Avian Habitat Response to Grazing, Haying, and Biofuels Production in Native Warm-Season Forages in the Mid-South

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Abstract

Declines in grassland birds have been attributed to loss of habitat, habitat degradation, and changes in land management. In the Mid-South, pasture and hayfield management has focused on maintaining dense stands of non-native forages that do not provide suitable vegetative structure for grassland birds or northern bobwhite. Native warm-season grasses have been promoted for livestock forage and biofuels feedstock. However, little information exists on how these practices affect habitat for grassland songbirds or northern bobwhite in the Mid-South. We conducted a study of two cattle grazing treatments, two hay harvest treatments and a biofuels harvest treatment on vegetative structure for nesting and brood-rearing grassland birds and northern bobwhite in native warm-season grasses. We evaluated vegetative composition and structure during a typical nesting period for grassland songbirds and a typical brood-rearing period for northern bobwhite across Tennessee, 2010 and 2011. We also evaluated invertebrate availability in each grazing treatment. Full-season grazing created suitable structure for nesting and brood-rearing grassland songbirds and northern bobwhite, whereas early-season grazing only provided suitable nesting structure for these species through early summer. Hay and biofuels stands provided adequate nesting cover for grassland songbirds and northern bobwhite, and hay harvests in May and June enhanced structure for brood-rearing northern bobwhite by reducing grass height. However, hay harvests in May or June are likely to impact nesting success for grassland songbirds and northern bobwhite. NWSG planted for biofuels only did not provide suitable structure for northern bobwhite broods. We recommend big bluestem and indiangrass for hay production, as these species mature later and hay harvest is less likely to impact grassland bird reproductive success. In areas where grassland birds and northern bobwhite are a management concern, grazing is a better management tool than haying or biofuels production.

We recommend full-season grazing in production stands of native warm-season forages to maximize benefits where grassland birds and northern bobwhite are a management concern.

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INTRODUCTION

Grassland birds are declining at alarming rates across the United States with declines frequently linked to loss of habitat and changes in agricultural management practices. In light of these declines, wildlife managers have looked at ways to modify agricultural lands to benefit grassland birds. A major focus has been on the use of native warm-season grasses for forage production and biofuels. While extensive research has been conducted on these grass species in the Midwest, none has been conducted on native warm-season forages in the Mid-South. Given this lack of information, the Center for Native Grasslands Management at the University of Tennessee undertook an experimental study to determine the use of native warm-season forages in the Mid-South. The study was designed to evaluate the use of native warm-season forages for grazing, haying, and biofuels production from an agronomic, livestock production, and wildlife management prospective.

Data were collected to evaluate avian habitat in various applications of native warm-season forages. From these data, I formatted two manuscript chapters under the requirements specified by the journal Rangeland Ecology and Management. Each chapter will be submitted for publication to either Rangeland Ecology and Management or another suitable academic journal. Chapter 1 evaluates avian habitat in grazed stands of native warm-season forages and Chapter 2 evaluates avian habitat in hay and biofuels production stands of native warm-season forages.

I. AVIAN HABITAT RESPONSE TO GRAZING NATIVE WARM-SEASON FORAGES IN THE MID-SOUTH

Abstract

Pasture and hayfield management in the Mid-South has focused on maintaining dense stands of non-native forages that do not provide suitable vegetative structure for grassland birds or northern bobwhite. Native warm-season grasses have been promoted for livestock forage and biofuels feedstock. However, little information exists on how these practices affect habitat for grassland songbirds or northern bobwhite in the Mid-South. We conducted a study of two cattle grazing treatments on native warm-season grass forages to evaluate suitability for nesting and brood-rearing grassland songbirds and northern bobwhite. We evaluated vegetative composition, vegetative structure, and invertebrate availability during a typical nesting period and a typical brood-rearing period for northern bobwhite across 3 sites in Tennessee, 2010 & 2011. Grazing treatments included a full-season treatment, with animals maintained from May-August, and an early-season treatment, with animals allowed to graze for 30 days initially, and then removed to allow subsequent forage growth to develop for a biofuels harvest the following fall. Native grass density was high in all pastures, with little to no bare ground. During the nesting period, both grazing treatments maintained similar structure. Full-season grazing maintained suitable structure through the brooding period, with greater openness at the ground level and better visibility for foraging chicks. Structure within early-season grazing grew dense with less visibility and openness at ground level than what northern bobwhites typically use. Invertebrate biomass was sufficient in both treatments to support northern bobwhite broods. We recommend full-season grazing in production stands of native warm-season forages to maximize benefits where grassland birds and northern bobwhite are a management concern.

Key Words: northern bobwhite, grazing, vegetation structure, grassland songbirds, native warm-season grasses

Introduction

Grassland birds are declining faster than any other group of North American birds with more than two-thirds of grassland species showing significant negative declines (Vickery and Herkert 2001, Sauer 2011). Among the species experiencing declines are the grasshopper sparrow (*Ammodramus savannarum*) and the northern bobwhite (*Colinus virginianus*). Habitat loss, habitat degradation, and agricultural intensification are primary factors contributing to grassland bird declines (Herkert 1994, Brennan and Kuvlesky 2005). Conversion to non-native forage species has been a persistent and growing threat to native grasslands globally (Peterjohn 2003, Brennan and Kuvlesky 2005), and changing grassland management practices have contributed to the decline of grassland birds throughout the United States (Rahmig et al. 2008). Wilson et al. (2005) identified two changes in agricultural practices in grassland systems that have had a particular impact on grassland bird species: an increase in the duration and intensity of grazing and an increase in forage harvest frequencies (Wilson et al. 2005).

In the Mid-South, native grasslands have nearly disappeared, but there are more than 20 million acres in non-native grasslands as either pasture or hay (Nickerson et al., 2011). Typical grazing and hay operations in the Mid-South are based on tall fescue (*Schedonorus phoenix* Scop.)**,** which is often grazed continually throughout the year or hayed 2 or 3 times from May through September (Ball et al. 2007). This type of management does not promote the vegetative structure necessary to maintain diverse grassland bird populations. Dense stands of non-native cool-season grasses, such as tall fescue, provide poor habitat for northern bobwhite as there is no bare ground, little vertical structure, and limited food resources (Barnes et al. 1995). Currently, native warm-season grasses (NWSG) such as big bluestem (*Andropogon gerardii* Vitman), indiangrass (*Sorghastrum nutans* L.), switchgrass (*Panicum virgatum* L.), and eastern gamagrass

(*Tripsacum dactyloides* L.), are being promoted by state and federal agencies for wildlife habitat improvement and forage production (NRCS 2005). NWSG can be used to compliment forage systems based on cool-season grasses because of their differing seasonality (Ball et al. 2007). Cool-season forages produce the majority of their growth during spring-fall, whereas NWSG produce most of their growth during the summer (Ball et al. 2007, Mulkey et al. 2008). Regardless of the grass species, pasture management ultimately determines suitability for many bird species.

The impact of livestock grazing on birds has been studied in the West and Midwest (George et al. 1979, Fuhlendorf et al. 2006, Rahmig et al. 2009) with mixed findings. Fuhlendorf et al. (2006) found combinations of grazing and prescribed fire in tallgrass prairies of Oklahoma increased avian diversity, particularly when several forage species were present. Grazed pastures had diverse bird communities in the Flint Hills of Kansas, but no differences in diversity were observed between season-long and intensive-early grazing systems (Rahmig et al. 2009). The impact of grazing on vegetative structure depends on stocking rate and duration of grazing. A 6-year study of grazing in tallgrass prairies in Kansas found grazed pastures had more diverse vegetative structure and higher species richness than ungrazed pastures (Hickman et al. 2004). Hickman et al. (2004) reported increased diversity in pastures grazed from 1 AU (animal unit)/1.8ha to 1 AU/3.8ha with the greatest diversity of native species at the highest stocking density. Hammerquist-Wilson and Crawford (1981) found high-intensity grazing systems had more bare ground and greater forb cover than continuous grazing systems, a characteristic that favors northern bobwhite by promoting more open space for foraging and travel at ground level (Stoddard 1931). Not all grassland bird species have the same structural requirements, thus grazing strategies influence bird species differently. Fuhlendorf et al. (2006) recommended increasing spatial heterogeneity in grasslands to address this issue, creating areas in various stages of growth through grazing and prescribed fire. The impact of grazing on vegetative structure and grassland birds in the Mid-South has not been evaluated.

Production of switchgrass for biofuels feedstock is being evaluated across the United States (Bies 2006, Fike et al. 2006). Few studies have assessed the impact of producing switchgrass for biofuels feedstock on birds or other wildlife. Switchgrass harvested for biofuels is typically cut once in late fall when biomass is highest (Parrish and Fike 2005). Cutting at this time does not impact grassland birds during the breeding season (Roth et al. 2005); however, it does remove winter cover. Harvested and unharvested switchgrass fields were studied in Iowa during the breeding season following a winter harvest (Murray and Best 2003, Murray et al. 2003). A mixture of harvested and unharvested fields provided habitat for some grassland birds, but unharvested fields did not provide suitable nesting cover for species that require shorter, less-dense vegetation, such as the grasshopper sparrow (*Ammodramus savannarum*). In both strip-harvested and total-harvested switchgrass biofuels fields, total bird abundance was greater than that in unharvested fields (Murray et al. 2003). Murray and Best (2003) suggested switchgrass stands kept dense and uniform were not optimal for grassland birds and that maintaining bare ground and diverse vertical structure in switchgrass stands could improve habitat quality. Roth et al. (2005) recommended a mixture of harvested and unharvested switchgrass biofuel stands to maximize the number of grassland bird species and recommended research investigate biofuels feedstock production and habitat potential of multi-species native grass fields. While these may be sound recommendations for grassland bird conservation, it is not compatible with biofuel production, which requires dense monocultures for optimal ethanol production (Fike et al. 2006, Keshwani and Cheng 2009). Only one study to date has investigated the impact of biofuels feedstock production on birds in the Mid-South (West 2011).

Few studies have examined the vegetative response of native warm-season forages to various grazing systems with respect to bird habitat (Giuliano and Daves 2002, Wilson et al. 2005, Fuhlendorf et al. 2006, Willcox et al. 2010). Research on biofuels feedstock production and its impact on birds is also scarce with few studies conducted in the Midwest (Murray et al. 2003, Roth et al. 2005). Given this lack of information regarding the impact of grazing systems and biofuels feedstock production on avian habitat in the Mid-South, we conducted a field experiment to evaluate avian habitat in production stands of NWSG. We tested two grazing strategies on various NWSG forages across Tennessee. In both strategies, pastures were grazed beginning in late spring, with full-season pastures grazed continuously through summer and early-season pastures grazed for only the first 30 days of the season. Early-season pastures were allowed to grow into mature stands that could be harvested for a biofuels crop. Vegetative structure, composition, and invertebrate abundance were measured in grazed NWSG stands to evaluate the influence of grazing treatment on grassland bird habitat.

