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Phillip J. Leonard

Douglas R. Wood

Wayne E. Meyer

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PHILLIP J. LEONARD, DOUGLAS R. WOOD, AND WAYNE E. MEYER

Department of Biological Sciences, Southeastern Oklahoma State University, Durant, OK, USA 74701 (PJL, DRW)
Biology Department, Austin College, Sherman, TX, USA 75090 (WEM)

ABSTRACT Over the last 50 years, grassland birds experienced rapid declines due to habitat loss and degradation as a result of agricultural practices. Our objective was to document the diversity, abundance, and nest success of bird communities using managed prairie and agricultural plots at the Tishomingo National Wildlife Refuge (NWR) in southern Oklahoma and Hagerman NWR in northern Texas. From April 1 to July 15, 2013–2014, point count surveys, nest searches, nest monitoring, and vegetation sampling were conducted among three habitat treatments: managed prairie, unharvested wheat, and fallow agricultural plots. Species richness values for potential nesting species were higher in managed prairies at both refuges, whereas species abundance rates varied among treatments. Nest success rates were low at both refuges due to nest abandonment and predators. Due to vegetation diversity, species were more likely to nest in managed prairies compared to agricultural plots with more homogenous vegetation at both refuges. Managed prairies at both refuges were relatively small and fragmented resulting in edge effects, such as increased nest predation and brood parasitism. We recommend increasing the area of managed prairies to provide more habitat for bird species at both refuges.

KEY WORDS Agriculture, grassland birds, nest success, Oklahoma, prairie, Texas.

Since the 1960s, the North American Breeding Bird Survey (hereafter BBS) has quantified the population trends of grassland bird species and found them to be declining more rapidly than any other bird community in North America (Robbins et al. 1986, Johnson and Igl 2001, Vickery and Herkert 2001, Ribic et al. 2009a, Sauer et al. 2014). Breeding bird survey trend data for Oklahoma show that species such as field sparrow (*Spizella pusilla*) and dickcissel (*Spiza americana*) have experienced declines in breeding populations (–2.52 %/year, and –0.14 %/year, respectively) since 1966 (Sauer et al. 2014). Currently, only 4% of the historical 68 million ha of prairie remain (Steinauer and Collins 1996, Herkert et al. 2003). The primary causes of these declines were the loss and degradation of grassland habitats, specifically, agroconversion of native prairies (Askins et al. 2007, Noss et al. 1995, Vickery and Herkert 2001). As a result of agroconversion, grassland birds were forced to use agricultural plots as an alternative to historical prairies. Agricultural fragmentation reduces both the occurrence and density of breeding birds in small habitat fragments leading to sink populations (Herkert 1994, Vickery et al. 1994, Winter and Faaborg 1999, Herkert et al. 2003). Habitat fragmentation also exposes birds to increased nest predation and brown-headed cowbird (*Molothrus ater*) brood parasitism. Birds nesting in agricultural plots are subject to anthropogenic disturbances such as pesticides and crop harvest (Nocera et al. 2011).

The U. S. Fish and Wildlife Service (hereafter USFWS) solicited regional field research to determine the impacts of site-specific management of prairie restoration and agricultural plots on grassland bird species' abundance, diversity, density, and nest success (Winter et al. 2006, Ribic et al. 2009b). This management strategy is employed by the USFWS to a complex of refuges in the Midwest region. Due to management paradigm shifts and funding, National Wildlife Refuges are exploring converting agricultural plots to native prairie plots in order to meet new management objectives. Our primary objectives were to 1) document the diversity, relative abundance, and density of bird communities using managed prairie, unharvested wheat, and fallow agricultural plots at the Tishomingo National Wildlife Refuge (hereafter Tishomingo NWR) in southern Oklahoma and the Hagerman National Wildlife Refuge (hereafter Hagerman NWR) in northern Texas, 2) determine avian nest success among treatments, and 3) use a conservation index score to rank the value of each treatment type for grassland bird species.

