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## Avian Habitat Following Grazing Native Warm-Season Forages in the Mid-South United States



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### ABSTRACT

Native warm-season grasses (NWSG) currently are being promoted for livestock forage and biofuels feedstock in the Mid-South. However, there are no published data on how NWSG managed with livestock in the Mid-South may affect habitat for wildlife. We conducted a study to evaluate habitat for grassland songbirds and northern bobwhite (*Colinus virginianus*) in response to two cattle grazing treatments in NWSG pastures across three sites in Tennessee, 2010 and 2011. We evaluated vegetation composition and structure along with invertebrate availability during the primary nesting season for grassland songbirds and the typical brood-rearing season for the northern bobwhite. Grazing treatments included full-season (May to August) grazing and early-season (30 days beginning in May) grazing, after which subsequent growth was taken as a biofuel harvest postdormancy. Forage treatments included big bluestem/indiangrass mixture, switchgrass, and eastern gamagrass. Vegetation composition was dominated by the planted forages in all pastures. All forage types and both grazing treatments provided suitable structure for grassland songbirds and bobwhite during the primary nesting season. Full-season grazing maintained suitable structure through the brooding period, with greater openness at the ground level and angle of obstruction, as well as optimal vegetation height (<60 cm). Structure within early-season grazing treatments became dense after cattle were removed with less openness at ground level than what brooding bobwhites typically use. Invertebrate biomass was sufficient in all forage types and grazing treatments to support bobwhite broods. We recommend livestock producers in the Mid-South use full-season grazing that maintains grass height of approximately 40 cm in production stands of NWSG to maximize benefits for grassland birds and northern bobwhite.

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### Introduction

Grassland birds are declining faster than any other group of North American birds with more than two-thirds of grassland species showing significant declines (Vickery and Herkert, 2001; Sauer et al., 2011). Among the species experiencing declines are the grasshopper sparrow (*Ammodramus savannarum*) and northern bobwhite (hereafter bobwhite). Habitat loss, habitat degradation, and

agricultural intensification are primary factors contributing to grassland bird declines (Herkert, 1994; Brennan and Kuvlesky, 2005).

Native grasslands have virtually disappeared in the Mid-South region of the United States. However, there are more than 20 million acres in non-native grasslands as either pasture or hayfield (Nickerson et al., 2011). Typical grazing and hay operations in the Mid-South are based on tall fescue (*Schedonorus phoenix* Scop.), which is typically grazed continually throughout the year or hayed two to three times from May through September (Ball et al., 2007). This type of management does not promote the vegetation structure necessary to maintain diverse grassland bird populations (Giuliano and Daves, 2002; Wilson et al., 2005; Rahmig et al., 2009).

The Natural Resources Conservation Service (NRCS) and state wildlife agencies in the Mid-South are promoting native warm-

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season grasses (NWSG), such as big bluestem (*Andropogon gerardii* Vitman), indiagrass (*Sorghastrum nutans* L.), switchgrass (*Panicum virgatum* L.), and eastern gamagrass (*Tripsacum dactyloides* L.), for forage production and wildlife habitat improvement (USDA-NRCS, 2005). NWSGs can complement forage systems dominated by cool-season grasses because of their differing seasonality (Ball et al., 2007) and can benefit various wildlife species because of a taller and more diverse structure (Harper et al., 2007). However, in grazing systems, stocking rate and duration determine suitability for grassland wildlife, regardless of grass species (Guthery et al., 1990; Hickman et al., 2004).

Incorporation of NWSG into grazing systems can provide a unique opportunity to provide high-quality forage with intensive grazing during the early part of the growing season and then defer grazing to allow grass growth for biofuels feedstock (Roth et al., 2005; Bies, 2006; Fike et al., 2006; Mulkey et al., 2008). Discontinuation of grazing through the remainder of summer will create a different vegetation structure than that following continuous grazing, which can have implications for wildlife (Hammerquist-Wilson and Crawford, 1981; Murray and Best, 2003; Murray et al., 2003).

Habitat quality for grassland wildlife following incorporation of NWSG into grazing systems or grazing strategies with NWSG have not been evaluated in the Mid-South. Although grazing strategies for NWSG have been evaluated for grassland wildlife in more arid regions (George et al., 1979; Hammerquist-Wilson and Crawford, 1981; Fuhlendorf et al., 2006; Rahmig et al., 2009), vegetation structure and amount of bare ground can differ greatly in a different region of the country where vegetation composition differs and there is increased precipitation.

Evaluation of grazing strategies for NWSG on grassland wildlife habitat is needed in order for federal and state agencies to provide accurate recommendations when delivering conservation programs. We conducted a field experiment to evaluate avian habitat in production stands of NWSG under two grazing management strategies in the Mid-South. We measured various structural parameters and invertebrate biomass, which is a key food resource for young birds and an important determinant of habitat quality. We hypothesized continuous grazing and mixtures of NWSG would create a more diverse and suitable structure for grassland birds than early, intensive grazing and monoculture stands. Furthermore, we hypothesized continuous grazing would encourage more forb cover, which would lead to more diverse and abundant invertebrate populations than monoculture plantings with less diverse structure.

