Wildlife Society Bulletin 44(4):705–712; 2020; DOI: 10.1002/wsb.1142

Original Article

Improving Coastal Plain Hardwoods for Deer and Turkeys with Canopy Reduction and Fire

MARK A. TURNER,[1] *School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL 36849, USA*
WILLIAM D. GULSBY, *School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL 36849, USA*
CRAIG A. HARPER, *Department of Forestry, Wildlife, and Fisheries, University of Tennessee, Knoxville, TN 37996, USA*
STEPHEN S. DITCHKOFF, *School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL 36849, USA*

ABSTRACT Prescribed fire and canopy reduction are accepted forest management practices used to increase forage and cover for white-tailed deer (*Odocoileus virginianus*) and wild turkeys (*Meleagris gallopavo*) in pine systems throughout the southeastern United States. However, use of prescribed fire to improve conditions for deer and turkeys has not been evaluated in upland hardwood forests of the Coastal Plain, and some land managers remain skeptical of the utility of fire in this ecoregion. We designed a manipulative experiment to measure deer and turkey habitat components following canopy reduction and prescribed fire in 4 upland hardwood stands in the Coastal Plain of Alabama, USA, during 2018 and 2019. Specifically, we used herbicide to kill trees with low value to deer and turkeys and retained oaks (*Quercus* spp.) and other species considered important as part of a forest stand improvement (FSI) operation to reduce canopy coverage. We then applied low-intensity prescribed fire to half of each treatment unit. One unit in each replicate served as a control. We measured total understory plant coverage, biomass of deer forage, and turkey brooding cover for 2 years following canopy reduction and one year after fire. Coverage of herbaceous plants increased by 134% in FSI/Burn, and coverage of woody and semiwoody plants increased by 33% and 97%, respectively, following FSI only. Deer forage biomass was greater in both FSI and FSI/Burn compared to control, but there was no difference in deer forage biomass between FSI and FSI/Burn. FSI/Burn provided better turkey brooding cover than FSI or control. No overstory trees were killed by fire. We detected minor cambium damage to 13% of water oaks (*Quercus nigra*) in the FSI/Burn units; other species only showed light bark charring or no sign of burning. We recommend FSI and low-intensity prescribed fire in Coastal Plain hardwoods to improve brooding cover for turkeys and understory forage for deer while retaining acorn production. © 2020 The Wildlife Society.

KEY WORDS Coastal Plain, deer forage, Forest Stand Improvement, hardwood forest, *Meleagris gallopavo*, *Odocoileus virginianus*, prescribed fire, white-tailed deer, wild turkey.

White-tailed deer (*Odocoileus virginianus*) and eastern wild turkey (*Meleagris gallopavo silvestris*) are the 2 most hunted upland game species in the southeastern United States (U.S. Department of the Interior et al. 2017). Millions of hectares of public land are managed to provide habitat for deer and turkeys, and approximately 85 million ha are owned or leased for hunting in the Southeast (Macaulay 2016). Therefore, understanding how forest management influences habitat quality for deer and turkeys is important for landowners and land managers across the region. Providing adequate nutrition for deer can have major effects on both body condition and productivity. For example, body growth and productivity of females is greater when adequate nutrition is available (Verme 1969). Additionally, antler growth is decreased when nutrition is suboptimal (French et al. 1956, Harmel et al. 1989). Although hard mast (i.e., acorns) can be an important food source for deer (Feldhamer et al. 1989, Wentworth et al. 1992), approximately 70% of their annual diet consists of forbs and browse (Hewitt 2011), both of which occur in the understory of woodland plant communities.

In addition to providing deer forage, composition and structure of understory plant communities are important for turkey brood-rearing. High-quality brooding cover is typically found in areas with an open canopy and herbaceous understory (Healy 1985, Metzler and Speake 1985, Campo et al. 1989, Wood et al. 2018). Without adequate groundcover, broods suffer high mortality rates from predation (Speake et al. 1985). Because structure of brooding cover may influence poult survival (Metzler and Speake 1985), managing for cover to reduce poult mortality during their

Received: 23 February 2020; Accepted: 26 May 2020
Published: 18 December 2020

[1]*E-mail: mat0073@auburn.edu*

most vulnerable flightless stage is beneficial where turkeys are a focal species (Speake et al. 1985, Vander Haegen et al. 1988, Peoples et al. 1995).

Forest management practices that decrease canopy coverage typically increase forage for deer and enhance cover for turkeys. Reductions in canopy coverage are often achieved using various commercial timber harvest methods, and previous work has indicated availability of deer forage improves following implementation of a clearcut, shelterwood harvest, or thinning (Blair and Enghardt 1976, Ford et al. 1994, Peitz et al. 2001, Lashley et al. 2011, Nanney et al. 2018). For landowners without merchantable timber, noncommercial techniques, such as forest stand improvement (FSI), are an option to reduce canopy closure. Forest stand improvement entails using herbicides to kill undesirable trees within a forest stand and has been shown to increase deer forage biomass and turkey brooding cover in hardwood forests of the Ridge-and-Valley physiographic province (Lashley et al. 2011, McCord et al. 2014). Additionally, FSI treatments that release oak crowns can increase acorn production among remaining trees (Bellocq et al. 2005, Brooke et al. 2019).

