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Research Article

Grasslands Bird Occupancy of Native Warm-Season Grass

ANDREW S. WEST, *Department of Forestry, Wildlife and Fisheries, Center for Native Grasslands Management, University of Tennessee, Knoxville, TN 37996, USA*

PATRICK D. KEYSER,[1] *Department of Forestry, Wildlife and Fisheries, Center for Native Grasslands Management, University of Tennessee, Knoxville, TN 37996, USA*

CHRISTOPHER M. LITUMA, *Department of Forestry, Wildlife and Fisheries, Center for Native Grasslands Management, University of Tennessee, Knoxville, TN 37996, USA*

DAVID A. BUEHLER, *Department of Forestry, Wildlife, and Fisheries, University of Tennessee, Knoxville, TN 37996, USA*

ROGER D. APPLEGATE, *Tennessee Wildlife Resources Agency, Nashville, TN 37204, USA*

JOHN MORGAN, *Kentucky Department of Fish and Wildlife Resources, Frankfort, KY 40601, USA*

ABSTRACT Grassland birds have declined more than any other guild in the United States because of loss and degradation of native grasslands. The United States Department of Agriculture Farm Bill programs have restored some native warm-season grasses (NWSG), but populations of many grassland bird species continue to decline. Market-based NWSG uses focused on hay, pasture, and biofuel feedstock may be more appealing to landowners, and may still provide grassland bird habitat on the landscape. We examined breeding grassland bird occupancy of 102 NWSG production fields including 5 treatments (control [$n=37$], grazing [$n=7$], hay [$n=22$], seed [$n=21$], and biofuel [$n=15$] production) in Kentucky and Tennessee during 2009–2010 breeding seasons. We used a robust design model in Program MARK to determine occupancy and detection rates for grassland birds. We modeled occupancy differences among treatments and sites (i.e., KY, TN), and included covariates (i.e., field-level vegetation metrics and landscape composition at 3 scales [250 m, 500 m, and 1 km]) for eastern meadowlark (*Sturnella magna*), field sparrow (*Spizella pusilla*), grasshopper sparrow (*Ammodramus savannarum*), northern bobwhite (*Colinus virginianus*), and red-winged blackbird (*Agelaius phoeniceus*). Covariates that influenced occupancy included treatment (field sparrow, 2009 only), site (eastern meadowlark, grasshopper sparrow, and northern bobwhite), percent NWSG cover (positive, red-winged blackbird), and percent forest cover within 250 m (negative for eastern meadowlark, grasshopper sparrow, northern bobwhite, and red-winged blackbird) or within 1 km (negative, field sparrow). Our results suggest that forest cover in the surrounding landscape negatively influences species occupancy, and species occupancy generally did not differ among NWSG production treatments. These treatments could be an alternative means to provide grassland bird habitat within an agriculture production landscape. © 2016 The Wildlife Society.

KEY WORDS biofuels, CRP, grassland birds, grazing, hay production, Kentucky, native warm-season grasses, occupancy, production stands, Tennessee.

Grasslands bird populations have declined more than any other guild of birds in the United States (Samson and Knopf 1994, Murphy 2003, Veech 2006, Askins et al. 2007). Based on North American Breeding Bird Survey data from 1985–2010, grassland birds have been declining at an average annual rate of −3.24% and −3.83%, respectively, in Kentucky and Tennessee (Pardieck et al. 2015). This population decline is predominantly linked to the loss of grassland habitat through intensive agriculture and urbanization (Johnson and Igl 2001, Peterjohn 2003); only about 4% of the pre-settlement, 60 million hectares tall grass prairie still remains in North America (Samson and Knopf 1996). Despite the success of various conservation efforts, such as the Conservation Reserve Program (CRP), in restoring grasslands (Johnson and Schwartz 1993, Warner et al. 2000, Veech 2006, Riffell et al. 2008), grassland bird populations in the Mid-South have continued to decline (Burger et al. 1994, Murphy 2003, Lituma 2014). The amount of CRP simply may be too limited within this region (218,000 ha or 1.2% of the landscape for KY and TN) to have affected population trends. Furthermore, only 3.9% of CRP (8,500 ha) in Kentucky and Tennessee has been planted to native warm-season grasses (NWSG; U.S. Department of

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[1]*E-mail: pkeyser@utk.edu*

Agriculture 2009). The lack of key disturbances, such as fire and grazing, may also be contributing to the ineffectiveness of CRP (Osborne et al. 2012). For many grassland bird species, disturbance of NWSG provide the necessary breeding habitat structure absent in typical, undisturbed CRP fields (Burger et al. 1994, Dykes 2005). Additionally, the strategic use of disturbances (e.g., grazing) could improve grassland bird habitat and provide landowners with a source of additional income through cattle production (Fuhlendorf and Engle 2004).

About 70% of the landscape in the United States is privately owned and still heavily engaged in production agriculture (Gray and Teels 2006, With et al. 2008). Because of the extent of private ownership, economically viable approaches for increasing use of NWSG on the landscape should be explored. The use of NWSG as a biofuel feedstock and conversion of some forage production to NWSG could provide millions of hectares of improved grassland bird habitat (Barnhart 1994, McLaughlin et al. 1999, Barnes 2004). However, occupancy of grassland birds within NWSG forage production systems needs to be documented to determine the extent and elasticity of breeding bird response to various production scenarios.

Documenting species occupancy is less expensive and time consuming than estimating abundance or density (MacKenzie et al. 2002). Occupancy models can be used to determine key variables affecting species distributions, especially in the context of grassland bird habitats (Olson et al. 2005, Nicholson and Van Manen 2009). Irvin et al. (2013) used multi-scale occupancy models to show that at broad scales (5–8 km), grasshopper sparrow (*Ammodramus savannarum*) occupancy on the Delmarva Peninsula was positively associated with the amount of grassland habitat, and negatively associated with amount of development and forest. Alternatively, Hill and Diefenbach (2014) reported that landscape-level variables did not influence grasshopper sparrow or Henslow's sparrow (*Ammodramus henslowii*) site occupancy on reclaimed minelands; rather field shape and size were the most influential variables explaining occupancy patterns. Lituma (2014) reported that for high-priority grassland bird species in the Central Hardwoods Bird Conservation Region (e.g., KY, MO, TN), occupancy was minimally affected by CRP in the surrounding landscape; rather, species' occupancy was influenced by land-cover within 200 m of a point count.

