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Original Article

Brood Cover and Food Resources for Wild Turkeys Following Silvicultural Treatments in Mature Upland Hardwoods

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ABSTRACT Closed-canopy, upland hardwood forests with limited understory development provide suboptimal habitat for wild turkey (*Meleagris gallopavo*) broods and may lead to low recruitment. Various forest management practices have been used to stimulate understory development within upland hardwoods, but evaluation of such practices on cover and food resources for wild turkey broods is incomplete. Therefore, we compared effects of 7 silvicultural treatments (repeated fire, shelterwood harvest, shelterwood harvest with one fire, retention cut, retention cut with repeated fire, retention cut with herbicide, and retention cut with herbicide and repeated fire) on cover and food resources for wild turkey broods in mature upland hardwoods of the Ridge and Valley Physiographic Province, Tennessee, USA, during 2000–2009. Canopy reduction treatments enhanced understory conditions for wild turkey broods. Eight years following initial treatment, light infiltration in retention cuts with repeated fire was 6 times greater than that within control, 5 times greater than that within shelterwood harvests, and twice that within shelterwood harvests with one prescribed fire. Woody species dominated understory composition following all treatments and controls. Understory disturbance (prescribed fire and broadcast herbicide treatments) reduced density of stems >1.4 m tall and <11.4 cm diameter at breast height (dbh) and created less visual obstruction above 1 m compared with canopy reduction treatments without understory disturbance. Following canopy reduction without repeated prescribed fire, woody vegetation exceeded ideal height for wild turkey broods after 3 growing seasons and light infiltration returned to control levels within 7 years. Soft mast production was greatest following treatments that included canopy reduction, but varied by year and site. Invertebrate biomass did not increase following any treatment, but all treatment areas contained enough invertebrates to meet the protein requirement for a wild turkey brood (10.1 poults) for 28 days on <30 ha. Where wild turkey is a focal species and understory structure in mature upland hardwoods is limiting for broods, we recommend reducing canopy coverage to 60–70% and using low-intensity fire every 3–5 years to enhance and maintain brood cover and increase food availability. © 2014 The Wildlife Society.

KEY WORDS forest management, habitat management, herbicide applications, prescribed fire, wild turkey.

Mature upland hardwoods typically provide roosting cover with autumn and winter hard-mast food resources for eastern wild turkeys (*Meleagris gallapavo silvestris*; Barwick and Speake 1973, Speake et al. 1975, Everett et al. 1979). However, these stands often lack the understory development that characterizes high-quality brood-rearing cover (Metzler and Speake 1985, Pack et al. 1988, Jackson et al. 2007). Ideal cover for wild turkey broods is composed of various groundcovers up to 50 cm tall that provide overhead protection and access to invertebrates, seeds, and soft mast (Metzler and Speake 1985, Campo et al. 1989, Peoples et al. 1996, Spears et al. 2007). Most wild turkey poult mortality occurs during the first 2 weeks after hatching while poults are still flightless (Vander Haegen et al. 1988, Peoples et al. 1995, Miller et al. 1998, Paisley et al. 1998). Understory structure is influential on wild turkey poult survival on large forested tracts (Metzler and Speake 1985), especially during this critical 2-week period.

Forest understories can be manipulated through canopy reduction and understory disturbance. Canopy reduction increases light infiltration into the understory and increases growing space for retained trees. Increased light infiltration stimulates understory development and increases soft mast production (Perry et al. 1999, Greenberg et al. 2007, 2011), which can improve habitat quality for wild turkey broods.

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Timber harvest can improve nesting and brood cover, but woody regeneration quickly dominates many harvested sites, reducing quality of brood cover within a few years (Sharp 1963, Crawford 1971, Jackson et al. 2007). Subsequent disturbance after timber harvest, such as prescribed fire and/or herbicide applications, can control hardwood regeneration and stimulate herbaceous groundcover (Pack et al. 1988, Jackson et al. 2007).

Information for managing upland hardwood stands for wild turkey broods is incomplete. Beneficial effect of various partial harvests and thinnings is ephemeral (Crawford 1971, Jackson et al. 2007), and there are few studies that have investigated effects of prescribed fire and/or herbicide applications on wild turkey habitat in upland hardwood stands. Pack et al. (1988) reported mixed results following a single fire and thinning in oak (*Quercus* spp.)–hickory (*Carya* spp.) forests, but understory conditions generally improved in stands that were thinned and then burned. Food availability was not reported. McCord and Harper (2011) reported the initial effects of the understory herbicide application reported in this paper, but comparisons with other treatments were not reported. Regardless, understory conditions for wild turkey broods had not improved by the second year post-treatment and food availability for poults was decreased (McCord and Harper 2011).

