Effects of Field Management Practices on Northern Bobwhite Habitat

John P. Gruchy[1], *University of Tennessee, Department of Forestry, Wildlife, and Fisheries 2143 Joe Johnson Drive, Knoxville, TN 37996*

Craig A. Harper, *University of Tennessee, Department of Forestry, Wildlife, and Fisheries 2143 Joe Johnson Drive, Knoxville, TN 37996*

Abstract: Native grasses and forbs have been promoted in conservation programs to enhance habitat for northern bobwhite (*Colinus virginianus*). However, high seeding rates and a lack of management result in vegetative structure that is less than optimal. We implemented six management practices (November disk, March disk, March burn, March mowing, strip-herbicide application, and September burn) with a control on an unmanaged field of planted native warm-season grass in East Tennessee, 2003–2004, to evaluate effects on habitat for northern bobwhite. We recorded vegetation composition, vegetation structure, and biomass of invertebrate orders preferred by bobwhite broods, 2004–2005. Disking treatments increased coverage of bobwhite food plants and reduced planted native grass cover. Disking and burning treatments enhanced vertical cover and openness at ground level and decreased litter in the season after treatment. March burning increased native grass cover and decreased undesirable grass cover. Structural and compositional variables did not differ between March mowing and control throughout the study. No treatment differences were observed in invertebrate biomass. We recommend burning and disking regimes to maintain an early succession community and improve vegetation structure for northern bobwhite. Further, we recommend mowing be discontinued as a habitat management practice for northern bobwhite.

Key Words: early succession, native warm-season grass, Farm Bill programs, mid-contract management, prescribed fire, disking, herbicide applications

Journal of the Southeastern Association of Fish and Wildlife Agencies 1:133–141

Declining habitat quality has been cited as a major factor for declining populations of northern bobwhite (hereafter, "bobwhite") throughout the Mid-South region (Brennan 1991). Widespread use of non-native grasses, especially tall fescue (*Lolium arundinaceum*), and rowcrop agriculture without fallow rotation are considered primary targets for habitat improvement (Brennan 1991, Barnes et al. 1995). Conservation programs offered through state and federal wildlife agencies, as well as those offered by the USDA through the Food Security Act have promoted planting native grasses and forbs as opposed to non-native cool-season grasses for conservation cover, especially on retired agricultural lands (Heard et al. 2000). Over 95,000 ha of native warm-season grass (hereafter, nwsg) have been planted in Conservation Practice 33 (the "buffers for bobwhites" program) since 2000, and increased bobwhite populations have been noted in these areas (Evans et al. 2009).

Dense nwsg planting rates and lack of management have been reported problematic within these programs for maintaining desirable vegetation structure for bobwhite (Burger et al. 1990, McCoy et al. 2001b, Riffell et al. 2010). In a survey of 43 CRP fields planted to nwsg across Tennessee, Dykes (2005) found all fields were dominated by grass and >70% of the landowners did not manage their fields or managed by mowing alone. Mowed and unmanaged fields contained dense grass cover with little bare ground and were frequently invaded by saplings (Dykes 2005). Dense stands of native grass have been characterized with low vegetative species diversity (Gill et al. 2006) and reduced wildlife habitat benefits (Burger et al. 1990, Millenbah et al. 1996, McCoy et al. 2001a).

Establishing nwsg can be relatively slow. However, grass density often increases rapidly within 3 years after planting (Jones et al. 2004, Gill et al. 2006). Depending on practice specifications, landowners enrolled in CRP are required to conduct management practices throughout the length of their contract, commonly known as mid-contract management, to reduce grass density, encourage additional forb cover, and maintain an early successional plant community (Burger 2000, Evans et al. 2009). Disturbance options for mid-contract management commonly include prescribed fire, disking, herbicide applications, and mowing. Although these management practices are commonly recommended to maintain early succession, an evaluation and comparison of these practices on vegetation composition and structure in fields planted to nwsg has not been conducted.

Buckner and Landers (1979) and Whitehead and McConnell (1980) found that annual burning, regardless of season, was an effective treatment for improving herbaceous seed supplies for bobwhites. Buckner and Landers (1979) also found that two-pass disking was more effective than rotational burning at increasing herbaceous food supplies. Carver et al. (2001) found that plots disked in the spring (March–April) had great occurrence of un-

1. Current address: Mississippi Department of Wildlife, Fisheries and Parks 272 CR 995 Tupelo, MS 38804

desirable agricultural weeds than plots disked during the fall (October–November). Olinde (2000) reported greater bobwhite food plant response from disking applied during November and February compared to May. In contrast, Jones et al. (1993) reported that annual disking applied in March resulted in greater amounts of bobwhite food plants than fall treatments, though results where highly variable based on the contents of the seed bank. The effect of various mid-contract management practices on fields of non-native grasses (Madison et al. 2001, Greenfield et al. 2003, Osborne et al. 2012) has been reported. These studies indicate that increases in bobwhite food plants and improved vegetation structure resulting from disking and/or burning are short-lived and that herbicide applications are the most effective means of eliminating undesirable grasses. A comparison of the effects of management practices used to rejuvenate dense, rank, planted fields of nwsg is needed to accurately recommend practices that will achieve specific objectives with regard to plant species composition and structure.

We implemented a field experiment to evaluate effects of disturbance practices similar to those recommended by USDA for mid-contract management, and timing of management practices on vegetation structure and composition variables related to bobwhite within fields planted to native grass/forb mixtures. Our objective was to provide management recommendations for landowners in the Mid-South who have planted native grass/forb mixtures that have grown rank over time and no longer provide desirable vegetation structure or composition for bobwhite or other wildlife species associated with these early successional communities. We predicted all of the disturbance practices would influence vegetation composition and structure. Further, we predicted disking and prescribed fire treatments would enhance openness at ground level for bobwhite more than other treatments. We also predicted herbicide applications would decrease native grass cover more than the other treatments. Finally, we predicted invertebrate abundance would increase following disking, prescribed fire, and herbicide treatments.