We developed robust design occupancy models for grassland birds during the breeding season within NWSG production fields in Kentucky and Tennessee in 2009–2010. We compared occupancy for fields managed for biofuel feedstock, seed, and forage (including grazing and haying) production to undisturbed NWSG fields. In addition, we examined the influence of field- and landscape-level variables on occupancy of grassland birds within these production stands of NWSG.

STUDY AREA

We examined fields in Tennessee and Kentucky (sites) with NWSG managed for biofuel feedstock, seed, or forage production (treatments). All samples were taken during the breeding season (May) and ran through fledging stage (Aug). Because of the limited amount of NWSG currently used in these enterprises in the region, neither site had all treatments represented. Most study fields were on privately owned, actively managed farms. Fields included in southeastern Tennessee were located in McMinn and surrounding counties in the Southern Appalachian Ridge and Valley region. Fields in south-central Kentucky were located in Hart and Monroe Counties, both in the Pennyroyal region. In Tennessee, the surrounding landscape was 57% forested and 20% row crops. In Kentucky, Hart County was 43% forested and 31% row crops, and Monroe County was 26% forested and 34% row crops (Vilsack 2009). Both sites had an average temperature of 21°C and an average rainfall of 142 mm/month during the field season (i.e., May–Aug) each year (National Oceanic and Atmospheric Administration 2014).

Both sites had unmanaged NWSG fields enrolled in CRP, Conservation Reserve Enhancement Program, or managed similarly to fields enrolled in those programs. These fields remained undisturbed during the course of the study and served as a control. Control fields were predominately planted in a mixture of big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), and little bluestem (*Schizachyrium scoparium*). Planting rates varied based on agency and year of planting, but all were fully stocked stands and had been established for >6 years and burned at least once since establishment but not in the year preceding the study.

In Tennessee, treatments included switchgrass (*Panicum virgatum*) being grown as a biofuel feedstock ($n = 15$), hay fields ($n = 15$) planted in a mixture of big bluestem, indiangrass, or switchgrass that were harvested for hay, and control fields ($n = 13$). In Kentucky, we examined fields managed for commercial NWSG seed production ($n = 21$; including big bluestem, indiangrass, and little bluestem fields), eastern gamagrass (*Tripsacum dactyloides*) hayfields ($n = 7$), eastern gamagrass pastures (grazing fields, $n = 7$), and control fields ($n = 24$).

We constrained our sample frame to 2–12-ha fields ($\bar{x} = 4.21$, SD = 2.26) to minimize any confounding effects potentially caused by variable field size. All fields were >250 m apart and were at least 1 full growing season post-establishment. Seed fields were burned annually (Feb–Mar) as a part of normal production operations to remove old vegetation that could interfere with seed harvest and sprayed to suppress weeds. Hay fields were harvested during June each year, seed fields during August–October, and biofuel fields during late fall to early winter (Nov–Jan). All grazing fields were rotationally grazed and had ≥1 rotation during May–June. Grazing intensity and duration varied with landowner, and all grazed fields were managed for cattle production.

METHODS

Surveys and Measurements

We surveyed birds on each field 3 times during the breeding season annually, once during each of 3 periods: 10–30 May, 1–15 June, and 16 June–1 July, 2009 and 2010. We used 10-minute, 100-m, fixed-radius point counts to record target bird species detected (i.e., seen or heard). Individuals observed outside of target fields were recorded as such. Because detection probability for these species declines beyond 100 m, we omitted such detections (Lituma 2014). We placed points in the center or on strategic vantage points within the fields to optimize detection of birds (Lanham and Guynn 1998, Jobes et al. 2004). We located points >25 m from field edges and >250 m from other points and we used a global positioning system to ensure the same point was sampled on all 6 visits. To ensure a consistent sampling effort per field, each field had 1 point. Target species were eastern meadowlark (*Sturnella magna*), field sparrow (*Spizella pusilla*), grasshopper sparrow, northern bobwhite (*Colinus virginianus*), and red-winged blackbird (*Agelaius phoeniceus*). We selected species based on Partners in Flight North American landbird conservation plan (Rich et al. 2004) conservation status, and grassland species that occurred in the study area. Although red-winged blackbirds are not a rare or declining species, they were common on our study sites and have the potential to be nuisance species in some circumstances. Though other species of grassland birds were present and recorded during point counts (e.g., Bachman's sparrow [*Aimophila aestivalis*], bobolink [*Dolichonyx oryzivorus*], and loggerhead shrike [*Lanius ludovicianus*]), they were not common enough to allow for occupancy analyses. We conducted surveys from sunrise to 4 hours after sunrise with each survey starting 2 minutes after arrival at the point. We did not conduct surveys in precipitation, fog, or high wind (>20 km/hr; Delisle and Savidge 1997, Fletcher and Koford 2002). Each year, 2 observers conducted surveys at each site and visited each field within their respective sites at least once.