## Methods

### Study Location

We conducted our research at three Research and Education Centers (REC) in Tennessee including Ames Plantation (APREC) located near Grand Junction, TN (35°6'N, 89°13'W), Highland Rim (HRREC) located near Springfield, TN (36°28'N, 86°50'W), and Greeneville (RECGRN) located near Greeneville, TN (36°6'N, 82°51'W). We planted three forages or forage mixtures (hereafter forages) in separate pastures in 2008: 1) Alamo switchgrass (SG), 2) OZ-70 big bluestem/Rumsey indiagrass mixture (BB/IG), and 3) Pete eastern gamagrass (EG). The big bluestem/indiagrass mixture included 65% big bluestem and 35% indiagrass based on seed mass. We used a no-till drill to plant each SG and BB/IG pasture and a corn planter to plant EG. We planted 6.72 kg Pure Live Seed (PLS)/ha, 10.08 kg PLS/ha, and 13.44 kg PLS/ha for SG, BB/IG, and EG, respectively. All pastures (1.2 ha each) were predominantly tall fescue before our study began. In the fall of 2007, pastures were clipped with a rotary mower and, after appropriate regrowth (>15 cm), treated

with glyphosate (2.24kg ai/ha) to control cool-season grass and weed competition. A final glyphosate treatment (1.12 kg ai/ha) was applied in April 2008 in preparation for planting. Pastures planted to BB/IG were sprayed with imazapic (0.11kg ai/ha) to control competition in the establishment year. Our SG plantings at APREC failed in 2008 and were successfully replanted in spring 2009. Soil samples were taken from pastures in 2010 and 2011. We amended soils with lime, nitrogen, phosphorus, and potassium in April each year according to soil test recommendations from the University of Tennessee Soil Testing Laboratory. We did not fertilize pastures during establishment to avoid stimulating competitive species.

We imposed two grazing strategies, early-season and full-season, in a factorial combination with the three forages for a total of six treatments. Early-season grazing lasted 30 days beginning each May and was designed to graze the high-quality early forage growth and allow regrowth to accumulate for a biofuels harvest in the fall. Full-season grazing was designed to maximize grazing days from early May through late summer. We managed grazing under a put-and-take system to maintain grass canopies at approximately 38–47 cm in full-season treatments. For early-season grazing, our target was to reduce canopies to 25 cm by the end of the 30-d period. Grazing strategies were designed to maximize forage performance and cattle weight gain. We initiated grazing for both grazing strategies and all three forages on the same date at each location when the average canopy for BB/IG reached approximately 30 cm. We used Angus-cross weaned steers (273 kg starting weight) in all years at all locations. Tennessee Livestock Producers (Columbia, TN) provided steers. All animal care was in accordance with UT-IACUC Protocol No. 1264. All grazing animals were provided a general cattle mineral free choice and access to water, and each pasture had adequate shade structures.

We planted SG, BB/IG, and EG at APREC in three replicates for a total of 18 experimental pastures. In the spring of 2010 and 2011, we burned the pastures to remove residual biomass from the previous year. In 2010, we initiated grazing on May 28. We concluded all early-season grazing on June 28 and concluded full-season grazing on August 9, July 26, and August 30 for SG, BB/IG, and EG, respectively. In 2011, we initiated grazing on May 4 on all pastures. We concluded early-season grazing on June 6 and concluded full-season grazing on August 9 for all pastures.

We planted SG and BB/IG at HRREC in three replicates for a total of 12 pastures. In the spring of 2010 and 2011, we clipped the pastures to 20 cm with a rotary mower to remove residual biomass from the previous year. In 2010, we initiated grazing on May 7. We concluded early-season grazing on all pastures on June 7, and we concluded full-season grazing on August 9. In 2011, we initiated grazing on May 6 on all pastures. We concluded early-season grazing on June 6 and concluded full-season grazing on August 29 for all pastures.

We planted BB/IG at RECGRN in three replicates for a total of 6 pastures. In the spring of 2010 and 2011, we burned the pastures to remove residual biomass from the previous year. In 2010, we initiated grazing on May 21. We concluded early-season grazing on June 21 and concluded full-season grazing on August 16 for all pastures. In 2011, we initiated grazing on May 20 for all pastures. We concluded early-season grazing on June 20 and concluded full-season grazing on August 15 for all pastures.

### Vegetation Surveys

We conducted vegetation surveys twice during 2010 and 2011, once during late May through mid-June, and once during late June through mid-July to evaluate vegetation corresponding to nesting periods for grassland songbirds and nesting and brood-rearing periods for northern bobwhite in the Mid-South region. We measured

vegetation composition and litter depth along five 10-m transects in each pasture, with observations made every 10 cm. At each 10-cm intercept, we recorded all plants bisecting the transect. We summed the total number of observations for the transect to determine percent cover by species. We recorded litter and bare ground when present. We defined litter as ground covered by dead vegetation without overhead cover of live plants, and bare ground was ground without dead vegetation or overhead cover of live plants. We established transects randomly throughout the pasture, and we used different locations during every sampling period. We measured litter depth at 1, 5, and 10 meters.