Methods

Study Area

We conducted our research on Ames Plantation Research and Education Center (APREC) located near Grand Junction, TN (35°6'N, 89°13'W), Highland Rim Research and Education Center (HRREC) located near Springfield, TN (36°28'N, 86°50'W), and The Research and Education Center at Greeneville (RECGRN) located near Greeneville, TN (36°6'N, 82°51'W). Three NWSG combinations were planted in 2008: 1) switchgrass (SG), 2) big bluestem/indiangrass mixture (BB/IG) and 3) eastern gamagrass (EG). We imposed two grazing treatments, early-season and full-season, on each NWSG. 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 summer.

Before initiation of this study, all pastures were predominantly tall fescue. 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 receiving BB/IG treatment were sprayed with imazapic (0.11kg ai/ha) to control competition in the establishment year. A no-till drill was used to plant each SG and BB/IG pasture and a corn planter was used to plant EG. Seeding rates were 6.72 kg PLS (pure live seed)/ha, 10.08 kg PLS/ha, and 13.44 kg PLS/ha for SG, BB/IG, and EG respectively. Cultivars of NWSG grass used were 1) Alamo switchgrass, 2) OZ-70 big bluestem/Rumsey indiangrass and 3) Pete eastern gamagrass. The big bluestem/indiangrass mixture included 65% big bluestem and 35% indiangrass. Soil samples were taken from pastures in 2010 and 2011. Amendments including lime, nitrogen, phosphorus, and potassium were added in April of each year according to soil test recommendations from the University of Tennessee Soil Testing Lab. Pastures were not fertilized during establishment to avoid stimulating competitive species.

Forages planted at APREC were SG, BB/IG, and EG. Each forage treatment was exposed to both grazing treatments, and these six combinations were replicated three times for a total of 18 (1.2-ha) pastures. In the spring of 2010 and 2011, pastures were burned to remove residual biomass from the previous year. In 2010, grazing began May 28. Early-season grazing concluded June 28 for all pastures and full-season grazing concluded August 9, July 26, and August 30 for

SG, BB/IG, and EG, respectively. In 2011, grazing began May 4 on all pastures. Early-season grazing concluded June 6 and full-season grazing concluded August 9 for all pastures.

At HRREC, SG and BB/IG pastures were established. Each forage treatment was replicated three times per grazing treatment for a total of 12 (1.2-ha) pastures. In the spring of 2010 and 2011, pastures were clipped to 20cm with a rotary mower to remove residual biomass from the previous year. In 2010, grazing began May 7. On all pastures, early-season grazing concluded June 7, and full-season grazing concluded August 9. In 2011, grazing began May 6 on all pastures. Early-season grazing concluded June 6, and full-season grazing concluded August 29 for all pastures.

The forage species treatment at RECGRN was BB/IG. The forage treatment was replicated three times per grazing treatment for a total of 6 (1.2-ha) pastures. In the spring of 2010 and 2011, pastures were burned to remove residual biomass from the previous year. In 2010, grazing began May 21 on all pastures. Early-season grazing concluded June 21 and full-season grazing concluded August 16 for all pastures. In 2011, grazing began May 20 for both treatments. Early-season grazing concluded June 20 and full-season grazing concluded August 15 for all pastures.

Tennessee Livestock Producers (Columbia, TN) provided steers for use in this project. A put-and-take grazing strategy was implemented. When forage growth was high, additional animals were added to pastures to maintain grass height at approximately 38 cm in full-season treatments and down to 30 cm in early-season treatments. Additional animals were then removed. All animal care was in accordance with UT-IACUC Protocol No. 1264. All grazing animals were provided a general cattle mineral free choice, access to water, and each pasture had adequate shade structures.

Vegetation Surveys

Vegetation surveys were conducted 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 and brood-rearing periods, respectively, for northern bobwhite (Stoddard 1931). Vegetation composition and litter depth were measured along five 10-m transects in each pasture, with observations made every 10 cm. At each 10-cm point, all plants bisecting the transect were recorded, then the total number of observations for the entire transect were summed to determine the percent coverage of any given species across a transect. Litter and bare ground were also recorded when present. Litter was defined as ground covered by dead vegetation without overhead cover of live plants, whereas bare ground was defined as ground without dead vegetation or overhead cover of live plants. Transects were established randomly throughout the pasture and different locations were used during every sampling period. Litter depth was measured at 1, 5, and 10 meters.

Vegetation structure was measured from a stationary point at the beginning of each 10-m transect, for 5 points per pasture during each sampling period. Ground sighting distance, a measure of the openness of vegetation 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 in a given direction 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.

Angle of obstruction, a measure of the openness of the vegetative canopy, was measured using a 2-m pole and clinometer. The pole was placed at the same point used for measuring ground sighting distance and while the bottom of the pole remained in one place, the top was leaned towards the nearest vegetation in a given direction 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, for 20 observations for each pasture in each sampling period.

Vertical structure was evaluated using digital visual obstruction readings (Limb et al. 2007). Photos were taken of vegetation against a 1-m x 1-m white board using a Canon EOS Rebel® camera (10.1 megapixels) at a distance of 4 meters and a height of 1 meter, similar to the standards used with a Nudds board (Nudds 1977). The white board was marked on each side at each 0.1 m increment. Two photos were taken in random locations at each vegetation transect, for a total of 20 pictures per pasture in each sampling period. All photos were uploaded to the software CS3 (Adobe Systems Inc., San Jose, CA) for analysis in Adobe Photoshop®. Threshold and histogram functions in CS3 were used to determine the total visual obstruction of each photo in three height sections: 0-30 cm (section 1), 30-60 cm (section 2), and 60-100 cm (section 3). This analysis was conducted based on Limb et al. (2007), with final visual obstruction equal to the percent of black pixels in each board section.

Invertebrate Surveys

Invertebrates were collected in July of 2010 and 2011 using a $0.25m^2$ bottomless box, 0.25m tall with a hinged lid and a modified hand-held blower-vac (Harper and Guynn 1998). Ten randomly selected samples were collected in each pasture each year. The box was quickly placed on vegetation and the blower-vac was used to vacuum the vegetation and litter within the box, collecting the sample into a cloth mesh bag. Sampling was conducted in the afternoons, when vegetation was dry and the temperature was > 27º C. Samples were frozen on site until they could be transferred to a forced-air oven, where they were dried for 48 hours at a constant temperature of 60º 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

Vegetation composition was analyzed by grouping plants into biologically significant associations. Groups included NWSG, other grass, forb, litter, or bare ground. Data were averaged across subsamples to obtain a mean for each treatment combination at each location. The experiment was analyzed in a two-factor randomized block design with nested treatments (forage by location), blocked on location, and with repeated measures. Data were analyzed using mixed models in SAS 9.3 (SAS Institute, Cary, N.C.) The assumptions of one-way analysis of variance (ANOVA) were tested 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 $\log_{10}$ (litter depth, invertebrate biomass) transformations. Tukey's Honestly Significant Difference test was used to determine significant differences between treatments with $\alpha = 0.05$. Experimental unit was the pasture. Fixed effects were grazing season (early or full) and forage species (SG, BB/IG, EG). Fixed effects included all vegetation structure, vegetation composition, and invertebrate variables. Random effects included location and year.

Results

Vegetation

Vegetation Composition

Vegetation composition varied among forage treatments, locations, year, and sampling period (Table 1, 2). NWSG coverage ranged from 36-86% and differed ($p=0.0057$, $F_{5,95}=3.53$) among treatments by location, year, and sampling period. Coverage by other grass species ranged from 2-43% and was greater ($p<0.0001$, $F_{1,95}=29.10$) across treatments in 2010 (18%) than 2011 (11%). No difference in other grass cover was observed between treatments during the 2011 nesting period. Forb cover ranged from 0-21% and was similar ($p=0.8321$, $F_{5,95}=0.42$) among all treatments during the 2010 nesting period and both periods in 2011. Litter coverage ranged from 0-43% and increased ($p<0.0001$, $F_{1,95}=109.54$) from the nesting period (6%) to the brooding period (17%) across treatments and years. There was little bare ground in any treatment (0-6%).

Vegetation Structure

Vegetation structure varied among forage treatments, locations, year, and sampling period (Table 3, 4). Average ground-sighting distance was similar during the nesting period in full-season (1.15 m) and early-season (1.25 m) treatments across all pastures in both years, but differed during the brooding period with 40% greater ground sighting distance in full-season treatments (1.37 m) than early-season treatments (0.97 m, $p<0.0001$, $F_{1,95}=53.63$). Angle of obstruction measurements showed a trend similar to ground-sighting distance, with the greatest measure across all treatments and years (indicating the greatest canopy openness) in full-season pastures during the brooding period ($p<0.0001$, $F_{1,95}=44.99$). Vertical structure in the 0-30 cm cover board section ranged from 64-100%, in the 30-60 cm section from 6-98%, and in the 60-100 cm section from 0-83%. Litter depth ranged from 0.74-12.5 cm.

Invertebrates

We collected 360 invertebrate samples each year. Invertebrates represented 13 orders from five classes., Three classes were excluded from the analysis because they are not common in the diet of young northern bobwhite (Doxon and Carroll 2010). No treatment differences were detected within sites during 2010 or 2011 for either invertebrate biomass ($p=0.2979$, $F_{5,47}=1.26$) or invertebrate order richness ($p=0.7528$, $F_{5,47}=0.53$, Table 5). Average invertebrate biomass was greater in 2010 (0.55 g/m^2) than in 2011 (0.23 g/m^2) across all treatments ($p<0.0001$, $F_{1,47}=78.50$). Average invertebrate order richness was greater in 2011 (4.52) than 2010 (3.51, $p<0.0001$, $F_{1,47}=35.87$).

Discussion

Grassland birds and northern bobwhite have specific structural requirements for nesting and brooding. We evaluated grazed NWSG pastures during both periods to assess the suitability of vegetation for nesting, brooding, or both. Both of our grazing treatments created structure suitable for nesting grassland birds; however, the full-season grazing treatment created structure more similar to what has been reported as selected by northern bobwhite broods. Density of NWSG was high in all pastures, as would be expected in stands established for forage and/or biomass production. However, grazing reduced grass canopy coverage. Full-season grazing increased and maintained the openness of vegetation structure at the ground level, whereas the height and density of vegetation increased from the nesting to the brooding period following early-season grazing. Invertebrate biomass was similar between most treatments.