STUDY AREA

The 6,663 ha Tishomingo NWR was located in southern Oklahoma (14S 717068 E, 3786016 N) and provided a diverse landscape for wildlife species including managed prairies and agricultural fields (Diggs and Wood 2010). Agricultural plots were established to provide forage for wintering waterfowl, whereas managed prairies were intended to provide nesting habitat for resident and migrant grassland bird species (U.S. Fish and Wildlife Service 2010). Hagerman NWR in northern Texas (14S 708300 E, 3735651 N) was a 4,856-ha refuge managed similarly to Tishomingo NWR. Although habitat management schemes were similar, Hagerman NWRs

agricultural plots were structurally and compositionally different than agricultural plots at Tishomingo NWR. Seven loam or sandy soil types occurred within the research plots selected at both refuges (Natural Resources Conservation Service 2014). We selected nine research plots at each refuge. Three habitat management types: managed prairies, fallow plots, and unharvested wheat plots were assigned to three plots each.

At Tishomingo NWR, we selected three agricultural fields that were divided into two halves with half assigned to the unharvested wheat treatment and the other half assigned to the fallow treatment. At Hagerman NWR, 3 plots were selected that had fallow (unplanted for 2–6 yr) or unharvested wheat patches. Unharvested wheat plots totaled 69.9 ha (6.5, 6.5, 7.5, 11.3, 17.5, 20.6 ha respectively), whereas fallow plots totaled 145.7 ha (6.1, 6.5, 10.7, 11.4, 25.5, 85.5 ha respectively). Unharvested wheat fields consisted of winter wheat (*Triticum aestivum*), arrowleaf clover (*Trifolium vesiculosum*), hairy vetch (*Vicia villosa*), and common sunflower (*Helianthus annua*), whereas fallow fields consisted of a variety of row crops, grasses, and herbaceous vegetation (Leonard 2015). Managed prairies totaled 83.4 ha (10, 10, 12, 12.5, 18.7, 20.2 ha respectively). Vegetation in managed prairies included Kaw big bluestem (*Andropogon gerardii*), Cimarron little bluestem (*Schizachyrium scoparium*), Cheyenne indiangrass (*Sorghastrum nutans*), Blackwell switchgrass (*Panicum virgatum*), El Reno sideoats grama (*Bouteloua curtipendula*), Texoka buffalo grass (*Buchloe dactyloides*), and Sabine

Table 1. Mean number of detections per point (± SD) of bird species among treatment plots at Tishomingo and Hagerman NWRs, 2013–2014.