We measured vegetation structure from a stationary point at the beginning of each 10-m transect, totaling 5 points per pasture during each sampling period. Ground sighting distance, a measure of structure and openness at ground level, was measured in each cardinal direction from a single, stationary point for a total of 20 observations for each pasture in each sampling period. One observer was stationed with a PVC tube (3.2-cm diameter, 15.2-cm length), mounted horizontally on a metal stake 15.2 cm aboveground. Another observer holding a PVC tube 2-m tall with the bottom 15 cm marked moved away from the first observer while the first observer looked through the tube and recorded the distance at which the bottom 15 cm of the 2-m tube was obscured by vegetation (Gruchy and Harper, 2015; Unger et al., in press).

We measured angle of obstruction, which represents openness of the vegetation canopy, with a 2-m pole and clinometer (Kopp et al., 1998). The pole was placed at the same point used for measuring ground sighting distance, and while the bottom of the pole remained in place, the top was leaned toward the nearest vegetation until making contact. A clinometer was placed on the pole to measure the angle of obstruction at 2-m high. This was done at each point in each cardinal direction with 0° recorded when the pole was vertical, for 20 observations for each pasture in each sampling period.

We evaluated vertical structure using visual obstruction readings (Limb et al., 2007). Photos were taken of vegetation against a 1 x 1 m white board using a Canon EOS Rebel camera (10.1 megapixels) at a distance of 4 m and a height of 1 m, similar to the protocol provided by Nudds (Nudds, 1977). The white board was marked on each side at each 0.1-m increment. We took two photos at random locations along each vegetation transect, for a total of 20 pictures per pasture per sampling period. We uploaded photos to CS3 software (Adobe Systems Inc., San Jose, CA) for analysis in Adobe Photoshop. We used threshold and histogram functions in CS3 to measure (instead of visually estimate) visual obstruction of each photo at three height sections: 0–30 cm (section 1), 30–60 cm (section 2), and 60–100 cm (section 3). The percent of black pixels in each board section represented visual obstruction.

#### *Invertebrate Surveys*

We used a 0.25-m<sup>3</sup> bottomless box with a hinged lid and a modified handheld blower-vac (Harper and Guynn, 1998) to collect invertebrates in July 2010 and 2011. We collected 10 randomly selected samples per pasture per year. We sampled in the afternoon when vegetation was dry and the temperature was > 27°C to maximize efficiency and correspond with peak invertebrate activity. Samples were frozen on-site until we could transfer them to a forced-air oven. Samples were dried for 48 hours at a constant temperature of 60°C. Invertebrates were then separated from debris, sorted to order, and weighed. Abundance and dry weight of each invertebrate order were recorded for each sample.

#### *Data Analysis*

We analyzed vegetation composition by grouping plants into biologically important associations: NWSG, other grass, forb, litter, or bare ground. Data were averaged across subsamples to obtain a

mean for each pasture. We analyzed data using a randomized, incomplete block analysis of variance (ANOVA), with replication, in SAS 9.3 (SAS Institute, Cary, NC). We used an incomplete block design because not all forage treatments were replicated across the three RECs, and we used location as the random term to control for variability between RECs. We tested the assumptions of one-way ANOVA by using the Shapiro-Wilk test ( $W \geq 0.90$ ) and Levene's test ( $P \geq 0.05$ ), and variables failing to meet these assumptions were transformed using arcsine square root (percent cover bare ground) or log<sub>10</sub> (litter depth, invertebrate biomass) transformations. We used Tukey's Honestly Significant Difference test to determine significant differences between treatments with  $\alpha = 0.05$ . Our experimental unit was the pasture. Fixed effects were grazing season (early or full) and forage (SG, BB/IG, EG). Dependent variables included vegetation structure, vegetation composition, and invertebrate measures.

## **Results**

### *Vegetation*

#### *Vegetation Composition*

Coverage of NWSG was similar among forage types and grazing treatments when we initiated grazing in spring 2010, except coverage of switchgrass in the switchgrass pastures was less than coverage of eastern gamagrass in some of the eastern gamagrass pastures ( $P = 0.0157$ ,  $F = 3.08$ , Table 1). By spring 2011, coverage of NWSG was similar in all pastures during the nesting season ( $P = 0.68$ ,  $F = 0.62$ , Table 2). During the brooding season, NWSG coverage in the full-season grazing treatments tended to be less than in early-season treatments, which is intuitive as cattle continued to graze NWSG through the summer ( $P = 0.003$ ,  $F = 4.16$ , Table 2). Coverage of other grasses (e.g., crabgrasses, tall fescue, and dallisgrass) tended to be greater in switchgrass pastures in 2010 ( $P = 0.001$ ,  $F = 4.67$ ) but was similar among all pastures by 2011 ( $P = 0.74$ ,  $F = 0.54$ ), averaging around 10% (Tables 1 and 2). Coverage of forbs was relatively low and did not exceed 10% in any of the pastures except for BB/IG (Tables 1 and 2). Coverage of litter tended to be less in the switchgrass pastures during the brooding period in summer 2010 ( $P = 0.001$ ,  $F = 4.75$ ), but otherwise, coverage of litter was similar among forages and grazing treatments for both years (Tables 1 and 2). There was very little bare ground, and by summer 2011, no pasture contained more than 3% bare ground (Table 2).