During the nesting period, all treatments provided adequate NWSG coverage for nest concealment, but not all treatments provided suitable substrate between clumps of NWSG. The density of other grass species (e.g., crabgrass (*Digitaria sanguinalis* L.), dallisgrass (*Paspalum dilatatum* L.)) in several SG pastures, for example, could limit mobility of species such as northern bobwhite (Klimstra and Roseberry 1975, Barnes et al. 1995). NWSG density was sufficient in all treatments to provide nesting cover for species that nest on the ground at the base of grass bunches. For northern bobwhite, grass densities of 10,000 grass clumps per acre (approximately 25% NWSG cover per ha) are desirable (Guthery 1986), with bobwhite nests commonly reported in areas with grass densities from 40-60% (Barnes et al. 1995, Lusk et al. 2006). For other species that nest on the ground, such as eastern meadowlarks, up to 90% grass coverage can provide suitable nesting cover (Roseberry and Klimstra 1970). The density of vegetation in cover board sections at 30-60 cm and 60-100 cm was suitable in all treatments for species such as field sparrows (*Spizella pusilla*) that nest within standing vegetation (Bollinger 1995, Patterson and Best 1996).

We did not detect differences in vegetation structure as a result of grazing treatment during the nesting period. Both grazing treatments used similar numbers of animals initially, so similarities in vegetation structure were not unexpected. Vegetation structure in eastern gamamgrass pastures during the nesting period was similar to that seen in another study of NWSG in the Mid-South (West 2011). Vegetative structure differed between grazing treatments during the brooding period when pastures that no longer contained cattle grew taller and more dense. During the brooding period, ground sighting distances decreased, litter depths increased, and vegetative cover increased in all strata of our vertical structure cover boards in pastures under the early-season treatment. For species with precocial young, such as northern bobwhite, pastures without grazing were likely unusable during the brooding period. Northern bobwhite chicks forage for themselves and require specific structure at the ground level to forage efficiently and safely (Stoddard 1931, Hurst 1972, Klimstra and Roseberry 1975, Taylor et al. 1999). Overhead cover with open structure at the ground level is needed for mobility as young birds search for invertebrates. A study of foraging bobwhite chicks in Kansas found dense vegetation at ground level greatly reduced a chick's mobility and limiting the area in which it could forage and its ability to locate invertebrate prey (Doxon and Carroll 2010).

We excluded three classes from the invertebrate biomass analysis, Chilopoda, Gastropoda, and Malacostraca, as these are not commonly eaten by young northern bobwhite (Doxon and Carroll 2010). Biomass analysis included all invertebrates sampled from Classes Insecta and Arachnida. Invertebrate biomass was similar among treatments. The difference in invertebrate biomass between years at APREC may have been associated with variation in annual environmental conditions. Invertebrate abundance is often correlated with forb cover (Smith et al. 1985, Gibson et al. 1992, Jonas et al. 2002, Engle et al. 2008), something that was lacking in our pastures. When extrapolated, invertebrate biomass ranged from 800 – 17,900 grams (dry weight) per ha in our study pastures. Northern bobwhite chicks require approximately 4 grams of invertebrates (dry weight) per day for normal growth and development during their first two 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 ample invertebrate prey within its home range. Previous studies have shown the relationship between invertebrates sampled by humans and those consumed by foraging chicks can be difficult to tease apart (Palmer 1995, Doxon and Carroll 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 NWSG pastures in the Mid-South. However, early-season pastures, with decreased ground-sighting distances and no bare ground, would not provide usable space for northern bobwhite broods, regardless of invertebrate biomass or density, because of their vegetative structure.

Finding a balance between NWSG density that provides nesting cover without limiting mobility of adult and young northern bobwhite during brooding has been evaluated with most studies reporting 20-50% NWSG coverage as ideal for use by northern bobwhites (Klimstra and Roseberry 1975, George et al. 1979). However, this range is unacceptable for many livestock and biomass producers that want greater grass density for increased production. Full-season grazing can be used to improve structure for northern bobwhite during the brooding season and maintain suitable nesting cover. Grassland obligate songbirds, such as grasshopper and Henslow's sparrows, nesting in NWSG pastures would benefit from full-season grazing that maintains lower vegetative heights. 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 ranged from 28 June-4 July; thus, early-season grazing, which ended in early June, would not maintain suitable nesting structure throughout the nesting period for species such as grasshopper sparrow that require 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 some areas (Giocomo et al. 2008).

Management Implications

We recommend full-season grazing (May-August) to create favorable structure for nesting and brood-rearing in pastures of switchgrass, eastern gamagrass, and big bluestem/indiangrass mixtures where producers are interested in grassland birds and northern bobwhite. Grazing intensity should maintain the pasture in a pre-reproductive state to maximize cattle weight gains by keeping forage palatable and digestible. Maintaining a stand height of approximately 45 cm will protect the growth point of tall NWSG, such as big bluestem and switchgrass, 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. NWSG can be used to compliment cool-season forage grazing systems to benefit both cattle production and grassland bird conservation. As NWSG continue to be promoted for livestock grazing where wildlife is a consideration, maintaining suitable structure will be required to ensure benefits for grassland birds and northern bobwhite.

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Appendix

Table 1. 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 2010.

Period	Site[1]	Treatment	NWSG [3,4]	Other Grass[5]	Forb[6]	Litter[7]	Bare [8]
Nesting[9]	APREC	BBIG Full	0.72 (0.05) abc	0.14 (0.09) abc	0.13 (0.05)	0.00 (0.00) b	0.00 (0.00) c
		BBIG Early	0.86 (0.02) a	0.05 (0.01) c	0.09 (0.01)	0.00 (0.00) b	0.00 (0.00) c
		SG Full	0.67 (0.03) abcd	0.28 (0.06) abc	0.05 (0.03)	0.00 (0.00) b	0.00 (0.00) c
		SG Early	0.57 (0.02) bcd	0.33 (0.05) ab	0.10 (0.04)	0.00 (0.00) b	0.00 (0.00) c
		EG Full	0.86 (0.03) a	0.09 (0.04) bc	0.06 (0.02)	0.00 (0.00) b	0.00 (0.00) c
		EG Early	0.80 (0.10) ab	0.14 (0.10) abc	0.06 (0.01)	0.00 (0.00) b	0.00 (0.00) c
	HRREC	BBIG Full	0.52 (0.06) cd	0.26 (0.07) abc	0.17 (0.03)	0.04 (0.02) b	0.01 (0.01) bc
		BBIG Early	0.66 (0.06) abcd	0.03 (0.03) c	0.11 (0.05)	0.19 (0.09) a	0.00 (0.00) c
		SG Full	0.44 (0.03) d	0.35 (0.03) a	0.16 (0.07)	0.05 (0.02) b	0.00 (0.00) c
		SG Early	0.48 (0.06) d	0.36 (0.08) a	0.10 (0.04)	0.07 (0.03) ab	0.00 (0.00) c
	RECGRN	BBIG Full	0.82 (0.01) a	0.06 (0.02) c	0.10 (0.01)	0.00 (0.00) b	0.02 (0.01) ab
		BBIG Early	0.66 (0.07) abcd	0.09 (0.02) bc	0.19 (0.02)	0.01 (0.01) b	0.04 (0.02) a
Brooding[10]	APREC	BBIG Full	0.36 (0.02) e	0.30 (0.13) abc	0.03 (0.03) ab	0.31 (0.09) ab	0.00 (0.00)
		BBIG Early	0.43 (0.06) de	0.30 (0.06) abc	0.07 (0.01) ab	0.20 (0.01) bc	0.00 (0.00)
		SG Full	0.61 (0.06) abcd	0.27 (0.09) abc	0.02 (0.01) ab	0.10 (0.03) cd	0.00 (0.00)
		SG Early	0.59 (0.05) abcd	0.29 (0.08) abc	0.03 (0.01) ab	0.09 (0.04) cd	0.00 (0.00)
		EG Full	0.65 (0.02) abc	0.02 (0.01) c	0.00 (0.00) b	0.33 (0.02) ab	0.00 (0.00)
		EG Early	0.70 (0.04) ab	0.10 (0.06) bc	0.02 (0.02) b	0.18 (0.04) bc	0.00 (0.00)

Table 1. Continued

HRREC	BBIG Full	0.52 (0.05) bcde	0.31 (0.07) abc	0.16 (0.01) a	0.00 (0.00) d	0.00 (0.00)
	BBIG Early	0.76 (0.03) a	0.11 (0.06) bc	0.13 (0.04) ab	0.00 (0.00) d	0.00 (0.00)
	SG Full	0.46 (0.02) cde	0.43 (0.05) a	0.11 (0.06) ab	0.00 (0.00) d	0.00 (0.00)
	SG Early	0.53 (0.02) bcde	0.36 (0.06) ab	0.11 (0.04) ab	0.00 (0.00) d	0.00 (0.00)
RECGRN	BBIG Full	0.44 (0.03) de	0.08 (0.04) bc	0.05 (0.02) ab	0.43 (0.02) a	0.00 (0.00)
	BBIG Early	0.62 (0.03) abc	0.03 (0.01) c	0.07 (0.03) ab	0.29 (0.02) ab	0.00 (0.00)

[1]APREC=Ames Plantation Research and Education Center, HRREC=Highland Rim Research and Education Center, and RECGRN=Research and Education Center at Greenville.
[2]BBIG=big bluestem/indiangrass, EG=eastern gamagrass, and SG=switchgrass. Full=full-season grazing treatment; Early=early-season grazing treatment.
[3] NWSG indicates native warm-season grass (e.g., big bluestem, switchgrass).
[4]Means within columns and sampling period followed by unlike letters are different by one-way ANOVA and Tukey's HSD test ($p<0.05$) for each year.
[5]Other Grass indicates species other than NWSG (e.g., crabgrass, tall fescue, dallisgrass).
[6]Forb=broadleaf herbaceous species (e.g., horse nettle, horseweed).
[7]Litter=ground covered with dead vegetation and without overheard cover of live vegetation.
[8]Bare=ground not covered with dead vegetation and without overhead cover of live vegetation.
[9]Nesting refers to sampling conducted June 1-June 24, 2010 & 2011.
[10]Brooding refers to sampling conducted July 13-July 30, 2010 & 2011.

