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Original Article

Breeding Songbird Use of Native Warm-Season and Non-Native Cool-Season Grass Forage Fields

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ABSTRACT Converting fields of non-native cool-season grasses to native warm-season grasses has been proposed as a strategy to enhance avian habitat and diversify forage production for livestock, but may yield poor-quality food and cover for birds. We measured territory density and reproductive effort for grassland and shrubland birds in 7 native warm-season grass forage fields (4 hayed and 3 grazed), 7 non-native cool-season grass forage fields (4 hayed and 3 grazed), and 3 native warm-season grass–forb fields managed for wildlife (hereafter, wildlife fields) during May–August 2009 and 2010 in the western Piedmont of North Carolina, USA. Eastern meadowlark (*Sturnella magna*) territory density was $\geq$2 times greater in grazed, non-native cool-season grass fields than other field types, but grasshopper sparrow (*Ammodramus savannarum*) territory density did not differ among field types. Field sparrow (*Spizella pusilla*) territory density was $\geq$3 times greater in wildlife fields than in all other field types. Indigo bunting (*Passerina cyanea*) territory density was 5.6 and 14.6 times greater in wildlife fields than in grazed and hayed, non-native cool-season fields, respectively. Reproductive effort for grassland and shrubland birds did not differ among field types. Our data suggest dense stands of tall, native warm-season grass are not a better alternative to non-native cool-season grass pastures for grassland songbirds, especially eastern meadowlark. Shrubland songbirds selected wildlife fields managed with less frequent disturbance than forage fields. Moderate grazing to maintain grass heights $\geq$25 cm may increase quality of non-native cool-season grass and native warm-season grass forage fields for grassland birds. © 2017 The Wildlife Society.

KEY WORDS agriculture, early succession, eastern meadowlark, field sparrow, forage production, grasshopper sparrow, grazing, haying, indigo bunting.

Native grasslands in the eastern United States have declined as a result of fire suppression, increasingly intense agriculture, and conversion to urban, pasture, or forest land cover (Peterjohn 2003, Brennan and Kuvlesky 2005). Additionally, the decline in small family farms has exacerbated the loss of early successional vegetation cover provided by fallow fields; modern commercial farm operations generally double or triple-crop fields, providing substantially less early successional vegetation (Harper and Moorman 2006). Fields not retained in agricultural production largely reverted to forest or were planted to non-native, cool-season grasses, especially tall fescue (*Schedonorus arundinaceus*), used as pasture for livestock grazing and hay production (Ball et al. 1996). As a result of these conversions and practices used to maintain pastures and hayfields, grassland birds have experienced broad-scale and rapid population declines throughout the eastern United States (Knopf 1994, Giuliano and Daves 2002, Brennan and Kuvlesky 2005, Veech 2006, Askins et al. 2007).

Native warm-season grasses have been promoted through federal and state conservation programs to offset the reduction and degradation of native grasslands and decline of grassland and shrubland birds in the eastern United States (Knopf 1994, McCoy et al. 2001, Giuliano and Daves 2002, Brennan and Kuvlesky 2005). Native warm-season grasses generally are promoted over non-native cool-season grasses, such as tall fescue and orchardgrass (*Dactylis glomerata*), because the structure provided by non-native cool-season grasses is suboptimal for wildlife species dependent on overhead cover and an open structure at ground-level, such as northern bobwhite (*Colinus virginianus*; Barnes et al. 1995,

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Washburn et al. 2000, Harper and Gruchy 2009). However, dense litter and shorter grass heights, whether provided through native or nonnative grasses, are favorable to some grassland songbirds (e.g., eastern meadowlark [*Sturnella magna*]; Roseberry and Klimstra 1970).

Native warm-season grasses also have been promoted for livestock forage because they are C4 grasses and produce more forage than cool-season grasses during the summer months (Harper et al. 2007, Lowe et al. 2016). Management of native warm-season grasses and non-native cool-season grasses also differ. Cool-season grasses produce the majority of their biomass during April and May and should be harvested before seedheads are produced for high-quality hay (Ball et al. 1996). However, non-native cool-season grasses usually are hayed or mowed after seedheads are produced (Ball et al. 1996), which typically is in May and June, during peak songbird nesting (Wiens 1969, Giocomo et al. 2008). Some native warm-season grasses (e.g., bluestems [*Andropogon gerardii* or *Schizachyrium scoparium*] and indiangrass [*Sorghastrum nutans*]) produce the majority of their biomass in June and can be optimally harvested after initial nesting attempts of most songbirds (Harper et al. 2007, Giocomo et al. 2008, Birckhead et al. 2014). These native warm-season grasses may be managed with moderate grazing intensity and maintain adequate vertical structure for nesting and brood-rearing cover for various grassland birds (Harper et al. 2015).