Prescribed fire is often applied following canopy reduction in pine stands to improve understory conditions for deer and turkeys, yet none have investigated use of prescribed fire within upland hardwood forests of the southeastern Coastal Plain. However, many upland hardwood forests of the region are composed of tree species that facilitate fire (Kane et al. 2008). Prescribed fire has been applied to hardwood forests managed for deer and turkeys in other regions (Lashley et al. 2011, McCord et al. 2014). Although some managers are hesitant to apply fire that may damage overstory oaks, low-intensity prescribed fire can be applied with little or no damage to residual trees (Brose and Van Lear 1999, Marschall et al. 2014, McCord et al. 2014). Thus, increasing our understanding of the effects of prescribed fire within Coastal Plain hardwoods could provide opportunities to improve understory structure and species composition for deer and turkeys while retaining acorn production in upland hardwoods.

Based on the potential for canopy reduction and prescribed fire to increase habitat quality for deer and turkeys, combined with limited information on these forestry practices in this region, we designed an experiment to evaluate the effects of prescribed fire and noncommercial canopy reduction on deer forage and turkey brooding cover, as well as response of retained overstory trees, in Coastal Plain hardwoods. We hypothesized that a combination of prescribed fire and noncommercial canopy reduction would increase forage biomass, increase herbaceous plant coverage, and improve understory vegetation structure for turkey broods. We predicted low to moderate damage to retained overstory trees.

STUDY AREA

We conducted our study in 4, 5-ha hardwood-dominated stands on Barbour County Wildlife Management Area (WMA) in Barbour County, Alabama, USA. The WMA was 11,418 ha in area, located in the Coastal Plain physiographic region, and managed by the Alabama Department of Conservation and Natural Resources. Composition of overstory species in the study stands included southern red oak (*Quercus falcata*), white oak (*Q. alba*), water oak (*Q. nigra*), yellow-poplar (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*), and red maple (*Acer rubrum*). Mean pretreatment basal area was approximately 27.5 m^2/ha, and stands had approximately 360 overstory trees per ha. Mean tree diameter was 27.7-cm diameter at breast height (DBH). All stands had northern aspects, and were located within different watersheds across the WMA. The climate in Barbour County was subtropical, with a mean annual temperature of 18° C and mean annual precipitation of 133 cm (NOAA 2019).

Soils in the northern replicate stand were well-drained and consisted primarily of Luverne-Springhill complex and Luverne sandy loam (NRCS 2017). Soils in the 2 central replicate stands were well-drained, and consisted primarily of Luverne-Springhill complex and Blanton-Bonneau complex. Soils in the southern replicate stand were well-drained, and consisted primarily of Springhill-Lucy complex, Cowarts loamy sand, and Springhill-Troup complex (NRCS 2017).

METHODS

Treatments

We divided each of the 4 replicates into 2, 2-ha treatment units and one, 1-ha untreated control. We randomly assigned treatments to each treatment unit; treatments included a FSI cut with and without prescribed fire. Our goal was to reduce canopy coverage and allow at least 30% sunlight into each stand by removing trees with relatively limited value to deer and turkeys (e.g., sweetgum, red maple, and yellow-poplar). Conversely, we typically retained trees that produce hard or soft mast used by deer and turkeys (e.g., oak, blackgum [*Nyssa sylvatica*], flowering dogwood [*Cornus florida*], black cherry [*Prunus serotina*], and common persimmon [*Diospyros virginiana*]), though we did kill trees of those species with poor growth form, or when necessary to reach canopy-reduction goals.

We treated trees selected for removal that were ≥13-cm DBH during January–February 2018 by girdling the stem with a chainsaw and spraying herbicide into the cut. We felled trees selected for removal that were <13-cm DBH, and applied herbicide to the stump. We used a 1:1 mixture of Garlon® 3A (Dow AgroSciences, Indianapolis, IN, USA) and water or a solution of 50% Garlon® 3A, 10% Arsenal® AC (BASF Corporation, Research Triangle Park, NC, USA), and 40% water to treat each stem. As part of an herbicide efficacy trial, we split each treatment unit in half and assigned an herbicide treatment to each. However, canopy closure did not differ between herbicide applications, so we pooled data across herbicide treatments for analysis (Turner 2020).

We applied low-intensity prescribed fire to half of each treatment unit during March 2019. We conducted burns with a mixing height >500 m, 20–35% relative humidity, 0–17° C temperature, and wind speeds of 8–13 km/hr. We used low-intensity backing and strip-heading fires, and limited flame heights to 15–45 cm in an effort to minimize damage to overstory trees. Additionally, we removed large woody debris from the base of residual trees prior to burning, as the presence of slash at the base of trees is associated with damage from prescribed burning (Brose and Van Lear 1999). Average rate of spread for the backing fires was 20 m/h.

Data Collection

We used line-intercept transects during May–June of 2018 and 2019 to determine percent coverage of plants, by species, in each treatment unit and control. We created 3 random points within each treatment unit, and located transects along 3, 11.3-m lines radiating at 0°, 120°, and 240° from each point. We recorded horizontal coverage of each plant along transects, and later grouped species based on the following growth habits: herbaceous (forbs, grasses, sedges, and rushes), semiwoody (vines and brambles), and woody (trees and shrubs). We also recorded whether each plant had been browsed by deer.