Species	Managed Prairie (Tishomingo)	Managed Prairie (Hagerman)	Fallow (Tishomingo)	Fallow (Hagerman)	Unharvested Wheat (Tishomingo)	Unharvested Wheat (Hagerman)
Wild Turkey	-	0.05 (0.19)	0.02 (0.08)	-	-	-
Killdeer	0.03 (0.04)	-	0.01 (0.03)	-	-	0.01 (0.03)
Mourning Dove	0.13 (0.12)	0.20 (0.18)	0.18 (0.17)	0.12 (0.13)	0.20 (0.23)	0.12 (0.13)
Yellow-billed Cuckoo	0.02 (0.04)	0.01 (0.02)	0.01 (0.03)	-	0.02 (0.04)	-
Ruby-throated Hummingbird	0.03 (0.03)	0.03 (0.04)	0.05 (0.07)	0.01 (0.04)	0.13 (0.08)	-
Western Kingbird	0.01 (0.02)	0.03 (0.01)	0.01 (0.02)	0.01 (0.02)	0.03 (0.07)	0.01 (0.02)
Eastern Kingbird	0.01 (0.02)	0.01 (0.05)	0.09 (0.15)	-	0.03 (0.06)	0.01 (0.02)
Scissor-tailed Flycatcher	0.04 (0.05)	0.05 (0.08)	0.14 (0.20)	0.06 (0.08)	0.09 (0.20)	0.08 (0.11)
White-eyed Vireo	0.01 (0.02)	-	-	-	-	-
Bell's Vireo	0.03 (0.09)	-	-	-	-	-
Carolina Wren	-	0.004 (0.01)	0.01 (0.03)	-	-	-
Bewick's Wren	-	0.01 (0.02)	-	-	-	-
Blue-gray Gnatcatcher	0.17 (0.19)	0.15 (0.18)	0.002 (0.01)	0.01 (0.02)	-	0.01 (0.04)
Eastern Bluebird	0.05 (0.03)	0.11 (0.17)	0.03 (0.09)	0.47 (0.38)	0.24 (0.57)	0.14 (0.16)
Gray Catbird	0.01 (0.02)	-	-	-	-	-
Northern Mockingbird	0.03 (0.05)	0.02 (0.05)	0.01 (0.03)	-	-	-
Brown Thrasher	0.01 (0.02)	-	0.002 (0.01)	-	0.01 (0.02)	-
Common Yellowthroat	0.01 (0.02)	-	0.01 (0.03)	-	0.02 (0.04)	-
Yellow-breasted Chat	0.06 (0.09)	-	-	-	-	-
Field Sparrow	0.01 (0.02)	0.004 (0.01)	0.01 (0.03)	-	-	-
Lark Sparrow	0.01 (0.02)	0.004 (0.01)	0.02 (0.05)	0.01 (0.02)	-	0.004 (0.01)
Grasshopper Sparrow	0.02 (0.05)	0.01 (0.02)	0.03 (0.05)	0.13 (0.16)	0.02 (0.04)	0.01 (0.02)
Northern Cardinal	0.22 (0.18)	0.29 (0.23)	0.02 (0.04)	0.06 (0.08)	0.05 (0.11)	0.01 (0.03)
Blue Grosbeak	0.01 (0.02)	0.03 (0.04)	0.01 (0.05)	0.02 (0.04)	0.01 (0.02)	0.01 (0.02)
Indigo Bunting	0.05 (0.04)	0.02 (0.06)	0.04 (0.07)	0.01 (0.02)	0.07 (0.09)	-
Painted Bunting	0.14 (0.08)	0.29 (0.28)	0.03 (0.06)	0.06 (0.08)	0.01 (0.02)	0.01 (0.02)
Dickcissel	0.32 (0.25)	1.47 (0.91)	0.57 (0.53)	1.36 (1.25)	3.14 (2.41)	0.97 (1.00)
Red-winged Blackbird	0.01 (0.02)	0.11 (0.14)	1.82 (4.12)	0.03 (0.07)	0.33 (0.37)	0.47 (0.61)
Eastern Meadowlark	-	-	0.002 (0.01)	-	0.06 (0.09)	0.01 (0.02)
Brown-headed Cowbird	0.72 (0.25)	0.33 (0.20)	0.87 (0.50)	0.09 (0.10)	0.95 (0.52)	0.17 (0.21)
American Goldfinch	0.01 (0.02)	0.004 (0.01)	0.02 (0.09)	0.02 (0.03)	-	-

Illinois bundleflower (*Desmanthus illinoensis*). Woody vegetation did occur in the managed prairies including sand plum (*Prunus angustifolia*), eastern red cedar (*Juniperus virginiana*), honey locust (*Gleditsia triacanthos*), winged elm (*Ulmus alata*), cedar elm (*U. crassifolia*), and honey mesquite (*Prosopsis glandulosa*). Although managed prairies were scheduled for prescribed burning, no prescribed burns were conducted during the course of the study (Leonard 2015).

METHODS

From 1 April to 15 July 2013–2014, we conducted weekly point count surveys following methods of Hutto et al. (1986) and Robbins et al. (1986). We conducted nest searches, nest monitoring, and vegetation sampling among managed prairie, unharvested wheat, and fallow plots at both refuges. At Tishomingo NWR, we selected 38 randomly-generated point count locations and 44 at Hagerman NWR. All points were > 100 m apart from each other and > 10 m from any hard edge. During the 2-yr study, we conducted 1,584 point count surveys, with each point count location surveyed weekly between sunrise and 1100 hr (Ralph et al. 1993). We observed an initial 1-min settling period at each point for birds to adjust to any disturbance (Ralph et al. 1993). We rescheduled surveys if inclement weather occurred (Robbins et al. 1986, Ralph et al. 1993). We recorded all birds heard or observed within a 50-m radius, with birds recorded at 10-m distance band intervals (Knutson et al. 2008). Each count was 10 min in length to follow sampling and analysis protocols for program DISTANCE 6.2 (hereafter DISTANCE; Knutson et al. 2008). Each week, we varied the order in which the point count surveys were conducted to account for variation in temporal detection rates (Knutson et al. 2008).