We measured field-level vegetation once annually from 1 June–11 July to reflect habitat conditions of the field during the breeding season. Hay fields that were harvested before vegetation measurements were taken and grazed fields that were never grazed in a given year were removed from the study for that year. Within each field, we measured vegetation on 12 sample points located along a systematic grid centered on the point-count location starting in a randomly selected cardinal direction and distance (0–25 m). From the first randomly located point, we spaced each subsequent vegetation sampling point along the transect at an interval based on field size as follows: 35 m for 2–3-ha fields; 40 m for 3.1–4-ha fields; 45 m for 4.1–5-ha fields; and 50 m for >5-ha fields. We scaled our sampling grid in this manner to ensure representative characterization of the habitat within each field; without this scaling, we would have sampled a limited portion of larger fields or incorrectly sampled smaller fields where the full grid would not have fit. At each of the 12 plots, we established a subplot consisting of a 20-m perpendicular line to sample cover (i.e., forbs, cool-season grasses, native warm-season grasses, woody plants, litter), litter depth, vegetation height, and vertical density. We recorded ground cover (bare or litter) and vegetation height (cm) at 5-m intervals, starting at the 0-m mark, for 5 measurements/transect, 60/field. We measured litter depth (cm) at the first location where litter was present, starting from both ends of the 20-m transect moving toward the center and from the center moving out in each direction for 4/transect, 48/field. We measured vertical density using a Robel pole (Robel et al. 1970) placed at the center of each transect. The 2-m pole had marks every 10 cm with alternating colors and a black line indicating the mid-point of each decimeter; we recorded the lowest visible mark (to the half decimeter). We recorded readings 4 m away from the pole, 1 m off the ground, and from the cardinal directions.

We used aerial photographs (1:12,000) taken in 2008 to quantify cover types on the landscape surrounding each field. We ground-truthed photographs in 2010 to ascertain current land-use practices for each discrete land cover unit (e.g., field or forest stand). We then digitized the photographs and land cover polygons and overlaid 3 concentric circles (250-m, 500-m, and 1-km radii), centered on the bird sampling point (Fletcher and Koford 2002, White et al. 2005). Within each circle, we classified landscape composition (% land cover; Fletcher and Koford 2002) into 1 of 6 categories: NWSG, pasture, hay, forest, developed, or row crops (Veech 2006). Because pasture and hay could not be differentiated based on aerial photos alone, and ground truthing was not always possible, we combined pasture and hay into a single category (pasture-hay). We used only a single year of landscape cover in our models because we had photography for only 1 year and because changes that occurred during the 2 years of the study among the broad cover types were minimal.

Statistical Analyses

Because we had 2 primary sampling periods (years), we used a multi-season, robust design occupancy model in Program MARK (White and Burnham 1999) to model species occupancy. This sampling structure is equivalent to Pollock's robust design (Pollock 1982) where population closure is assumed within secondary sampling periods (within-year visits) but open between primary periods (years). Some points were not used both years for logistical reasons, but occupancy modeling for missing data is allowed with this method (MacKenzie et al. 2003). We incorporated covariates into the model for each field based on annual averages for field-level metrics and landscape cover percentages at each of the 3 scales (i.e., 250 m, 500 m, 1 km) for that field.

We modeled occupancy (ψ) and detection probabilities (p) and used Akaike's Information Criterion with small sample adjustment (AIC_c) to determine which model had the most support (Burnham and Anderson 2002). We developed our models in 3 stages. First we examined year, treatment, site, and null models in all combinations simultaneously for both occupancy and detection probability. We included visit (within season) models of detection probability. We did not include observer effects because we had a limited number of target species and we constrained our data to a 100-m radius, a range within which detection probabilities for these species remain high (Lituma 2014). Second, we added field-level vegetation metrics as covariates to the top model(s) from the first stage ($\Delta AIC_c < 2$). We did not include field size as a covariate because we constrained field size within our sample frame and as a result, there was minimal variability in this measure. Third, we added landscape-level metrics to the top model from the second stage. We used 95% confidence intervals of beta estimates to compare differences among treatments for occupancy and considered parameters significant if confidence intervals did not overlap 0. We were not interested in colonization (γ) between years because we surveyed for only 2 years, thus we did not model, or include covariates affecting colonization. We assessed model goodness of fit (GOF) by bootstrapping 1,000 simulations, and using the mean bootstrapped $\hat{c}$ divided by the model $\hat{c}$ to determine if there was need for an overall $\hat{c}$ adjustment. We adjusted models only if the overall $\hat{c}$ was greater than 1.2 (Cooch and White 2016). We did not use model averaging because of the relative simplicity of our models and models below the top model did not include additional informative covariates; rather, we inspected the magnitude of beta estimates and 95% confidence intervals to determine parameter importance. We present parameter estimates based on the mean covariate values for the most parsimonious models.

RESULTS

We sampled 102 different fields (90 in 2009 and 87 in 2010) that ranged from 1.6 to 12.1 ha. Because of field management changes or access restriction, we were able to survey only 75 fields in both years, and we replaced 15 fields from 2009 that became unavailable in 2010 with 12 new fields that met all of our other criteria. We detected 853 and 1,154 individuals during 2009 and 2010, respectively. Field sparrow was the most frequently detected species (369 in 2009 and 550 in 2010; 46% of all detections), followed by red-winged blackbird (246 and 339; 29%), eastern meadowlark (93 and 104; 10%), northern bobwhite (78 and 98; 9%), and grasshopper sparrow (67 and 63; 6%).

Vegetation and Landscape Composition

Mean vegetation height ranged from 24.8 cm (grazing, 2010) to 142.0 cm (biofuel); biofuel fields had the tallest and densest (based on non-overlapping confidence intervals) vegetation in both years (Table 1). Litter depth in the undisturbed control fields was greater both years than for other treatments. Cover for NWSG and forb varied widely by treatment but were lowest and greatest, respectively, in control fields both years. Woody cover was always relatively low by comparison. Vegetation was shorter in 2010 for all treatments except biofuel, which increased in 2010 and also increased in vertical density. Litter cover for seed and hay fields increased from 2009 to 2010. Conversely, NWSG cover declined in control fields from 2009 to 2010 (Table 1).

Percent cover for row crop and developed were low for all distance categories (<8%; Table 2) and were never included in the best-supported occupancy models. Percent cover for NWSG for all treatments was greater at the 250-m scale than the 500-m or 1-km scales. At the 500-m and 1-km scales, forest was the most common land cover followed by pasture-hay.