Study Area

We implemented treatments on a privately owned property in McMinn County, Tennessee, within the Ridge and Valley Physiographic Province. Soils in the field were Dewey silty clay loams of the Fulerton-Clarksville-Greendale Association (Bacon et al. 1948). Average annual rainfall in the region was 148 cm. Treatments were implemented in a 15.8-ha field that was previously dominated by tall fescue. The field was converted from tall fescue in May 2000 using an application of a tank-mix of glyphosate and imazapic. Big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and Maximilian sunflower (*Helianthus maximiliani*) were planted at 7 kg/ha Pure Live Seed (PLS) using a no-till drill. By September 2003, the dominant plants in the field included the planted native grasses as well as nimblewill (*Muhlenbergia shreberi*), brambles (*Rubus* spp.), American pokeweed (*Phytolacca americana*), and *Rhus* spp. (sumac). Tall fescue, orchardgrass (*Dactylis glomerata*), and thistles (*Cirsium* spp.) were also present.

Methods

Treatment Application

We applied seven treatments, including control, to 0.2-ha plots in a completely randomized design with three plots per treatment ($n = 21$) November 2003 – May 2004 and September 2004. Treatments included November disk, March disk, March burn, March mow, strip-herbicide application, and September burn. November disk was conducted 11 November 2003 using a 3.1-m hydraulic offset disk. Plots were disked 3–6 passes, or until >50% of the aboveground residue was incorporated into the soil. The same equipment and procedures were used for March disk. March burn, March disk, and March mow treatments were conducted 11 March 2004. September burn was conducted 28 September 2004. March burns were completed under the following conditions: temperature 15.5 C, 20%–35% relative humidity, wind speed 8–16 km/hr, and a mixing height >500 m. September burns were completed under the following conditions: < 26.7 C, 35%–45% relative humidity, wind speed 3–12 km/hr, and a mixing height >500 m. Flame lengths were estimated at 0.5–3 m. Strip-herbicide applications were conducted 5 May 2004 by closing off alternating nozzle tips of an agricultural spray coupe with a 6.5-m spray boom and applying a grass-selective herbicide (clethodim 1.8 kg ai/ha; Select 2 EC 10 oz/ac) using a total spray solution volume of 235 L/ha. Non-ionic surfactant was added at 0.25% total solution volume as recommended by the herbicide label. Plots treated with strip-herbicide applications were prepared by mowing in March. Planted native grasses where approximately 45 cm when the strip-herbicide treatment was applied.

Data Collection

We measured plant species composition using a 10-m line transect (Canfield 1941) placed along the cardinal azimuth passing through the center of each plot during summer (July–August) 2004 and 2005. We identified plants to species, then grouped species into planted native warm-season grasses, unplanted desirable native warm-season grasses, bobwhite food plants, undesirable warm-season grasses, undesirable cool-season grasses, undesirable forbs, and desirable brushy cover, which included sumac and blackberry. All "brushy cover" was considered desirable because there were minimal amounts of undesirable woody species, such as sweetgum (*Liquidambar styraciflua*) or green ash (*Fraxinus pennsylvanica*), pioneering into the study site.

We classified desirable bobwhite food plants as plants producing seed commonly consumed by bobwhites (Buckner and Landers 1979, Brennan and Hurst 1995). Undesirable forbs included aggressively growing broadleaf plants, such as thistles, Canadian horseweed (*Conyza canadensis*), pigweeds (*Amaranthus*), and sericia lespedeza (*Lespedeza cuneata*). Although these forbs may provide adequate structure for bobwhites and may be commonly consumed, we classified them as undesirable because they often dominate sites and reduce overall plant diversity. Undesirable warm-season grasses included aggressively growing grasses, such as johnsongrass (*Sorghum halepense*) and crabgrass (*Digitaria sanguinalis*). Seed from johnsongrass and crabgrass have been reported in the crops of bobwhites (Brennan and Hurst 1995). However, no study makes inference about the use of these grasses in proportion to their availability. We classified these grasses as undesirable because they often dominate sites, leading to reduced vegetation diversity and creating a problem when managing for more desirable plants. Tall fescue, orchardgrass, and cheat (*Bromus tectorum*) were grouped as undesirable cool-season grasses. Several plants did not fit into any category and were accounted for in plant species richness, but were not included in plant species composition analysis to ensure conservative estimates. A list of plants encountered along transects and plant species groupings can be found in Gruchy (2003).

We used visual obstruction reading (Robel et al. 1970), angle of obstruction (Kopp et al. 1998), ground sighting distance, litter depth, and vegetation height to quantify vegetation structure. Visual obstruction reading, angle of obstruction, and ground sighting distance were measured during July and December 2004 and February, April, July 2005. Litter depth and vegetation height were measured during July 2004 and 2005. We measured visual obstruction, a measure of vertical structure, by counting the number of 10-cm segments obscured by vegetation to a kneeling observer 4 m away from a 2-m pole (Robel et al. 1970). We measured angle of obstruction, a measure of herbaceous canopy cover density, by leaning a 2-m pole from a central sampling point until it made contact with vegetation. The angle of the pole at the point of contact was measured using a clinometer (Kopp et al. 1998). We measured ground sighting distance, an index of the openness at ground level, by looking 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. The observer was positioned directly south of the sampling point and ground sighting distance was recorded towards the north, east, and west within each quadrant. Visual obstruction reading, ground sighting distance, and angle of obstruction were measured from the same sampling point within each quadrant of each plot during each sampling period.

We measured invertebrate abundance using a 0.25-m^2 bottomless box and modified hand-held blower-vac (Harper and Gyunn 1998) during June 2004 and 2005. We collected four samples within each plot by systematically locating the sampling box near the center of each quadrant. Samples were collected when vegetation was dry and daytime temperatures were >26.7 C (Palmer 1995). Samples were stored in a freezer to prevent decomposition (Murkin et al. 1996). Invertebrates were separated from vegetation and debris, placed in plastic vials, and dried for 48 hours in a forced air oven at a constant temperature of 60 C (Murkin et al. 1996). We identified invertebrates to order and recorded dry weights, then combined orders preferred by bobwhites into one variable. Statistical tests were performed on total invertebrate biomass, biomass of orders preferred by bobwhites, total abundance, and abundance of orders preferred by bobwhites.

