Structure of Avian Habitat Following Hay and Biofuels Production in Native Warm-season Grass Stands in the Mid-South

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Abstract: Changing pasture and hayfield management practices have impacted grassland songbird and northern bobwhite (*Colinus virginianus*) populations in the Mid-South in the past 50 years. Non-native species, such as tall fescue (*Schedonorus phoenix)* and orchardgrass (*Dactylis glomerata)*, are commonly used for hay production, where they are managed in dense stands that are harvested during peak nesting periods for grassland birds. Native warm-season grasses, including switchgrass (*Panicum virgatum*) have been promoted for hay and biofuels production and are often touted as beneficial for wildlife. The benefits of native warm-season grasses for grassland birds and northern bobwhite are influenced by stand management. We conducted a study during 2010 and 2011 to evaluate the impact of two hay harvest treatments and one biofuels harvest treatment on vegetative structure for nesting and brood-rearing grassland birds and northern bobwhite in three native warm-season grass (nwsg) mixtures in Tennessee. 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 did not provide suitable structure for northern bobwhite broods. We recommend big bluestem (*Andropogon gerardii)* and indiangrass (*Sorghastrum nutans)* for hay producers who have an interest in grassland songbirds as these species mature later and their harvest in mid- to late June is more likely to allow successful initial nesting attempts.

Key words: avian habitat, native warm-season grasses, haying, biofuels

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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 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). Increased duration and intensity of livestock grazing and an increase in forage harvest frequencies have had a particular impact on grassland bird species (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, more than 20 million acres are currently in non-native grasslands as either pasture or hay (Nickerson et al. 2011). The current hay management paradigm is primarily 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*) that require diverse vertical structure for both nesting and brood-rearing (Barnes et al. 1995). Native warm-season grasses (nwsg) have been promoted for both forage production and wildlife management (NRCS 2005, Harper et al. 2007). 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 because of different seasonality (Ball et al. 2007). Cool-season forages, such as tall fescue, produce the

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majority of their growth when temperatures range from 65 to 75°F whereas nwsg produce the majority of their growth when temperatures range from 85 to 95°F (Ball et al. 2007, Mulkey et al. 2008). This difference in growth pattern impacts how cool-season grasses and nwsg are managed. In the Mid-South, cool-season grasses should be hayed initially in April – mid-May to realize an optimal balance of digestible nutrients and yield, whereas nwsg should be hayed initially in late May–late June (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. 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. 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 which are making a second nesting attempt in hayfields but would still allow two hay harvests. 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, decreased digestible protein, and is less palatable (Ball et al. 2007), so whereas a late harvest may favor nesting cover for birds, it has severe consequences for the producer who wants to use the hay to feed livestock. 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), and 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 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. These recommendations may be sound for grassland bird conservation, but they are 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 a field experiment to evaluate vegetation structure for grassland birds and northern bobwhite during the nesting and brood-rearing periods in production stands of nwsg. This study was conducted concurrently with agronomic research investigating yield and quality of nwsg hay and biofuels under three harvest treatments, and thus agronomic small plots were used. Our objectives were to 1) determine the vegetative characteristics of nwsg managed for hay and biofuel; and 2) evaluate the impact of three harvest treatments on nesting and brood-rearing cover for grassland birds and northern bobwhite.

Study Area

We conducted our research at the East Tennessee Research and Education Center (ETREC) in Knoxville, Tennessee, the Plateau Research and Education Center (PREC) in Crossville, Tennessee, and the Highland Rim Research and Education Center (HRREC) in Springfield, Tennessee. We established 36 2.0- × 7.6-m plots at all sites on conventionally prepared seedbeds using a small-plot seed 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 in different plots: 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 3 (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.

Methods

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, we collected nesting period data in early May, prior to MAY and JUNE harvest treatments. In 2010, we collected brooding period data in early July, after both MAY and JUNE treatments were implemented. In 2011, we collected brooding period data in late June, after MAY treatments were implemented, but prior to JUNE treatments at all sites. We measured vegetation composition and litter depth along a diagonal 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 m.

We measured vegetation structure 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 above ground. 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. This metric is a measurement of structure at ground level which influences both mobility and food availability for birds.

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 four observations for each.

We evaluated vertical structure using digital visual obstruction readings (Limb et al. 2007). Photos were taken of vegetation against a 1-×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 standards described by 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, California) 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). 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. 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). 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*).

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, and a factorial treatment design. Years were analyzed separately because of differences in time of data collection. Data were analyzed using mixed models in SAS 9.3 (SAS Institute, Cary, North Carolina). 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 log10 transformations. Least significant difference (LSD) values were used to determine significant differences among 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 ($P < 0.0001$, $F1,180 = 175.65$, Tables 1 and 2). Nwsg coverage was least in the plots most recently harvested during the brooding periods in 2010 and 2011 (Tables 1 and 2). 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 ($P < 0.0001$, $F1,180 = 211.67$) from 2010 (27%–46%) to 2011 (5%–16%) because all haying treatments were implemented between these periods.