Native warm-season grasses and forbs also may be managed exclusively for wildlife without any concern for forage production (hereafter, wildlife fields). These areas should contain a diverse mixture of grasses, forbs, and scattered shrubs and typically are managed by burning, disking, or selective herbicide applications (Harper 2007, Gruchy and Harper 2014). The heterogeneous structure of these areas may be more attractive to grassland or shrubland birds than fields managed for livestock production. We are unaware of any previous study that compared bird use between non-native cool-season and native warm-season grass fields managed for the production of livestock forage. Hence, measuring effects of these different field types (i.e., forage fields and wildlife fields) and management strategies (e.g., haying, grazing, and burning) on avian breeding ecology would help natural resource professionals identify the most appropriate recommendations for programs focused on conserving avian species in agricultural landscapes.

We compared territory density and an index of reproductive effort of breeding grassland and shrubland songbirds among native warm-season grass forage fields, non-native cool-season grass forage fields, and native warm-season grass–forb fields managed for wildlife associated with early successional communities in the eastern United States. We monitored birds in hayed and grazed forage fields to compare songbird territory density and an index of reproductive effort among the field type and forage management combinations. Our objectives were to determine how breeding grassland and shrubland birds use different field types, measure the vegetation composition and structure in each field type, and develop management recommendations to better conserve grassland and shrubland birds in the context of agricultural production systems.

STUDY AREA

We studied breeding songbird use of forage fields during 2009 and 2010 in the western Piedmont of North Carolina, USA, on privately owned land in Iredell, Davie, Rowan, and Lincoln counties. We surveyed songbirds in 4 hayed, native warm-season grass fields (1.89–9.06 ha, $\bar{x} = 5.97$ ha); 3 grazed, native warm-season grass fields (2.12–3.43 ha, $\bar{x} = 2.69$ ha); 4 hayed, non-native cool-season grass fields (1.54–7.85 ha, $\bar{x} = 5.1$ ha); 3 grazed, non-native cool-season grass fields (3.23–12.58 ha, $\bar{x} = 9.05$ ha); and 3 wildlife fields (2.91–3.32 ha, $\bar{x} = 3.07$ ha). Of the 7 non-native cool-season grass fields, 3 hayed and 3 grazed fields were dominated by tall fescue and 1 hayed field was dominated by orchardgrass. Six native warm-season grass fields were converted from tall fescue to single-species forage production stands: 1 hayed big bluestem, 1 grazed big bluestem, 3 hayed switchgrass (*Panicum virgatum*), and 1 grazed eastern gamagrass (*Tripsacum dactyloides*). One grazed, native warm-season grass field was planted as a forage production stand with a mix of little bluestem, big bluestem, and indiangrass. Grazed, native warm-season grass fields were grazed moderately until average grass height was approximately 25 cm, and then rested until average grass height returned to approximately 76 cm. Wildlife fields were managed to maintain a mix of native grasses and forbs and provide food and cover resources for a variety of wildlife. However, landowners were most interested in the benefits these fields provided to white-tailed deer (*Odocoileus virginianus*), eastern cottontail (*Sylvilagus floridanus*), and northern bobwhite. Two of the wildlife fields were planted to indiangrass, little bluestem, sideoats grama (*Bouteloua curtipendula*), and partridge pea (*Cassia chamaecrista*), and one was planted to switchgrass and eastern gamagrass. The switchgrass and eastern gamagrass field was enrolled in the Conservation Reserve Program and a third mowed every year and the other 2 fields were burned approximately every 3 years. All native warm-season grass fields (forage and wildlife) were planted between 2002 and 2008; thus, field age varied from 1 to 8 years since planting. The non-native cool-season grass fields were planted between 1999 and 2007; thus, field age varied from 2 to 11 years since planting. The average annual temperature for the study area was 13.2° C and the average annual precipitation was 111.8 cm. The average temperature and total precipitation in 2009 were 13.9° C and 86.2 cm, respectively. The average temperature and total precipitation in 2010 were 14.4° C and 78 cm, respectively.