Detection and Occupancy

All models met GOF criteria, and were left unadjusted. Top detection probability models for eastern meadowlark, field sparrow, grasshopper sparrow, and northern bobwhite included treatment effects; models for grasshopper sparrow and northern bobwhite also included visit, and those for red-winged blackbird included only visit (Table 3). Site and year were not influential in models for any species for detection probability. Eastern meadowlark detection probability was above 0.61 except for in biofuel fields (0.27) and control fields (0.21) and detection was greater in seed (0.71 ± 0.10) than control fields (0.21 ± 0.05). Field sparrow detection probabilities were relatively high (>0.78) and generally consistent except detection was slightly less for biofuel fields (0.61). Grasshopper sparrow detection probabilities showed a pattern of consistent declines over the season and remained lower in control and biofuel fields than the other 3 treatments (Table 4). Northern bobwhite detection probabilities tended to increase between the first and second visits and be greater in hay than grazing or biofuel fields. Red-winged blackbird detection probability declined from the first to the second visit (Table 4).

Based on these results, we developed post hoc models for eastern meadowlark, grasshopper sparrow, and northern bobwhite to determine if field-level vegetation covariates influenced detection probabilities. Post hoc models indicated that covariates related to vegetation height and canopy complexity (i.e., vegetation height and woody cover) exerted a weak influence on detection probabilities associated with our treatments. In the case of northern bobwhite, detection probability was positively related to vegetation height ($\beta = 0.94$, SE = 0.56, 95% CI: $-0.15 \leq \beta \leq 2.04$). Additionally, vegetation height (negative relationship) was in the second best model for eastern meadowlark detection and percent woody cover (negative relationship) was in the second best model for grasshopper sparrow detection (Table 3), although confidence intervals of beta estimates overlapped 0 in both cases (eastern meadowlark, $\beta = -0.52$, SE = 0.54, 95% CI: $-1.58 \leq \beta \leq 0.53$; grasshopper sparrow, $\beta = -13.19$ SE = 10.41, 95% CI: $-33.60 \leq \beta \leq 7.21$).

Only field sparrow occupancy varied among treatments (Table 3). Occupancy for field sparrows was lowest in seed in 2009 (0.52 ± 0.14) versus other treatments (Table 5), and in 2010 was 1.00 for all 5 treatments. Occupancy for eastern meadowlark, grasshopper sparrow, and northern bobwhite differed by site; grasshopper sparrow and northern bobwhite occupancy was greater on Tennessee fields than Kentucky fields, whereas eastern meadowlarks were virtually absent from Tennessee fields (Table 5). The best-supported occupancy models included vegetation or landscape composition covariates. For all species, occupancy was negatively related to percent forest cover in the surrounding landscape (Fig. 1, Table 3). Additionally, eastern meadowlark occupancy was positively related to vertical density, though confidence intervals of beta estimates overlapped 0 ($\beta = 0.025$, SE = 0.014, 95% CI: $-0.003 \leq \beta \leq 0.052$). Northern bobwhite occupancy was positively related to litter depth, though confidence intervals of beta estimates

Table 1. Means and standard errors (SE) for 9 vegetation measures for 4 types of native warm-season grass (NWSG) production stands and an unmanaged control in Kentucky and Tennessee, USA, 2009–2010. Control = idle or unmanaged stands (e.g., Conservation Reserve Program, Conservation Reserve Enhancement Program); biofuel = biomass production; seed = commercial seed production; grazing = pasture; hay = hay production.

	Control	Biofuel	Seed	Grazing	Hay
2009					
Height (cm)	85.9 (3.4)	120.1 (5.4)	66.0 (4.1)	56.2 (8.4)	82.0 (5.3)
Litter depth (cm)	4.4 (0.3)	1.1 (0.1)	1.3 (0.4)	1.2 (0.1)	1.4 (0.1)
Vertical density	93.9 (4.6)	120.9 (7.2)	64.9 (5.7)	64.4 (6.3)	76.9 (6.2)
Cover (%)					
Litter	97.0 (0.6)	72.7 (3.7)	42.7 (7.7)	80.8 (2.4)	66.1 (4.0)
NWSG	33.3 (2.3)	56.1 (3.1)	82.4 (2.5)	39.3 (5.8)	42.2 (3.6)
Cool-season grass	8.0 (1.0)	10.2 (2.4)	0.8 (0.2)	17.7 (5.2)	9.1 (1.5)
Forbs	35.1 (2.2)	16.9 (2.7)	6.1 (1.3)	20.1 (3.9)	14.4 (2.0)
Woody	4.7 (0.6)	0.4 (0.1)	1.1 (0.4)	0.0 (0.0)	1.5 (0.3)
2010					
Height (cm)	60.9 (3.8)	142.0 (6.0)	30.6 (2.5)	24.8 (1.0)	70.7 (4.3)
Litter depth (cm)	5.5 (0.0)	1.9 (0.3)	1.5 (0.2)	1.5 (0.2)	2.6 (0.3)
Vertical density	89.9 (4.2)	168.0 (6.6)	52.3 (3.7)	34.3 (2.1)	93.2 (5.9)
Cover (%)					
Litter	96.5 (0.8)	80.2 (1.9)	64.4 (4.2)	77.8 (6.6)	81.6 (4.5)
NWSG	17.8 (1.7)	61.0 (2.6)	77.2 (2.5)	30.0 (0.8)	38.4 (3.1)
Cool-season grass	6.8 (0.7)	4.7 (0.8)	0.7 (0.2)	30.6 (4.2)	14.4 (2.0)
Forbs	48.3 (2.5)	19.0 (2.0)	7.0 (1.4)	11.4 (4.0)	25.9 (1.9)
Woody	8.1 (0.8)	0.8 (0.2)	1.2 (0.4)	0.0 (0.0)	1.0 (0.2)

overlapped 0 ($\beta = 1.34$, SE = 0.96, 95% CI: $-0.54 \leq \beta \leq 3.22$). Red-winged blackbird occupancy was positively related to percent NWSG cover ($\beta = 2.42$, SE = 0.77, 95% CI: $0.91 \leq \beta \leq 3.93$).