In foraging trials using pen-reared bobwhite chicks in different vegetation types, several invertebrate orders, including Aranea, Coleoptera, Diptera, Hemiptera, Homoptera, Hymenoptera, Lepedoptera larva, and Orthoptera, have been reported as preferred (Hurst 1972, Jackson et al. 1987, Palmer 1995, Doxon and Carroll 2010). We included Coleoptera, Hemiptera, Homoptera, and Orthoptera as preferred by bobwhite chicks because these orders were most consistently cited as preferred (Burger et al. 1993, DeVos and Muller 1993).

Data Analysis

A one-way analysis-of-variance (ANOVA) was used to test for differences in vegetation structure and composition among treatments. Within each sampling period, several variables used to describe vegetation structure and composition failed to meet the assumptions of ANOVA. We used arcsine square root and natural log plus 0.5 transformations to resolve violation of heterogeneity of variables. We used Tukey's Honest Significant Difference to test pair-wise differences between treatments (*t*) when *F*-tests were significant ($\alpha = P < 0.05$), using PROC GLM in the SAS system (Littell et al. 2002).

Results

Vegetation Composition

We detected treatment differences for all vegetation composition variables except undesirable cool-season grasses ($F_{5, 48} = 1.23$; $P = 0.310$) and desirable brushy cover ($F_{5, 48} = 1.86$; $P = 0.119$) during the first growing season following treatment (2004; Table 1). March mow was similar to control for all vegetation composition variables.

Table 1. Mean (±SE) vegetation composition and structure characteristics following management practices in a field planted to nwsg in McMinn County, Tennessee, July 2004 and 2005. Means for composition variables represent the distance (m) covered by each vegetation cover variable along a 10-m line transect. The sum of all vegetation cover types may add up to greater than 10 m because of over-lapping canopy cover types.

	Treatment																				
	Control			March mow			Strip herbicide			March burn			September burn			November disk			March disk		
Variable	x[a]	(SE)		x	(SE)		x	(SE)		x	(SE)		x	(SE)		x	(SE)		x	(SE)	
2004																					
Planted nwsg[b]	5.27	(1.41)	ab	8.00	(0.88)	a	4.64	(0.57)	bc	7.95	(0.43)	ab				0.86	(0.26)	c	0.77	(0.24)	c
Unplanted nwsg[c]	0.16	(0.05)	ab	0.08	(0.08)	ab	0.29	(0.13)	a	0.06	(0.03)	ab				0.00	(0.00)	b	0.02	(0.02)	ab
Bobwhite food plants[d]	2.46	(0.49)	b	2.21	(0.86)	b	2.20	(0.58)	b	4.09	(1.35)	b				9.96	(0.87)	a	10.00	(0.96)	a
Undesirable wsg[e]	4.68	(1.24)	a	3.00	(0.67)	ab	1.77	(0.70)	b	1.67	(0.45)	b				0.81	(0.26)	b	1.23	(0.41)	b
Undesirable csg[f]	0.69	(0.40)		0.57	(0.33)		1.48	(0.78)		0.14	(0.07)					1.31	(0.54)		0.40	(0.21)	
Undesirable forbs[g]	0.38	(0.12)	ab	0.32	(0.07)	b	0.52	(0.12)	ab	0.31	(0.12)	b				1.48	(0.57)	a	1.05	(0.21)	ab
Brushy cover	1.65	(0.63)		1.30	(0.53)		1.43	(0.61)		0.67	(0.35)					0.05	(0.03)		0.40	(0.21)	
Species richness	13.67	(1.12)	b	15.11	(0.48)	ab	18.56	(1.20)	a	17.33	(1.77)	ab				17.44	(1.00)	ab	18.00	(0.93)	ab
Vegetation height (m)	1.47	(0.14)	a	1.48	(0.04)	a	1.08	(0.11)	b	1.24	(0.03)	ab				1.03	(0.04)	b	1.50	(0.11)	a
Litter depth (cm)	5.25	(0.66)	a	2.63	(0.10)	b	1.21	(0.11)	b	0.00	(0.00)	c				0.00	(0.00)	c	0.00	(0.00	c
2005																					
Planted nwsg	5.43	(1.29)	b	7.12	(1.12)	ab	4.56	(0.64)	b	9.64	(0.59)	a	6.27	(0.57)	ab	1.80	(0.29)	c	0.96	(0.28)	
Unplanted nwsg	0.01	(0.01)	b	0.02	(0.02)	b	0.69	(0.34)	a	0.00	(0.00)	b	0.13	(0.09)	ab	0.10	(0.05)	ab	0.31	(0.10)	
Bobwhite food plants	0.76	(0.24)	ab	0.73	(0.21)	ab	0.54	(0.18)	b	0.26	(0.06)	b	2.45	(0.79)	a	1.83	(0.60)	ab	1.35	(0.51)	
Undesirable wsg	3.18	(0.81)	a	2.12	(0.69)	abc	0.67	(0.27)	bcd	0.15	(0.15)	d	0.25	(0.13)	cd	1.49	(0.44)	abc	1.89	(0.57)	
Undesirable csg	1.17	(0.42)	ab	0.37	(0.24)	bc	2.05	(0.60)	a	0.00	(0.00)	c	0.05	(0.04)	c	1.84	(0.53)	a	0.60	(0.20)	
Undesirable forbs	0.93	(0.22)	bc	1.00	(0.31)	bc	0.82	(0.24)	c	1.14	(0.62)	c	2.09	(0.41)	bc	3.00	(0.73)	ab	5.73	(0.84)	
Brushy cover	2.59	(1.24)	ab	3.58	(0.74)	a	0.30	(0.15)	bc	0.09	(0.07)	c	1.51	(0.79)	abc	0.58	(0.16)	bc	1.16	(0.52)	
Species richness	12.75	(0.49)	abc	10.22	(0.92)	c	15.22	(0.86)	a	9.50	(0.98)	c	14.22	(1.15)	ab	12.56	(0.80)	abc	10.67	(1.18)	
Vegetation height (m)	1.25	(0.18)		1.25	(0.09)		0.97	(0.06)		0.98	(0.12)		0.97	(0.15)		1.00	(0.14)		1.19	(0.12)	
Litter depth (cm)	5.10	(1.10)	a	4.52	(0.70)	a	3.40	(1.01)	ab	2.13	(0.51)	b	0.00	(0.00)	c	0.23	(0.08)		0.60	(0.21)	