METHODS

Bird Survey Methods

We used spot mapping (Robbins 1970, Engstrom 1988, Ralph et al. 1993) to determine male territory densities of 4 focal songbird species: eastern meadowlark, grasshopper sparrow (*Ammodramus savannarum*), field sparrow (*Spizella pusilla*), and indigo bunting (*Passerina cyanea*). We also recorded observations of loggerhead shrike (*Lanius ludovicianus*), American kestrel (*Falco sparverius*), northern bobwhite, blue grosbeak (*Passerina caerulea*), and eastern kingbird (*Tyrannus tyrannus*), but we did not have sufficient sample sizes for analyses. Eastern meadowlark, grasshopper sparrow, and field sparrow were listed in the North Carolina Wildlife Action Plan (NCWRC 2005) as species of concern. We included indigo bunting because it occurs commonly along the margins of croplands and pastures. We conducted spot mapping from 15 April to 1 August 2009 and 2010. We surveyed the entire field during each visit; all visits on a given day were completed between sunrise and 1100 hours (Bibby et al. 1992). Walking routes of each field came within 50 m of all points within the field (Bibby et al. 1992). We walked each field at a slow pace and varied our routes and start and finish locations to diversify the direction and timing of site visits (Bibby et al. 1992). Simultaneous locations (i.e., counter-singing males) of individuals of all target species were recorded on a single grid map (1:2,500) during each of 8 visits to each field and later transcribed to maps of detections for each individual species for each field. Next, we delineated territories for each map based on clusters of detections and records of simultaneous singing during the 8 visits (Bibby et al. 1992). Clusters of detections that extended beyond the boundary of the field were assigned a fraction of a territory proportional to the amount of the territory contained in the field. Also, we recorded behaviors indicating stage of the breeding cycle and calculated an index of reproductive effort (Vickery et al. 1992). We ranked breeding cycle stage of each male territory according to the reproductive index described by Vickery et al. (1992) as follows: 1) establishing a territory; 2) presence of a female; 3) building a nest or laying–incubating eggs; 4) feeding nestlings; 5) feeding fledglings; 6) 1 successful brood and a second nest; and 7) 2 successful broods.

Vegetation Sampling

We sampled vegetation during July and August 2010. We did not sample vegetation in 2009 and assumed vegetation conditions in 2010 were representative of conditions in 2009 as weather conditions were similar between years. We measured vegetation structure and composition along 3, 30-m transects in each of the 17 fields. We stratified each field into 3 equal-area units, with a single transect randomly positioned in each unit. If a transect extended outside the field, we discarded it and generated a new transect position. We used a vegetation profile board (2.0-m tall $\times$ 30.5-cm wide with alternating colors every 25 cm along the length of the board) to measure visual obstruction from 2 positions (i.e., 0-m and 15-m mark) along each transect (Nudds 1977). An observer remained at each position while the board was placed 15 m away in each cardinal direction. The observer estimated and recorded the percentage (i.e., $1 = 0$–25%, $2 = 26$–50%, $3 = 51$–75%, $4 = 76$–100%) of vegetation obscuring their view of the profile board for all 8 of the 25-cm sections of the board. We recorded centimeters of horizontal coverage by vegetation category (i.e., native grass, non-native grass, forb, and woody), bare ground, and leaf litter directly beneath the first 5 m of each transect, and calculated an index of cover as the percent of the 5 m covered by each vegetation category. Density scores for each 25-cm section of the vegetation profile board and the index of horizontal cover by plant species, bare ground, and leaf litter were averaged for each field.

Statistical Analysis

We conducted an analysis of variance to test for differences in territory density among field types (SAS Institute, Inc., Cary, NC, USA). The model for territory density included year and field type as independent variables. We used Tukey's HSD tests to separate means when models were significant. Vickery indices were concentrated at the lower levels of the index, which did not allow for analysis as ordinal data because maximum likelihood estimates cannot be calculated with excessive zero values for higher index levels. To correct for lower sample sizes at higher Vickery index levels, we combined grasshopper sparrow and eastern meadowlark for estimating reproductive effort of grassland birds, and field sparrow and indigo bunting for estimating reproductive effort of shrubland birds. We removed wildlife fields from the grassland bird Vickery index analysis because there were no observations of reproductive effort in this treatment type. We collapsed Vickery index levels into 2 groups (i.e., A includes categories 1 and 2 and represents a male establishing a territory and attracting a mate and B includes categories 3–7 and represents nest-building or egg-laying and any further advanced reproductive behavior) and used a binomial logistic regression model to test the differences in probabilities of the dichotomous Vickery index with field type and year as independent variables. We constructed contrasts between field types and used odds ratios to show effect sizes for the logistic regression analysis. We used hayed, cool-season grass fields as the baseline field type for contrasts for grassland birds because this was the most common forage-management system in the study area and we had no detections in wildlife fields. We used wildlife fields as the baseline field type for contrasts for shrubland birds because we considered this the reference, or ideal, condition for this guild of birds.