We conducted a field experiment to evaluate effects of canopy reduction (shelterwood harvests and retention cuts) alone and in combination with understory disturbance (prescribed fire and herbicide application) on structure and composition of understory vegetation relative to cover and resulting food resources (invertebrate availability and soft mast production) for wild turkey broods in closed-canopy, upland hardwood forests. We expected herbaceous groundcover and soft mast production to increase following canopy reduction and prescribed fire treatments and woody vegetation to decline following prescribed fire and herbicide applications. We also predicted invertebrate availability would increase with the herbaceous groundcover response.

STUDY AREA

We conducted our study on Chuck Swan State Forest and Wildlife Management Area, which was managed by the Tennessee Department of Agriculture Division of Forestry and the Tennessee Wildlife Resources Agency. Chuck Swan State Forest and Wildlife Management Area encompassed 9,825 ha and was in the Southern Appalachian Ridge and Valley physiographic province in eastern Tennessee, USA. Elevation ranged from 310 m to 520 m with approximately 130 cm of annual rainfall.

Approximately 92% of Chuck Swan State Forest and Wildlife Management Area was forested and the primary forest type was mixed hardwoods and oak–hickory with scattered shortleaf pine (*Pinus echinata*). Common overstory species included chestnut oak (*Q. montana*), white oak (*Q. alba*), northern red oak (*Q. rubra*), black oak (*Q. velutina*), mockernut hickory (*C. tomentosa*), pignut hickory (*C. glabra*), yellow-poplar (*Liriodendron tulipifera*), blackgum (*Nyssa sylvatica*), American beech (*Fagus grandifolia*), and red maple (*Acer rubrum*). Sassafras (*Sassafras albidum*), flowering dogwood (*Cornus florida*), and sourwood (*Oxydendrum arboreum*) were common in the midstory. Hardwood stands were managed on an 80-year rotation, with clearcutting the most common regeneration method. Soils belonged to the Clarksville–Fullerton–Claiborne association, and were characterized as well-drained, acidic soils with shallow, rocky A horizons (NRCS 2009).

METHODS

We used a randomized complete block design with 4 stands (blocks) to compare vegetation structure and food resources in response to 7 silvicultural practices and 1 control. We selected 4 stands in separate watersheds, but with similar overstory composition, aspect (N to NW), and slope (24–30%). Each 9.6-ha stand was divided into 12 0.8-ha treatment units. Treatment area size was designed to evaluate effects on vegetation, not wildlife use (Jackson et al. 2007, Lashley et al. 2011). Treatment units were adjacent to each other. We placed vegetation sampling plots $\geq$30.5 m from treatment edges to minimize potential effects of adjacent treatments. We randomly assigned treatments to the 12 experimental units in each stand. We selected 2 units/stand as controls that received no treatment. We burned 2 units in each stand without canopy reduction (F) in 2001, 2005, 2007, and 2009. We implemented a shelterwood harvest (S) on 4 units in each stand in 2001; 2 of these (per stand) were burned (SF) once in 2005, following the shelterwood-burn regeneration technique described by Brose et al. (1999). We conducted retention cutting (R) in the remaining 4 units in each stand in 2001; we burned 2 of these/stand in 2001, 2005, 2007, and 2009. We sprayed the 2 unburned retention cut units with a broadcast application of triclopyr (Garlon® 4; Dow Agrosciences LLC, Indianapolis, IN) via backpack sprayer (RH) after sampling in 2006. We selected triclopyr because it is effective in killing most hardwood species, but does not have residual soil activity and is safe to apply beneath mature hardwoods (Dow Agrosciences 2008). We burned one RH unit at each stand in 2007 and 2009 (RHF).

We used shelterwood harvest and retention cutting for canopy reduction treatments. Shelterwood harvest is an even-aged regeneration method distinguished by a succession (usually two) of partial commercial harvests. Trees are retained after the initial harvest to shelter regenerating trees and the residual timber is harvested after the regeneration is established, usually 6–8 years after initial harvest. At Chuck Swan State Forest and Wildlife Management Area, we retained high-quality stems with good form and vigor. The target canopy closure was 60% after the initial cut. Initial shelterwood harvests were completed June–July 2001. Retention cutting is a non-commercial timber-stand improvement practice that can be used to kill or remove tree species undesirable for focal wildlife species. We killed trees with relatively low value to wild turkeys, such as maples and yellow-poplar, and retained oaks, blackgum, black cherry (*Prunus serotina*), persimmon (*Diospyros virginiana*), and an occasional American beech—species that provide hard and soft mast for wild turkeys. We reduced canopy cover in retention cuts to 60%. We girdled or hacked undesirable stems and treated the wound with a 1:1 solution of triclopyr (Garlon® 3-A; Dow Agrosciences LLC) and water. We also killed midstory trees, with the exception of a few flowering dogwoods, by felling and treating stumps with the herbicide solution. We completed R cuts in February and March 2001.