From each of the 3 random points, we measured visual obstruction using a 2-m vegetation profile board with alternating black and white 50-cm intervals (Nudds 1977). We defined visual obstruction within each segment on a scale of 1–5, where 1 = 0–19%, 2 = 20–39%, 3 = 40–59%, 4 = 60–79%, and 5 = 80–100%. We placed the profile board 15 m downslope and 15 m upslope of plot center, and measured visual obstruction facing the board from plot center at a height of 1 m.

During July 2019, we collected deer forage biomass samples from 10, 1.2-m^2 frames randomly placed throughout each treatment unit. We identified deer forage plants as any plant species that had been browsed on our line-intercept transects, or those noted as moderately to highly selected deer forages in the literature (Miller and Miller 2005, Harper 2019). We collected growing tips and leaves of deer forage plants following the technique outlined in Lashley et al. (2014) to mimic deer herbivory. We dried forage samples to constant mass at 50° C and weighed them to determine the biomass (kg) of deer forage within each frame. The samples were then extrapolated to estimate biomass of deer forage per hectare within each stand.

We also measured infiltration of photosynthetically active radiation (PAR) using an AccuPAR® LP-80 PAR/LAI ceptometer (Decagon Devices, Inc., Pullman, WA, USA) along a diagonal transect across each treatment unit. We recorded PAR readings every 1 m at a height of 1.4 m above ground. We did not include measurements ≤20 m from each end of the transect to avoid sampling the edge of a unit. We paired these measurements with measurements taken simultaneously by a ceptometer in full sunlight to determine the percent PAR reaching the understory in each stand.

Finally, we established 5, 0.04-ha timber cruise plots in each FSI/Burn unit during the 2019 growing season to document effects of prescribed fire on overstory oaks, as well as other species that produce mast consumed by deer and turkeys, including flowering dogwood, black cherry, black gum, and common persimmon. First, we measured DBH of each tree, and documented mortality of any trees not treated with herbicide. We also categorized basal char within 4 quadrants around each tree according to Thies et al. (2006). The categories were: 0 (no char), 1 (superficial, light scorching), 2 (moderate scorch with uniformly black bark), 3 (deep charring to the point that some surface characteristics of the bark are lost), and 4 (bare wood visible). Trees that had at least one quadrant with category 3 or 4 scorch were considered to have cambium damage (Thies et al. 2006). In addition to the categorical char classification, we measured bole char height on each tree, which has been used previously to predict mortality following fire (Keyser et al. 2018).

Analysis

We used a mixed-effects analysis of variance (ANOVA) in package nlme in Program R to examine the relationships among canopy reduction, fire, and the change in percent coverage of herbaceous, woody, and semiwoody plants from 2018–2019 (Pinheiro et al. 2017, R Core Team 2018). We analyzed the change in percent coverage to standardize each unit according to vegetation conditions present prior to treatment application, and nested treatment unit within stand as random effects to account for variation within and among stands.

We used a mixed-effects ANOVA to evaluate effects of FSI and prescribed fire on visual obstruction in 2019. We analyzed visual obstruction of the stratum <0.5 m, 0.5–1 m stratum, and sum of the 2 strata >1 m. We analyzed the 2 strata above 1 m together because vegetation below this height offers concealment for poults, whereas vegetation above this height may block the vision of hens, inhibiting their ability to detect predators (Healy 1985, Peoples et al. 1995, McCord et al. 2014). We used a mixed-effects ANOVA to evaluate effects of FSI and prescribed fire on deer forage biomass within each stand, with treatment unit nested within stand as a random effect. To determine effects of fire on overstory species, we calculated the average maximum bole char height on mast-producing trees within FSI/Burn. We also calculated the proportion of trees that had a bole char rating of 3 or 4 (visible cambium damage) within at least one quadrant. Finally, we used a mixed-effects ANOVA to evaluate effects of FSI and prescribed fire on PAR, with stand as a random effect. We set $\alpha = 0.05$ for all statistical tests.

RESULTS

During January–February 2018, we reduced average overstory basal area from 28–13 m^2/ha in the FSI and FSI/Burn treatment units, which allowed 35.9% (±1.3) total sunlight into the stands. Percent PAR infiltration was greater in FSI and FSI/Burn compared to control (Fig. 1). We sampled vegetation along 180 transects/yr during 2018 and 2019. Commonly observed understory plants present in each treatment unit included Virginia creeper (*Parthenocissus*

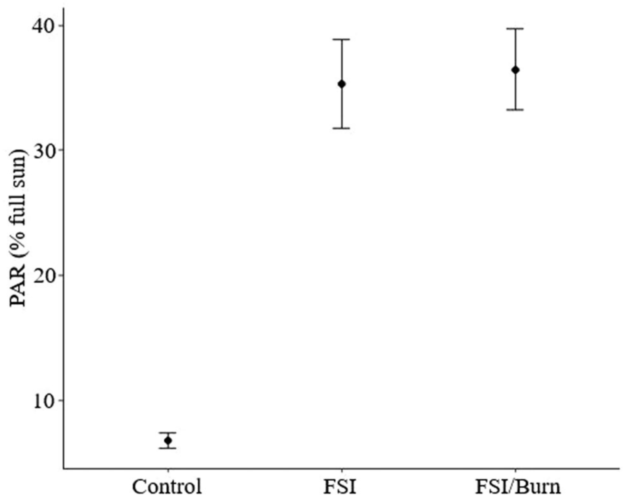

Figure 1. Photosynthetically active radiation (PAR) infiltration in hardwood stands in the Coastal Plain of Alabama, USA, in August 2019. Calculated based on the percent (%) infiltration in-stand compared to measurements taken simultaneously in full sunlight. Error bars represent 95% confidence limits.

quinquefolia), spike uniola (*Chasmanthium laxum*), low panicgrass (*Dichanthelium* spp.), muscadine (*Vitis rotundifolia*), greenbriar (*Smilax* spp.), burnweed (*Erechtites hieraciifolius*), and blackberry (*Rubus* spp.).