We conducted individual analysis of variance tests for differences among field types for each of the profile board and index of horizontal vegetation cover variables (SAS Institute, Inc.). We used Tukey's HSD tests to separate means when models were significant. We log-transformed vegetation profile-board data and square-root-transformed percent horizontal cover indices to achieve normality; however, we report untransformed means for vegetation variables. For all analyses, we considered statistical significance as $P \leq 0.05$.

RESULTS

Mean $\pm$ SD territories per 40 ha for eastern meadowlark (3.31 ± 4.93 and 2.82 ± 3.80), grasshopper sparrow (8.43 ± 10.26 and 7.18 ± 10.38), field sparrow (8.73 ± 13.89 and 6.84 ± 8.59), and indigo bunting (17.98 ± 21.51 and 11.59 ± 10.66) did not differ between 2009 and 2010, respectively ($P > 0.05$). Eastern meadowlarks were absent from wildlife fields and territory density was greater in grazed,

Table 1. Mean territories per 40 ha and standard deviation (SD) for eastern meadowlark, grasshopper sparrow, field sparrow, and indigo bunting in native warm-season grass (NWSG), non-native cool-season grass (CSG), and wildlife fields based on 8 visits/individual field. Means in the same row followed by the same superscript letter were not different according to analysis of variance and Tukey's HSD tests ($P \geq 0.05$). Territory density data were collected in April–August 2009 and 2010 (Iredell, Davie, Rowan, and Lincoln counties, NC, USA).

	Field type											
	NWSG				CSG				Wildlife			
	Grazed		Hayed		Grazed		Hayed					
Species	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$F_{5,28}$	P
Eastern meadowlark	1.98^{AB}	3.31	2.48^{AB}	3.73	7.40^{A}	4.92	3.51^{AB}	4.92	0.0^{B}	0.0	2.87	0.04
Grasshopper sparrow	6.59	11.36	8.14	10.38	11.56	11.14	11.42	10.94	0.0	0.0	1.39	0.26
Field sparrow	2.60^{B}	3.46	8.29^{B}	6.78	1.43^{B}	1.79	1.31^{B}	1.82	27.29^{A}	13.01	17.04	<0.001
Indigo bunting	13.20^{AB}	5.51	21.98^{AB}	23.98	5.79^{B}	6.21	2.22^{B}	3.63	32.52^{A}	14.41	5.52	0.002

non-native cool-season grass fields than in wildlife fields but not different from other field types (Table 1). Grasshopper sparrows were absent from wildlife fields, but territory density did not differ among field types (Table 1). Field sparrow territory density was ≥ 3 times greater in wildlife fields than in all other field types (Table 1). Indigo bunting territory density was 14.6 and 5.6 times greater in wildlife fields than in hayed and grazed non-native cool-season grass fields, respectively (Table 1). Modified Vickery indices for reproductive effort for grassland birds and shrubland birds did not differ among field types or between years (Table 2).

Vegetation structure and composition varied among field types (Table 3). In general, visual obstruction was greatest in wildlife fields and least in grazed, non-native cool-season grass fields, especially at the lower heights on the vegetation profile board. Forbs were more prevalent in grazed fields of both grass types and wildlife fields than in hayed fields of both grass types. Bare ground coverage did not vary among field types, but wildlife fields had no bare ground. There was more litter in hayed, non-native cool-season grass, and wildlife fields than in all other field types. Grazed, native warm-season grass fields, and non-native cool-season grass fields had >17 times more litter than hayed, native warm-season grass fields. There were few woody stems present and woody coverage did not differ among field types.

Table 2. Results from binomial logistic regression model comparing modified Vickery indices of reproductive effort among grazed, native warm-season grass (Field Type 1); grazed, cool-season grass (Field Type 2); hayed, native warm-season grass (Field Type 3); hayed, cool-season grass (Field Type 4); and wildlife fields (Field Type 5). Vickery index data were collected in April–August 2009 and 2010 (Iredell, Davie, Rowan, and Lincoln counties NC, USA).

Guild	Variable	df	Odds ratio	Wald χ^2	P
Grassland	Year	1	2.69	1.79	0.18
	Field Type	3		0.53	0.91
	1 vs. 4		0.92		
	2 vs. 4		1.42		
	3 vs. 4		1.79		
Shrubland	Year	1	0.57	0.72	0.40
	Field Type	4		0.85	0.93
	1 vs. 5		0.55		
	2 vs. 5		0.61		
	3 vs. 5		1.14		
	4 vs. 5		0.93		

DISCUSSION

Territory density of 3 of the 4 focal species differed among the field types, most likely a result of the variable vegetation structure afforded by different grass types and management practices. Eastern meadowlarks used grazed, non-native cool-season grass fields that had relatively short grass heights, a moderately dense litter layer, no woody vegetation, and high percent coverage (50%) of forbs. Grasshopper sparrows were less selective, but not found in wildlife fields that had the tallest structure of all field types. Field sparrows and indigo buntings used wildlife fields, which were characterized by taller grass structure than forage fields.