a. Means followed by the same letter within the same row are not different, Tukey's HSD ($P > 0.05$).
b. Native grasses that were planted from seed (e.g., big bluestem, indiangrass).
c. All native warm-season grasses that were not planted from seed (e.g., broomsedge, fall panicum).
d. Plants that produce seed commonly eaten by bobwhites (Buckner and Landers 1979, Brennan and Hurst 1995).
e. Warm-season grasses, native or non-native, that tend to dominate sites reducing plant diversity (e.g., johnsongrass, crabgrass).
f. Cool-season grasses that tend to dominate sites reducing plant diversity (e.g., tall fescue, cheat).
g. Forbs, native or non-native, that tend to dominate sites reducing plant diversity (e.g., thistles, pigweeds).

November and March disk treatments contained less planted nwsg and more bobwhite food plants than all other treatments. There was less planted native grass following strip-herbicide than March mow ($t_{48} = 3.23$; $P = 0.026$), but similar to control ($t_{48} = 1.36$; $P = 0.749$). All treatments except March mow decreased undesirable warm-season grasses. November disk had more undesirable forb cover than March burn ($t_{48} = -3.33$; $P = 0.020$) or March mow ($t_{48} = -3.01$; $P = 0.045$) treatments. Species richness was greater in strip-herbicide than control ($t_{48} = -3.07$; $P = 0.045$).

We detected treatment differences for all vegetation composition variables during the 2005 growing season (Table 1). Control and March mow were still similar for all variables. November and March disking were similar for all variables. Density of planted native grass was greater in March burn ($t_{54} = -3.58$; $P = 0.012$). There was less planted native grass in disking treatments than all other treatments. September burn had more bobwhite food plants than March burn ($t_{54} = -3.72$; $P = 0.008$) or strip-herbicide ($t_{54} = 3.15$; $P = 0.039$). Coverage of undesirable warm-season grasses was less following March ($t_{54} = 5.01$; $P = <0.001$) and September burn ($t_{54} = 4.14$; $P = <0.001$) and strip herbicide ($t_{54} = 3.50$; $P = 0.016$). November disk, strip-herbicide, and control contained more undesirable cool-season grass than the burn treatments. Brushy cover was less following March burn than March mow ($t_{54} = 4.45$; $P = 0.002$) and control ($t_{54} = 3.77$; $P = 0.006$). Disking treatments contained less brushy cover than March mow. Strip-herbicide contained greater species richness than March mow ($t_{54} = -3.78$; $P = 0.007$), March burn ($t_{54} = -4.20$; $P = 0.002$), and March disk ($t_{54} = 3.45$; $P = 0.020$).

Vegetation Structure

We detected treatment differences for all structural variables during July 2004 (Figures 1–3, Table 1). March mow plots were similar to control for all structural variables except litter depth ($t_{66} = 10.38$; $P = <0.001$). Vegetation height was lower following

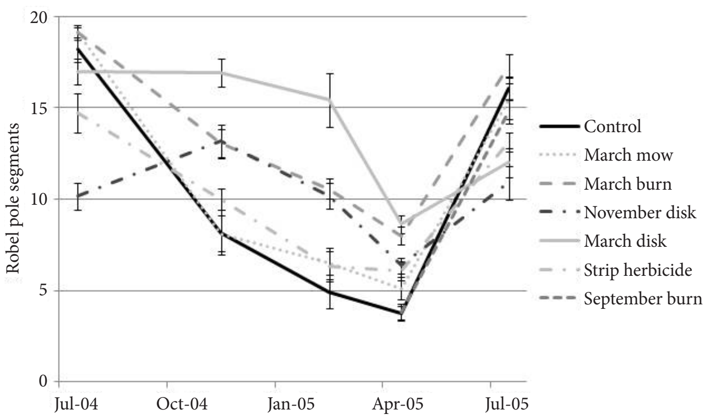

Figure 1. Visual obstruction reading (Robel pole segments covered) following management practices in a previously unmanaged field planted to native warm-season grasses June 2000, McMinn County, Tennessee, July – August 2004 and 2005. Symbols represent means and vertical bars are SE.

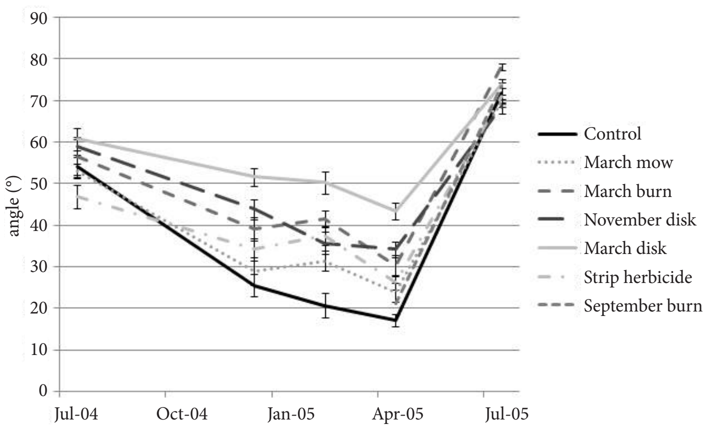

Figure 2. Angle of obstruction following management practices in a previously unmanaged field planted to native warm-season grasses June 2000, McMinn County, Tennessee, July – August 2004 and 2005. Symbols represent means and vertical bars are SE.