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	Site[1]	Treatment	NWSG [3,4]	Other Grass[5]	Forb[6]	Litter[7]	Bare [8]
Nesting[9]	APREC	BBIG Full	0.67 (0.07) abcd	0.15 (0.07)	0.16 (0.11)	0.01 (0.01) d	0.01 (0.01) abc
		BBIG Early	0.67 (0.04) bcd	0.16 (0.04)	0.11 (0.02)	0.04 (0.01) cd	0.02 (0.02) abc
		SG Full	0.82 (0.04) ab	0.07 (0.02)	0.08 (0.02)	0.02 (0.02) d	0.01 (0.01) bc
		SG Early	0.66 (0.03) bcd	0.12 (0.03)	0.09 (0.02)	0.07 (0.01) bcd	0.05 (0.02) ab
		EG Full	0.74 (0.02) ab	0.12 (0.06)	0.02 (0.01)	0.11 (0.04) abc	0.01 (0.01) bc
		EG Early	0.70 (0.02) abc	0.09 (0.05)	0.05 (0.02)	0.14 (0.02) ab	0.01 (0.01) abc
	HRREC	BBIG Full	0.52 (0.07) d	0.19 (0.04)	0.20 (0.04)	0.09 (0.02) bcd	0.00 (0.00) c
		BBIG Early	0.84 (0.02) a	0.04 (0.01)	0.10 (0.01)	0.01 (0.01) d	0.00 (0.00) c
		SG Full	0.54 (0.02) cd	0.20 (0.03)	0.07 (0.02)	0.18 (0.02) a	0.00 (0.00) c
		SG Early	0.73 (0.03) ab	0.11 (0.02)	0.03 (0.01)	0.13 (0.01) ab	0.00 (0.00) c
	RECGRN	BBIG Full	0.74 (0.02) ab	0.05 (0.01)	0.15 (0.04)	0.05 (0.01) bcd	0.00 (0.00) c
		BBIG Early	0.65 (0.01) bcd	0.06 (0.03)	0.13 (0.03)	0.09 (0.01) bcd	0.06 (0.02) a
Brooding[10]	APREC	BBIG Full	0.49 (0.08) cd	0.15 (0.05) ab	0.17 (0.11)	0.15 (0.03) bc	0.03 (0.02) ab
		BBIG Early	0.60 (0.05) abcd	0.17 (0.03) ab	0.22 (0.07)	0.01 (0.01) c	0.00 (0.00) b
		SG Full	0.59 (0.03) abcd	0.16 (0.02) ab	0.10 (0.03)	0.13 (0.01) bc	0.01 (0.01) ab
		SG Early	0.75 (0.04) ab	0.07 (0.01) b	0.12 (0.02)	0.03 (0.03) c	0.02 (0.02) ab
		EG Full	0.63 (0.04) abcd	0.13 (0.01) ab	0.04 (0.01)	0.15 (0.04) bc	0.06 (0.01) a
		EG Early	0.80 (0.06) a	0.09 (0.05) ab	0.08 (0.02)	0.03 (0.02) c	0.00 (0.00) b

Table 2. Continued

HRREC	BBIG Full	0.53 (0.08) bcd	0.16 (0.04) ab	0.17 (0.01)	0.13 (0.05) bc	0.00 (0.00) b
	BBIG Early	0.52 (0.04) bcd	0.08 (0.02) ab	0.12 (0.06)	0.28 (0.10) ab	0.00 (0.00) b
	SG Full	0.44 (0.04) d	0.24 (0.06) a	0.07 (0.01)	0.25 (0.06) ab	0.00 (0.00) b
	SG Early	0.55 (0.04) bcd	0.06 (0.04) b	0.02 (0.01)	0.35 (0.02) a	0.00 (0.00) b
RECGRN	BBIG Full	0.49 (0.01) cd	0.13 (0.02) ab	0.18 (0.01)	0.19 (0.03) abc	0.01 (0.01) ab
	BBIG Early	0.68 (0.06) abc	0.07 (0.03) b	0.21 (0.03)	0.04 (0.01) c	0.01 (0.01) ab

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[2]BBIG=big bluestem/indiangrass, EG=eastern gamagrass, and SG=switchgrass. Full=full-season grazing treatment; Early=early-season grazing treatment.
[3] NWSG indicates native warm-season grass (e.g., big bluestem, switchgrass).
[4]Means within columns and sampling periods followed by unlike letters are different by one-way ANOVA and Tukey's HSD test ($p<0.05$) for each year.
[5]Other Grass indicates species other than NWSG (e.g., crabgrass, tall fescue, dallisgrass).
[6]Forb=broadleaf herbaceous species (e.g., horse nettle, horseweed).
[7]Litter=ground covered with dead vegetation and without overheard cover of live vegetation.
[8]Bare=ground not covered with dead vegetation and without overhead cover of live vegetation.
[9]Nesting refers to sampling conducted June 1-June 24, 2010 & 2011.
[10]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	Site[1]	Treatment[2]	GSD[3,4]	AO[5]	VS S1[6]	VS S2[7]	VS S3[8]	L Depth[9]
Nesting[10]	APREC	BBIG Full	0.63 (0.04) de	25.57 (6.29) abcd	0.97 (0.03) a	0.79 (0.12) a	0.28 (0.08) bcd	1.49 (0.29) bcd
		BBIG Early	0.58 (0.05) de	23.45 (1.94) abcd	1.00 (0.00) a	0.82 (0.01) a	0.28 (0.06) bc	1.53 (0.04) bcd
		SG Full	0.50 (0.02) e	16.63 (1.75) d	1.00 (0.00) a	0.95 (0.02) a	0.74 (0.09) a	1.24 (0.06) cd
		SG Early	0.64 (0.03) de	20.50 (1.08) bcd	0.99 (0.01) a	0.88 (0.05) a	0.65 (0.10) a	1.43 (0.16) bcd
		EG Full	0.65 (0.02) de	15.73 (1.42) d	0.94 (0.02) ab	0.83 (0.03) a	0.58 (0.10) a	1.59 (0.29) bcd
		EG Early	0.69 (0.03) de	20.62 (2.42) bcd	0.96 (0.02) a	0.82 (0.01) a	0.51 (0.08) ab	1.92 (0.18) abc
	HRREC	BBIG Full	1.20 (0.11) abc	34.20 (1.23) a	0.79 (0.06) bcd	0.18 (0.12) bc	0.00 (0.00) d	2.18 (0.25) abc
		BBIG Early	0.94 (0.13) bcd	27.02 (2.80) abcd	0.65 (0.08) d	0.09 (0.06) c	0.00 (0.00) d	2.78 (0.22) a
		SG Full	1.28 (0.03) ab	29.87 (2.07) abc	0.84 (0.03) abc	0.47 (0.04) b	0.03 (0.02) cd	2.77 (0.45) a
		SG Early	1.45 (0.19) a	32.68 (2.45) ab	0.86 (0.02) abc	0.41 (0.07) b	0.02 (0.01) cd	2.41 (0.23) ab
	RECGN	BBIG Full	0.86 (0.03) cde	15.98 (1.48) d	0.66 (0.02) d	0.42 (0.03) b	0.06 (0.01) cd	1.09 (0.24) cd
		BBIG Early	0.85 (0.06) cde	19.77 (1.33) cd	0.72 (0.03) cd	0.36 (0.07) bc	0.02 (0.01) cd	0.74 (0.12) d
Brooding[11]	APREC	BBIG Full	1.06 (0.12) b	40.70 (3.61) a	0.94 (0.01) ab	0.63 (0.04) abcd	0.17 (0.03) efg	7.60 (1.31) a
		BBIG Early	0.89 (0.08) bc	34.45 (1.42) abc	0.98 (0.01) ab	0.82 (0.06) abc	0.45 (0.07) bcd	12.50 (3.95) a
		SG Full	1.02 (0.04) b	32.53 (1.71) abcd	0.98 (0.01) ab	0.87 (0.02) ab	0.62 (0.05) ab	6.70 (2.84) a
		SG Early	0.88 (0.05) bc	29.80 (1.67) bcd	0.99 (0.01) ab	0.92 (0.06) a	0.73 (0.10) a	7.05 (3.36) a
		EG Full	1.14 (0.08) b	38.75 (1.67) bcd	0.93 (0.06) ab	0.70 (0.10) abcd	0.18 (0.05) efg	4.30 (1.57) abc
		EG Early	1.03 (0.01) b	34.97 (2.26) abc	1.00 (0.00) a	0.90 (0.07) ab	0.39 (0.05) cde	5.29 (1.44) abc

Table 3. Continued

HRREC	BBIG Full	0.91 (0.04) bc	38.07 (1.75) ab	0.79 (0.01) cd	0.22 (0.04) e	0.01 (0.01) g	1.98 (0.06) bc
	BBIG Early	0.55 (0.02) c	26.23 (3.01) cd	0.98 (0.00) ab	0.78 (0.03) abc	0.31 (0.04) def	1.94 (0.29) bc
	SG Full	1.06 (0.12) b	35.38 (2.94) abc	0.87 (0.02) bcd	0.54 (0.13) cd	0.12 (0.05) fg	1.74 (0.11) c
	SG Early	0.88 (0.10) bc	23.38 (1.92) d	0.90 (0.04) abc	0.79 (0.07) abc	0.58 (0.06) abc	1.78 (0.30) bc
RECGN	BBIG Full	1.74 (0.15) a	42.45 (0.15) a	0.76 (0.03) d	0.40 (0.07) abc	0.06 (0.01) g	5.82 (0.93) ab
	BBIG Early	1.26 (0.07) b	34.58 (1.02) abc	0.78 (0.01) d	0.60 (0.01) bcd	0.23 (0.03) defg	4.85 (0.73) abc

[1]APREC=Ames Plantation Research and Education Center, HRREC=Highland Rim Research and Education Center, and RECGRN=Research and Education Center at Greenville.
[2]BBIG=big bluestem/indiangrass, EG=eastern gamagrass, and SG=switchgrass. Full=full-season grazing treatment; Early=early-season grazing treatment.
[3] GSD=ground-sighting distance (m).
[4]Means within columns and sampling periods followed by unlike letters are different by one-way ANOVA and Tukey's HSD test ($p<0.05$) for each year.
[5]AO=angle of obstruction (degrees).
[6]VS S1=vertical structure (%) in the 0-30 cm strata of the cover board.
[7]VS S2=vertical structure (%) in the 30-60 cm strata of the cover board.
[8]VS S3=vertical structure (%) in the 60-100 cm strata of the cover board.
[9]L Depth=litter depth (cm).
[10]Nesting refers to sampling conducted June 1-June 24, 2010 & 2011.
[11]Brooding refers to sampling conducted July 13-July 30, 2010 & 2011.

Table 4. Vegetation structure measurements (SE) in native warm-season pastures grazed under two treatments at three locations across Tennessee, May-July 2011.