#### *Vegetation Structure*

Vegetation structure as measured by cover board photos was fairly similar during the nesting season for both years, which should be expected as all pastures were grazed similarly during the spring of both years (Table 1). Full-season grazing reduced vegetation structure during summer (brooding season) of both years, especially at the VS S2 and VS S3 levels (Tables 3 and 4). There was no difference in ground sighting distance in 2010, but by summer of 2011, openness at ground level was consistently greater in the full-season grazing treatments ( $P = 0.006$ ,  $F = 3.63$ , Table 4). Likewise, angle of obstruction readings were similar among all forages during the nesting period ( $P = 0.25$ ,  $F = 1.38$ ) but greater during the brooding period ( $P = 0.001$ ,  $F = 5.06$ , Tables 3 and 4), which also reflects how full-season grazing reduced vegetation canopy closure and height. Litter depth was variable and insignificantly different in any treatment but generally greater in early-grazing pastures during the brooding season after cattle were removed (Tables 3 and 4).

#### *Invertebrates*

We collected 360 invertebrate samples each year. Invertebrates represented 13 orders from five classes. Three classes (Chilopoda,

**Table 1**

Percent cover (SE) of vegetation, litter, and bare ground in native warm-season pastures grazed under two treatments at three locations across Tennessee, May–July 2010.

Period	Treatment <sup>1</sup>	NWSG <sup>2,3</sup>	Other Grass <sup>4</sup>	Forb <sup>5</sup>	Litter <sup>6</sup>	Bare <sup>7</sup>
Nesting <sup>8</sup>	BBIG Early	0.73 (0.05) AB	0.06 (0.05) B	0.13 (0.02) A	0.07 (0.04) A	0.016 (0.00) A
	BBIG Full	0.69 (0.03) AB	0.16 (0.06) AB	0.13 (0.02) A	0.01 (0.07) A	0.010 (0.00) A
	EG Early	0.79 (0.04) AB	0.12 (0.06) AB	0.08 (0.02) A	0.00 (0.04) A	0.000 (0.00) A
	EG Full	0.85 (0.02) A	0.07 (0.01) AB	0.08 (0.00) A	0.00 (0.02) A	0.000 (0.00) A
	SG Early	0.53 (0.03) B	0.31 (0.05) A	0.10 (0.03) A	0.06 (0.03) A	0.001 (0.00) A
	SG Full	0.56 (0.04) B	0.28 (0.06) A	0.11 (0.03) A	0.04 (0.03) A	0.000 (0.00) A
Brooding <sup>9</sup>	BBIG Early	0.60 (0.04) A	0.15 (0.01) AB	0.09 (0.02) A	0.16 (0.04) AB	0.000 (0.01) A
	BBIG Full	0.44 (0.05) A	0.23 (0.04) AB	0.08 (0.02) A	0.25 (0.01) AB	0.001 (0.00) A
	EG Early	0.69 (0.10) A	0.08 (0.10) AB	0.05 (0.01) A	0.18 (0.00) AB	0.000 (0.00) A
	EG Full	0.64 (0.03) A	0.00 (0.04) B	0.03 (0.02) A	0.33 (0.00) A	0.000 (0.00) A
	SG Early	0.56 (0.04) A	0.29 (0.04) A	0.07 (0.02) A	0.07 (0.02) B	0.000 (0.00) A
	SG Full	0.54 (0.05) A	0.31 (0.03) A	0.06 (0.04) A	0.07 (0.01) B	0.000 (0.00) A

<sup>1</sup> BBIG indicates big bluestem/indiangrass; Early, early-season grazing treatment; EG, eastern gamagrass; Full, full-season grazing treatment; SG, switchgrass.

<sup>2</sup> NWGS, native warm-season grass.

<sup>3</sup> Means within column and sampling period followed by unlike letters are different according to one-way ANOVA and Tukey's HSD test ( $P < 0.05$ ).

<sup>4</sup> Other Grass, species other than NWGS (e.g., large crabgrass, tall fescue, dallisgrass).

<sup>5</sup> Forb, broadleaf herbaceous species (e.g., horseweed, red clover).

<sup>6</sup> Litter, ground covered with dead vegetation and without overhead cover of live vegetation.