Understory disturbance included low-intensity prescribed fire and understory herbicide applications. We used low-intensity fires to reduce injury to overstory trees. All prescribed fires occurred during the early growing season, April–early May, in an effort to control woody groundcover and stimulate herbaceous groundcover. Burns were initiated with backing fires, and strip-heading fires were used to burn the remainder. Low-intensity fire (flame heights <1 m) was maintained by appropriately spacing strips. Prescribed fires were conducted under the following conditions: 10–21°C, 20–40% relative humidity, 8–16 km/hr wind speed, and a >500-m mixing height for the smoke plume.

We measured vegetation response using 4 randomly placed subplots within each treatment unit in 2006, 2008, and 2009, and in 3 subplots in 2007. We sampled plots June through September. We sampled fewer subplots in 2007 because of limited field assistance. However, we used repeated-measures analysis (see below), and discrepancy in subplot sampling effort had no influence on statistical power. We measured overstory (stems >11.4 cm dbh) basal area and stem density within 0.04-ha, fixed-radius circular plots. We used a diameter tape to measure dbh of each stem and used this to calculate basal area. We measured density of stems >1.4 m in height and <11.4 cm dbh within a 5.7-m-radius (0.01-ha) circular plot centered on each plot center.

We measured infiltration of photosynthetically active radiation (PAR) along a transect in each treatment unit using 2 AccuPAR® LP-80 PAR/LAI ceptometers (Decagon Devices, Inc., Pullman, WA). Each transect was oriented diagonally from one corner of the treatment unit to the opposite corner. We recorded measurements every 1 m for 30 m, beginning 20 m from the end of each transect to minimize edge effect. All measurements were taken 1.4 m aboveground. We calculated PAR measurements as a percentage of full sun by taking paired, simultaneous measurements with a ceptometer within each treatment unit and another ceptometer monitoring full PAR in the closest opening (field).

We measured visual obstruction to quantify vertical structure using a vegetation profile board (Nudds 1977). The board was divided into 4 50-cm intervals, marked in alternating Overstory plot black and white. We measured visual obstruction for each increment on a scale of 1–5, where 1 = 0–20%, 2 = 21–40%, 3 = 41–60%, 4 = 61–80%, and 5 = 81–100% coverage. We measured visual obstruction 15 m upslope and 15 m downslope from each plot center. We analyzed visual obstruction of the 0–0.5-m stratum, the 0.51–1.0-m stratum, and the sum of the 2 strata from 1.01–2.0 m. We combined these strata because visual obstruction <0.5 m aboveground is important for turkey broods (Healy 1985, Peoples et al. 1996), but vegetation above this stratum may interfere with a hen's ability to detect predators.

We measured cover by herbaceous plants, woody vines, brambles (*Rubus* spp.), and cover by tree and shrub species using 3 11.3-m line-intercept transects radiating from plot center at 0°, 120°, and 240° (McCord and Harper 2011). We recorded each species group and its coverage to the nearest cm. We measured percent woody cover <1.4 m high by recording species present at every 0.5-m increment on 3 11.3-m point-intercept transects radiating from plot center at 0°, 120°, and 240°.

We measured soft mast production along 3 50-m transects in each treatment unit in early July, August, and October 2007, and late June, July, August, and September 2008. Transects were systematically placed approximately 25 m apart and ≥5 m from treatment unit edges. We tallied all fruits within 0.61 m of each transect and ≤2 m above ground by species or species group. We report soft mast production by species commonly consumed by wild turkeys, including American pokeweed (*Phytolacca americana*), blackberry (*Rubus* spp.), blueberry (*Vaccinium* spp.), greenbriar (*Smilax* spp.), huckleberry (*Gaylussacia baccata*), sumac (*Rhus* spp.), and viburnum (*Viburnum* spp.; Dalke et al. 1942, Hamrick and Davis 1971, Hurst and Stringer 1975). We initiated transect measurements when soft mast first began to ripen and sampled monthly through late September–early October. We gathered representative fruit samples outside of the research stands, dried them at 55°C to constant mass, and weighed them (whole fruit including seeds) to estimate soft mast biomass. We used the sampling period with peak soft mast biomass for each treatment unit and species as a production estimate for each unit (Greenberg et al. 2007).