Period	Site[1]	Treatment[2]	GSD[3,4]	AO[5]	VS S1[6]	VS S2[7]	VS S3[8]	L Depth[9]
Nesting[10]	APREC	BBIG Full	1.19 (0.03) abc	25.57 (6.29) abcd	0.97 (0.03) a	0.79 (0.12) a	0.28 (0.08) bcd	0.79 (0.27) c
		BBIG Early	0.58 (0.05) de	23.45 (1.94) abcd	1.00 (0.00) a	0.82 (0.01) a	0.28 (0.06) bc	0.67 (0.34) c
		SG Full	0.50 (0.02) e	16.63 (1.75) d	1.00 (0.00) a	0.95 (0.02) a	0.74 (0.09) a	0.85 (0.07) bc
		SG Early	0.64 (0.03) de	20.50 (1.08) bcd	0.99 (0.01) a	0.88 (0.05) a	0.65 (0.10) a	0.87 (0.06) bc
		EG Full	0.65 (0.02) de	15.73 (1.42) d	0.94 (0.02) ab	0.83 (0.03) a	0.58 (0.10) a	1.33 (0.18) abc
		EG Early	0.69 (0.03) de	20.62 (2.42) bcd	0.96 (0.02) a	0.82 (0.01) a	0.51 (0.08) ab	1.35 (0.21) abc
	HRREC	BBIG Full	1.20 (0.11) abc	34.20 (1.23) a	0.79 (0.06) bcd	0.18 (0.12) bc	0.00 (0.00) d	1.98 (0.57) abc
		BBIG Early	0.94 (0.13) bcd	27.02 (2.80) abcd	0.65 (0.08) d	0.09 (0.06) c	0.00 (0.00) d	2.69 (0.22) a
		SG Full	1.28 (0.03) ab	29.87 (2.07) abc	0.84 (0.03) abc	0.47 (0.04) b	0.03 (0.02) cd	1.64 (0.30) abc
		SG Early	1.45 (0.19) a	32.68 (2.45) ab	0.86 (0.02) abc	0.41 (0.07) b	0.02 (0.01) cd	2.39 (0.06) ab
	RECGN	BBIG Full	0.86 (0.03) cde	15.98 (1.48) d	0.66 (0.02) d	0.42 (0.03) b	0.06 (0.01) cd	1.07 (0.28) abc
		BBIG Early	0.85 (0.06) cde	19.77 (1.33) cd	0.72 (0.03) cd	0.36 (0.07) bc	0.02 (0.01) cd	1.29 (0.02) abc
Brooding[11]	APREC	BBIG Full	1.15 (0.03) bcde	39.55 (1.62) abc	0.81 (0.03) bcde	0.42 (0.11) cde	0.10 (0.07) de	1.51 (0.65) abc
		BBIG Early	0.84 (0.03) de	32.73 (1.78) abcd	0.99 (0.00) ab	0.87 (0.04) a	0.35 (0.04) bcd	1.76 (0.35) abc
		SG Full	1.35 (0.11) bcd	36.00 (1.83) abcd	0.86 (0.01) abcd	0.56 (0.07) bcd	0.14 (0.05) cde	1.23 (0.34) abc
		SG Early	0.87 (0.01) de	23.58 (1.27) d	1.00 (0.00) a	0.98 (0.01) a	0.83 (0.04) a	0.76 (0.12) c
		EG Full	0.92 (0.28) a	45.17 (2.07) ab	0.81 (0.02) abcde	0.17 (0.04) ef	0.00 (0.00) e	1.18 (0.13) abc
		EG Early	0.82 (0.03) e	30.53 (1.20) cd	1.00 (0.00) ab	0.94 (0.05) a	0.52 (0.09) ab	1.07 (0.16) bc

Table 4. Continued

HRREC	BBIG Full	1.36 (0.16) bcd	45.32 (7.23) ab	0.64 (0.07) e	0.06 (0.02) f	0.00 (0.00) e	2.15 (0.54) abc
	BBIG Early	0.96 (0.09) de	32.68 (5.25) bcd	0.93 (0.02) abc	0.51 (0.09) cd	0.06 (0.02) de	3.23 (0.61) a
	SG Full	1.56 (0.11) ab	46.55 (3.09) a	0.76 (0.06) cde	0.19 (0.04) ef	0.00 (0.00) e	2.07 (0.44) abc
	SG Early	1.17 (0.03) bcde	22.63 (0.99) d	0.95 (0.02) ab	0.84 (0.06) ab	0.41 (0.16) de	2.91 (0.78) ab
RECGN	BBIG Full	1.50 (0.08) abc	43.18 (0.36) abc	0.74 (0.09) de	0.28 (0.04) def	0.04 (0.01) de	2.18 (0.20) abc
	BBIG Early	0.98 (0.07) cde	34.83 (1.74) abcd	0.90 (0.05) abcd	0.70 (0.10) abc	0.31 (0.09) bcde	1.58 (0.27) abc

[1]APREC=Ames Plantation Research and Education Center, HRREC=Highland Rim Research and Education Center, and RECGRN=Research and Education Center at Greenville.
[2]BBIG=big bluestem/indiangrass, EG=eastern gamagrass, and SG=switchgrass. Full=full-season grazing treatment; Early=early-season grazing treatment.
[3] GSD=ground-sighting distance (m).
[4]Means within columns and sampling periods followed by unlike letters are different by one-way ANOVA and Tukey's HSD test ($p<0.05$) for each year.
[5]AO=angle of obstruction (degrees).
[6]VS S1=vertical structure (%) in the 0-30 cm strata of the cover board.
[7]VS S2=vertical structure (%) in the 30-60 cm strata of the cover board.
[8]VS S3=vertical structure (%) in the 60-100 cm strata of the cover board.
[9]L Depth=litter depth (cm).
[10]Nesting refers to sampling conducted June 1-June 24, 2010 & 2011.
[11]Brooding refers to sampling conducted July 13-July 30, 2010 & 2011.

Table 5. Mean invertebrate biomass and ordinal richness in native warm-season pastures grazed under two treatments at three locations across Tennessee, July 2010 & 2011.

		2010	2011	2010	2011
Site[1]	Treatment[2]	Total Biomass[3]	Total Biomass	Order Richness[4]	Order Richness
APREC	BBIG Full	1.79 (0.16)	0.10 (0.03)	3.80 (0.65)	3.03 (0.75)
	BBIG Early	1.52 (0.42)	0.38 (0.09)	3.63 (0.62)	3.93 (0.52)
	SG Full	0.90 (0.32)	0.08 (0.02)	4.07 (0.55)	3.27 (0.77)
	SG Early	1.38 (0.31)	0.16 (0.03)	3.53 (0.69)	3.67 (0.79)
	EG Full	1.33 (0.26)	0.08 (0.02)	3.33 (0.68)	2.93 (0.69)
	EG Early	0.87 (0.27)	0.18 (0.04)	3.57 (0.64)	3.60 (0.71)
HRREC	BBIG Full	0.25 (0.03)	0.26 (0.04)	3.83 (0.57)	4.47 (0.66)
	BBIG Early	0.33 (0.04)	0.32 (0.04)	3.92 (0.41)	5.17 (0.61)
	SG Full	0.30 (0.06)	0.20 (0.03)	3.70 (0.59)	4.43 (0.47)
	SG Early	0.45 (0.06)	0.31 (0.04)	4.27 (0.57)	5.27 (0.61)
RECGN	BBIG Full	0.41 (0.09)	0.37 (0.07)	3.27 (0.62)	5.50 (0.66)
	BBIG Early	0.39 (0.06)	0.32 (0.81)	2.63 (0.51)	5.13 (0.81)

[1]APREC=Ames Plantation Research and Education Center, HRREC=Highland Rim Research and Education Center, and RECGRN=Research and Education Center at Greenville.
[2]BBIG=big bluestem/indiangrass, EG=eastern gamagrass, and SG=switchgrass. Full=full-season grazing treatment; Early=early-season grazing treatment.
[3]Total Biomass refers to g/m^2 of invertebrates collected.
[4]Order Richness refers to the number of orders collected.

Table 6. Scientific and common names of plants considered NWSG in native warm-season pastures grazed under two treatments at three Research and Education Centers across Tennessee, 2010 & 2011.

Scientific Name	Common Name
Andropogon gerardii	big bluestem
Panicum virgatum	switchgrass
Schizachyrium scoparium	little bluestem
Sorghastrum nutans	indiangrass
Tripsacum dactyloides	eastern gamagrass

Table 7. Scientific and common names of plants considered other grasses in native warm-season pastures grazed under two treatments at three Research and Education Centers across Tennessee, 2010 & 2011

Scientific Name	Common Name
Aristida ramose	purple wiregrass
Cynodon dactylon	bermudagrass
Cyperus esculentus	yellow nutsedge
Dactylis glomerata	orchardgrass
Digitaria sanguinalis	crabgrass
Eleusine indica	goosegrass
Juncus tenuis	slender rush
Paspalum dilatatum	dallisgrass
Poa pratensis	Kentucky bluegrass
Schedonorus phoenix	tall fescue
Setaria glauca	yellow foxtail
Sorghum halepense	johnsongrass

Table 8. Scientific and common names of forbs in native warm-season pastures grazed under two treatments at three Research and Education Centers across Tennessee, 2010 & 2011

Scientific Name	**Common Name**
Agastache nepetoides	giant yellow hyssop
Amaranthus spp.	pigweed
Ambrosia artemisiifolia	common ragweed
Ambrosia trifida	giant ragweed
Asclepias syriaca	common milkweed
Cichorium intybus	chicory
Cirsium arvense	Canada thistle
Conyza canadensis	horseweed
Desmodium spp.	beggar's-lice
Erigeron spp.	fleabane
Eupatorium capillifolium	dogfennel
Eupatorium spp.	Joe-pye weed
Geranium carolinianum	Carolina geranium
Ipomoea spp.	morningglory
Lespedeza cuneata	sericea lespedeza
Oxalis stricta	yellow woodsorrel
Passiflora spp.	passionflower
Phytolacca americana	common pokeweed
Plantago lanceolata	buckhorn plantain
Ranunculus spp.	buttercup
Rubus spp.	blackberry
Rumex crispus	curly dock
Sida spinosa	prickly sida
Solanum carolinense	horsenettle
Solidago spp.	goldenrod
Toxicodendron radicans	poison ivy
Trifolium repens	white clover
Verbesina alternifolia	wingstem
Vernonia gigantea	ironweed
Vicia villosa	hairy vetch

Table 9. Invertebrate classes and orders collected in native warm-season pastures grazed under two treatments at three Research and Education Centers across Tennessee, 2010 & 2011.