<sup>7</sup> Bare, ground not covered with dead vegetation and without overhead cover of live vegetation.

<sup>8</sup> Nesting refers to sampling conducted June 1–June 24, 2010 & 2011.

<sup>9</sup> Brooding refers to sampling conducted July 13–July 30, 2010 & 2011.

Gastropoda, and Malacostraca) were excluded from the analysis because they are not common in the diet of young northern bobwhite (Doxon and Carroll, 2010). We retained and analyzed data from Arachnida and Insecta. There was no difference in total biomass of invertebrates ( $P = 0.91$ ,  $F = 0.09$ ) or order richness ( $P = 0.86$ ,  $F = 0.15$ ) among years, but invertebrate biomass was greater in 2010 than 2011 (Table 5).

**Discussion**

We recorded vegetation composition and measured various structural variables, as well as food availability (invertebrates) important for avian species that use grasslands following two grazing strategies in pastures dominated by NWGS in the Mid-South. Vegetation structure and invertebrate availability were similar regardless of forage type. However, vegetation structure differed greatly with grazing treatment, which influences suitability of nesting and brood-rearing cover for various bird species. Vegetation structure was

similar among forage types during the nesting season because we managed grazing pressure equally across all pastures. Once we concluded early-season grazing, those pastures were not disturbed until the following fall; thus height and structure in those pastures were taller and denser than in the pastures grazed through the brood-rearing period (full-season grazing).

Grassland songbirds and northern bobwhite have specific structural requirements for nesting and brooding. Density of NWGS was sufficient in all treatments to provide nesting cover during spring for species that nest on the ground at the base of grass bunches. Grass density of 10,000 grass clumps per acre (approximately 25% NWGS cover per ha) is desirable for northern bobwhite (Hernandez and Guthery, 2012), and bobwhite commonly nest in areas with 40–60% native grass cover (Barnes et al., 1995; Lusk et al., 2006). Grazing also reduces overall height of NWGS, which can be beneficial for bobwhite because they typically nest in clumps of NWGS < 46 cm tall. Up to 90% grass cover can provide suitable nesting cover for other species that nest on the ground, such as grasshopper sparrow or

**Table 2**

Percent coverage (SE) of vegetation, litter, and bare ground in native warm-season pastures grazed under two treatments at three locations across Tennessee, May–July 2011.

Period	Treatment <sup>1</sup>	NWSG <sup>2,3</sup>	Other Grass <sup>4</sup>	Forb <sup>5</sup>	Litter <sup>6</sup>	Bare <sup>7</sup>
Nesting <sup>8</sup>	BBIG Early	0.72 (0.03) A	0.09 (0.02) A	0.11 (0.03) A	0.05 (0.05) A	0.03 (0.00) A
	BBIG Full	0.64 (0.03) A	0.13 (0.02) A	0.17 (0.03) A	0.05 (0.02) A	0.00 (0.01) A
	EG Early	0.68 (0.06) A	0.08 (0.05) A	0.05 (0.02) A	0.20 (0.02) A	0.01 (0.00) A
	EG Full	0.72 (0.04) A	0.10 (0.01) A	0.01 (0.01) A	0.17 (0.04) A	0.01 (0.01) A
	SG Early	0.71 (0.05) A	0.10 (0.02) A	0.06 (0.02) A	0.10 (0.07) A	0.03 (0.01) A
	SG Full	0.69 (0.04) A	0.12 (0.03) A	0.08 (0.02) A	0.10 (0.04) A	0.01 (0.01) A
Brooding <sup>9</sup>	BBIG Early	0.60 (0.03) AB	0.11 (0.02) A	0.18 (0.01) A	0.11 (0.01) A	0.00 (0.01) A
	BBIG Full	0.51 (0.04) B	0.15 (0.03) A	0.17 (0.04) A	0.16 (0.01) A	0.02 (0.00) A
	EG Early	0.78 (0.02) A	0.07 (0.05) A	0.08 (0.02) A	0.09 (0.02) A	0.00 (0.00) A
	EG Full	0.61 (0.02) AB	0.11 (0.06) A	0.04 (0.01) A	0.20 (0.04) A	0.06 (0.01) A
	SG Early	0.66 (0.02) AB	0.05 (0.02) A	0.07 (0.02) A	0.19 (0.02) A	0.02 (0.01) A
	SG Full	0.52 (0.06) B	0.19 (0.03) A	0.09 (0.01) A	0.19 (0.04) A	0.01 (0.00) A

<sup>1</sup> BBIG indicates big bluestem/indiangrass; Early, early-season grazing treatment; EG, eastern gamagrass; Full, full-season grazing treatment; SG, switchgrass.

<sup>2</sup> NWGS, native warm-season grass.

<sup>3</sup> Means within column and sampling period followed by unlike letters are different according to one-way ANOVA and Tukey's HSD test ( $P < 0.05$ ).

<sup>4</sup> Other Grass, species other than NWGS (e.g., large crabgrass, tall fescue, dallisgrass).