DISCUSSION

With the exception of field sparrow, and then only in 2009 for seed treatment, occupancy rates among grassland birds for 5 types of production stands of native warm-season grasses did not differ. This result was in contrast to our expectation that production treatments, which had numerous differences in management (i.e., disturbance) and resulting structure (Table 1), would differ in terms of species occupancy. Indeed, the species we studied have different habitat requirements and are associated with grasslands in varying stages of succession and with varying degrees of disturbance. Furthermore, other workers have reported differences in bird occupancy, abundance, and nest survival associated with structural features of managed grasslands (Cunningham and Johnson 2006, Jacobs et al. 2012, Lituma et al. 2012, Irvin et al. 2013).

Table 2. Means and standard errors (SE) for landscape cover (%) measures at 3 scales (i.e., 1 km, 500 m, and 250 m) for 4 types of native warm-season grass (NWSG) production stands and an unmanaged control in Kentucky and Tennessee, USA, 2009–2010. Control = idle or unmanaged stands (e.g., Conservation Reserve Program, Conservation Reserve Enhancement Program); biofuel = biomass production; seed = commercial seed production; grazing = pasture; hay = hay production.

	Control	Biofuel	Seed	Grazing	Hay
Forest					
1 km	44.9 (1.5)	39.7 (3.4)	45.6 (4.9)	50.2 (6.2)	42.0 (2.0)
500 m	44.6 (1.8)	30.8 (3.3)	39.6 (5.2)	46.4 (5.8)	41.4 (2.2)
250 m	41.9 (2.3)	29.8 (3.0)	33.1 (4.6)	48.1 (5.2)	34.3 (2.7)
NWSG					
1 km	12.0 (1.7)	6.1 (1.0)	11.9 (1.3)	1.7 (0.4)	4.6 (0.5)
500 m	19.9 (1.6)	17.6 (2.8)	24.6 (2.7)	5.8 (1.1)	11.8 (1.3)
250 m	32.3 (2.0)	35.9 (3.1)	42.2 (3.5)	23.8 (4.4)	25.8 (2.8)
Developed					
1 km	6.7 (0.8)	18.7 (2.4)	7.1 (1.0)	6.2 (2.9)	7.9 (1.1)
500 m	5.7 (1.0)	16.4 (2.5)	7.5 (1.3)	6.5 (2.8)	4.5 (0.8)
250 m	5.6 (0.5)	16.6 (2.7)	5.7 (1.1)	1.7 (0.5)	1.7 (0.5)
Pasture-hay					
1 km	27.4 (1.8)	30.2 (2.7)	28.1 (3.3)	34.0 (3.9)	38.6 (2.0)
500 m	21.8 (1.7)	29.6 (3.5)	22.1 (2.9)	35.4 (5.9)	34.6 (2.8)
250 m	11.2 (1.7)	14.6 (2.7)	16.3 (2.4)	25.6 (5.1)	32.4 (3.0)
Crop					
1 km	3.1 (0.5)	4.6 (1.0)	7.6 (1.5)	6.4 (1.7)	4.8 (0.8)
500 m	3.1 (0.9)	4.7 (1.1)	5.5 (1.4)	5.1 (3.3)	5.2 (1.4)
250 m	3.1 (1.1)	2.3 (0.6)	2.4 (0.8)	0.3 (0.3)	4.9 (1.6)

Grassland birds respond to a range of disturbances, which create structural differences similar to our treatments, though responses are species specific. Undisturbed fields may not provide sufficient habitat structure for declining grassland bird species (Dykes 2005). Harvest timing in hayfields may influence field sparrow and grasshopper sparrow relative abundance (Giuliano and Daves 2002) and eastern meadowlark, dickcissel (*Spiza americana*), field sparrow, and red-winged blackbird densities (Luscier and Thompson 2009). Burning has reduced short-term grasshopper sparrow, Henslow's sparrow, dickcissel, and eastern meadowlark abundance, whereas grazing has increased grasshopper sparrow and reduced Henslow's sparrow abundance (Powell 2006). Grasshopper sparrow and eastern meadowlark abundances increased the year following a harvest in switchgrass biomass fields (Murray and Best 2003, Roth et al. 2005). However, in our case the varied conditions associated with our 5 treatments apparently remained within the range of habitat conditions required for occupancy by the species we studied within the landscapes we examined. Other parameters such as density or nest success may have proven more sensitive to treatments and their associated structure.

A single landscape metric, percent forest cover within the surrounding landscape (250-m scale for all species except

Table 3. Top-ranked models ($\Delta AIC_c < 4.0$) sorted by Akaike's Information Criterion with small sample adjustment (AIC_c), for grassland bird occupancy (ψ), colonization (γ), and detection probability (p) for production stands of native warm-season grasses in Kentucky and Tennessee, USA, 2009–2010, investigating differences among field treatments (control, biofuel, seed, grazing, hay). We also provide number of parameters (K) and model weights (w_i).