The increase in total understory vegetation coverage between 2018–2019 was greater in both FSI and FSI/Burn treatments compared to control (Table 1). However, analyzing plant coverage by growth form revealed the increase in herbaceous plants was greater in FSI/Burn compared to control, whereas the increase in woody and semiwoody plants was greater in FSI compared to control or FSI/Burn (Table 1; Fig. 2). Specifically, coverage of herbaceous plants increased by 134% and 53% in FSI/Burn and FSI, respectively, but decreased by 27% in control (Table 2). Coverage of semiwoody plants increased by 97% in FSI, and decreased by 33% in control and 10% in FSI/burn. Woody

Table 1. Parameter estimates (β), standard errors (SE), 95% confidence limits (LCL and UCL), and *P*-values predicting the effect of forest stand improvement (FSI) and prescribed fire (Burn) on the change in percent (%) coverage of understory vegetation between 2018–2019 in upland hardwood stands in the Coastal Plain of Alabama, USA.

	β	SE	LCL	UCL	*P*
All plants					
Control	−6.2	6.1	−18.4	5.7	0.31
FSI	19.7	5.1	9.8	29.6	<0.001
FSI/Burn	7.4	5.1	−2.6	17.3	0.03
Herbaceous					
Control	−1.8	3.6	−8.8	5.2	0.56
FSI	5.7	2.8	0.2	11.2	0.07
FSI/Burn	11.5	2.8	2.8	6	0.003
Semiwoody					
Control	−3.3	3.2	−9.5	2.9	0.30
FSI	10.3	2.4	5.6	15.1	0.001
FSI/Burn	−1.2	2.4	−6	3.6	0.55
Woody					
Control	−1	1.9	−4.7	2.6	0.58
FSI	3.8	1.4	1	6.5	0.04
FSI/Burn	−3.2	1.4	−5.9	−0.4	0.33

plant coverage increased by 33% in FSI, but declined by 9% in control and 26% in FSI/Burn (Table 2).

Deer forage biomass was similar in FSI and FSI/Burn, but both produced more than control (Table 3; Fig. 3). In 2019, visual obstruction was greater among all heights in FSI than control (Table 4). Visual obstruction was less in the >1-m stratum but greater in the <0.5-m stratum in FSI/Burn compared to control (Fig. 4).

We did not observe any mortality among untreated trees in FSI/Burn. Average bole char height in treatment units was 0.4 m (±0.08), and 96% of mast producers were in scorch categories 0–2 (i.e., no cambium damage). No mast producers had category 4 (bare wood visible) scorch. We recorded 5 water oaks (13% of species sample) with category 3 (some surface characteristics of bark lost) scorch (Table 5). No other mast-producing species had greater than category 2 damage. There was no apparent relationship between DBH and scorch category (Table 5).

DISCUSSION

The application of FSI and prescribed fire increased deer forage availability and improved turkey brooding cover within our study areas. Canopy reduction of 30% allowed sufficient sunlight to increase biomass of deer forage compared to control. Pairing FSI treatments with a single prescribed fire did not change forage biomass estimates compared to FSI alone, but it changed plant composition with increased coverage of herbaceous plants. Brooding cover was improved in stands that received additional sunlight. Vegetation that would obscure vision of a female attempting to detect predators, which hens select against (Campo et al. 1989, Wood et al. 2018), was least (offering better visibility) in FSI/Burn. Herbaceous vegetation, especially forbs, also is important for insect production for broods (Healy 1985, Harper et al. 2001). We measured the greatest increase in herbaceous plant cover following the FSI/Burn.

Our results are similar to those Lashley et al. (2011) and McCord et al. (2014) observed in the Ridge-and-Valley. However, they evaluated vegetation response beginning 5 years after initial canopy reduction, and after multiple prescribed fires. Our results 2 years after canopy reduction and immediately following a single fire indicate that implementing these practices in Coastal Plain hardwoods can quickly result in improved understory vegetation composition and structure for deer and turkeys. Specifically, understory vegetation in our study responded similarly to what has been documented in other systems, as canopy reduction resulted in an increase in woody and semiwoody plants, and application of prescribed fire increased coverage of herbaceous plants (Masters et al. 1993, Peitz et al. 2001, Iglay et al. 2010, Nanney et al. 2018). Although we did not document a difference in deer forage biomass between FSI and FSI/Burn, we did not conduct nutrient analysis on the collected forage. Forbs typically are greater quality forage plants than semiwoody or woody plants (Lashley et al. 2011, Nanney et al. 2018), and it is likely that nutritional carrying