Class	**Order**
Arachnida	Acari
	Araneae
	Pseudoscorpiones
Chilopoda	Geophilomorpha
Gastropoda	Stylommatophora
Insecta	Coleoptera
	Diptera
	Hemiptera
	Hymenoptera
	Lepidoptera
	Mantodea
	Orthoptera
Malacostraca	Isopoda

II. AVIAN HABITAT RESPONSE TO HAY AND BIOFUELS PRODUCTION IN NATIVE WARM-SEASON GRASS STANDS IN THE MID-SOUTH

Abstract

Changing pasture and hayfield management practices have impacted grassland songbird and northern bobwhite populations in the Mid-South in the past fifty years. Non-native species, such as tall fescue and orchardgrass, are commonly used for hay production in the Mid-South, where they are managed in dense stands that are harvested during peak nesting periods for grassland birds. Native warm-season grasses have been promoted for hay production and are often touted as beneficial for wildlife. Switchgrass is also being promoted for biofuels production. The benefits of native warm-season grass hay and biofuels stands for grassland birds and northern bobwhite is influenced by management. We conducted a study in Tennessee, 2010 & 2011, to evaluate the impact of two hay harvest treatments and a biofuels harvest treatment on vegetative structure for nesting and brood-rearing grassland birds and northern bobwhite in three native warm-season grass mixtures. Hay and biofuels stands provided adequate nesting cover for grassland songbirds and northern bobwhite through May, and hay harvests in May and June created suitable structure for brood-rearing northern bobwhite. However, hay harvests in May or June negatively impact nesting success for grassland songbirds and northern bobwhite. NWSG planted for biofuels only do not provide suitable structure for northern bobwhite broods. We recommend big bluestem and indiangrass for hay production, as these species mature later and harvest in mid- to late June is more likely to allow successful initial nesting attempts.

Key Words: northern bobwhite, haying, grassland songbirds, biofuels, native warm-season grasses

Introduction

Grassland birds are declining faster than any other group of North American birds with more than two-thirds of grassland bird species showing significant negative declines (Vickery and

Herkert 2001, Sauer 2011). Changing agricultural practices have contributed to the decline of grassland birds throughout the United States (Rahmig et al. 2008). Wilson et al. (2005) identified two changes in agricultural practices in grassland systems that have had a particular impact on grassland bird species: an increase in the duration and intensity of grazing and an increase in forage harvest frequencies (Wilson et al. 2005). Management on agricultural grasslands (i.e., pastures, hayfields) often does not promote the vegetative structure necessary to maintain diverse grassland bird populations.

In the Mid-South, native grasslands have nearly disappeared, but more than 20 million acres are currently in non-native grasslands as either pasture or hay (Nickerson et al. 2011). Current hay harvesting practices focus on dense stands of non-native forages, such as tall fescue (*Schedonorus phoenix* Scop.) and orchardgrass (*Dactylis glomerata* L.) These grasses provide poor habitat for species such as northern bobwhite (*Colinus virginianus*) who require diverse vertical structure for both nesting and brood-rearing (Barnes et al. 1995).NWSG have been promoted for both forage production and wildlife management (NRCS 2005, Harper et al. 2007). Native warm-season grasses (NWSG), such as switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon gerardii* L.), indiangrass (*Sorghastrum nutans* L.), and eastern gamagrass *(Tripsacum dactyloides* L.), can provide high forage yields, and can be used to compliment forage systems based on cool-season grasses, as the two have differing seasonality (Ball et al. 2007). Cool-season forages, such as tall fescue, produce the majority of their growth when temperatures range from 65-75° whereas NWSG produce the majority of their growth when temperatures range from 85-95° (Ball et al. 2007, Mulkey et al. 2008). These differences in seasonality impact how cool-season grasses and NWSG are managed. In the Mid-South, cool-season grasses should be hayed April – mid-May to realize an optimal balance of digestible nutrients and yield, whereas NWSG should be hayed late May-early July (depending upon species).

The impact of hay harvesting on bird communities has been studied in the West, Midwest, and Northeast. Hay harvest in late-May was responsible for 94% mortality among bobolinks *(Dolichonyx oryzivorus)* nesting in hayfields (Bollinger et al. 1990). George et al. (1979) recommended switchgrass, big bluestem, and indiangrass for forage production in Iowa, and suggested late hay harvests to promote nest cover for upland bird species. Late hay harvests occurring from late July through August also have been recommended for grassland bird species in Illinois, Vermont, and New York to preserve cover during nesting and brood-rearing periods (Bollinger et al. 1990, Perlut et al. 2008). Perlut et al. (2008) speculated an initial hay harvest completed in May followed by a late hay harvest after birds have fledged would maintain cover for grassland birds making a second nesting attempt in hayfields while still allowing for two hay harvests. Delaying haying dates until later in the breeding season has led to increased nest success in grassland birds (Giuliano and Daves 2002, Giocomo et al. 2008) as vegetation is left intact during a greater proportion of the nesting period. Although these recommendations maintain nesting cover for grassland birds throughout a portion of their breeding season, little attention is given to how changes in timing of hay harvesting affects forage quality and yield. Delaying hay harvests may not decrease the quantity of available forage, however, nutritive value decreases as the forage matures (Ball et al. 2007). Hay cut after seedheads emerge has increased fiber, decreaseddigestible protein, and is less palatable (Ball et al. 2007), so while a late harvest may favor nesting cover for birds, it has severe consequences for the producer. Understanding the effect of hay harvest timing on nest success and forage quality is requisite to meet producer needs with bird conservation.

Production of switchgrass for biofuels feedstock is being evaluated across the United States (Bies 2006, Fike et al. 2006). Few studies have assessed the impact of producing switchgrass for biofuels feedstock on birds or other wildlife. Switchgrass harvested for biofuels is typically cut once in late fall when biomass is highest (Parrish and Fike 2005). Cutting at this time does not impact grassland birds during the breeding season (Roth et al. 2005). Harvested and unharvested switchgrass fields were studied in Iowa during the breeding season following a winter harvest (Murray and Best 2003, Murray et al. 2003). A mixture of harvested and unharvested fields provided habitat for some grassland birds; however, unharvested fields did not provide suitable nesting cover for species that require shorter, less dense vegetation, such as the grasshopper sparrow (*Ammodramus savannarum*). In both strip-harvested and total-harvested switchgrass biofuels fields, bird abundance was higher than in unharvested fields (Murray et al. 2003). Murray and Best (2003) suggested switchgrass stands kept dense and uniform were not optimal for grassland birds and that maintaining bare ground and diverse vertical structure in switchgrass stands could improve habitat quality. However, this is difficult, if not impossible, for fields managed for biofuels harvest. Roth et al. (2005) recommended a mixture of harvested and unharvested switchgrass when grown for biofuels in order to maximize grassland bird diversity and recommended research investigating biofuels feedstock production and habitat potential of multi-species native grass fields. While these may be sound recommendations for grassland bird conservation, it is not compatible with biofuel production, which requires dense, monoculture stands for optimal ethanol production (Fike et al. 2006, Keshwani and Cheng 2009).

Few studies have examined the vegetative response of native warm-season forages to hay harvest systems with respect to bird habitat (Giuliano and Daves 2002, Giocomo et al. 2008, Perlut et al. 2008) and research on biofuels feedstock production and its impact on birds is also scarce. Given the increasing use of NWSG for both hay and biofuel production in the Mid-South, more information is needed regarding the impact of haying native grass systems and biofuels feedstock production on grassland birds and northern bobwhite in this region. We conducted this experimental study to evaluate vegetation structure for grassland birds and northern bobwhite during the nesting and brood-rearing periods in production stands of NWSG. The specific objectives were to 1) determine the vegetative characteristics of NWSG planted for hay and biofuel harvest; and 2) evaluate the impact of three harvest treatments on nesting and brood-rearing cover for grassland birds and northern bobwhites.

Methods

Study Area

We conducted our research at the East Tennessee Research and Education Center (ETREC) in Knoxville, Tennessee, Plateau Research and Education Center (PREC) in Crossville, Tennessee, and Highland Rim Research and Education Center (HRREC) in Springfield, Tennessee. We established 2.0 x 7.6-m plots at all sites on conventionally prepared seedbeds using a small plot drill. Prior to planting, soil samples were collected, and lime, phosphorous, and potassium were applied based on soil test results. HRREC was planted in 2008 and ETREC and PREC were planted in 2009. We used three NWSG species mixtures at each site: 1) 100% switchgrass (SG), 2) 50% switchgrass, 35% big bluestem, and 15% indiangrass (SGBBIG), and 3) 65% big bluestem and 35% indiangrass (BBIG). We sprayed all plots with glyphosate (2.24kg ai/ha) in spring prior to planting. We applied imazapic (0.11kg ai/ha) preemergence on all BBIG plots immediately after planting. In the second year (2009 for HRREC, 2010 for ETREC and PREC), plots were treated in late April and mid-June with metsulfuron methyl (14.0g ai/ha) to control weeds postemergence. No additional weed control was used during year three (2010 for HRREC, 2011 for ETREC and PREC).

We implemented three harvest treatments at each location using a flail small-plot harvester with a 15-cm residual height. The first treatment (MAY) was a hay harvest in May followed by a biomass harvest in late October. The second treatment (JUNE) was a hay harvest in late June followed by a biomass harvest in late October. The third treatment (FALL) was a biofuels harvest taken after the first frost in late October. The MAY and JUNE treatments were designed to evaluate the impact of early hay harvest options on the biomass crop harvested in fall. At each location, treatments were replicated four times (NWSG species by harvest) for a total of 36 plots.

Vegetation Surveys

Vegetation surveys were conducted twice during 2010 and 2011 to evaluate vegetation during the nesting and brood-rearing periods for northern bobwhite and grassland birds in the Mid-South (Palmer 1995, Giocomo et al. 2008). In both 2010 and 2011, nesting data were collected in early May, prior to MAY and JUNE harvest treatments. In 2010, brooding data were collected in early July, after both MAY and JUNE treatments were implemented. In 2011, brooding data were collected in late June, after MAY treatments were implemented, but prior to JUNE treatments at all sites. Vegetation composition and litter depth were measured along a line transect across each plot, with total coverage (cm) of every plant recorded. The sum of observations for the entire transect was used to determine the percent coverage for each species. Litter and bare ground were recorded when present. Litter coverage was defined as any ground covered by dead vegetation, whereas bare ground was defined as any ground without dead vegetation coverage or overhead cover by live plants. Litter depth was recorded at 1, 3, 5, and 7 meters.

Vegetation structure was measured the length of each plot during each sampling period from a stationary point centered at the end of each plot and located 30 cm into the plot. Ground-sighting distance, a measure of openness at ground level, was measured by viewing through a PVC tube 3.2 cm in diameter and 15.2 cm in length, mounted horizontally on a metal stake 15.2 cm aboveground. As one observer looked through the tube, another observer holding a pole 2-m tall with the bottom 15 cm marked moved in a straight line across the plot. Ground-sighting distance was recorded as the distance at which the bottom 15 cm of the 2-m tube was obscured by vegetation.