We measured invertebrate abundance using a modified leaf blower vacuum sampler (Harper and Guynn 1998) and a 0.25-m^2 (0.5-m-wide × 0.5-m-long × 0.5-m-tall) bottomless sampling box with a lid. We sampled during early July 2007 and 2008. In 2007, 4 samples were randomly taken throughout each treatment unit. With additional assistance in 2008, we vacuumed 9 litter samples from each treatment unit. Each invertebrate sample was taken ≥30.5 m from the treatment unit edges and other invertebrate sampling points. We vacuumed the top layer of litter and all vegetation. We did not sample during windy conditions (wind gusts >16 km/hr at ground level) or rain to avoid biasing results (Hughes 1955). We froze all samples to prevent decomposition until they were dried to constant mass (about 48 hr) at 60°C (Murkin et al. 1994). We sorted all invertebrates to order and weighed them to the nearest 0.0001 g. We report biomass of taxa commonly consumed by wild turkeys: classes Gastropoda and Malacostraca, and orders Arachnida, Coleoptera, Diptera, Hemiptera, Homoptera, Hymenoptera, Lepidoptera, and Orthoptera as reported by Dalke et al. (1942), Hamrick and Davis (1971), Hurst and Stringer (1975), Healy (1985), and Iglay et al. (2005).

We estimated minimum foraging area (*A*) required for a brood of 10.1 wild turkey poults (Godfrey and Norman 1999) to meet their dietary invertebrate requirements for the first 28 days after hatching. Mean daily intake of invertebrates by wild turkey poults has not been reported, so we used weekly body mass (g_w) and mean daily food intake (f_w) by week for blue grouse (*Dendragapus obscurus*) chicks (Stiven 1961), which have a similar dietary protein requirement (Stiven 1961, Hurst and Stringer 1975, Nenno and Lindzey 1979, Healy 1985), and adjusted daily food requirements to correspond with the weekly mass (p_w) of domestic turkey poults (Knížetová et al. 1995). To calculate A, we used the following formula:

$$A_t = \frac{\sum p_w/g_w \times f_w \times 0.35 \times 10.1}{I_t}$$

where I_t is the mean invertebrate biomass for each treatment × year, p_w is mean poult mass of domestic turkeys for the wth week (Knížetová et al. 1995), g_w is the mean chick mass of blue grouse for the wth week (Stiven 1961), and f is the daily invertebrate food requirement for the wth week for blue grouse (Stiven 1961). Stiven's (1961) daily intake values were based on live invertebrate biomass, so we converted the mean daily intake to dry weight assuming dry weight ≈35% of live weight (Carrel 1990, Klein-Rollais and Daguzan 1990, Studier and Sevick 1992).

We used a 2-way, repeated-measures analysis of variance (ANOVA; PROC MIXED) in SAS 9.1 (SAS Institute, Cary, NC) to test the hypotheses that overstory basal area and stem density, vegetation structure, groundcover by herbaceous plants, woody vines, and brambles, groundcover by woody regeneration, midstory stem density, soft mast production, and invertebrate biomass and abundance did not differ among treatments and across years. The fixed effect was treatment × year. Year was the repeated effect. Stand was the random effect. Each stand ($n = 4$) was treated as a replication. Although treatments were replicated in 2 separate treatment units within each stand, we did not consider within-stand replicates independent, so we used the mean of the 2 as the value for the treatment in each stand. We used log-transformation to correct for non-normality in soft mast production, but report non-transformed values for all data.

We used a 1-way mixed-model ANOVA (PROC MIXED) to test the hypothesis that PAR infiltration did not differ among treatments. The fixed effect was treatment. Stand was the random effect. Each stand ($n = 4$) was treated as a replication. Data for PAR infiltration were normal, so no transformation was needed.

When ANOVAs were significant at $\alpha = 0.05$, we used Tukey's Honestly Significant Differences comparison test to determine differences in treatments and year(treatment).

RESULTS

We sampled vegetation structure and composition in 912 plots across 5 years. We identified 143 plant species, 50 of which were trees or shrubs. We measured PAR infiltration at 1,440 points within treatment units and 1,440 times in adjacent clearings. We collected soft mast along 288 transects and encountered 12 species groups, 5 of which are commonly eaten by wild turkeys. We vacuumed 624 litter samples, yielding 5,709 individual invertebrates.