Vegetation Structure

In 2010, ground-sighting distance was generally greater in the MAY and JUNE harvest treatments than the yet uncut FALL treatments during the brooding season (Table 1, $P = 0.0002$, F2, $97 = 9.59$). 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 1, $P < 0.0001$, F2, $97 = 54.34$). 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 1, $P = 0.5577$, F2, $97 = 0.59$).

In 2011, visual obstruction in the middle and upper strata of plots containing switchgrass was greater than those containing big bluestem and indiangrass during the nesting season (Table 2, $P < 0.0001$, F2, $97 = 36.08$). 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 2). The JUNE harvest plots had not been implemented when the 2011 brooding season data were collected.

Table 1. Mean vegetation characteristics (SE) of small plots planted to nwsg at three locations across Tennessee, 2010.

Harvest[b]	Species	NWSG %[d,e]	GSD[f]	AO[g]	Ldepth[h]	Bottom[i]	Middle[j]	Top[k]
Nesting[a]								
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[c]								
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

a. Nesting sampling period late-spring to early summer.
b. Harvest refers to harvest treatment
c. Brooding sampling period mid-late summer.
d. Means within columns followed by unlike letters within each sampling period are different by one-way ANOVA ($P < 0.05$).
e. NWSG% refers to the percent coverage of planted native warm-season grass species in each treatment.
f. GSD refers to ground sighting distance (m).
g. AO refers to the angle of obstruction (^{0}).
h. Ldepth refers to the depth of litter in each treatment (cm).
i. Bottom refers to the percent of vegetative cover in the 0–30 cm section of a visual cover board.
j. Middle refers to the percent of vegetative cover in the 30–60 cm section of a visual cover board.
k. Top refers to the percent of vegetative cover in the 60–100 cm section of a visual cover board.

Table 2. Mean vegetation characteristics (SE) of small plots planted to NWSG at three locations across Tennessee, 2011.

Harvest[b]	Species	NWSG %[d,e]	GSD[f]	AO[g]	Ldepth[h]	Bottom[i]	Middle[j]	Top[k]
Nesting[a]								
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[c]								
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
	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

a. Nesting sampling period late-spring to early summer.
b. Harvest refers to harvest treatment
c. Brooding sampling period mid-late summer.
d. Means within columns followed by unlike letters within each sampling period are different by one-way ANOVA ($p<0.05$).
e. NWSG% refers to percent coverage of planted warm-season grass species in each treatment.
f. GSD refers to ground sighting distance (m).
g. AO refers to the angle of obstruction (^{0}).
h. Ldepth refers to the depth of litter in each treatment (cm).
i. Bottom refers to the percent of vegetative cover in the 0–30 cm section of a visual cover board.
j. Middle refers to the percent of vegetative cover in the 30–60 cm section of a visual cover board.
k. Top refers to the percent of vegetative cover in the 60–100 cm section of a visual cover board.

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- to 30-cm stratum within two weeks after harvest. Vertical cover within the 30- to 60-cm and 60- to 100-cm 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 growth pattern 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 two to four 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 four weeks earlier than big bluestem or indiangrass, resulting in taller, denser stands earlier in the nesting season.

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, could have an 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, whereas delaying harvest until 17–26 June caused 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 an impact on hay quality. Hay must be harvested prior to seedhead production to maximize nutritional quality (Ball et al. 2007). As grasses mature, fiber content increases, crude protein content decreases, and digestibility decreases (Nocera et al. 2005, Ball et al. 2007). Thus, delaying hay harvest presents a conflict when incorporating grassland bird conservation into hayfield management. Nocera (2005) looked at the tradeoffs between delaying harvest for both grassland bird reproductive success and hay quality and found small delays (one-two 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 would 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 16 April; for field sparrow (*Spizella pusilla*), 29 April; Henslow's sparrows (*Ammodramus henslowii*), 27 April; grasshopper sparrows, 1 May; and dickcissel (*Spiza americana*), 10 May. All species required a minimum of 23 days from laying to fledging, and nest initiation ended between 28 June and 4 July 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 in late June 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 or September (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- to 30-cm stratum within two 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 improves the structure of tall native grass fields for northern bobwhite broods. However, without a complement of desirable forbs, food availability and the overall quality of brooding cover is limited. Further, haying in May or June could be detrimental for bobwhites if they are using the fields for nesting. Future studies should evaluate vegetation structure along with bird use and nest success data in large experimental stands of nwsg under these treatments to expand on our findings.

Management Implications

Grass phenology and nutritive value are critical considerations when selecting native grasses for haying operations where grassland birds and northern bobwhite are a concern. We recommend big bluestem/indiangrass for hay producers who have an interest in grassland birds because they mature later than switchgrass or eastern gamagrass and harvest can be conducted in late June, allowing more time for grassland birds 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, biofuels stands will not provide high-quality habitat for northern bobwhite during the brood-rearing period, and managers interested in this species should consider prescribed grazing where production stands occur and northern bobwhite is a focal species.

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