Angle of obstruction, a measure of the openness of the vegetative canopy, was measured using a 2-m pole and clinometer. The pole was placed at the same point used for measuring ground-sighting distance. As the bottom of the pole remained in place, the top was leaned towards 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 in each cardinal direction once per plot, for 4 observations for each.

Vertical structure was evaluated using digital visual obstruction readings (Limb et al. 2007). Photos were taken of vegetation against a 1-m x 1-m white board using a Canon EOS Rebel® camera (10.1 megapixels) at a distance of 4 meters and a height of 1 meter, similar to the standards used with a Nudds board (Nudds 1977). The white board was marked on each side at each 0.1 m increment. A photo was taken in each plot during each sampling period. All photos were uploaded to CS3 software (Adobe Systems Inc., San Jose, CA) for analysis in Adobe

Photoshop®. Threshold and histogram functions in CS3 were used to determine total visual obstruction of each photo in three height sections: 0-30 cm (section 1), 30-60 cm (section 2), and 60-100 cm (section 3). These sections were selected based on their biological significance to northern bobwhite and grassland birds (Whitmore 1981, Taylor et al. 1999, Giocomo et al. 2008). The density of vegetation in each of these sections relates to species with differing structural requirements. For example, greater coverage in the 0-30 cm section with lower coverage in the 30-60 cm and 60-100 cm sections indicates suitable structure for species such as the northern bobwhite and eastern meadowlark (*Sturnella* magna) that nest on the ground in shorter vegetation .This analysis was conducted based on Limb et al. (2007), with final visual obstruction equal to the percent of black pixels in each board section.

Data Analysis

Vegetation composition was analyzed by grouping plants into biologically significant associations. Groups included NWSG, other grass, forb, litter, or bare ground. Data were averaged across subsamples to obtain a mean for each treatment combination at each location. The experiment was conducted in a two-factor ANOVA with a completely randomized design blocked on location, a factorial treatment design, and repeated measures. Years were analyzed separately, due to differences in time of data collection. Data were analyzed using mixed models in SAS 9.3 (SAS Institute, Cary, N.C.) The assumptions of one-way analysis of variance (ANOVA) were tested 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 $\log_{10}$ transformations. Least significant difference (LSD) values were used to determine significant differences between treatments with $\alpha = 0.05$.

Results

Vegetation Composition

Across years and sampling periods, forb cover ranged from 0-5% and cover of other grass species ranged from 0-8%. Little or no bare ground was recorded in either sampling period in any plots in 2010 or 2011 (0-1%). NWSG coverage increased during the nesting period from 52-64% in 2010 to 77-93% in 2011 ($p<0.0001$, $F_{1,180}=175.65$, Tables 10 and 11). NWSG coverage was least in the plots most recently harvested during the brooding periods in 2010 and 2011 (Tables 10 and 11). NWSG coverage in plots containing switchgrass was generally greater during the 2011 nesting season than those containing big bluestem and indiangrass. Litter coverage during the nesting period decreased ($p<0.0001$, $F_{1,180}=211.67$) from 2010 (27-46%) to 2011 (5-16%) because all haying treatments were implemented between these periods.

Vegetation Structure

Ground-sighting distance was generally greater in the MAY and JUNE harvest treatments than the yet uncut FALL treatments during the 2010 brooding season (Table 10, $p=0.0002$, $F_{2,97}=9.59$). Angle of obstruction was greater and vertical vegetation structure was less in plots harvested in JUNE than those harvested in MAY or the yet uncut FALL harvest treatments during the 2010 brooding season (Table 10, $p<0.0001$, $F_{2,97}=54.34$). Thus, grass density and structure following the MAY harvest was similar to that of unharvested plots (FALL) by 6 weeks post-harvest. Litter depth was not appreciably affected by harvest treatment (Table 10, $p=0.5577$, $F_{2,97}=0.59$).

Visual obstruction in the middle and upper strata of plots containing switchgrass was greater than those containing big bluestem and indiangrass during the 2011 nesting season (Table 11, $p<0.0001$, $F_{2,97}=36.08$). Ground-sighting distance and angle of obstruction were greatest in the MAY harvest plots during the 2011 brooding season. Litter depth and vertical vegetation cover were less in MAY harvest plots (Table 11). The JUNE harvest plots had not been implemented when the 2011 brooding season data were collected.

Discussion

The MAY and JUNE harvest treatments had a significant impact on the structure of nesting and brooding cover for grassland songbirds and northern bobwhite. However, following these harvests, grass canopy coverage increased quickly and provided adequate cover (similar to the yet uncut FALL treatment in 2010) for broods within the 0 – 30cm stratum within 2 weeks after harvest. Vertical cover within the 30 – 60cm and 60 – 100cm strata remained lower and the angle of obstruction greater in the MAY and JUNE treatments than the uncut FALL treatment through the 2010 brooding season. Ground-sighting distance increased slightly immediately after harvest, but remained relatively open throughout the brooding season. The biofuels harvest in the FALL following the MAY and JUNE treatments did not influence nesting cover in 2011. Plots containing switchgrass generally had greater grass coverage with a taller structure during the nesting season of 2011. These results are similar to those seen in a study of biofuels plantings in Tennessee and Kentucky, where switchgrass stands contained tall, dense vegetation (West 2001). This is typical as switchgrass develops and matures earlier than big bluestem and indiangrass (Parrish and Fike 2005, Fike et al. 2006, Ball et al. 2007).

Grass growth rates and phenology are important considerations when managing native grasses for forage or grassland birds. The general increase in NWSG coverage from 2010 to 2011 was expected as NWSG coverage typically increases after planting for 2 – 4 years before full stand density is realized (Barnes 2004, Harper et al. 2007). BBIG plots had less vegetative coverage in the upper sections of the cover board than either SG or SGBBIG plots in both nesting periods. The taller structure in plots containing switchgrass during the nesting period was a result of differences in seasonality between switchgrass and big bluestem/indiangrass. Switchgrass matures approximately 4 weeks earlier than big bluestem or indiangrass.

The harvest treatments had no impact on vegetative structure during the 2011 nesting period. Thus, grassland birds attracted to tall native grass structure would be attracted to sites hayed the previous fall. Hay timing in spring/summer, however, has a tremendous impact on nest survival. Many grass species, both warm- and cool-season, are harvested while grassland birds are nesting, especially in May and early June. A delayed hay harvest can enable successful initial nesting attempts. In Arkansas, hay harvested from 26-31 May caused significant decreases in survival and nest success for grassland birds, while delaying harvest until 17-26 June had only minimal impact (Luscier and Thompson 2009). Many studies have recommended delayed hay cutting to preserve nesting opportunities for grassland birds (Bollinger et al. 1990, Dale et al. 1997, Walk and Warner 2000).

Timing of haying also has a tremendous impact on hay quality. Hay must be harvested prior to seedhead production to maximize nutritional quality (Ball et al. 2007). As grasses mature, their fiber content increases, their crude protein content decreases, and they become much less digestible (Nocera et al. 2005, Ball et al. 2007). This presents a conflict when incorporating grassland bird conservation into hayfield management, Nocera (2004) looked at the tradeoffs between delaying harvest for both grassland bird reproductive success and hay quality and found small delays (1-2 weeks) in cutting time could be used to increase nesting success with minimal declines in hay quality in June (Nocera et al. 2005). Although the use of later maturing forage species may allow for small harvest delays, recommendations to delay harvest beyond late June in the Mid-South will completely sacrifice hay quality.

In the Mid-South, grassland bird nest initiation dates vary greatly among species. Giocomo et. al. (2008) found nest initiation for Eastern meadowlark (*Sturnella magna*) began April 16, for field sparrow (*Spizella pusilla*) April 29, Henslow's sparrows (*Ammodramus henslowii*) April 27, grasshopper sparrows May 1, and dickcissel (*Spiza* americana) May 10. All species required a minimum of 23 days from laying to fledging, and nest initiation ended between June 28 and July 4 for re-nesting and multiple nest attempts (Giocomo et al. 2008). Given the nesting phenology of these birds, switchgrass, which must be hayed by late May to obtain good-quality hay, is a poor choice for hayfields where grassland birds are a concern. Big bluestem and/or indiangrass can be harvested late June to early July without critical decline in hay quality; thus, these species allow grassland birds a full initial nesting attempt before harvest. Northern bobwhite in the Mid-South can initiate nesting in mid-April and continue nesting attempts until late-August (Burger et al. 1995), so any hay harvest conducted during this period could impact nesting success.

Ground-sighting distance and angle of obstruction provide quantitative measures of structure that relate to habitat quality for several species, including northern bobwhite. Openness at ground level was greatest following MAY or JUNE treatments, allowing greater mobility for broods. The rapid grass growth following harvest provided adequate cover for broods in the 0 – 30cm stratum within 2 weeks post-harvest. Taylor et. al. (1999) reported northern bobwhite broods in Kansas selected areas with taller vegetation which provided concealment from predators. NWSG hayfields provide better structure than non-native cool-season hayfields, which lack the overhead cover and openness required for broods (Barnes et al. 1995, Taylor et al. 1999). In both 2010 and 2011 brooding periods, FALL plots had dense grass cover and limited openness at ground level. These plots were typical of biofuels plantings and did not provide suitable brood-rearing structure for species such as northern bobwhite or eastern wild turkey (*Meleagris gallopavo*). Our data suggest haying in MAY or JUNE improved the structure of the tall native grass fields we studied for northern bobwhite broods. However, haying in May or June could be detrimental for bobwhites if they are using the fields for nesting.

Management Implications

Grass phenology and nutritive value are critical considerations when selecting native grasses for haying operations where grassland birds are a concern. We recommend big bluestem/indiangrass because they mature later than switchgrass or eastern gamagrass and harvest can be made in mid to late-June, allowing more time for grassland birds and northern bobwhite to fledge initial nests. Switchgrass matures earlier and should be harvested in mid- to late May when birds are actively nesting. Regardless of the grass species used, biofuels stands will not provide high-quality habitat for northern bobwhite during the brood-rearing period, and managers interested in this species should consider grazing where production stands occur and northern bobwhite is a focal species.

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Appendix

Table 10. Mean vegetation characteristics (SE) of small plots planted to NWSG at three locations across Tennessee, 2010.