Basal area in S harvests and R cuts was reduced following treatment to approximately 60% of C (Table 1). Basal area in F remained constant after 4 low-intensity prescribed fires. Density of stems >11.4 cm dbh differed following silvicultural treatments ($F_{7,21} = 21.42$, $P < 0.001$). Density of stems >11.4 cm dbh was reduced following shelterwood harvest and retention cutting, but did not change following repeated prescribed fire (F). When the initial S harvests were conducted, some high-value stems (large-diam oaks) were cut, and some intermediate stems were retained. In R cuts, most of the large-diameter oaks were retained and midstory stems removed, so fewer trees composed the same basal area following S. PAR infiltration in 2009 differed among treatments ($F_{6,18} = 15.18$, $P < 0.001$). Eight years following shelterwood harvests, regeneration progressed such that PAR levels in S (5.8%, SE = 2.4%) were similar to C (4.7%, SE = 1.0%). Following herbicide application, light infiltration was greater in RH (19.8%, SE = 4.6%) and RHF (26.6%, SE = 7.4%) than S where the midstory was still intact. In RF, which was maintained by repeated prescribed fire, PAR levels (29.4%, SE = 5.4%) were 5 times greater than C and 4 times greater than S. Groundcover comprised

Table 1. Mean basal area (m^2/ha) of stems ≥11.4 cm dbh following silvicultural treatments to enhance wild turkey brood habitat, Chuck Swan State Forest, Tennessee, USA, 2000–2009.

	Yr									
	2000[b]		2006[c]		2007[c]		2008[c]		2009[c]	
Silvicultural treatment[a]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
C	24	1	33 A	3	29 A	3	30 A	2	34 A	2
F	25	2	26 AB	1	26 AB	4	26 AB	3	27 AB	1
S	24	1	20 C	2	17 C	1	16 C	1		
SF	28	3	20 BC	3	21 BC	3	24 BC	3		
R	23	3	16 C	4						
RF	27	2	21 BC	11	21 BC	2	25 BC	2	23 BC	1
RH					15 C	4	18 C	3	22 C	1
RHF					21 BC	3	21 BC	3	24 BC	3

[a] Silvicultural treatments: C = control, F = multiple prescribed fires, S = shelterwood harvest, SF = shelterwood harvest with one prescribed fire, R = retention cut, RF = retention cut with multiple prescribed fires, RH = retention cut with understory herbicide application, RHF = retention cut with understory herbicide application and multiple prescribed fires. After sampling in 2006, R treatment was replaced by RH and RHF.
[b] Pretreatment data. Treatment units did not differ ($F_{5,15} = 0.77$, $P = 0.589$).
[c] Different letters indicate differences among treatments ($F_{7,20.3} = 8.58$, $P < 0.001$).

Table 2. Mean percent cover by trees and shrubs <1.4 m tall following silvicultural treatments to enhance wild turkey brood habitat, Chuck Swan State Forest, Tennessee, USA, 2006–2009.

	Yr[b]							
	2006		2007		2008		2009	
Silvicultural treatment[a]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
C	11.5 E	1.8	17.9 DE	3.7	18.1 DE	2.8	19.2 CDE	3.4
F	9.6 E	3.2	17.5 DE	5.6	27.7 BCDE	1.2	19.6 CDE	4.0
S	38.3 ABCDE	4.6	28.0 BCDE	5.2	32.4 ABCDE	9.1		
SF	17.5 DE	3.2	35.3 ABCDE	4.8	47.8 ABC	7.0		
R	52.2 AB	9.0						
RF	30.6 BCDE	6.9	40.7 ABCD	5.1	57.6 A	4.2	40.9 ABCD	8.9
RH			8.6 E	1.5	23.0 CDE	3.6	25.6 BCDE	4.1
RHF			11.4 DE	3.3	21.1 CDE	5.5	20.9 CDE	4.2

[a] Silvicultural treatments: C = control, F = multiple prescribed fires, S = shelterwood harvest, SF = shelterwood harvest with one prescribed fire, R = retention cut, RF = retention cut with multiple prescribed fires, RH = retention cut with understory herbicide application, RHF = retention cut with understory herbicide application and multiple prescribed fires. After sampling in 2006, R treatment was replaced by RH and RHF.
[b] Different letters indicate differences among yr(treatment) ($F_{14,45.1} = 2.48$, $P = 0.011$).

of herbaceous plants, woody vines, and brambles ranged from 8.9% in F in 2007 to 32.4% in R in 2006. However, variability among stands, with year(treatment) standard errors >50% of the mean, prevented detection of differences among treatments ($F_{7,21.7} = 2.22$, $P = 0.072$). Woody groundcover was more prevalent than herbaceous cover and dominated most sites (Table 2). Woody regeneration was dominated by yellow-poplar, red maple, or sassafras in all treatments.

