKY. 2006. Patch size and landscape effects on density and nesting success of grassland birds. Journal of Wildlife Management 70: 158–172.

WOOD, W. E., AND S. M. YEZERINAC. 2006. Song Sparrow (