Other studies have indicated eastern meadowlarks select grasslands with considerable litter cover and dense ground vegetation (Bollinger 1995, Warren and Anderson 2005, Jaster et al. 2012). Therefore, the absence of meadowlarks in wildlife fields that had these vegetation characteristics suggests vertical structure was the overriding factor influencing meadowlark use of forage fields in our study. Although eastern meadowlarks used hayed and grazed, native warm-season grass fields, the taller structure of those fields relative to cool-season grass fields likely rendered them less attractive to meadowlarks (McCoy et al. 2001); hence, there were fewer territories in native warm-season grass fields. However, it should be noted that moderate full-season grazing can reduce vertical structure, encourage plant species diversity, allow some litter accumulation, and promote open structure at ground level for eastern meadowlark and other grassland songbirds throughout the breeding season (Walk and Warner 2000, Harper et al. 2015).

Previous studies also have indicated grasshopper sparrow presence and abundance are influenced more by structure than plant species composition (Walk and Warner 2000, McCoy et al. 2001, Fletcher and Koford 2002). Grasshopper sparrows typically select grasslands with moderate herbaceous cover and considerable bare ground (Whitmore 1981, Vickery 1996), which likely explains why they were absent from the wildlife fields with no bare ground. Grasshopper sparrow territory densities in our study were greater in all field types than in wildlife fields, which had the tallest vertical structure.

Haying, mowing, and intensive grazing remove vegetation structure necessary for grassland songbird reproduction,

Table 3. Mean and standard error (SE) for profile-board vegetation cover estimates (i.e., 1 = 0–25%, 2 = 26–50%, 3 = 51–75%, 4 = 76–100%) in 25-cm increments and index of cover in native warm-season grass (NWSG), non-native cool-season grass (CSG), and wildlife fields. Means in the same row followed by the same superscript letter were not statistically different according to analysis of variance and Tukey's HSD tests ($P \geq 0.05$). Vegetation data were collected in July–August 2010 (Iredell, Davie, Rowan, Lincoln counties, NC, USA).

	Field Type										
	NWSG				CSG				Wildlife		
	Grazed		Hayed		Grazed		Hayed				
Variable	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*P*
Profile board											
25 cm	4.00^{A}	0.00	4.00^{A}	0.00	3.64^{B}	0.18	3.50^{C}	0.10	4.00^{A}	0.00	<0.001
50 cm	3.69^{A}	0.16	3.94^{A}	0.06	2.50^{B}	0.40	1.00^{C}	0.00	4.00^{A}	0.00	<0.001
75 cm	2.92^{B}	0.33	3.71^{A}	0.11	1.53^{C}	0.22	1.00^{D}	0.00	3.97^{A}	0.03	<0.001
100 cm	2.17^{B}	0.37	2.54^{B}	0.33	1.04^{C}	0.06	1.00^{C}	0.00	3.53^{A}	0.19	<0.001
125 cm	1.39^{B}	0.17	1.58^{B}	0.24	1.00^{C}	0.00	1.00^{C}	0.00	2.61^{A}	0.30	0.003
150 cm	1.03	0.03	1.04	0.03	1.00	0.00	1.00	0.00	1.61	0.34	0.161
175 cm	1.00	0.08	1.00	0.00	1.00	0.00	1.00	0.00	1.14	0.09	0.406
200 cm	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	n/a[a]
Index of horizontal cover											
Native grass	75.49^{A}	7.19	102.87^{A}	9.94	1.18^{B}	1.18	0.00^{B}	0.00	84.96^{A}	14.67	<0.001
Non-native grass	6.96^{B}	2.64	5.28^{B}	3.54	78.56^{A}	10.94	79.33^{A}	7.39	0.98^{B}	0.98	<0.001
Forbs	45.20^{A}	15.87	16.95^{B}	10.64	49.49^{A}	11.78	9.98^{B}	6.25	54.40^{A}	12.10	0.002
Woody	0.00	0.00	2.17	2.00	0.00	0.00	0.00	0.00	0.25	0.61	0.63
Bare ground	8.82	2.63	16.72	7.14	12.78	7.03	7.07	3.26	0.00	0.00	0.36
Leaf litter–thatch	23.04^{B}	7.00	1.30^{C}	0.94	32.49^{B}	16.20	68.67^{A}	7.10	78.84^{A}	11.10	0.002