<sup>5</sup> Forb, broadleaf herbaceous species (e.g., horseweed, red clover).

<sup>6</sup> Litter, ground covered with dead vegetation and without overhead cover of live vegetation.

<sup>7</sup> Bare, ground not covered with dead vegetation and without overhead cover of live vegetation.

<sup>8</sup> Nesting refers to sampling conducted June 1–June 24, 2010 & 2011.

<sup>9</sup> Brooding refers to sampling conducted July 13–July 30, 2010 & 2011.

**Table 3**

Vegetation structure measurements (SE) in native warm-season pastures grazed under two treatments at three locations across Tennessee, May–July 2010.

Period	Treatment <sup>1</sup>	GSD <sup>2,3</sup>	AO <sup>4</sup>	VS S1 <sup>5</sup>	VS S2 <sup>6</sup>	VS S3 <sup>7</sup>	Litter depth <sup>8</sup>
Nesting <sup>9</sup>	BBIG Early	0.79 (0.11)	A 23.41 (1.71)	A 0.79 (0.03)	A 0.42 (0.04)	A 0.10 (0.04)	B 1.70 (2.14)
	BBIG Full	0.90 (0.14)	A 25.25 (1.32)	A 0.81 (0.03)	A 0.46 (0.06)	A 0.11 (0.03)	B 1.63 (0.98)
	EG Early	0.91 (0.01)	A 21.08 (2.26)	A 0.84 (0.00)	A 0.59 (0.07)	A 0.30 (0.05)	AB 1.93 (1.44)
	EG Full	0.87 (0.08)	A 16.20 (2.43)	A 0.82 (0.06)	A 0.61 (0.10)	A 0.37 (0.05)	A 1.64 (1.57)
	SG Early	1.15 (0.05)	A 26.08 (1.83)	A 0.88 (0.03)	A 0.62 (0.05)	A 0.30 (0.06)	AB 1.94 (2.19)
	SG Full	0.99 (0.06)	A 22.74 (1.65)	A 0.87 (0.03)	A 0.68 (0.09)	A 0.36 (0.12)	A 2.04 (1.82)
Brooding <sup>10</sup>	BBIG Early	0.90 (0.07)	A 31.76 (1.67)	AB 0.91 (0.06)	A 0.73 (0.11)	A 0.33 (0.05)	B 6.96 (0.31)
	BBIG Full	1.24 (0.09)	A 40.41 (3.24)	A 0.83 (0.05)	A 0.42 (0.10)	B 0.08 (0.05)	C 5.24 (0.20)
	EG Early	1.25 (0.03)	A 35.43 (2.42)	AB 0.88 (0.01)	A 0.68 (0.01)	AB 0.18 (0.08)	BC 5.62 (0.18)
	EG Full	1.37 (0.02)	A 39.22 (1.42)	AB 0.81 (0.02)	A 0.47 (0.03)	AB 0.03 (0.10)	C 4.76 (0.29)
	SG Early	0.98 (0.20)	A 26.08 (2.98)	B 0.89 (0.03)	A 0.82 (0.11)	A 0.63 (0.15)	A 5.37 (0.25)
	SG Full	1.14 (0.17)	A 33.45 (3.20)	AB 0.87 (0.04)	A 0.67 (0.11)	AB 0.34 (0.16)	B 4.67 (0.41)

<sup>1</sup> BBIG indicates big bluestem/indiangrass; Early, early-season grazing treatment; EG, eastern gamagrass; Full, full-season grazing treatment; SG, switchgrass.<sup>2</sup> GSD, ground-sighting distance (m).<sup>3</sup> Means within column and sampling period followed by unlike letters are different according to one-way ANOVA and Tukey's HSD test ( $P < 0.05$ ) for each year.<sup>4</sup> AO, angle of obstruction (degrees).<sup>5</sup> VS S1, vertical structure (%) in the 0–30 cm stratum of the cover board.<sup>6</sup> VS S2, vertical structure (%) in the 30–60 cm stratum of the cover board.<sup>7</sup> VS S3, vertical structure (%) in the 60–100 cm stratum of the cover board.<sup>8</sup> L Depth, litter depth (cm).<sup>9</sup> Nesting refers to sampling conducted June 1–June 24, 2010 & 2011.<sup>10</sup> Brooding refers to sampling conducted July 13–July 30, 2010 & 2011.

eastern meadowlark (*Sturnella magna*; Roseberry and Klimstra, 1970) or for Henslow's sparrow (*Ammodramus henslowii*), which nests among grass cover off the ground (Winter, 1999). The density and height of vegetation at 30–60 cm and 60–100 cm were suitable during spring in all treatments for species such as dickcissel (*Spiza americana*) and field sparrow (*Spizella pusilla*) that typically nest above the ground within standing vegetation (Bollinger, 1995; Patterson and Best, 1996).