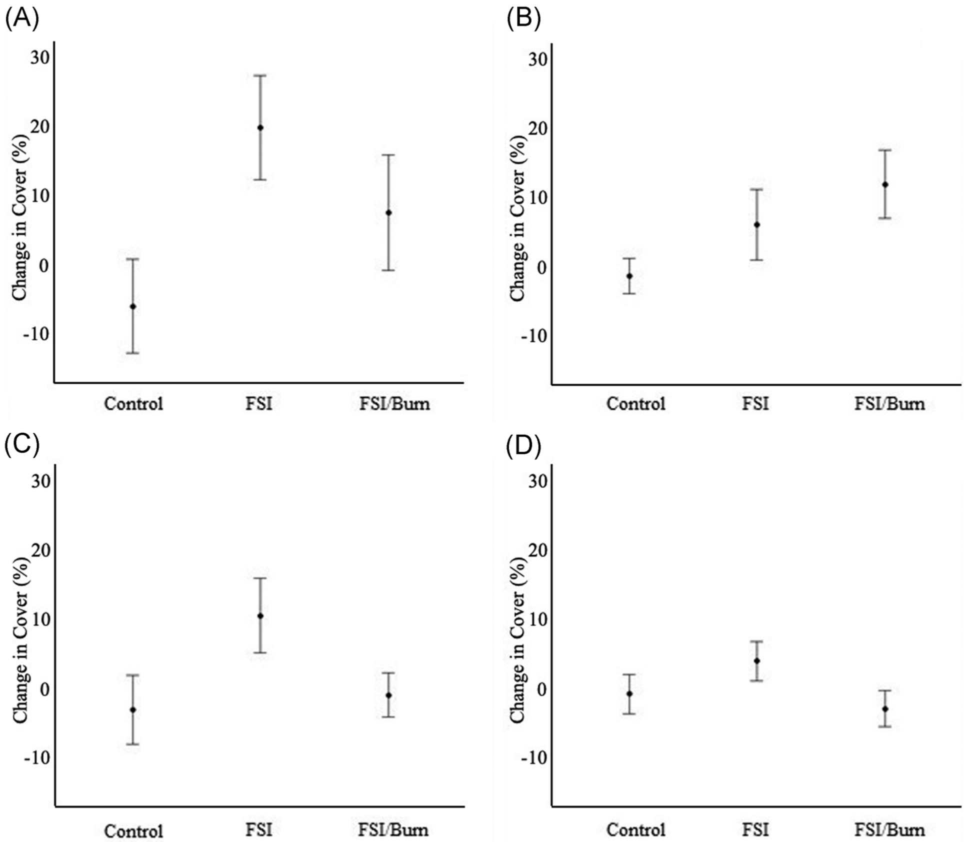

Figure 2. Change in percent (%) coverage of understory vegetation, including A) all plants, B) herbaceous plants, C) semiwoody plants, and D) woody plants from 2018–2019 following forest stand improvement, with and without prescribed fire, in upland hardwood stands in the Coastal Plain of Alabama, USA. Error bars represent 95% confidence limits.

capacity in FSI/Burn was greater than FSI because of increased coverage of herbaceous plants.

Despite the concern associated with application of prescribed fire in upland hardwoods in the Coastal Plain, continued disturbance is necessary to maintain desirable conditions for deer and turkeys. We expected low to moderate damage to overstory mast producers following the application of fire to our stands, as species such as water oak are not considered to be fire tolerant (Heyward 1939, Dey and Schweitzer 2015). Despite the lower tolerance of many Coastal Plain hardwood species compared to southern yellow pine species, the low-intensity, dormant-season fires we applied resulted in cambium damage to <5% of retained mast-producing trees, and we documented no fire-associated mortality. Furthermore, based on our bole char height results, subsequent mortality associated with low-intensity fires we prescribed is unlikely (Keyser et al. 2018). Water oak was the only species with visible cambium damage on a portion of the stem, but this only occurred on 13% of water oaks we evaluated. Thus, we saw limited damage to oaks within the stand, even in the species most susceptible to fire

Table 2. Percent (%) coverage of understory vegetation in upland hardwood stands in the Coastal Plain of Alabama, USA, during May–June, and average percent (%) change in coverage between 2018–2019. Stands in forest stand improvement (FSI) and prescribed fire (FSI/Burn) were treated with FSI during January–February 2018, and prescribed fire was applied to FSI/Burn in March 2019.

	2018 Coverage	SE	2019 Coverage	SE	Percent Change
All plants					
Control	27.8	2.5	21.6	2.6	−22.2
FSI	32.9	2.2	52.6	4.5	59.9
FSI/Burn	32.4	1.2	39.8	1	22.8
Herbaceous					
Control	6.7	1.2	4.9	0.8	−26.6
FSI	10.7	1.7	16.4	2.8	52.8
FSI/Burn	8.6	0.4	20.1	0.4	134
Semiwoody					
Control	10.2	1.3	6.8	0.7	−32.7
FSI	10.6	1.5	21	3.6	97.3
FSI/Burn	11.3	1	10.1	1.2	−10.5
Woody					
Control	10.9	2.6	9.9	1.3	−9.4
FSI	11.4	0.7	15.2	1.7	32.9
FSI/Burn	12.2	1.4	9.1	0.3	−25.9

Table 3. Mean predicted values ($\bar{x}$), standard errors (SE), 95% confidence limits (LCL and UCL), and *P*-values from mixed-effects ANOVA predicting the effect of forest stand improvement (FSI) and prescribed fire (FSI/Burn) on white-tailed deer forage biomass (kg/ha) in upland hardwood stands in the Coastal Plain of Alabama, USA, 2019.