[a] *P*-value could not be calculated.

disrupt nesting, and can lead to lower nest survival and decreased densities of birds (Dale et al. 1997, Sutter and Ritchison 2005, Giocomo et al. 2008, Luscier and Thompson 2009, Birckhead et al. 2014). Altering the timing of haying has been proposed (Luscier and Thompson 2009), but delayed hay harvest leads to decreased hay quality (Harper et al. 2007) and may require livestock producers to provide supplemental feed to livestock, which is not economically efficient (Ball et al. 1996). Although eastern meadowlark and grasshopper sparrow continued to frequent hayed fields in our study, occurrence of a species does not necessarily equate to population persistence. Multiple successful nesting attempts may be required for population persistence or growth in some areas (Giocomo et al. 2008).

The Vickery index of reproductive effort implied an apparent uniform reproductive effort across field types, but the method may have performed poorly. Density estimates alone can provide biased estimates of habitat quality (Van Horne 1983), so Vickery et al. (1992) developed the index as a metric of reproduction for grassland birds with cryptic nests that are difficult to locate and monitor. However, field evaluations of the method suggest it may function poorly as a surrogate for nest location and monitoring (Rivers et al. 2003, Morgan et al. 2010) and may require large numbers of treatment replicates to generate sufficient power to detect differences (Rangen et al. 2000). Yet, the method has shown promise as a course indicator of relative differences in reproductive effort in other studies (Vickery et al. 1992, Dale et al. 1997, Winiarski 2016). Regardless, we suggest results of our comparison of reproductive effort based on the Vickery index should be interpreted with caution and that future research should attempt to estimate survival of grassland bird nests in relation to grass type and management practice in forage production systems.

The vegetation structure in wildlife fields favored field sparrows and indigo buntings. Wildlife fields had tall, dense native grasses, greater forb coverage, and dense litter layers, and often were located close to woody edges. In previous studies, eastern meadowlarks did not select fields with woody vegetation and avoided fields with woody edges (Larkin et al. 2001, Coppedge et al. 2008). In our study, indigo bunting territory densities were greatest in wildlife fields and native warm-season grass forage fields, where perches required for singing and territory defense and field-perimeter shrubs for nesting were present (Payne 2006). Similarly, field sparrows used the vegetation in wildlife fields and shrubs and trees adjacent to fields for nesting (Best 1978, 1979).

Field sizes varied, which could have confounded bird response to field type. Grazed, cool-season grass fields were larger on average than other field types, which could explain why meadowlarks were most abundant in these fields. Conversely, wildlife fields and native warm-season grass grazed fields were relatively small and likely less attractive for area-sensitive birds such as meadowlarks. Helzer and Jelinski (1999) reported the effect of edges on area-sensitive birds was reduced in fields >50 ha because fields this large increased interior area and maximized species richness. Although total grassland area with the inclusion of grassland surrounding our study fields rarely was >50 ha, Ribic et al. (2009) reported eastern meadowlark density increased with an increased proportion of grassland within 200 m of a field. Therefore, cool-season grass fields bordering all study fields except wildlife fields may have increased the effective size of study fields.

MANAGEMENT IMPLICATIONS

Agricultural producers can integrate focal-bird-species habitat requirements and forage production objectives to conserve avian habitat within forage production systems. Use of fields by grassland birds is influenced by landscape composition, field size, and structure of vegetation. In our study, larger fields with shorter structure received more use by eastern meadowlark and grasshopper sparrow. Our data suggest land managers should not try to restore or enhance habitat for these species by planting tall native warm-season grasses, especially in fields no larger than 3 ha in a forested landscape matrix. Instead, larger fields with shorter structure, whether short native warm-season grasses or non-native cool-season grasses, must be provided. Haying or grazing may allow use of these fields, but haying must be delayed until after initial nesting attempts. Use of native warm-season grasses, such as little bluestem, will still provide high-quality hay for livestock when hayed later in the season (mid- to late-June). Grazing intensity should be moderated to maintain grass height of 25–60 cm to provide cover for nesting and foraging grassland birds. If shrubland birds, such as field sparrow and indigo bunting, are of interest, we recommend borders of appropriate width around relatively large fields, or separate smaller fields, be managed to maintain taller vegetation structure required by those species.