Our full-season grazing treatment provided structural requirements similar to what has been reported as selected by northern bobwhite broods (Taylor et al., 1999). Full-season grazing increased and maintained openness of vegetation structure at the ground level while maintaining a canopy height (30–40 cm) desirable for foraging and brood-rearing. Conditions for brooding bobwhite declined after cattle were removed from the early-season grazing pastures with decreased ground sighting distance, increased litter, and increased

vegetation density. Pastures without cattle may have become unusable by midsummer for species with precocial young, such as bobwhite, whose chicks forage for themselves and require an open structure at the ground level to forage efficiently while avoiding predators (Stoddard, 1931; Hurst, 1972; Klimstra and Roseberry, 1975; Taylor et al., 1999). A study of foraging bobwhite chicks in Kansas reported dense vegetation at ground level greatly reduced mobility of chicks and limited the area in which they could forage and their ability to locate invertebrate prey (Doxon and Carroll, 2010). Presence of other grasses filling voids between native grasses, such as those we recorded (crabgrass [*Digitaria sanguinalis* L.], dallisgrass [*Paspalum dilatatum* L.]) in several switchgrass pastures, also can limit mobility of northern bobwhite chicks and ground-feeding songbirds, such as grasshopper sparrow, in pastures with NWSG.

Grassland obligate songbirds, such as grasshopper and Henslow's sparrows, nesting in pastures with NWSG also benefit from full-

**Table 4**

Vegetation structure measurements (SE) in native warm-season pastures grazed under two treatments at three locations across Tennessee, May–July 2011.

Period	Treatment <sup>1</sup>	GSD <sup>2,3</sup>	AO <sup>4</sup>	VS S1 <sup>5</sup>	VS S2 <sup>6</sup>	VS S3 <sup>7</sup>	Litter depth <sup>8</sup>
Nesting <sup>9</sup>	BBIG Early	1.59 (0.04)	AB 47.11 (1.71)	A 0.64 (0.02)	B 0.14 (0.07)	B 0.01 (0.06)	A 1.63 (0.35)
	BBIG Full	1.32 (0.07)	B 41.94 (2.22)	AB 0.78 (0.04)	AB 0.35 (0.06)	A 0.04 (0.02)	A 1.37 (0.26)
	EG Early	1.86 (0.03)	A 40.14 (1.20)	AB 0.77 (0.00)	AB 0.34 (0.05)	AB 0.01 (0.09)	A 1.38 (0.16)
	EG Full	1.79 (0.28)	AB 48.66 (2.07)	AB 0.70 (0.02)	AB 0.23 (0.04)	AB 0.01 (0.00)	A 1.36 (0.13)
	SG Early	1.55 (0.07)	AB 38.00 (0.75)	AB 0.78 (0.02)	AB 0.37 (0.04)	AB 0.06 (0.12)	A 1.63 (0.64)
	SG Full	1.43 (0.08)	AB 36.00 (2.85)	B 0.84 (0.03)	A 0.52 (0.09)	A 0.12 (0.04)	A 1.28 (0.31)
Brooding <sup>10</sup>	BBIG Early	0.93 (0.12)	C 33.42 (2.98)	BC 0.94 (0.08)	A 0.69 (0.04)	B 0.24 (0.00)	BC 2.27 (0.30)
	BBIG Full	1.34 (0.09)	B 42.89 (1.80)	AB 0.73 (0.06)	B 0.25 (0.09)	CD 0.05 (0.02)	D 2.10 (0.27)
	EG Early	0.97 (0.19)	BC 32.92 (4.77)	ABC 0.94 (0.03)	AB 0.85 (0.04)	AB 0.46 (0.02)	AB 1.09 (0.21)
	EG Full	2.06 (0.20)	A 47.91 (5.68)	A 0.76 (0.06)	AB 0.07 (0.10)	D 0.05 (0.03)	D 1.19 (0.18)
	SG Early	1.04 (0.07)	BC 23.85 (1.93)	C 1.01 (0.05)	A 0.96 (0.10)	A 0.64 (0.03)	A 1.97 (0.34)
	SG Full	1.47 (0.12)	B 42.02 (2.23)	AB 0.84 (0.05)	AB 0.42 (0.10)	C 0.09 (0.04)	CD 1.73 (0.23)

<sup>1</sup> BBIG indicates big bluestem/indiangrass; Early, early-season grazing treatment; EG, eastern gamagrass; Full, full-season grazing treatment; SG, switchgrass.<sup>2</sup> GSD, ground-sighting distance (m).<sup>3</sup> Means within column and sampling period followed by unlike letters are different according to one-way ANOVA and Tukey's HSD test ( $P < 0.05$ ) for each year.<sup>4</sup> AO, angle of obstruction (degrees).<sup>5</sup> VS S1, vertical structure (%) in the 0–30 cm stratum of the cover board.<sup>6</sup> VS S2, vertical structure (%) in the 30–60 cm stratum of the cover board.<sup>7</sup> VS S3, vertical structure (%) in the 60–100 cm stratum of the cover board.<sup>8</sup> L Depth, litter depth (cm).<sup>9</sup> Nesting refers to sampling conducted June 1–June 24, 2010 & 2011.<sup>10</sup> Brooding refers to sampling conducted July 13–July 30, 2010 & 2011.