Models[a] by species	K	AIC_c	ΔAIC_c	w_i
Eastern meadowlark				
ψ(year + site + ROBE + FOR250 + FOR250^2) γ(.) p(treatment)	12	391.88	0.00	0.48
ψ(year + site + ROBE + FOR250 + FOR250^2) γ(.) p(treatment + HGT)[b]	13	393.34	1.45	0.23
ψ(year + site + ROBE + FOR250 + FOR250^2) γ(.) p(treatment + ROBE)[b]	13	394.10	2.22	0.16
ψ(.) γ(.) p(year)	4	465.32	73.44	0.00
Field sparrow				
ψ(year + treatment + FOR1K) γ(.) p(treatment)	10	552.33	0.00	0.29
ψ(year + treatment + FOR250) γ(.) p(treatment)	10	552.96	0.63	0.21
ψ(year + treatment + FOR1K + LIT) γ(.) p(treatment)	11	554.60	2.27	0.09
ψ(year + treatment + FOR500) γ(.) p(treatment)	10	555.24	2.91	0.07
ψ(year + treatment + NWSG250) γ(.) p(treatment)	10	555.87	3.55	0.05
ψ(year + treatment + DEV1K) γ(.) p(treatment)	10	556.06	3.73	0.04
ψ(.) γ(.) p(year)	4	582.79	30.46	0.00
Grasshopper sparrow				
ψ(site + FOR250 + FOR250^2) γ(.) p(visit + treatment)	12	308.77	0.00	0.47
ψ(site + FOR250 + FOR250^2) γ(.) p(visit + treatment + WOOD)[b]	13	309.18	0.41	0.22
ψ(site + FOR250) γ(.) p(visit + treatment)	11	310.46	1.69	0.20
ψ(site + FOR250 + FOR250^2) γ(.) p(visit + treatment + ROBE)[b]	13	311.05	2.28	0.09
ψ(site + FOR250 + FOR250^2) γ(.) p(visit + treatment + HGT)[b]	13	311.10	2.32	0.09
ψ(site + FOR250 + WOOD) γ(.) p(visit + treatment)	12	311.27	2.50	0.08
ψ(site + FOR250 + CSP) γ(.) p(visit + treatment)	12	312.69	3.92	0.04
ψ(.) γ(.) p(year)	4	362.74	53.98	0.00
Northern bobwhite				
ψ(site + FOR250 + LIT) γ(.) p(visit + treatment + HGT)[b]	13	454.00	0.00	0.19
ψ(site + FOR250 + LIT) γ(.) p(visit + treatment)	12	454.74	0.74	0.13
ψ(site + FOR250 + LIT) γ(.) p(visit + treatment + ROBE)[b]	13	454.78	0.77	0.13
ψ(site + FOR250) γ(.) p(visit + treatment)	11	455.18	1.18	0.10
ψ(site + FOR250 + LIT) γ(.) p(visit + treatment + CSP)[b]	13	455.75	1.75	0.07
ψ(site + FOR250 + LIT) γ(.) p(visit + treatment + NWSG)[b]	13	456.08	2.08	0.06
ψ(site + FOR1K) γ(.) p(visit + treatment)	11	456.39	2.39	0.06
ψ(site + FOR250 + FOR250^2 + LIT) γ(.) p(visit + treatment)	13	456.85	2.85	0.04
ψ(site + FOR250 + LIT + LIT^2) γ(.) p(visit + treatment)	13	456.93	2.93	0.04
ψ(.) γ(.) p(year)	4	510.69	55.95	0.00
Red-winged blackbird				
ψ(NWSG + FOR250) γ(.) p(visit)	7	541.32	0.00	0.26
ψ(NWSG + NWSG^2 + FOR250) γ(.) p(visit)	8	542.10	0.78	0.18
ψ(NWSG + FOR250 + FOR250^2) γ(.) p(visit)	8	542.23	0.91	0.17
ψ(treatment + NWSG + FOR250) γ(.) p(visit)	11	542.77	1.45	0.13
ψ(site + NWSG + FOR250) γ(.) p(visit)	8	543.15	1.82	0.10
ψ(treatment + FOR250) γ(.) p(visit)	10	543.55	2.23	0.09
ψ(treatment + NWSG + FOR250 + FOR250^2) γ(.) p(visit)	12	545.02	3.70	0.04
ψ(treatment + NWSG + NWSG^2 + FOR250) γ(.) p(visit)	12	545.03	3.71	0.04
ψ(.) γ(.) p(year)	4	577.18	35.85	0.00

[a] Covariates: "." = constant; CSP = % cool-season grass cover; DEV1K = % developed cover in the surrounding landscape at the 1-km scale; FOR250, FOR500, and FOR1K = % forested cover in the surrounding landscape at the 250-m, 500-m, or 1-km scale, respectively; HGT = vegetation height (cm); LIT = % litter cover; NWSG = % native warm-season grass cover within study field; NWSG250 = % native warm-season grass cover in the surrounding landscape at the 250-m scale; ROBE = vertical density as estimated by a Robel pole; site = Kentucky or Tennessee; WOOD = % woody plant cover; visit = point counts conducted either from 10–30 May, 1–15 June, or 16 June–1 July.

[b] Post hoc models.

field sparrow, 1 km) was retained in the best-supported model ($\Delta AIC_c < 2.0$) and had a negative relationship with occupancy for all species (Fig. 1). Our target species were, at least, grassland facultative, thus it was not surprising that occupancy of these species would decrease with increasing percent forest cover in the landscape. Indeed, this negative trend for forest cover has been previously documented for grassland species (Fletcher and Koford 2002, Cunningham and Johnson 2006, Winter et al. 2006, Lituma 2014). There was a threshold of approximately 40% forest cover within 250 m of a field, below which the probability of occupancy for eastern meadowlark, grasshopper sparrow, northern bobwhite, and red-winged blackbird declined (Fig. 1). This relationship was quadratic and particularly pronounced for the 2 grassland obligates (i.e., eastern meadowlark and grasshopper sparrow), with occupancies approaching a zero asymptote when forest cover was >40%. Field sparrow occupancy was influenced less by forest cover and the influence occurred at a broader landscape scale (1 km). Field sparrows commonly use forested edges adjacent to open fields with tall, dense vegetation (Herkert 1994, Jacobs et al. 2012). These relationships further confirm that for many grassland bird species, occupancy appears to be more sensitive to forest cover in the surrounding landscape than field-level vegetation structure (Cunningham and Johnson 2006, Riffell et al. 2008, Lituma 2014).

Table 4. Detection probability (p_n), where n = visit number, and standard errors (SE) for grassland birds during the breeding season on 4 types of native warm-season grass production stands and an unmanaged control in Kentucky and Tennessee, USA, 2009–2010.