Density of stems <11.4 cm dbh and >1.4 tall differed by year(treatment) ($F_{14,45.1} = 2.85$, $P = 0.004$). Repeated prescribed fire in RF reduced density of stems <11.4 cm dbh and >1.4 tall from 4,740/ha (SE = 1750) in 2006 to 920/ha (SE = 373) in 2007. Following the understory herbicide application, density of stems >1.4 m tall and <11.4 cm dbh declined 99% in RHF and 87% in RH in 2007 compared with R in 2006.

Visual obstruction was least in C and F and immediately following herbicide application with fire (Table 3). Increased light resulting from canopy reduction with and without fire (S, SF, and RF) stimulated vegetation at ground level and increased visual obstruction in the 1.0–2.0-m stratum. Soft mast production varied among sites (Table 4), and may have resulted from differences in the seedbank. Soft mast production was greater in 2008 than 2007 in RF, F, and RH because stands were not disturbed in 2008. Soft mast production in C, F, S, SF, and RF was dominated by blackberry. Pokeweed produced most of the soft mast in RHF, and blueberries were the dominant fruit-producing plant in RH.

We collected invertebrates from 10 taxa considered important to wild turkey poults: Gastropoda, Malacostraca, Araneae, Coleoptera, Diptera, Hemiptera, Homoptera, Hymenoptera, Lepidoptera, and Orthoptera. Invertebrate biomass did not differ among treatments or year by treatment (Table 5).

DISCUSSION

Moderate levels (30–40%) of canopy reduction (S and R) increased light infiltration (PAR) to the forest floor to sufficiently stimulate groundcover and enhance structure for wild turkey brood cover. However, without periodic

Table 3. Mean visual obstruction measured using a density board following silvicultural treatments to enhance wild turkey brood habitat, Chuck Swan State Forest, Tennessee, USA, 2007–2008.

	0–0.5 m[b]				0.5–1.0 m[c]				1.0–2.0 m[d]			
	2007		2008		2007		2008		2007		2008	
Silvicultural treatment[a]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
C	2.2 D	0.4	2.2 D	0.2	1.9 D	0.4	1.3 D	0.3	3.2 B	1.3	2.7 B	0.6
F	2.1 D	0.4	2.9 BCD	0.4	1.3 D	0.2	1.7 D	0.3	2.0 B	0.0	3.0 B	0.4
S	4.3 ABCD	0.4	5.0 A	0.3	3.8 AB	0.4	4.1 A	0.2	7.6 A	0.7	7.8 A	0.5
SF	4.3 ABCD	0.2	4.6 ABCD	0.2	3.5 ABC	0.3	3.9 AB	0.4	4.4 B	0.6	7.3 A	1.0
RF	4.1 ABCD	0.3	4.7 AB	0.1	2.5 BCD	0.5	4.1 A	0.1	3.0 B	0.7	7.1 A	0.2
RH	2.9 BCD	0.7	3.5 ABCD	0.5	2.2 CD	0.4	2.5 BCD	0.4	3.3 B	1.2	4.5 B	1.5
RHF	1.7 D	0.2	2.8 CD	0.6	1.5 D	0.2	2.1 CD	0.3	2.4 B	0.4	3.7 B	0.6

[a] Silvicultural treatments: C = control, F = multiple prescribed fires, S = shelterwood harvest, SF = shelterwood harvest with one prescribed fire, RF = retention cut with multiple prescribed fires, RH = retention cut with understory herbicide application, RHF = retention cut with understory herbicide application and multiple prescribed fires.
[b] Different letters indicate differences among yr(treatment) ($F_{13,28.6} = 7.17$, $P < 0.001$).
[c] Different letters indicate differences among yr(treatment) ($F_{13,28.6} = 11.18$, $P < 0.001$).
[d] Sum of visual obstruction scores from 1.0–1.5-m and 1.5–2.0-m strata. Different letters indicate differences among yr(treatment) ($F_{13,28.6} = 16.50$, $P < 0.001$).

Table 4. Mean soft mast production (g/ha) ≤2 m above ground level by species commonly consumed by wild turkeys following silvicultural treatments, Chuck Swan State Forest, Tennessee, USA, 2007–2008.