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LITERATURE CITED

Askins, R. A., F. Chavez-Ramirez, B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knopf, and P. D. Vickery. 2007. Conservation of grassland birds in North America: understanding ecological processes in different regions. Ornithological Monographs 64.

Ball, D. M., C. S. Hoveland, and G. D. Lacefield. 1996. Southern forages. Second edition. Potash and Phosphate Institute, Norcross, Georgia, USA.

Barnes, T. G., L. A. Madison, J. D. Sole, and M. J. Lacki. 1995. An assessment of habitat quality for northern bobwhite in tall fescue-dominated fields. Wildlife Society Bulletin 23:231–237.

Best, L. B. 1978. Field sparrow reproductive success and nesting ecology. Auk 95:9–22.

Best, L. B. 1979. Effects of fire on a field sparrow population. American Midland Naturalist 101:434–442.

Bibby, C. J., N. C. Burgess, and D. A. Hill. 1992. Bird census techniques. Academic Press, San Diego, California, USA.

Birckhead, J. L., C. A. Harper, P. D. Keyser, G. E. Bates, D. McIntosh, J. C. Waller, and E. D. Holcomb. 2014. Avian habitat response to hay and biofuels production in native warm-season grass stands in the Mid-South. Journal of the Southeastern Association of Fish and Wildlife Agencies 1:115–121.

Bollinger, E. K. 1995. Successional changes and habitat selection in hayfield bird communities. Auk 112:720–730.

Brennan, L. A., and W. P. Kuvlesky Jr. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69:1–13.

Coppedge, B. R., S. D. Fuhlendorf, W. C. Harrell, and D. M. Engle. 2008. Avian community response to vegetation and structural features in grasslands managed with fire and grazing. Biological Conservation 141:1196–1203.

Dale, B. C., P. A. Martin, and P. S. Taylor. 1997. Effects of hay management on grassland songbirds in Saskatchewan. Wildlife Society Bulletin 25:616–626.

Engstrom, T. R. 1988. The Breeding Bird Census: a half century in review. BirdScope 2:1–3.

Fletcher, R. F., and R. R. Koford. 2002. Habitat and landscape associations of breeding birds in native and restored grasslands. Journal of Wildlife Management 66:1011–1022.

Giocomo, J. J., E. D. Moss, D. A. Buehler, and W. G. Minser III. 2008. Nesting biology of grassland birds at Ft. Campbell, Kentucky and Tennessee. Wilson Journal of Ornithology 120:111–119.

Giuliano, W. M., and S. E. Daves. 2002. Avian response to warm-season grass use in pasture and hayfield management. Biological Conservation 106:1–9.

Gruchy, J. P., and C. A. Harper. 2014. Effects of management practices on northern bobwhite habitat. Journal of the Southeastern Association of Fish and Wildlife Agencies 1:133–141.

Harper, C. A. 2007. Strategies for managing early succession habitat for wildlife. Weed Technology 21:932–937.

Harper, C. A., G. E. Bates, M. P. Hansbrough, M. J. Gudlin, J. P. Gruchy, and P. D. Keyser. 2007. Native warm-season grasses: identification, establishment and management for wildlife and forage production in the Mid-South. University of Tennessee, Knoxville, USA.

Harper, C. A., J. L. Birckhead, P. D. Keyser, J. C. Waller, M. M. Backus, G. E. Bates, E. D. Holcomb, and J. M. Brooke. 2015. Avian habitat following grazing native warm-season grass forages in the Mid-South United States. Rangeland Ecology and Management 68:166–172.

Harper, C. A., and J. P. Gruchy. 2009. Eradicating tall fescue and other non-native perennial cool-season grasses for improved early successional wildlife habitat. Pages 90–99 *in* L. W. Burger Jr., and K. O. Evans, editors. Managing working lands for northern bobwhite: The USDA NRCS Bobwhite Restoration Project, Washington, D.C., USA.

Harper, C. A., and C. E. Moorman. 2006. Qualifying native warm-season grasses and early succession habitat. Proceedings of Triennial National Wildlife and Fisheries Extension Specialists Conference 11:76–80.

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

Jaster, L. A., W. E. Jensen, and W. E. Lanyon. 2012. Eastern meadowlark (*Sturnella magna*). In A. Poole, editor. The birds of North America online. Cornell Lab of Ornithology, Ithaca, New York, USA. Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/160. doi: 10.2173/bna.160

Knopf, F. L. 1994. Avian assemblages on altered grasslands. Studies in Avian Biology 15:247–257.

Larkin, J. L., T. G. Barnes, M. Depoy-Smith, and D. S. Maehr. 2001. A comparison of avian communities occupying native and exotic grasslands in Kentucky: a preliminary study. North America Prairie Conference 17:201–205.