	Detection probability		
Species	p_1 (SE)	p_2 (SE)	p_3 (SE)
Eastern meadowlark			
Control	0.21 (0.05)	—	—
Biofuel	0.27 (0.10)	—	—
Seed	0.71 (0.06)	—	—
Grazing	0.65 (0.13)	—	—
Hay	0.61 (0.09)	—	—
Field sparrow			
Control	0.82 (0.03)	—	—
Biofuel	0.61 (0.06)	—	—
Seed	0.78 (0.05)	—	—
Grazing	0.87 (0.06)	—	—
Hay	0.86 (0.03)	—	—
Grasshopper sparrow			
Control	0.15 (0.07)	0.09 (0.05)	0.04 (0.02)
Biofuel	0.33 (0.10)	0.21 (0.08)	0.09 (0.04)
Seed	0.75 (0.08)	0.62 (0.10)	0.38 (0.10)
Grazing	0.71 (0.16)	0.57 (0.19)	0.33 (0.17)
Hay	0.59 (0.13)	0.44 (0.12)	0.22 (0.09)
Northern bobwhite			
Control	0.31 (0.07)	0.63 (0.08)	0.53 (0.08)
Biofuel	0.13 (0.05)	0.38 (0.09)	0.29 (0.08)
Seed	0.29 (0.09)	0.62 (0.11)	0.53 (0.11)
Grazing	0.11 (0.10)	0.33 (0.22)	0.25 (0.18)
Hay	0.58 (0.10)	0.84 (0.06)	0.78 (0.07)
Red-winged blackbird	0.80 (0.04)	0.67 (0.05)	0.56 (0.05)

Alternatively, we expected increased pasture-hay or NWSG in the surrounding landscape would be positively related to occupancy for these grassland species. The amount of NWSG was the next landscape variable included in the best-supported models for all species. In every case the beta coefficient was positive, although 95% confidence intervals overlapped 0, suggesting that the strength of the relationships were generally weak. Crop and developed, neither of which were particularly common in our study sites, had virtually no support in models and were never included in top models. Because NWSG was the second most supported landscape variable, and forest cover was such an influential variable, it seems apparent that open spaces with high grass and limited forest cover can have a positive impact on grassland bird occupancy.

Table 5. Breeding-season occupancy (ψ) estimates and standard errors (SE) for 4 species of grassland birds in 4 types of native warm-season grass production stands and an unmanaged control in Kentucky and Tennessee, USA, 2009–2010.

	Occupancy (SE)	
Species	2009	2010
Eastern meadowlark		
TN	0 (0)	0.03 (0.07)
KY	0.67 (0.13)	0.70 (0.14)
Field sparrow		
Control	0.85 (0.07)	1 (0)
Biofuel	0.83 (0.11)	1 (0)
Seed	0.52 (0.14)	1 (0)
Grazing	1 (0)	1 (0)
Hay	0.95 (0.05)	1 (0)
Grasshopper sparrow		
TN	0.39 (0.14)	—
KY	0.10 (0.07)	—
Northern bobwhite		
TN	0.62 (0.09)	0.64 (0.10)
KY	0.28 (0.08)	0.30 (0.08)
Red-winged blackbird	0.62 (0.05)	0.58 (0.05)

We explored the influence of scale on landscape-level covariates but found only limited indication of any multi-scale impact on occupancy (field sparrow models included 250-m and 1-km covariates for forest cover) in models with $\Delta AIC_c < 2.0$. No other landscape-level covariate was supported in any of our models at any spatial scale. However, covariates at 2 scales, field- and landscape-level, were retained in top models for 3 (eastern meadowlark, northern bobwhite, and red-winged blackbird) of our 5 species. Thus for 4 of the 5 species for which we developed occupancy models, there was support for at least 2 scales. Cunningham and Johnson (2006) considered a wide range of landscape scales (200 m, 400 m, 800 m, 1,200 m, and 1,600 m) and reported that adding landscape information improved the ability of their models to predict presence for 17 of 19 species they studied. Models that included variables at larger scales (800–1,600 m) were more frequently competitive among these individual species, although variables at smaller scales were also important (Cunningham and Johnson 2006).

Site was also retained in our top occupancy models. Apparently, regional influences on occupancy were more important than those associated with treatment for grasshopper sparrow, northern bobwhite, and eastern meadowlark. Site-level populations may explain more variability in occupancy of these species on NWSG fields than structural or disturbance differences occurring within the treatment fields (Askins et al. 2007).

Influential field-level variables were retained in the top model for red-winged blackbird (NWSG cover, positive) and northern bobwhite (litter cover, positive). Red-winged blackbirds typically use tall and dense vegetation for nesting (Burger et al. 1994, Coppedge et al. 2001, McCoy et al. 2001). Fletcher and Koford (2002) reported vegetation height was positively related to relative abundance for red-winged blackbirds, whereas Delisle and Savidge (1997) reported no correlations for red-winged blackbird relative abundance and vegetation measurements. Northern bobwhite use NWSG areas that include open, interstitial spaces between grass clumps because mobility is easier for foraging and brood rearing (Barnes et al. 1995, Birkhead et al. 2014). Therefore, our finding that northern bobwhite occupancy was positively influenced by the amount of litter was unexpected. One possible explanation for this relationship is that northern bobwhite could have been using the fields for nesting rather than brood rearing (Taylor et al. 1999, Collins et al. 2009).