	$\bar{x}$	SE	LCL	UCL	*P*
Control	18.01	20.63	−22.43	58.45	0.38
FSI	128.40	17.84	93.45	163.36	0.003
FSI/Burn	99.12	17.84	64.15	134.06	0.01

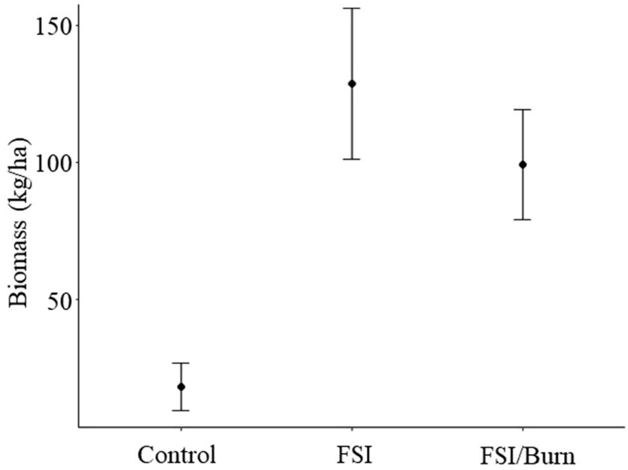

Figure 3. Biomass of deer forage (kg/ha) in July 2019 following forest stand improvement, with and without prescribed fire, in upland hardwood stands in the Coastal Plain of Alabama, USA. Error bars represent 95% confidence limits.

Table 4. Mean predicted values ($\bar{x}$), standard errors (SE), 95% confidence limits (LCL and UCL), and *P*-values from mixed-effects ANOVA predicting the effect of forest stand improvement (FSI) and prescribed fire (FSI/Burn) on visual obstruction scores in Coastal Plain hardwood stands in Alabama, USA, 2019. Scores were assigned on a scale of 1–5, where 1 = 0–19%, 2 = 20–39%, 3 = 40–59%, 4 = 60–79%, and 5 = 80–100%.

	$\bar{x}$	SE	LCL	UCL	*P*
<0.5 m					
Control	1.97	0.33	1.33	2.61	<0.001
FSI	4.39	0.22	3.80	4.98	<0.001
FSI/Burn	3.97	0.22	3.38	4.56	<0.001
0.5–1 m					
Control	1.63	0.30	1.04	2.21	<0.001
FSI	2.56	0.28	2.06	3.07	0.02
FSI/Burn	1.75	0.28	1.24	2.26	0.67
1–2 m					
Control	4.38	0.50	3.40	5.35	<0.001
FSI	3.11	0.60	2.22	4.00	0.08
FSI/Burn	2.45	0.60	1.56	3.35	0.02

Table 5. Scorch on oaks and other tree species that produce mast for deer and turkeys in Coastal Plain hardwood stands in Alabama, USA, following a single low-intensity prescribed fire in 2019. Scorch categories are as follows: 1 = superficial, light scorching; 2 = moderate scorch with uniformly black bark; 3 = deep charring to the point that some surface characteristics of the bark are lost; and 4 = bare wood visible. Diameter at breast height (DBH) measurements represent means for categories with >1 tree.

Oak species			Other mast producers		
Scorch category	*n*	DBH (cm)	Scorch category	*n*	DBH (cm)
No scorch			No scorch		
Post oak	1	35.6	Dogwood	1	20.8
Scarlet oak	1	58.2			
Southern red oak	1	13.2			
Water oak	5	38.1			
White oak	9	31.1			
One			One		
Post oak	4	20.4	Black cherry	5	25.2
Southern red oak	24	40.2	Persimmon	2	16
Water oak	13	36.6	Black gum	3	28.6
White oak	21	33			
Two			Two		
Southern red oak	6	29.6	Black cherry	2	18.3
Water oak	16	30.2			
White oak	1	43.2			
Three			Three		
Water oak	5	37.5	None		
Four			Four		
None			None		

damage. Cambium severance on a portion of the stem does not necessarily lead to mortality, as trees with cambium damage often survive (Marschall et al. 2014). Nonetheless, reduced fire tolerance of water oak should be considered before prescribing fire in stands dominated by the species. However, most upland forests of the Coastal Plain contain a variety of oak and other mast-producing species, and our findings of minimal fire damage to mast producers is consistent with research conducted in other regions (Brose and Van Lear 1999, Marschall et al. 2014,