Nest Searching and Monitoring

We searched for nests using both methodical search methods (i.e., walking transects spaced every 5 m apart across each plot) and behavior-specific searches based on observations of territorial birds and birds carrying nesting material (Ralph et al. 1993). We georeferenced each nest with a hand-held Global Positioning System device and a piece of flagging tape was placed 3 m away from the nest to facilitate find the nest during subsequent monitoring.

We checked nests every 3–4 days to determine status and then checked daily near expected fledging dates. We minimized time spent at a nest to reduce the potential for nest depredation and brood parasitism. For each nest, we recorded clutch size, number of eggs hatched, and number of young fledged. We defined nest success as a nest that produced ≥ 1 fledgling (Wood and Reasor 2006). We documented all nest loss and cowbird parasitism events. When nest depredation occurred, we attempted to classify the predator species based upon nest camera photos, animal sign, or observations of a predator species at the nest (Fies and Puckett 1999, Staller et al. 2005).

Nest Cameras

We used Bushnell Trophy Cam HDs™ Model #11-9437c to monitor 23 nests to observe nest loss and brood parasitism events. We mounted cameras on tripods and placed them nearby to limit nest disturbance. We set nest cameras to take

Table 2. Estimated population sizes ($\hat{N}$) and species-specific densities [D (#/ha)] with 95% confidence intervals (95% CI) for potential nesting species at the Tishomingo and Hagerman NWRs, 2013–2014.

	Tishomingo NWR				Hagerman NWR			
Species	$\hat{N}$ (180 ha)	95% CI	*D*	95% CI	$\hat{N}$ (118 ha)	95% CI	*D*	95% CI
Mourning Dove	98	69–139	0.01	0.006–0.01	43	22–81	0.01	0.004–0.01
Yellow-billed Cuckoo	5	2–11	0.001	0.001–0.003	-	-	-	-
Ruby-throated Hummingbird	101	74–302	0.02	0.02–0.03	-	-	-	-
Eastern Kingbird	24	12–46	0.01	0.003–0.01	-	-	-	-
Scissor-tailed Flycatcher	36	23–56	0.01	0.006–0.01	-	-	-	-
Blue-gray Gnatcatcher	7	3–16	0.002	0.001–0.004	-	-	-	-
Eastern Bluebird	23	13–38	0.01	0.003–0.01	35	23–54	0.01	0.004–0.01
Lark Sparrow	5	2–15	0.001	0.0004–0.004	-	-	-	-
Grasshopper Sparrow	6	2–15	0.002	0.001–0.004	-	-	-	-
Northern Cardinal	14	8–28	0.004	0.002–0.01	21	13–35	0.01	0.01–0.02
Indigo Bunting	13	8–21	0.003	0.002–0.005	-	-	-	-
Painted Bunting	11	5–21	0.003	0.001–0.01	22	14–34	0.01	0.01–0.02
Dickcissel	269	212–340	0.02	0.02–0.03	239	183–312	0.04	0.03–0.05
Red-winged Blackbird	357	193–601	0.07	0.05–0.13	48	17–63	0.02	0.01–0.03
Brown-headed Cowbird	335	237–1047	0.11	0.07–0.23	36	25–53	0.06	0.04–0.09

Table 3. Estimated population sizes ($\hat{N}$) and treatment specific densities [D (#/ha)] with 95% confidence intervals (95% CI) for potential nesting species at the Tishomingo and Hagerman NWRs, 2013–2014.