Lowe, J. K., C. N. Boyer, A. P. Griffith, J. C. Waller, G. E. Bates, P. D. Keyser, J. A. Larson, and E. D. Holcomb. 2016. The cost of feeding bred dairy heifers on native warm-season grasses and harvested feedstuffs. Journal of Dairy Science 99:634–643.

Luscier, J. D., and W. L. Thompson. 2009. Short-term responses of breeding birds of grassland and early successional habitat to timing of haying in northwestern Arkansas. Condor 111:538–544.

McCoy, T. D., E. W. Kurzejeski, L. W. Burger Jr., and M. R. Ryan. 2001. Effects of conservation practice, mowing, and temporal changes on vegetation structure on CRP fields in northern Missouri. Wildlife Society Bulletin 29:979–987.

Morgan, M. R., C. Norment, and M. C. Runge. 2010. Evaluation of a reproductive index for estimating productivity of grassland breeding birds. Auk 127:86–93.

North Carolina Wildlife Resources Commission. 2005. North Carolina Wildlife Action Plan. North Carolina Wildlife Resources Commission, Raleigh, North Carolina, USA.

Nudds, T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife Society Bulletin 5:113–117.
Payne, R. B. 2006. Indigo bunting (*Passerina cyanea*). In A. Poole, editor. The birds of North America online. Cornell Lab of Ornithology, Ithaca, New York, USA. Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/004. DOI: 10.2173/bna.4
Peterjohn, B. G. 2003. Agricultural landscapes: can they support healthy bird populations as well as farm products? Auk 120:14–19.
Ralph, J. C., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. U.S. Department of Agriculture Forest Service General Technical Report PSW-GTR-144. University of Nebraska, Lincoln, USA.
Rangen, S. A., K. A. Hobson, and R. G. Clark. 2000. A comparison of density and reproductive indices of songbirds in young and old boreal forest. Wildlife Society Bulletin 28:110–118.
Ribic, C. A., M. J. Guzy, and D. W. Sample. 2009. Grassland bird use of remnant prairie and Conservation Reserve Program fields in an agricultural landscape in Wisconsin. American Midland Naturalist 161:110–122.
Rivers, J. W., D. P. Althoff, P. S. Gipson, and J. S. Pontius. 2003. Evaluation of a reproductive index to estimate dickcissel reproductive success. Journal of Wildlife Management 67:136–143.
Robbins, C. S. 1970. Recommendations for an international standard for a mapping method in bird census work. Audubon Field Notes 24:723–726.
Roseberry, J. L., and W. D. Klimstra. 1970. The nesting ecology and reproductive performance of the eastern meadowlark. Wilson Bulletin 82:243–267.
Sutter, B., and G. Ritchison. 2005. Effects of grazing on vegetation structure, prey availability, and reproductive success of grasshopper sparrows. Journal of Field Ornithology 76:345–351.
Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893–901.
Veech, J. A. 2006. A comparison of landscapes occupied by increasing and decreasing populations of grassland birds. Conservation Biology 20:1422–1432.
Vickery, P. D. 1996. Grasshopper sparrow (*Ammodramus savannarum*). In A. Poole, editor. The birds of North America online. Cornell Lab of Ornithology, Ithaca, USA. Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/239. doi: 10.2173/bna.239
Vickery, P. D., M. L. Hunter Jr., and J. V. Wells. 1992. Use of a new reproductive index to evaluate relationship between habitat quality and breeding success. Auk 109:697–705.
Walk, J. W., and R. E. Warner. 2000. Grassland management for the conservation of songbirds in the midwestern USA. Biological Conservation 94:165–172.
Warren, K. A., and J. T. Anderson. 2005. Grassland songbird nest-site selection and response to mowing in West Virginia. Wildlife Society Bulletin 33:285–292.
Washburn, B. E., T. G. Barnes, and J. D. Sole. 2000. Improving northern bobwhite habitat by converting tall fescue fields to native warm-season grasses. Wildlife Society Bulletin 28:97–104.
Whitmore, R. C. 1981. Structural characteristics of grasshopper sparrow habitat. Journal of Wildlife Management 45:811–814.
Wiens, J. A. 1969. An approach to the study of ecological relationships among grassland birds. The American Ornithologists' Union. Ornithological Monographs 8.
Winiarski, J. 2016. Breeding ecology and space-use of Bachman's sparrow (*Peucaea aestivalis*) at the northern periphery of its range. Thesis, North Carolina State University, Raleigh, USA.

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