Silvicultural treatment[a]	Yr			
	2007[b]		2008[b]	
	$\bar{x}$	SE	$\bar{x}$	SE
C	15 ABCD	8	1,261 ABCD	1,229
F	3 CD	3	821 AB	337
S	1,700 A	1,030	12,233 A	9,301
SF	2,457 A	790	8,690 A	5,575
RF	25 BCD	25	22,112 A	16,945
RH	0 D	0	67 ABC	23
RHF	6,216 ABC	4,690	9,267 A	8,008

[a] Silvicultural treatments: C = control, F = multiple prescribed fires, S = shelterwood harvest, SF = shelterwood harvest with one prescribed fire, RF = retention cut with multiple prescribed fires, RH = retention cut with understory herbicide application, RHF = retention cut with understory herbicide application and multiple prescribed fires.

[b] Different letters indicate differences among yr(treatment) ($F_{6, 21} = 4.58$, $P = 0.004$).

disturbance, regenerating woody stems >1.4 m tall and <11.4 cm dbh quickly increased and developed into a dense midstory, limiting PAR to control levels within 7 years following S harvests. Wild turkey hens select areas with well-developed groundcover and an open midstory for brood habitat (Campo et al. 1989, Spears et al. 2007). These conditions can lead to increased brood survival because poults are relatively well-concealed and hens are able to see above the groundcover (Metzler and Speake 1985, Spears et al. 2007). In our study, prescribed fire following canopy reduction produced the most visual obstruction at ground level while reducing visual obstruction in the upper strata.

Realizing the ephemeral nature of enhanced brood habitat conditions is important for land managers. Low-intensity prescribed fire following overstory reduction maintained an open midstory, stimulated soft mast production, and maintained a well-developed groundcover for wild turkey broods, and our data (Table 1) indicate low-intensity prescribed fire can be used in upland hardwood stands without reducing basal area.

Table 5. Mean biomass (g/ha) of invertebrates commonly consumed by wild turkeys and minimum foraging area (ha) following silvicultural treatments, Chuck Swan State Forest, Tennessee, USA, 2007–2008.

Silvicultural treatment[a]	Invertebrate biomass[b]				Min. foraging area[c]	
	2007		2008			
	$\bar{x}$	SE	$\bar{x}$	SE	2007	2008
C	1,406	375	2,132	338	8	5
F	395	174	1,465	331	29	8
S	1,006	232	1,228	234	12	9
SF	886	204	1,197	390	13	10
RF	1,188	662	606	99.6	10	19
RH	755	199	791	108	15	15
RHF	689	166	1,069	373	17	11

[a] Silvicultural treatments: C = control, F = multiple prescribed fires, S = shelterwood harvest, SF = shelterwood harvest with one prescribed fire, RF = retention cut with multiple prescribed fires, RH = retention cut with understory herbicide application, RHF = retention cut with understory herbicide application and multiple prescribed fire.

[b] Yr(treatment) ($F_{6,21} = 1.72$, $P = 0.165$) and treatment ($F_{6, 21} = 1.75$, $P = 0.159$) did not differ.

[c] Min. area in ha required for a brood of 10.1 poults (Godfrey and Norman 1999) to meet their dietary invertebrate requirements for the first 28 days after hatching assuming no mortality.

A common objective when managing for wild turkey brood cover is to develop a robust and diverse herbaceous layer (Peoples et al. 1996, Godfrey and Norman 1999). Dormant-season and early growing-season burning has been promoted as a management tool to improve wild turkey brood habitat by increasing forb cover and decreasing woody vegetation (Lewis and Harshbarger 1976, Holzmueller et al. 2009). Pack et al. (1988) reported herbaceous cover increased on some sites following a single burn after thinning, but it is common for seedbanks to vary across sites (Schiffman and Johnson 1992). At Chuck Swan State Forest and Wildlife Management Area, stand-to-stand variation may have prevented us from detecting differences in herbaceous groundcover among treatments, including retention cutting followed by 4 early growing-season prescribed fires. Competition from woody species and seedbank variability across sites may have contributed to the overall variability and lack of herbaceous response at Chuck Swan State Forest and Wildlife Management Area. Land managers should consider site history and recognize that species composition may vary from site to site. Although groundcover response to canopy reduction and prescribed fire was dominated by woody regeneration at Chuck Swan State Forest and Wildlife Management Area, this is not necessarily undesirable when managing for wild turkeys. Increased woody cover at ground level has been associated with lower poult mortality (Hubbard et al. 2001).