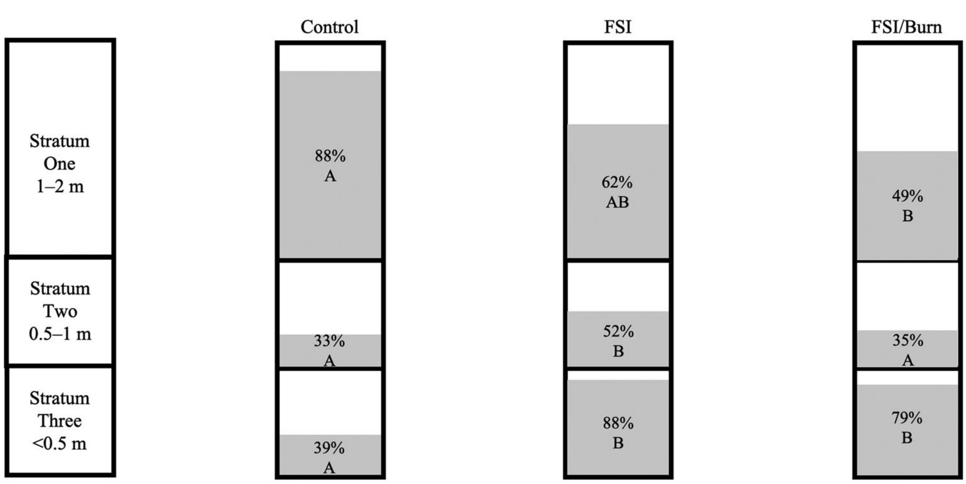

Figure 4. Visual obstruction scores in May/June 2019 in upland hardwood stands treated with forest stand improvement and prescribed fire in the Coastal Plain of Alabama, USA. Scores were assigned on a scale of 1–5, where 1 = 0–19%, 2 = 20–39%, 3 = 40–59%, 4 = 60–79%, and 5 = 80–100%. Average scores within each stratum were divided by 5 to calculate the percent visual obstruction within this figure. Within each stratum, different letters signify treatments with different visual obstruction scores ($P < 0.05$).

McCord et al. 2014, Keyser et al. 2018). Moreover, many landowner objectives would be better met, even if substantial proportions of water oaks were killed, by the increased warm-season forage for deer and enhanced brooding structure for wild turkeys.

For managers interested in deer and turkeys, understanding the effect of our treatments on both understory and acorn production is important. Previous measures of acorn production following canopy reduction and prescribed fire indicate that acorn production is increased by cutting/killing undesirable species and releasing crowns of desirable trees (Lombardo and McCarthy 2008, Brooke et al. 2019). Therefore, management of hardwood stands using similar techniques will allow managers to improve forage and cover for deer and turkeys during the growing season without sacrificing acorn availability during fall and winter. Hardwood forests managed with canopy reduction and fire will have much greater value for deer and turkeys, as acorns are only available for a few months each year, and oak species do not produce mast crops annually (Johnson et al. 2009, Brooke et al. 2019). Future efforts should focus on understanding long-term effects of using frequent, low-intensity fire in Coastal Plain hardwoods on understory structure, forage quantity and quality, and acorn production.

MANAGEMENT IMPLICATIONS

Our study and others indicate allowing 30% sunlight into the stand with FSI is sufficient to stimulate the understory and increase deer forage and improve turkey brooding cover. We recommend this level of FSI along with low-intensity prescribed fire to improve Coastal Plain hardwoods for these species. Trees that produce mast for deer and turkeys should be retained after reaching the desired canopy reduction during FSI operations. Low-intensity prescribed fire may be implemented to increase the herbaceous understory component, provide increased visibility, and prevent a woody midstory from developing, which would shade out the herbaceous understory and reduce brood cover. Large woody debris should be removed from the base of residual trees before applying fire, as this fuel may damage residual trees while burning. Continued disturbance using fire or additional FSI will be necessary to maintain woodland conditions in these stands.

ACKNOWLEDGMENTS

We would like to thank A. Pritchett, D. Nix, W. Gray, and the Barbour WMA staff for their critical contributions to this project, and to S. Grado (Associate Editor), D. Haukos (Editor-in-Chief), J. Wallace (Editorial Assistant) and 2 reviewers provided valuable comments that improved the manuscript. We would also like to thank A. Neilan, D. Knowles, and S. Cain for their assistance in treatment implementation and data collection. Funding was provided by the Wildlife Section of the Alabama Division of Wildlife and Freshwater Fisheries through the Federal Aid in Wildlife Restoration Program.

LITERATURE CITED

Bellocq, M. I., C. Jones, D. C. Dey, and J. J. Turgeon. 2005. Does the shelterwood method to regenerate oak forests affect acorn production and predation? Forest Ecology and Management 205:311–323.

Blair, R. M., and H. G. Enghardt. 1976. Deer forage and overstory dynamics in a loblolly pine plantation. Journal of Range Management 29:104–108.

Brooke, J. M., P. S. Basinger, J. L. Birckhead, M. A. Lashley, J. M. McCord, J. S. Nanney, and C. A. Harper. 2019. Effects of fertilization and crown release on white oak (*Quercus alba*) masting and acorn production. Forest Ecology and Management 433:305–312.

Brose, P., and D. Van Lear. 1999. Effects of seasonal prescribed fires on residual overstory trees in oak-dominated shelterwood stands. Southern Journal of Applied Forestry 23:88–93.

Campo, J. J., W. G. Swank, and C. R. Hopkins. 1989. Brood habitat use by eastern wild turkeys in east Texas. Journal of Wildlife Management 53:479–482.

Dey, D. C., and C. J. Schweitzer. 2015. Timing fire to minimize damage in managing oak ecosystems. Proceedings of the Biennial Southern Silvicultural Research Conference 17:143–153.

Feldhamer, G. A., T. P. Kilbane, and D. W. Sharp. 1989. Cumulative effect of winter on acorn yield and deer body weight. Journal of Wildlife Management 53:292–295.

Ford, W. M., A. S. Johnson, and P. E. Hale. 1994. Nutritional quality of deer browse in southern Appalachian clearcuts and mature forests. Forest Ecology and Management 67:149–157.

French, C. E., L. C. McEwen, N. D. Magruder, R. H. Ingram, and R. W. Swift. 1956. Nutrient requirements for growth and antler development in the white-tailed deer. Journal of Wildlife Management 20:221–232.

Harmel, D. E., J. D. Williams, and W. E. Armstrong. 1989. Effects of genetics and nutrition on antler development and body size of white-tailed deer. Texas Parks and Wildlife Department PWD-BK 7100–155, Austin, USA.