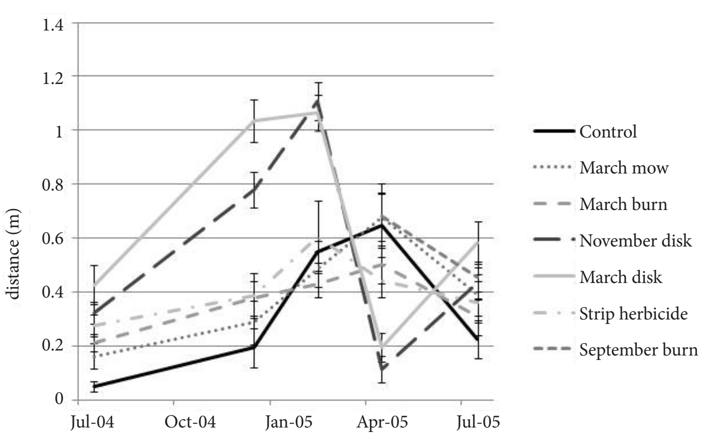

Figure 3. Ground sighting distance (openness at ground level) following management practices in a previously unmanaged field planted to native warm-season grasses June 2000, McMinn County, Tennessee, July – August 2004 and 2005. Symbols represent means and vertical bars are SE.

November disk and strip-herbicide than control, March mow, and March disk. Litter depth decreased following November and March disking and March burn.

During July 2005, we detected treatment differences for all vegetation structure variables except vegetation height ($F_{5,\,66} = 1.10$; $P = 0.140$; Table 1). As in July 2004, March mow was similar to control for all vegetation structure variables. November and March disk were also similar for all vegetation structure variables. Litter depth also remained lower in the burned and disked treatments.

The general structure of vegetation in all treatment areas and controls can be seen in Figures 1–3. We detected treatment differences for visual obstruction reading, angle of obstruction, and ground sighting distance, during all dormant-season sampling periods (Figures 1–3). March mow and control were similar through the dormant season for all but angle of obstruction in January ($t_{66} = -3.01$; $P = 0.041$). Angle of obstruction was greater following November ($t_{66} = 2.94$; $P = 0.048$) and March ($t_{66} = -3.41$; $P = 0.014$) disking treatments than strip-herbicide during the first growing season following treatment. Disking treatments and March burn improved both vertical and overhead cover throughout the dormant season as evident by greater visual obstruction (Figure 1) and angle of obstruction (Figure 2) than control. Openness at ground level was improved by all treatments except mowing ($t_{66} = -2.79$; $P = 0.079$) during the first growing season following treatment (2004), but only the March disking treatment ($t_{77} = -3.28$; $P = 0.025$) remained more open that control in the growing season of 2005. Openness at ground level remained greater in disking treatments than in control or March mowing during the fall and winter, but was reduced in November ($t_{66} = 5.12$; $P = <0.001$) and March ($t_{66} = 3.83$; $P = 0.005$) disking treatments compared to control during the spring because of vernal weeds responding to the disking treatments that were inhibited by grass thatch in control.

Invertebrate Biomass

We did not detect any treatment differences in total invertebrate biomass ($F_{5,\,66} = 1.83$; $P = 0.119$), biomass of preferred orders ($F_{5,\,66} = 1.47$; $P = 0.211$), total abundance ($F_{5,\,66} = 2.01$; $P = 0.089$), or abundance of orders preferred by bobwhites ($F_{5,\,66} = 1.26$; $P = 0.292$) during 2004. We detected treatment differences for total invertebrate abundance ($F_{5,\,77} = 2.71$; $P = 0.019$) in 2005. March mow contained more invertebrates than November disk or strip herbicide treatments. No differences were detected in abundance of orders preferred by bobwhites ($F_{5,\,77} = 1.52$; $P = 0.182$), total biomass ($F_{5,\,77} = 0.31$; $P = 0.928$), or biomass of orders preferred by bobwhites ($F_{5,\,77} = 0.90$; $P = 0.496$) in 2005.

Discussion

Most of the disturbance treatments we implemented impacted habitat for bobwhite through changes in vegetation composition and structure. Bobwhite food availability was impacted primarily through changes in vegetation composition; we did not detect differences in abundance or biomass of invertebrates in orders preferred by bobwhites. Disking treatments, regardless of season, were most effective in reducing grass density and increasing coverage of bobwhite food plants. Disking and burning treatments, regardless of season, enhanced structure for bobwhite at the ground level, which supported our prediction. Strip herbicide was effective in reducing undesirable warm-season grass coverage but did not reduce coverage of native warm-season grasses, which did not support our prediction. Mowing had no effect on vegetation composition or structure. Thus, our prediction that all of the disturbance practices would influence vegetation composition and structure was not supported.

Clearly, disturbance practices can affect plant composition and structure differently. Disking reduced grass coverage more than any other treatment. Although bobwhite habitat quality declines as fields become rank with grass (Burger et al. 1990), bobwhites benefit from scattered clumps of grasses representing 10%–50% ground cover for nesting and brood-rearing (Taylor and Burger 2000, Collins et al. 2009, Martin et al. 2009). In our study, there was 10%–20% coverage of nwsg in the second growing season following disking treatments, which provided adequate nesting structure along with increased food availability and a more open structure at ground level, facilitating movement. We used a heavy offset disk and conducted multiple passes to incorporate at least 50% of the vegetation into the soil.

Timing of disking has been shown to influence vegetation composition. Fall disking was reported to promote more preferred bobwhite food plants (Olinde 2000) and fewer undesirable plants (Jones et al. 1993, Carver et al. 2001) than disking in the spring or summer. However, disking in February or March promoted plant communities similar to disking in October (Jones et al. 1993, Olinde 2000). At a different site than the one we used in this study, Gruchy and Harper (2006) reported similar plant composition following disking in November and March, but nonnative warm-season grass coverage increased when disking was conducted in April. There seems to be a consistent trend that disking at any time during the dormant season produces similar results within the dormant season, and disking at any time during the growing season produces similar results during growing season. We found no difference with regard to plant composition between disking in the fall or late winter during the first growing season following disking. However, spring disking had more undesirable forbs (primarily thistles) than control during the second growing season following disking. Plant composition following disking should be expected to vary in different areas with different soils, seedbanks, climates, and land-use history. Disking in spring (relative to latitude of location) or early summer will likely increase coverage of undesirable warm-season species if they are present in the seedbank.