Refuge	Estimate	Mourning Dove	Eastern Bluebird	Dickcissel	Brown-headed Cowbird
Tishomingo	Managed Prairie $\hat{N}$ (32 ha)	15	-	13	38
	95% CI	6–35	-	7–27	27–51
	Managed Prairie *D*	0.004	-	0.003	0.01
	95% CI	0.002–0.01	-	0.002–0.01	0.01–0.09
	Fallow $\hat{N}$ (117.5 ha)	72	-	90	321
	95% CI	48–111	-	71–114	69–1287
	Fallow *D*	0.02	-	0.02	0.08
	95% CI	0.01–0.03	-	0.02–0.03	0.03–0.27
	Unharvested Wheat $\hat{N}$ (31.5 ha)	11	-	165	91
	95% CI	5–23	-	116–236	43–212
	Unharvested Wheat *D*	0.003	-	0.04	0.02
	95% CI	0.001–0.01	-	0.03–0.06	0.01–0.05
Hagerman	Managed Prairie $\hat{N}$ (51.4 ha)	30	8	95	21
	95% CI	13–71	3-19	75–122	12–35
	Managed Prairie *D*	0.02	0.004	0.05	0.01
	95% CI	0.01–0.04	0.002–0.01	0.04–0.06	0.01–0.02
	Fallow $\hat{N}$ (28.2 ha)	7	19	56	7
	95% CI	3-16	11–35	31–104	3–17
	Fallow *D*	0.003	0.01	0.03	0.004
	95% CI	0.001–0.01	0.01–0.02	0.02–0.05	0.002–0.01
	Unharvested Wheat $\hat{N}$ (38.4 ha)	6	8	87	8
	95% CI	2–14	3–19	51–150	4–17
	Unharvested Wheat *D*	0.003	0.004	0.05	0.01
	95% CI	0.001–0.01	0.002–0.01	0.03–0.08	0.002–0.01

three images per motion-based triggering with a field scan interval of 15-min and a motion trip interval of 10-min. These rates were decreased to 10-min and 5-min respectively when nestlings were present.

Statistical Analysis

We defined relative abundance as the number of individuals of each species/point, as well as by treatment type. We used SPSS Statistics 21 software to run general linear models to determine if there were any significant differences among treatments ($\alpha = 0.05$). We defined species density as the number of individuals of each species/ha. We used DISTANCE software to analyze distance-based point count data. We set the distance value for each detection at the midpoint value for each 10-m band. We fitted uniform, half-normal and hazard-rate distributions with no expansions, cosine expansions, and simple polynomial expansions to each species' data set (Buckland et al. 2004). We used Akaike's Information Criterion corrected for small sample sizes (AIC_c) to identify the best model for each species (Burnham and Anderson 2002). After initial density analysis, we post-stratified each species' data to provide species-specific density and population estimates within treatments (Buckland et al. 2004).

We used point count detection data from the complete 10-min count to calculate a Shannon-Wiener Diversity Index to analyze avian species diversity and evenness for all three treatments (Shannon and Wiener 1949). The Shannon-Wiener Diversity Index consists of three components: the diversity observed (H), the maximum possible diversity (H_{max}), and how evenly each species is distributed among treatment plots (E).

We used Partners in Flight Continental Concern Scores (hereafter, PIF scores) for each species to calculate a conservation index score for each treatment type by summing the PIF scores for each species (Nuttle et al. 2003, Partners in Flight Science Committee 2012). We calculated index scores for both potential nesting species and for species that did nest in each treatment type.

RESULTS

Species Richness

At Tishomingo NWR, the highest number of potential nesting species were detected in managed prairies ($n = 27$), followed by fallow plots ($n = 26$), and unharvested wheat plots ($n = 18$). Similarly, at Hagerman NWR, the highest

number of potential nesting species were detected in managed prairies (n = 23), followed by fallow plots (n = 16) and unharvested wheat plots (n = 16). At both refuges, managed prairies had diversity H values of 2.34 and 1.95, maximum possible diversity H_{max} values of 3.30 and 3.14, and evenness E values of 0.71 and 0.65, respectively. Fallow plots at both refuges had diversity H values of 1.76 and 1.55, maximum possible diversity H_{max} values of 3.26 and 2.77, and evenness E values of 0.54 and 0.56, respectively. At both refuges, unharvested wheat plots had diversity H values of 1.49 and 1.67, maximum possible diversity H_{max} values of 2.89 and 2.77, and evenness E values of 0.52 and 0.60, respectively.

Relative Abundance

At Tishomingo NWR, mean relative abundance was calculated for each treatment type (Table 1). White-eyed vireo ($F_{2,1540}$ = 4.55, P = 0.01), Bell's vireo ($F_{2,1540}$ = 11.6, P < 0.01), gray catbird ($F_{2,1540}$ = 4.55, P = 0.01), and yellow-breasted chat ($F_{2,1540}$ = 14.99, P < 0.01) abundances were greater in managed prairies than other treatments. Ruby-throated hummingbird ($F_{2,1540}$ = 6.9, P = 0.01), dickcissel ($F_{2,1540}$ = 66.37, P < 0.01), and eastern meadowlark ($F_{2,1540}$ = 6.13, P < 0.01) abundances were greater in unharvested wheat plots than other treatments.