**Table 5**

Mean invertebrate biomass (SE) and ordinal richness in native warm-season pastures grazed under two treatments at three locations across Tennessee, July 2010 & 2011.

Treatment <sup>1</sup>	2010		2011		2010		2011	
	Total Biomass <sup>2,3</sup>		Total Biomass		Order Richness <sup>4</sup>		Order Richness	
BBIG Early	0.33 (0.07)	A	0.09 (0.01)	A	3.4 (0.1)	A	4.6 (0.1)	A
BBIG Full	0.22 (0.04)	A	0.07 (0.01)	AB	3.7 (0.1)	A	4.3 (0.1)	A
EG Early	0.28 (0.09)	A	0.05 (0.01)	AB	3.6 (0.2)	A	3.5 (0.2)	A
EG Full	0.38 (0.08)	A	0.02 (0.01)	B	3.5 (0.2)	A	2.9 (0.2)	A
SG Early	0.24 (0.05)	A	0.06 (0.01)	AB	3.9 (0.2)	A	4.4 (0.2)	A
SG Full	0.19 (0.05)	A	0.04 (0.01)	B	3.9 (0.1)	A	4.0 (0.1)	A

<sup>1</sup> BBIG indicates big bluestem/indiangrass; Early, early-season grazing treatment; EG, eastern gamagrass; Full, full-season grazing treatment; SG, switchgrass.

<sup>2</sup> Means within column followed by unlike letters are different according to one-way ANOVA and Tukey's HSD test ( $P < 0.05$ ) for each year.

<sup>3</sup> Total Biomass refers to g/m<sup>2</sup> of invertebrates collected.

<sup>4</sup> Order Richness refers to the number of orders collected.

season grazing that maintains lower vegetation heights through summer for multiple nesting attempts. In a study of grassland bird nesting phenology in Tennessee and Kentucky, *Giocomo et al. (2008)* reported the last nest initiation dates for grassland birds occurred in early July. Thus early-season grazing, which ended by early or mid-June in our study, may not maintain vegetation height desirable for nesting throughout the nesting period for species that typically use shorter vegetation. Although both grazing treatments provided suitable nesting structure early in the breeding season, full-season grazing maintained suitable structure for additional nesting attempts later in the summer, which are critical for population persistence of these species in the Mid-South (*Giocomo et al., 2008*).

We detected no difference in invertebrate biomass between treatments, but a large difference between years. Invertebrate abundance has been correlated with forb cover (*Smith et al., 1985; Gibson et al., 1992; Jonas et al., 2002; Engle et al., 2008*), and there was little forb cover in any of our pastures. Invertebrate biomass was variable across pastures and years, ranging from 200–3800 g (dry weight) ha<sup>-1</sup> among experimental units and years. Northern bobwhite chicks require approximately 4 g of invertebrates (dry weight) per day for normal growth and development during their first 2 weeks of life (*Palmer, 1995*). Average clutch size for northern bobwhites is 14 chicks, and brood home range size averages 13 ha (*Taylor et al., 1999*). Thus even in treatments with the lowest invertebrate biomass, a brood would have more than ample invertebrate prey within 0.3 ha. Previous studies have shown the relationship between invertebrates sampled by humans and those consumed by foraging chicks may not be directly comparable (*Palmer, 1995; Doxon and Carroll, 2010; Osborne, 2010*). However, in pastures with suitable vegetation structure, chicks can forage efficiently. Our data suggest invertebrate availability is not a limiting factor for brood-rearing northern bobwhite in grazed pastures with NWSG in the Mid-South. However, pastures grazed only during the early growing season, with decreased ground sighting distances and no bare ground by mid-summer, may not provide usable space for northern bobwhite broods, regardless of invertebrate biomass, because of the dense vegetation structure.

## Implications

Our data suggest forage and livestock producers in the Mid-South who are interested in grassland birds and bobwhite can use full-season grazing (May–August) to create and maintain structure suitable for nesting and brood-rearing in pastures of switchgrass, eastern gamagrass, and big bluestem/indiangrass mixtures. Early-season

grazing also provides suitable structure during spring, but conditions decline for many species after cattle are removed during midsummer. Grazing intensity should maintain the pasture in a prereproductive, vegetative state to maximize cattle weight gains by keeping forage palatable and digestible. Maintaining a stand height of approximately 40 cm will protect the growth point of tall NWSG, such as big bluestem and switchgrass, provide ample grazing, maintain stand vigor, and retain cover for nesting and brooding birds. During the brooding period, grazing pressure should promote an open structure at ground level required by foraging chicks but not remove overhead cover for the birds. As NWSG continue to be promoted for livestock grazing in the Mid-South, maintaining suitable structure will be required to ensure benefits for grassland birds and northern bobwhite.

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