Cut[2]	Species	NWSG %[3,4]	GSD[5]	AO[6]	Ldepth[7]	VS 0-30[8]	VS 30-60[9]	VS 60-100[10]
NESTING[1]								
N/A	BBIG	0.52 (0.03) B	1.24 (0.15)	33.33 (2.95) A	1.81 (0.29) A	0.62 (0.03) B	0.13 (0.03) B	0.01 (0.01) B
	SG	0.64 (0.03) A	1.14 (0.09)	25.32 (2.35) B	1.27 (0.15) B	0.83 (0.03) A	0.43 (0.05) A	0.04 (0.01) A
	SGBBIG	0.61 (0.04) A	1.01 (0.08)	29.53 (2.66) A	1.53 (0.19) AB	0.77 (0.04) A	0.37 (0.05) A	0.05 (0.01) A
BROODING								
MAY	BBIG	0.83 (0.03) C	0.70 (0.05) CD	31.29 (3.86) B	3.31 (0.60) AB	0.87 (0.07) B	0.45 (0.11) D	0.12 (0.05) CD
	SG	0.85 (0.03) BC	0.89 (0.09) ABC	27.88 (4.45) BC	2.85 (0.67) AB	0.95 (0.03) AB	0.77 (0.10) BC	0.40 (0.11) B
	SGBBIG	0.87 (0.05) ABC	0.75 (0.05) BCD	29.90 (3.80) B	3.71 (0.77) AB	0.94 (0.03) AB	0.65 (0.12) C	0.28 (0.08) BC
JUNE	BBIG	0.64 (0.02) D	1.14 (0.11) A	36.56 (6.11) A	3.42 (0.62) AB	0.74 (0.08) C	0.15 (0.05) E	0.00 (0.00) D
	SG	0.72 (0.03) D	1.43 (0.46) A	40.71 (6.69) A	2.80 (0.82) AB	0.72 (0.10) C	0.27 (0.08) E	0.02 (0.02) D
	SGBBIG	0.68 (0.03) D	1.24 (0.24) AB	39.79 (5.67) A	3.06 (0.51) AB	0.72 (0.09) C	0.24 (0.06) E	0.02 (0.01) D
FALL	BBIG	0.86 (0.06) ABC	0.76 (0.04) BCD	24.23 (2.59) CD	4.51 (0.67) A	0.99 (0.01) AB	0.79 (0.06) BC	0.29 (0.07) BC
	SG	0.93 (0.02) AB	0.87 (0.10) ABCD	21.00 (2.55) D	2.48 (0.68) B	0.99 (0.01) AB	0.93 (0.03) AB	0.59 (0.09) A
	SGBBIG	0.95 (0.02) A	0.63 (0.06) D	22.02 (2.42) CD	4.08 (0.81) AB	1.00 (0.00) A	0.98 (0.01) A	0.71 (0.07) A

[1]Nesting sampling period late-spring to early summer, Brooding sampling period mid-late summer.
[2]Cut refers to harvest treatment
[3]Means within columns followed by unlike letters within each sampling period are different by one-way ANOVA ($p<0.05$).
[4]NWSG% refers to the percent coverage of planted native warm-season grass species in each treatment.
[5] GSD refers to ground sighting distance (m).
[6]AO refers to the angle of obstruction (^{0}).
[7]Ldepth refers to the depth of litter in each treatment (cm).
[8]VS 0-30 refers to the percent of vegetative cover in the 0-30 cm section of a visual cover board.
[9]VS 30-60 refers to the percent of vegetative cover in the 30-60 cm section of a visual cover board.
[10]VS 60-100 refers to the percent of vegetative cover in the 60-100 cm section of a visual cover board.

Table 11. Mean vegetation characteristics (SE) of small plots planted to NWSG at three locations across Tennessee, 2011.

Cut[2]	Species	NWSG %[3,4]	GSD[5]	AO[6]	Ldepth[7]	Bottom[8]	Middle[9]	Top[10]
NESTING[1]								
MAY	BBIG	0.78 (0.04) D	1.01 (0.22) A	38.06 (3.18) A	0.60 (0.14)	0.98 (0.01) AB	0.59 (0.05) C	0.10 (0.07) D
	SG	0.83 (0.06) ABCD	0.85 (0.13) AB	29.92 (4.74) BCD	0.72 (0.17)	0.99 (0.01) A	0.92 (0.04) A	0.45 (0.08) A
	SGBBIG	0.79 (0.07) CD	0.65 (0.07) AB	32.71 (3.65) ABCD	0.65 (0.17)	1.00 (0.00) A	0.83 (0.05) AB	0.14 (0.04) BCD
JUNE	BBIG	0.77 (0.04) D	0.76 (0.06) AB	34.31 (3.00) ABC	0.85 (0.16)	0.97 (0.02) AB	0.57 (0.05) C	0.02 (0.01) D
	SG	0.89 (0.05) ABC	0.61 (0.11) B	31.00 (3.57) BCD	0.59 (0.12)	0.98 (0.01) A	0.90 (0.05) A	0.39 (0.08) AB
	SGBBIG	0.90 (0.03) AB	0.73 (0.10) AB	28.81 (3.46) CD	0.62 (0.11)	0.98 (0.01) AB	0.81 (0.07) AB	0.40 (0.10) AB
FALL	BBIG	0.80 (0.05) BCD	0.91 (0.23) AB	36.73 (4.89) AB	0.76 (0.15)	0.87 (0.09) B	0.65 (0.08) BC	0.11 (0.04) CD
	SG	0.93 (0.02) A	0.84 (0.13) AB	28.13 (2.35) BCD	0.51 (0.13)	0.96 (0.04) AB	0.88 (0.04) A	0.58 (0.10) A
	SGBBIG	0.91 (0.03) A	0.65 (0.07) AB	28.88 (3.80) D	0.59 (0.16)	0.97 (0.03) AB	0.86 (0.06) A	0.36 (0.09) ABC
BROODING								
MAY	BBIG	0.69 (0.04) B	1.38 (0.22) A	46.86 (2.76) A	1.05 (0.25) BC	0.65 (0.05) D	0.08 (0.02) D	0.01 (0.00) D
	SG	0.71 (0.05) B	1.34 (0.13) A	42.01 (2.86) A	0.82 (0.20) BC	0.76 (0.08) C	0.22 (0.07) CD	0.01 (0.01) D
	SGBBIG	0.71 (0.05) B	1.30 (0.14) A	45.10 (3.44) A	0.49 (0.10) C	0.77 (0.06) C	0.28 (0.07) C	0.02 (0.01) D
JUNE	BBIG	0.91 (0.02) A	0.62 (0.02) BC	29.50 (2.43) B	1.77 (0.41) A	0.97 (0.02) AB	0.57 (0.05) B	0.06 (0.03) CD
	SG	0.95 (0.03) A	0.60 (0.04) BC	22.23 (2.10) C	0.82 (0.17) BC	0.99 (0.01) A	0.94 (0.04) A	0.68 (0.08) AB
	SGBBIG	0.99 (0.01) A	0.59 (0.06) BC	22.04 (2.00) C	1.28 (0.21) AB	0.95 (0.03) AB	0.82 (0.08) A	0.65 (0.11) B
FALL	BBIG	0.91 (0.06) A	0.88 (0.19) B	28.15 (2.35) B	1.88 (0.28) A	0.88 (0.05) B	0.61 (0.07) B	0.23 (0.08) C

Table 11. Continued

SG	0.99 (0.01) A	0.68 (0.08) BC	20.56 (2.42) C	1.23 (0.33) AB	1.00 (0.00) A	0.95 (0.05) A	0.84 (0.09) A
SGBBIG	0.99 (0.01) A	0.56 (0.05) C	22.19 (2.13) C	1.83 (0.31) A	0.98 (0.02) AB	0.94 (0.04) A	0.73 (0.09) AB

[1]Nesting sampling period late-spring to early summer, Brooding sampling period mid-late summer.
[2]Cut refers to harvest treatment
[3]Means within columns followed by unlike letters within each sampling period are different by one-way ANOVA ($p<0.05$).
[4] GSD refers to ground sighting distance (m).
[5]AO refers to the angle of obstruction (^{0}).
[6]Ldepth refers to the depth of litter in each treatment (cm).
[7]VS 0-30 refers to the percent of vegetative cover in the 0-30 cm section of a visual cover board.
[8]VS 30-60 refers to the percent of vegetative cover in the 30-60 cm section of a visual cover board.
[9]VS 60-100 refers to the percent of vegetative cover in the 60-100 cm section of a visual cover boar

CONCLUSIONS

We recommend full-season grazing (May-August) to create favorable structure for nesting and brood-rearing in pastures of switchgrass, eastern gamagrass, and big bluestem/indiangrass mixtures where producers are interested in grassland birds and northern bobwhite. Grazing intensity should maintain the pasture in a pre-reproductive state to maximize cattle weight gains by keeping forage palatable and digestible. Maintaining a stand height of approximately 45 cm will protect the growth point of tall NWSG, such as big bluestem and switchgrass, 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. NWSG can be used to compliment cool-season forage grazing systems to benefit both cattle production and grassland bird conservation. As NWSG continue to be promoted for livestock grazing where wildlife is a consideration, maintaining suitable structure will be required to ensure benefits for grassland birds and northern bobwhite.

Grass phenology and nutritive value are critical considerations when selecting native grasses for haying operations where grassland birds are a concern. We recommend big bluestem/indiangrass because they mature later than switchgrass or eastern gamagrass and harvest can be made in mid to late-June, allowing more time for grassland birds and northern bobwhite to fledge initial nests. Switchgrass and eastern gamagrass mature earlier and should be harvested in mid- to late May when birds are actively nesting. Regardless of the grass species used, it is unlikely that biofuels stands will provide high-quality habitat for northern bobwhite during the brood-rearing period, and managers interested in this species should consider grazing where production stands occur and northern bobwhite are a focal species.

VITA

Jessie Lee Birckhead was born in Raleigh, North Carolina on February 10th, 1987. After completing high school, she attended North Carolina State University where she earned a Bachelor of Science degree in Wildlife and Fisheries Science in 2009. While at NCSU she was a University Scholar, a Caldwell Fellow, and participated in study abroad programs in Namibia, Thailand, Belize, and Nicaragua. Jessie worked as an environmental educator at the North Carolina Museum of Natural Science, a teaching assistant for the Fisheries and Wildlife Program and Plant Science Department at NCSU, and a MAPS bird banding technician while completing her degree at NCSU. In August 2009 she began a graduate research assistantship at the University of Tennessee under the direction of Dr. Craig A. Harper. During her time at UT, she worked on numerous research projects, including studies of white oak mast production, food plot management, and use of prescribed fire in upland hardwoods. Upon completion of her Master of Science Degree, Jessie will be moving to Durham, North Carolina to begin work for the North Carolina Chapter of The Nature Conservancy.