At Hagerman NWR, painted bunting ($F_{2,1540}$ = 6.72, P < 0.01) abundances were greater in managed prairies than other treatments. Killdeer ($F_{2,1540}$ = 3.04, P = 0.05) abundances were greater in unharvested wheat plots than other treatments. Eastern bluebird ($F_{2,1540}$ = 21.98, P < 0.01), lark sparrow ($F_{2,1540}$ = 3.12, P = 0.04) and grasshopper sparrow ($F_{2,1540}$ = 5.05, P = 0.01) abundances were greater in fallow plots than other treatments.

Conservation Index

At Tishomingo NWR, managed prairies had the greatest conservation value for potential nesting species detected during point counts (236), followed by fallow plots (232) and unharvested wheat plots (164). Similarly, managed prairies at Hagerman NWR had the greatest conservation value for potential nesting species (200), followed by fallow plots (134) and unharvested wheat plots (132). Managed prairies also had the highest conservation score (87) for species that nested at Tishomingo NWR, followed by unharvested wheat plots (10) and fallow plots (5); however, at Hagerman NWR, fallow plots had the highest conservation score (17) for nesting species, followed by managed prairies (15) and unharvested wheat plots (10).

Population Density

Of the 30 potential nesting species at Tishomingo NWR, 15 had high enough detection rates to provide density and population estimates (Table 2). Half-normal functions with no expansions provided the model of best fit for 13 of 15 species. For ruby-throated hummingbird and brown-headed cowbird, hazard-rate functions with no expansions provided the model of best fit. Only three of 15 species, had enough observations to be post-stratified by treatment type to provide a population estimate and density data for each treatment (Table 3). Mourning dove population densities and estimated population sizes were greater in fallow plots than in unharvested wheat and managed prairies (Table 3). Dickcissel population densities were greater in unharvested wheat plots than in fallow plots and managed prairies (Table 3). Brown-headed cowbird population densities were greater in fallow plots than in unharvested wheat and managed prairies (Table 3).

Of the 25 potential nesting species at Hagerman NWR, seven had high enough detection rates to provide density and population estimates (Table 2). Half-normal functions with no expansions provided the model of best fit for all seven species. Four of the seven species had enough observations to be post-stratified by treatment type to provide a population estimate and density data for each treatment (Table 3). Mourning dove, dickcissel, and brown-headed cowbird densities were greater in managed prairies than other treatments; however, eastern bluebird density was greater in fallow plots than other treatments (Table 3).

Nest Success

Forty-eight nests of 10 species (Table 4) were found among treatment plots at Tishomingo NWR. Thirty-nine (81%) occurred in managed prairies, eight (17%) in unharvested wheat plots, and one (2%) in a fallow plot. Nine species nested in managed prairies and unharvested wheat plots and fallow plots had one species nesting within them (Table 4). Nest success was low among all treatments at Tishomingo NWR. Only 17% of nests successfully fledged young (Table 4). Eleven nests were parasitized by cowbirds: Bell's vireo (5), dickcissel (2), yellow-breasted chat (1), northern cardinal (1), indigo bunting (1), and painted bunting (1). Of the 17 cowbird eggs laid, only 2 hatched, one egg in a yellow-breasted chat nest and one egg in a dickcissel nest. Neither chick fledged as both nests were depredated. Twenty-four nests were abandoned due to brood parasitism, inclement weather, snake activity, and unknown reasons. Fourteen nests were depredated by a variety of snake and mammalian predators (Leonard 2015).

Twenty-five nests of three species were located among treatment plots at Hagerman NWR. Of these nests, 12 occurred in managed prairies, eight occurred in fallow plots, and five

Table 4. Avian nest distribution and nest success among agricultural and managed prairie plots at the Tishomingo and Hagerman NWRs, 2013–2014.