Designation of "undesirable" plants is subjective. Most landowners would likely consider common ragweed (*Ambrosia artemisifolia*), which is an excellent food plant for bobwhites, as undesirable. The structure presented by a majority of the forbs we labeled undesirable, such as pigweeds, horseweed, thistles, and even sericea lespedeza, is useable to bobwhites with regard to brood-rearing (Manley 1994, Yates et al. 1995, Carver et al. 2001) and summer coverts (Hiller et al. 2007). Thus, we do not believe the potential of increased coverage of "undesirable" forbs should necessarily be viewed as a deterrent to conduct management. If undesirable species are present in the seedbank, they will inevitably respond to the frequent disturbance regime that is needed to maintain early seral plant communities for bobwhites and other wildlife that require early successional habitat. We view undesirable species responding to disturbance as an opportunity for controlling them.

Our findings of decreased coverage of undesirable grasses and increased coverage of native warm-season grass following dormant-season fire are consistent with studies conducted in the South (Whitehead and McConnell 1980, Manley 1994) and other regions (Towne and Owensby 1984, Howe 2000). Native warm-season grass cover had nearly doubled by the second growing season following March burning. Burning in September also favored native warm-season grass coverage. We anticipated September burning would decrease nwsg coverage. Howe (1995) and Towne and Kemp (2008) reported reduced coverage of late-flowering plants, including native warm-season grasses, following a single late growing-season fire in Wisconsin and Kansas respectively, with more pronounced results following multiple growing season fires.

Coverage of planted nwsg and cool-season grasses following strip-herbicide application did not differ from control in the first or second growing season after application. However, coverage of undesirable warm-season grasses, such as johnsongrass, crabgrass, and nimblewill, was decreased. It is not surprising that cool-season grasses were not reduced because they had already flowered and produced seed. The timing of application (early May) was intended to reduce warm-season grass coverage. Although the initial impacts of strip herbicide application were evident (plants turned brown and died), we believe the lack of reduction in planted nwsg coverage was a result of planted nwsg plants that were not killed by the herbicide expanding and filling the space that was temporarily created. We recommend evaluation of other herbicides and application techniques to reduce native warm-season grass cover where coverage is excessive. For example, closing fewer nozzles on the spray boom or not closing any nozzles and using a different herbicide may produce more favorable results.

Mowing is the most commonly used disturbance practice by private landowners in native warm-season grass conservation programs in Tennessee (Dykes 2005). And conversations with state agency biologists throughout the Mid-South make it clear that mowing is a common disturbance practice, even on lands managed by state wildlife agencies. Our results, consistent with McCoy et al. (2001b), suggest mowing does not enhance bobwhite habitat. Mowing did not influence vegetation composition compared with control. Vegetation structure, openness at ground level, litter depth, and litter coverage did not differ from control. Further, our results are consistent with others (Welch et al. 2004, Gruchy et al. 2009) in that mowing did not reduce woody cover—a primary reason most landowners mow fields (Dykes 2005). For these reasons, we recommend mowing be discontinued as a management option to enhance early successional cover where bobwhite is a focal species.

Previous studies have reported increased invertebrate abundance following disking (Manley 1994, Madison et al. 1995, Yates et al. 1995), burning (Hurst 1972), and herbicide applications (Madison et al. 1995). We failed to detect any difference in invertebrate biomass or abundance of orders preferred by bobwhites following treatments. Efficacy of invertebrate sampling techniques varies greatly with regard to vegetation structure (Southwood et al. 1979, Palmer et al. 2001). We used a vacuum sampler because vacuum sampling has been reported more representative of invertebrate populations than other methods of invertebrate collection, such as sweep nets (Race 1960, Byerly et al. 1978). When sampling invertebrates as food for bobwhites, it is obviously important to collect invertebrates at the ground level where bobwhite chicks feed, and that is not possible with a sweep net.

We believe invertebrate availability is more important than invertebrate abundance or biomass per area. Invertebrate abundance is irrelevant if bobwhite chicks cannot forage effectively because of dense vegetation at ground level or if there is inadequate overhead cover for foraging chicks. Based on an assessment of the nutritional requirements of bobwhites 1–14 days old (Palmer 1995), invertebrate biomass was sufficient for bobwhite broods within all treatments as well as control in our study.

Management Implications

Landowners participating in many conservation programs designed to promote bobwhite habitat may be required to establish nwsg and maintain desirable early successional vegetation through mid-contract management practices. We recommend prescribed fire to maintain an early seral stage, stimulate bobwhite food plants, and consume litter, which will enhance openness at ground level for bobwhite. We recommend disking anytime from fall through late winter where nwsg have become too dense (>50% coverage), to stimulate annual bobwhite food plants, and improve openness at ground level. We also recommend disking to maintain an early seral stage where the use of prescribed fire is not possible. The strip-herbicide application treatment we tested did not show considerable promise for improving bobwhite habitat. Although undesirable plants may respond to disturbance, such as disking, management should not be influenced by fear of releasing undesirable plants. Rather, we recommend a proactive management regime to improve vegetation structure for bobwhites combined with adaptive management approaches that target undesirable plants for eradication or control using integrated weed control strategies. Our study and others have shown mowing perpetuates undesirable habitat conditions for bobwhite. Thus, mowing should not be used to manage bobwhite habitat. Further, we recommend that mowing not be allowed as a cost-shared mid-contract management practice in Farm Bill programs designed to improve habitat for bobwhites.