The best-supported detection models included treatment (all species except red-winged blackbird) and visit (grasshopper sparrow, northern bobwhite, and red-winged blackbird). Detection probability differences among treatments may have been related to differences in vegetative

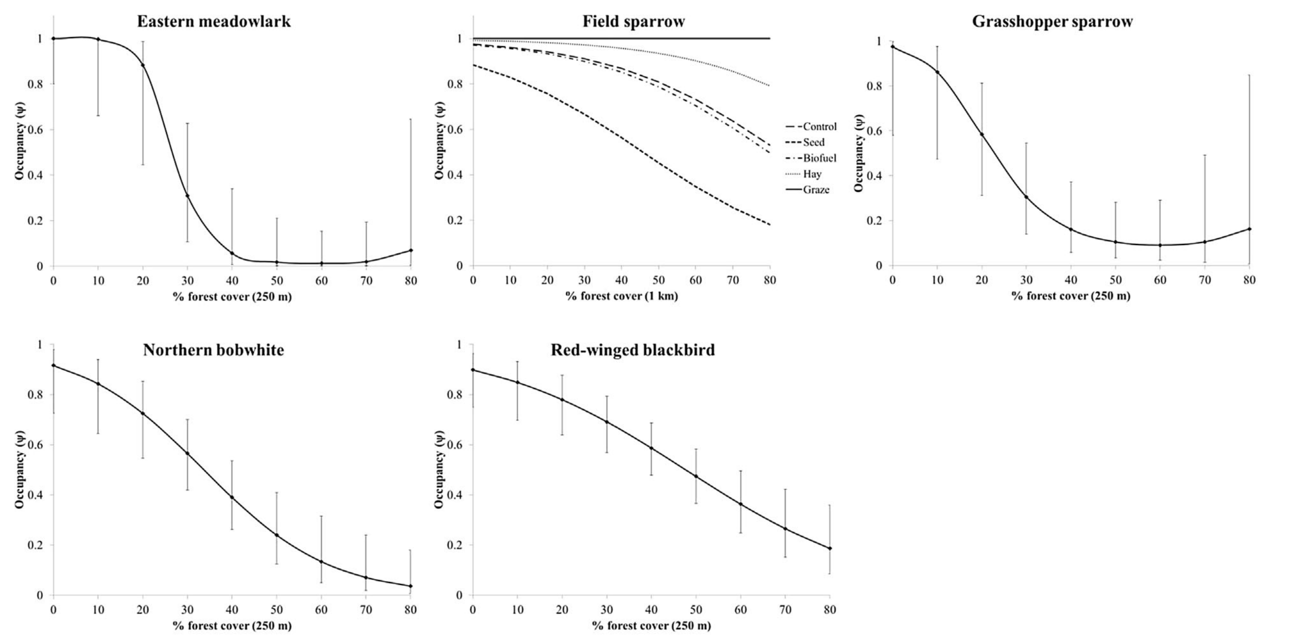

Figure 1. Probability of occupancy (ψ) as predicted by percent forest cover at 2 scales (250 m and 1 km) included in top occupancy models for eastern meadowlark, field sparrow, grasshopper sparrow, northern bobwhite, and red-winged blackbird in McMinn County Tennessee, and Hart and Monroe counties, Kentucky, USA. For field sparrow, treatments (control, seed, biofuel, hay, graze) are presented because treatment was included in the top model. Vertical bars represent one standard deviation.

structure. Structure could affect detection by either reducing or increasing the probability that an observer heard or saw a target species, or by reducing or increasing the probability that an individual bird was available and could have been detected. Eastern meadowlark and grasshopper sparrow are typically associated with habitats with minimal vertical structure, sparse vegetation density, and greater bare ground (Vickery 1996, Jaster et al. 2012). Thus, increased vegetation height may have contributed to reduced eastern meadowlark detection probability in control and biofuel fields as a result of reduced security associated with too much cover. Similarly, grasshopper sparrow detection probabilities were negatively related to percent woody cover and were lowest in control and biofuel fields. Alternatively, northern bobwhite use heterogeneous habitats with woody cover and significant vertical grass structure (Barnes et al. 1995, Lusk et al. 2006). Thus, northern bobwhite may have been less likely to call in areas with reduced cover (e.g., biofuel fields where woody cover was limited or grazing fields, where heights were low) because there was greater potential exposure to predators. However, because none of these relationships were particularly strong, detection among treatment types was apparently being influenced by additional factors that we did not measure.

Incorporating NWSG into production systems, regardless of treatment, appears to cover the range of variability needed to provide habitat for the species we examined in our landscape. That we did not detect any difference in species occupancy among control and production fields suggests that managed production NWSG fields may have comparable conservation value to those managed specifically for wildlife for the species we studied. Converting just 10% of pastures in the southeastern United States could create 1.5 million hectares (U.S. Department of Agriculture 2009) of NWSG, which would far exceed the current cover of NWSG established through CRP and other Farm Bill programs. In addition, biofuel feedstock has been predicted to result in as much as 7.8 million hectares, much of which would be in the southeastern United States (Walsh et al. 2003).

However, we caution that occupancy is not necessarily a direct measure of grassland bird habitat quality (Van Horne 1983). In Missouri, restored CRP grasslands acted as an ecological source for eastern meadowlark, field sparrow, and grasshopper sparrow but were ecological traps for red-winged blackbirds and dickcissels (McCoy et al. 1999). Similarly, in Texas, restored NWSG fields may have been acting as ecological traps for dickcissels, when compared with non-native bermudagrass (*Cynodon dactylon*) pastures (Lituma et al. 2012). Additional research is needed to evaluate grassland bird demographics when the grass is being managed for production objectives and how those contributions are affected by landscape context.

MANAGEMENT IMPLICATIONS

Conservation strategies for grassland birds have not affected a great enough percentage of the landscape in the mid-south United States to elicit a population-level response. The use of NWSG in production agriculture is an alternative approach that has the potential to greatly increase the extent of NWSG on the landscape. This alternative benefits landowners by allowing them to establish grassland habitat while realizing potential profits from their land. Disturbance is also an important factor in grassland ecosystems and production practices may provide acceptable forms of disturbance.

Further, placement of NWSG production fields in areas with limited forest cover appears to be a strategy that will provide maximum benefit for grassland birds. Promotion of these market-based agricultural enterprises that use NWSG may provide as much benefit—or more—than what can be provided through existing conservation programs and thus, may make a substantial contribution to the conservation of grassland birds.

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