Species	Refuge	Management Type	Number of Nest Attempts	Number of Successful Nests	Nest Success (%)
Wild Turkey	Hagerman	Fallow	1	0	0
Mourning Dove	Tishomingo	Fallow	1	0	0
Bell's Vireo	Tishomingo	Managed Prairie	9	1	11
Blue-gray Gnatcatcher	Tishomingo	Managed Prairie	3	0	0
Northern Mockingbird	Tishomingo	Managed Prairie	3	0	0
Yellow-breasted Chat	Tishomingo	Managed Prairie	2	0	0
Field Sparrow	Tishomingo	Managed Prairie	2	0	0
Northern Cardinal	Tishomingo	Managed Prairie	6	2	33
Northern Cardinal	Hagerman	Managed Prairie	2	0	0
Indigo Bunting	Tishomingo	Managed Prairie	1	0	0
Painted Bunting	Tishomingo	Managed Prairie	6	1	17
Dickcissel	Tishomingo	Unharvested Wheat	8	4	50
Dickcissel	Hagerman	Unharvested Wheat	5	1	20
Dickcissel	Hagerman	Fallow	7	1	14
Dickcissel	Tishomingo	Managed Prairie	7	0	0
Dickcissel	Hagerman	Managed Prairie	10	3	30

in unharvested wheat plots (Table 4). Nest success was low among all treatment plots at Hagerman NWR, with only 5 of 25 nests successfully fledging young; all dickcissel nests (Table 4). Of these 5, 3 occurred in managed prairies, 1 nest was in an unharvested wheat plot, and 1 nest was located in a fallow plot. We documented no instances of nest parasitism at Hagerman NWR; however, 3 nests were abandoned for unknown reasons, 2 were lost due to anthropogenic causes, and 13 nests were depredated, and the cause of two nest losses could not be conclusively determined. Of the 13 depredated nests, 10 were depredated by snakes, 2 by small mammal species, and 1 by feral hog.

DISCUSSION

Species Richness

At both refuges, managed prairies had the highest species richness and Shannon-Wiener Index scores followed by fallow and unharvested wheat plots. Managed prairies also had the highest species evenness, indicating that species abundance was more evenly distributed within managed prairies. The diversity of native vegetation in managed prairie plots likely caused the highest species richness scores. Similarly, grassland bird species are often positively associated with prairie habitats devoid of woody vegetation. However, as succession occurs, habitat plots are used by a diverse avifauna, including Bell's vireo and lark sparrow. These species utilize scrub-shrub habitat for nesting (Fitch 1958, Budnik et al. 2000). However, managed prairies at both refuges have patches of woody vegetation and progressive succession which negatively affects habitat quality for grassland birds (U.S. Fish and Wildlife Service 2010).

Fallow plots had the second highest species richness values, likely due to vegetation diversity in these plots. In North Dakota, Lokemoen and Beiser (1997) documented greater species richness and species density in minimum tillage fallow fields over other agricultural practices. Species selected these plots because they may have provided greater vegetation diversity and cover than other agricultural practices.

Unharvested wheat plots had the lowest species richness among treatments due to low vegetation diversity within these plots; predominantly winter wheat, arrowleaf clover, and hairy vetch. Agricultural plots are a primary contributor to low landscape diversity, resulting in lower avian diversity. These plots cannot support a variety grassland bird species, as these birds require a variety of vegetation types and structures (Ribic and Sample 2001, Jacobs et al. 2012).

Relative Abundance

Species abundance rates were variable across treatments at both refuges due to habitat use. At Tishomingo NWR,

ruby–throated hummingbirds were more abundant in unharvested wheat plots where we observed them foraging on hairy vetch. Dickcissels used unharvested wheat plots for foraging and nesting, whereas eastern meadowlark appeared to use these plots predominantly for foraging. Managed prairies had greater abundance of white-eyed vireo, Bell's vireo, gray catbird, and yellow-breasted chat, which used woody shrubs for nesting or foraging sites. At Hagerman NWR, Killdeer were more abundant in unharvested wheat fields, particularly during the early growing season. They likely used this treatment type for foraging or early nesting activity. Painted bunting were more abundant in managed prairies and used woody shrubs for foraging. Fallow habitat had greater abundance of eastern bluebird, lark sparrow, and grasshopper sparrow. Eastern bluebirds used fallow habitat for foraging and used nest boxes nearby for nesting. Lark sparrow and grasshopper sparrows used fallow habitats for foraging, but no nests were detected for these species were found in fallow habitat.