Acknowledgments

We thank the Mayfield family for the use of their property for this study as well as the Tennessee Wildlife Resources Agency (TWRA) for assistance implementing treatments. Funding was provided by the USDA-NRCS/MSU Bobwhite Restoration Project and the University of Tennessee Department of Forestry, Wildlife, and Fisheries. We thank Dr. Matt Gray and Dr. Bronson Strickland for assistance with data analysis and Carla Dilling for assistance with field data collection and invertebrate analysis.

Literature Cited

Bacon, S. R., E. W. Knobel, and T. E. Beesley. 1948. Soil Survey of McMinn County, Tennessee. Division of Soil Survey, Bureau of Plant, Industry, Soils, and Agricultrual Engineering, U.S. Department of Agriculture. Series 1948, No. 4.

Barnes, T. G., A. L. Madison, J. D. Sole, and M. J. Lacki. 1995. An assessment of habitat quality for northern bobwhite in tall fescue dominated fields. Wildlife Society Bulletin 23(2):231–237.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19(4):544–555.

_____ and G. A. Hurst. 1995. Summer diet of northern bobwhite in eastern Mississippi: implications for habitat management. Proceedings of the

Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:516–524.

Buckner, J. L. and J. L. Landers. 1979. Fire and disking effects on herbaceous food plants and seed supplies. Journal of Wildlife Management. 43:807–811.

Burger, L. W., Jr. 2000. Wildlife responses to the conservation reserve program in the southeast. i*n* A comprehensive review of farm bill contributions to wildlife conservation, 1985–2000. W.L. Holman and D.J. Halloum, editors. U.S. Department of Agriculture, Natural Recourses Conservation Service, Wildlife Habitat Management Institute, Technical Report, USDA/NRCS/WHMI-2000.

_____, E. W. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1990. Structural characteristics of vegetation in CRP fields in northern Missouri and their suitability as bobwhite habitat. Transactions of the North American Wildlife and Natural Resources Conference 55:74–83.

_____, _____, _____, and _____. 1993. Relative invertebrate abundance and biomass in Conservation Reserve Program plantings in northern Missouri. Pages 102–108 *in* K. E. Church and T. V. Dailey, editors. Quail III: National Quail Symposium. Kansas Department of Wildlife and Parks, Pratt.

Byerly, K. F., A. P. Gutierrez, R. E. Jones, and R. K. Luck. 1978. A comparison of sampling methods for some arthropod populations in cotton. Hilgardia 46:257–282.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry. 39:388–394.

Carver, A. V., L. W. Burger, Jr., L. A. Brennan, and W. E. Palmer. 2001. Vegetation characteristics in seasonal-disked fields and at bobwhite brood locations. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 55:437–443.

Collins, B. M., C. K. Williams. P. K. Castelli, 2009. Reproduction and microhabitat selection in a sharply declining northern bobwhite population. The Wilson Journal of Ornithology 121:688–695.

DeVos, T. and B. S. Mueller. 1993. Reproductive ecology of northern bobwhite in north Florida. Pages 83–90 *in* Proceedings of the Third National Quail Symposium. K. E. Church and T. V. Dailey, editors. Kansas Department of Wildlife and Parks, Pratt.

Doxon, E. D. and J. P. Carroll. 2010. Feeding ecology of ring-necked pheasant and northern bobwhite chicks in Conservation Reserve Program fields. Journal of Wildlife Management 74:249–256.

Dykes, S. A., 2005, Effectiveness of native grassland restoration in restoring grassland bird communities in Tennessee. Thesis. University of Tennessee, Knoxville, Tennessee.

Evans, K. O., L. W. Burger, Jr., M. D. Smith, and S. K. Riffell. 2009. Conservation Reserve Program CP33—habitat buffers for upland birds: bird monitoring and evaluation plan. 2006–2008 Final Report. Mississippi State University, Mississippi State.

Gill, D. E., P. Blanks, J. Parks, J. B. Guerard, B. Lohr, E. Schwartzman, J. G Gruber, G. Dodge, C. A. Rewa, and H. F. Sears. 2006. Plant and breeding bird response on a managed Conservation Reserve Program grassland in Maryland. Wildlife Society Bulletin 34:944–956.

Greenfield, K. C., L. W. Burger, Jr., and M. J. Chamberlain. 2001. Herbicide and prescribed fire as habitat management tools for northern bobwhite in Conservation Reserve Program fields. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 55:445–455.

Greenfield, K. C., M. J. Chamberlain, L. W. Burger, Jr., and E. W. Kurzejeski. 2003. Effects of burning and discing Conservation Reserve Program fields to improve habitat quality for northern bobwhite (*Collinus virginianus*). American Midland Naturalist 149:344–353.

Gruchy, J. P. 2003. An evaluation of field management practices to improve bobwhite habitat. Thesis. University of Tennessee, Knoxville, Tennessee.

_____ and C. A. Harper. 2006. When is the best time to disk native warm-season grasses for wildlife? Pages 296–303 *in* M.A. Sanderson et al., editors. Proceedings of the Fifth Eastern Native Grass Symposium. Harrisburg, Pennsylvania.

_____, _____, and M. J. Gray. 2009. Methods for controlling woody invasion into CRP fields in Tennessee. Pages 148–154 *in* S. B. Cederbaum, B. C. Faircloth, T. M. Terhune, J. J. Thompson, and J. P. Carroll, editors. Proceedings of Gamebird 2006: Quail VI and Perdix XII. May 31–June 4, 2006. Warnell School of Forestry and Natural Resources, Athens, Georgia.

Harper, C. A. and D. C. Guynn. 1998. A terrestrial vacuum sampler for macroinvertebrates. Wildlife Society Bulletin 26:302–304.

Hiller, T. L., F. S. Guthery, A. R. Rybak, S. D. Fuhlendorf, S. G. Smith, W. H. Puckett, R. A. Baker. 2007. Management implications of cover selection data: northern bobwhite example. Journal of Wildlife Management 71:195–201.

Howe, H. F. 1995. Succession and fire season in experimental prairie plantings. Ecology 76:1917–1925.