Timing of burning can influence plant composition. Gruchy et al. (2009) reported low-intensity prescribed fire during September was more effective at reducing coverage of woody species than burning during the dormant-season and was as effective as applications of triclopyr or imazapyr. Burning during September also increased coverage of desirable legumes more than dormant-season burning or applications of triclopyr or imazapyr (Gruchy et al. 2009). Additional work is needed to document effects of season of burning on plant composition (including food resources and brood cover for wild turkeys) in upland hardwood stands. Low-intensity prescribed fire during the late growing season (late Aug–early Oct) has not been examined as a tool to enhance brood habitat in upland hardwoods, and may prove more effective at transitioning understory composition from woody to more herbaceous species.

McCord and Harper (2011) reported effects of herbicide application following canopy reduction on our study site. Herbicide application killed >87% of the midstory, reduced visual obstruction in all strata, and allowed PAR to reach the forest floor. However, herbaceous groundcover 2 growing seasons after herbicide treatment was 49–61% of pre-herbicide levels. Broadcast herbicide treatments to the understory have limited application when managing upland hardwood stands for wild turkeys. Herbicide treatments in our study were costly (approx. US$690.00/ha for RHF, US $653.00/ha for RH) compared with prescribed fire (approx.

US$37.00/ha when assisted by Tennessee Division of Forestry), and did little to enhance quality of brood cover for wild turkeys. Nonetheless, more long-term monitoring with different herbicides and in different areas may be warranted to determine how plant communities respond following broadcast herbicide applications in hardwoods.

Soft mast production was greater in 2008 than 2007 in undisturbed treatments (C and S), most likely because of a record drought in 2007 (NOAA 2008). There was more soft mast in RH in 2008 than in 2007 because of weather and vegetation recovery 1-year post-herbicide application. Soft mast availability was greatest in RF the second growing season following fire. Most of the soft mast in S, SF, and RF consisted of blackberries. Blackberries are produced on mature floricanes, so little soft mast was available immediately after prescribed fire in 2007. Soft mast production in RF increased nearly 1,000-fold in 2008. Blackberries are the most commonly consumed soft mast by wild turkeys (Korschgen 1967, Blackburn et al. 1975, Kennamer et al. 1980). Blackberry can also provide escape cover and overhead protection from avian predators for wild turkey broods. Blackberries were present in all retention cut units before herbicide application. Following herbicide application, blackberry coverage was greatly reduced and absent from some treated units. American pokeweed was the most prevalent soft mast in RHF. Although pokeweed is commonly consumed by wild turkeys, it is relatively unimportant in their diets compared with blackberries (Blackburn et al. 1975, Kennamer et al. 1980). Nonetheless, soft mast retained into autumn and winter, such as pokeweed and sumac, can provide buffer food for wild turkeys in years of poor hard-mast production and is important for many other wildlife species (McCarty et al. 2002, Greenberg et al. 2007).

Wild turkey poults require a diet of 28% crude protein (Marsden and Martin 1955), and these demands are most easily met consuming arthropods and other invertebrates (Beck and Beck 1955, Stiven 1961, Despins and Axtell 1994, Zuidhof et al. 2003). Most of the invertebrates we collected were ground-dwelling, which potentially are within reach of poults. Enough invertebrates were present in F in 2007 for a 10.1-poult brood to meet its invertebrate needs for the first 28 days post-hatching/29 ha. Godfrey and Norman (1999) reported the average home range for wild turkey broods during the first 28 days post-hatching was approximately 200 ha in upland hardwood stands, suggesting understory structure is more of a limiting factor on wild turkey recruitment in mainly forested areas than invertebrate biomass. Although we did not measure poult foraging efficiency, the improved understory structure present in RF would most likely enable wild turkey poults to search and feed upon invertebrates and other foods with less exposure and vulnerability than within untreated (C) stands.

MANAGEMENT IMPLICATIONS

Where cover for wild turkey broods may be limiting in closed-canopy upland hardwoods, we recommend reducing canopy closure by 30–40% to increase light and improve understory development and seed and soft mast production. If desirable advanced regeneration is present, a shelterwood harvest may be implemented to offset expenses associated with prescribed fire, depending on management objectives. If timber value does not warrant commercial harvest or if the stand is not ready to regenerate, a retention cut should be considered. We do not recommend understory broadcast applications of triclopyr because this treatment reduced understory structure and invertebrate availability, and herbaceous groundcover did not increase within 3 growing seasons post treatment. Following a shelterwood harvest or retention cut, we recommend a 3–5-year fire-return interval, depending on understory response, to stimulate the seedbank, maintain groundcover and soft mast production, and maintain visibility >1 m aboveground for wild turkey hens. Because early growing-season fire did not influence groundcover composition, future research should investigate efficacy of prescribed fire during the late growing season in upland hardwoods to enhance brood cover for wild turkeys.

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