Population Density

At Tishomingo NWR, breeding densities of dickcissels were estimated to be 0.02 birds/ha, whereas breeding densities at Hagerman NWR were 0.04 birds/ha. Both these values were lower than Tweit (2006) estimated for dickcissel breeding densities (0.75–2.50 birds/ha) in the Red River Valley of Texas. This is an indication that poor habitat quality and landscape composition contributed to low species densities.

Conservation Index

At Tishomingo NWR, managed prairies had the greatest conservation value for potential nesting species over both fallow and unharvested wheat plots. These values indicated that a higher number of potential nesting species, and species of higher conservation concern, used managed prairies and fallow plots over unharvested wheat plots. Managed prairies also had the greatest conservation value of nesting species compared to agricultural plots. Of the 10 species that nested within treatment plots at Tishomingo NWR, nine occurred in managed prairies. This is a sharp contrast to the one species each in unharvested wheat and fallow agricultural plots. Managed prairies had higher realized conservation value than unharvested wheat and fallow plots.

Three of the species detected in managed prairies: Bell's vireo, field sparrow and painted buntings, are listed as species of regional concern in the Oaks and Prairies region by the Partner's in Flight Species Assessment Database (Partners in Flight Science Committee 2012). Bell's vireos also are listed as a Tri-Nation Concern Species and a United States-Canada Concern species; whereas field sparrows are listed as a common bird in steep decline. Based upon BBS trend data from 1966-2013, Bell's vireo (–2.87%/yr), field sparrow (–3.41%/yr), and painted bunting (–0.88%/yr) exhibited declines across the Oak and Prairies ecoregion of the southern United States (Sauer et al. 2014). Additionally, Bell's vireo and painted bunting are listed as near threatened species by the IUCN Red List (BirdLife International 2012).

At Hagerman NWR, managed prairies also had the greatest conservation value for potential nesting species, and species of higher conservation concern, over both fallow and unharvested wheat plots. However, fallow plots had the greatest conservation value of nesting species followed by managed prairies and unharvested wheat plots. We interpret this result with caution, given that the presence of one wild turkey nest caused the high conservation score. These values indicated that species of higher conservation concern used fallow plots over the other treatments types, although the scores were similar.

Nest Success

Of the 73 nests located at refuges, only 13 nests successfully fledged young. Species such as the Bell's vireo had low reproductive success at Tishomingo NWR. In contrast, Budnik et al. (2000), in Missouri, documented a nest success rate of 31% in similar habitat. The primary causes of nest failure at Tishomingo NWR were brood parasitism and nest depredation (Leonard 2015). From 2013–2014, 11 nests (all of which occurred in managed prairies) were parasitized by cowbirds. No brood parasitism events were detected in unharvested wheat or fallow plots; however, this is likely a result of small sample sizes for nest attempts in these treatments. Six parasitized nests were abandoned and five parasitized nests failed due to nest predation. In Kansas, Parker (1999) documented a 74% abandonment rate for Bell's vireos after cowbird parasitism.

High nest depredation in managed prairies was likely due to edge effect created by patches of woody vegetation within the plots (Wilcove 1985, Johnson and Igl 2001). Birds in the managed prairies often nested in woody shrubs, which were exposed to predators (Pedlar et al. 1997, Kuehl and Clark 2002). In southwestern Missouri, Burger et al. (1994) documented increased depredation rates (28.7%) on artificial grassland bird nests located < 60 m from a woody edge, whereas nests placed ≥ 60 m from a woody edge had a significantly lower depredation rate (7.9%) (Burger et al. 1994). Winter et al. (2000) documented a higher rate of depredation on dickcissel and Henslow's sparrow (Ammodramus henslowii) nests by small and medium-sized mammalian predators < 50 m from a transitional edge in the same region.

MANAGEMENT IMPLICATIONS

To maximize the positive effects of habitat management

at similar USFWS refuges, we recommend conversion of agricultural plots to prairie restoration plots. The USFWS should implement prescribed burn regimes that include both growing and dormant season burns to set back succession and mimic historic landscape factors. Native mixed-grass prairie seeds should be planted to reestablish prairie vegetation for grassland birds.

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