_____. 2000. Grass response to seasonal burns in experimental plantings. Journal of Range Management 53:437–441.

Hurst, G. A. 1972. Insects and bobwhite quail brood management. Pages 65–82 *in* J.A. Morrison and J.C. Lewis, editors. Proceedings of the First National Quail Symposium. Oklahoma State University, Stillwater.

Jackson, J. R., G. A. Hurst, and E. A. Gluesing. 1987. Abundance and selection of invertebrates by northern bobwhite chicks. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 41:303–310.

Jones, P. D., J. R. Sweeney, and T. Ivey. 1993. Effects of six disking regimes on quail foods in fallowed fields. Proceedings of the Annual Conference the Southeastern Association of Fish and Wildlife Agencies 47:239–250.

Jones, B.C., J.P. Gruchy, and C.A. Harper. 2004. Rate of increase among native warm-season grasses using conventional and no-till technology with various applications of Plateau herbicide. Pages 15–19 *in* Barnes, T.G. and L.R. Kiesel, editors. Proceedings of the Fourth Eastern Native Grass Symposium, Lexington, Kentucky.

Kopp, S. D., F. S. Guthery, N. D. Forrester, and W. E. Cohen. 1998. Habitat selection modeling for northern bobwhites on subtropical rangeland. Journal of Wildlife Management. 62:884–895.

Littell, R. C., W. W. Stroup, and R. J. Freund. 2002. SAS for linear models. SAS Institute, Cary, North Carolina.

Madison, L. A., T. G. Barnes, and J. D. Sole. 1995. Improving northern bobwhite brood rearing habitat in tall fescue dominated fields. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:525–536.

_____, _____, and _____. 2001. Effectiveness of fire, disking, and herbicide to renovate tall fescue fields to northern bobwhite habitat. Wildlife Society Bulletin 29:706–712.

Manley, S. W. 1994. Evaluation of old-field habitat manipulations for breeding northern bobwhites. Thesis. Mississippi State University, Mississippi State.

_____, R. S. Fuller, J. M. Lee, and L. A. Brennan. 1994. Arthropod response to strip disking in oldfields managed for northern bobwhites. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 48:227–235.

Martin, N. C., J. A. Martin, and J. P. Carroll. 2009. Northern bobwhite brood habitat selection in South Florida. Pages 88–97 in S. B.Cederbaum, B. C. Faircloth, T. M. Terhune, J. J. Thompson, J. P. Carroll, editors. Gamebird 2006: Quail VI and Perdix XII. 31 May – 4 June 2006. Warnell School of Forestry and Natural Resources, Athens, Georgia.

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

______, M.R. Ryan, L.W. Burger, E.W. Kurzejeski. 2001a. Grassland bird conservation: CP1 vs. CP2 plantings in Conservation Reserve Program fields in Missouri. American Midland Naturalist 145:1–17.

Millenbah, K. F., S. R. Winterstein, H. Campa, III, L. T. Furrow, and R. B. Minnis. 1996. Effects of Conservation Reserve Program field age on avian relative abundance, diversity and productivity. Wilson Bulletin 108:760–770.

Murkin, H. R., D. A. Wrubleski, and F. A. Reid. 1996. Pages 349–369 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats: Sampling invertebrates in aquatic and terrestrial habitats. Allen Press, Lawrence, Kansas.

Olinde, M. W. 2000. Vegetation response to disking on a longleaf pine site in southeastern Louisiana. Pages 32–35 *in* L. A. Brennan, W. E. Palmer, L. W. Burger, Jr., and T. L. Pruden, editors. Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, Florida.

Osborne, D. C., D. W. Sparling, and R. L. Hopkins II. 2012. Influence of Conservation Reserve Program mid-contract management and landscape composition on northern bobwhite in tall fescue monocultures. Journal of Wildlife Management 76:566–574.

Palmer, W. E. 1995. Effects of modern pesticides and farming systems on northern bobwhite quail brood ecology. Dissertation. North Carolina State University. Raleigh, North Carolina.

______, M. W. Lane, and P. T. Bromley. 2001. Human-imprinted northern bobwhite chicks and indexing arthropod foods in habitat patches. Journal of Wildlife Management 65:861–870.

Race, S. R. 1960. A comparison of two sampling techniques for Lygus bugs and stink bugs on cotton. Journal of Economic Entomology 53:689–90.

Riffell, S. K., D. Scognamillo, L. W. Burger, Jr., and S. Bucholtz. 2010. Broad scale relations between Conservation Reserve Program and grassland birds: do cover type, configuration, and contract age matter? Open Ornithology Journal 3:112–123.

Robel, R., J. Briggs, A. Dayton, and L. Hubert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

Southwood, T. R. E., V. K. Brown, and P. M. Reader. 1979. The relationship of plants and insect diversities in succession. Biological Journal of the Linnaean Society 12:327–348.

Taylor, J. D., II, and L. W. Burger, Jr. 2000. Habitat use by breeding northern bobwhites in managed old-field habitats in Mississippi. Pages 7–15 *in* L. A. Brennan, W. E. Palmer, L. W. Burger, Jr., and T. L. Pruden, editors. Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, Florida.

Towne, G. and C. Owensby. 1984. Long-term effects of annual burning at different dates in ungrazed Kansas tallgrass prairie. Journal of Range Management 37:392–397.

______ and K. E. Kemp. 2008. Long-term response patters of tallgrass prairie to frequent summer burning. Rangeland Ecology and Management 61:509–520.

Welch, J. R., K. V. Miller, W. E. Palmer, and T. B. Harrington. 2004. Response of understory vegetation important to northern bobwhite following imazapyr and mechanical treatments. Wildlife Society Bulletin 32:1071–107

Whitehead, C. J. and C. A. McConnell. 1980. Controlled burning studies in oldfields. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 33: 88–95.

Yates, S. W., D.C. Sisson, H. L. Stribling, and D. W. Speake. 1995. Northern bobwhite brood habitat use in South Georgia. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:498–504.