Harper, C. A. 2019. Wildlife food plots and early successional plants. NOCSO Publishing, Maryville, Tennessee, USA.

Harper, C. A., J. K. Knox, D. C. Guynn, J. R. Davis, and J. G. Williams. 2001. Invertebrate availability for wild turkey poults in the southern Appalachians. Proceedings of the National Wild Turkey Symposium 8:145–156.

Healy, W. M. 1985. Turkey poult feeding activity, invertebrate abundance, and vegetation structure. Journal of Wildlife Management 49:466–472.

Hewitt, D. G. 2011. Nutrition. Pages 75–106 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. Taylor & Francis Group, LLC, Boca Raton, Florida, USA.

Heyward, F. 1939. The relation of fire to stand composition of longleaf pine forests. Ecology 20:287–304.

Iglay, R. B., P. D. Jones, D. A. Miller, S. Demarais, B. D. Leopold, and L. W. Burger, Jr. 2010. Deer carrying capacity in mid-rotation pine plantations of Mississippi. Journal of Wildlife Management 75:1003–1012.

Johnson, P. S., S. R. Shifley, and R. Rogers. 2009. The ecology and silviculture of oaks. Second edition. CAB International, Cambridge, Massachusetts, USA.

Kane, J. M., J. M. Varner, and J. K. Hiers. 2008. The burning characteristics of southeastern oaks: discriminating fire facilitators from fire impeders. Forest Ecology and Management 256:2039–2045.

Keyser, T. L., V. L. McDaniel, R. N. Klein, D. G. Drees, J. A. Burton, and M. M. Forder. 2018. Short-term stem mortality of 10 deciduous broadleaved species following prescribed burning in upland forests of the southern US. International Journal of Wildland Fire 27:42–51.

Lashley, M. A., M. C. Chitwood, C. A. Harper, C. E. Moorman, and C. S. DePerno. 2014. Collection, handling, and analysis of forages for concentrate selectors. Wildlife Biology in Practice 10:6–15.

Lashley, M. A., C. A. Harper, G. E. Bates, and P. D. Keyser. 2011. Forage availability for white-tailed deer following silvicultural treatments in hardwood forests. Journal of Wildlife Management 75:1467–1476.

Lombardo, J. A., and B. C. McCarthy. 2008. Silvicultural treatment effects on oak seed production and predation by acorn weevils in southeastern Ohio. Forest Ecology and Management 255:2566–2576.

Macaulay, L. 2016. The role of wildlife-associated recreation in private land use and conservation: providing the missing baseline. Land Use Policy 58:218–233.

Marschall, J. M., R. P. Guyette, M. C. Stambaugh, and A. P. Stevenson. 2014. Fire damage effects on red oak timber production value. Forest Ecology and Management 320:182–189.

Masters, R. E., R. L. Lochmiller, and D. M. Engle. 1993. Effects of timber harvest and prescribed fire on white-tailed deer forage production. Wildlife Society Bulletin 21:401–411.
McCord, J. M., C. A. Harper, and C. H. Greenberg. 2014. Brood cover and food resources for wild turkeys following silvicultural treatments in mature upland hardwoods. Wildlife Society Bulletin 38:265–272.
Metzler, R., and D. W. Speake. 1985. Wild turkey mortality rates and their relationship to brood habitat structure in northeast Alabama. Proceedings of the National Wild Turkey Symposium 5:103–111.
Miller, J. H., and K. V. Miller. 2005. Forest plants of the southeast and their wildlife uses. University of Georgia Press, Athens, USA.
Nanney, J. S., C. A. Harper, D. A. Buehler, and G. E. Bates. 2018. Nutritional carrying capacity for cervids following disturbance in hardwood forests. Journal of Wildlife Management 82:1219–1228.
National Oceanic and Atmospheric Administration [NOAA]. 2019. Climate at a glance: county time series. <https://www.ncdc.noaa.gov/cag/>. Accessed 21 Aug 2019.
Natural Resource Conservation Service [NRCS]. 2017. Web soil survey. <https://websoilsurvey.sc.egov.usda.gov/>. Accessed 5 Nov 2017.
Nudds, T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife Society Bulletin 5:113–117.
Peitz, D. G., M. G. Shelton, and P. A. Tappe. 2001. Forage production after thinning a natural loblolly pine-hardwood stand to different basal areas. Wildlife Society Bulletin 29:697–705.
Peoples, J. C., D. C. Sisson, and D. W. Speake. 1995. Mortality of wild turkey poults in coastal plain pine forests. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 49:448–453.
Pinheiro, J., D. Bates, S. DebRoy, D. Sarkar and R Core Team. 2017. nlme: linear and nonlinear mixed effects models. R Package version 3.1-131. <https://CRAN.R-project.org/package=nlme>. Accessed 13 Nov 2020.
R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org>. Accessed 13 Nov 2020.
Speake, D. W., R. Metzler, and J. McGlincy. 1985. Mortality of wild turkey poults in northern Alabama. Journal of Wildlife Management 49:472–474.
Thies, W. G., D. J. Westlind, M. Loewen, and G. Brenner. 2006. Prediction of delayed mortality of fire-damaged ponderosa pine following prescribed fires in eastern Oregon, USA. International Journal of Wildland Fire 15:19–29.
Turner, M. A. 2020. Improving coastal plain hardwoods for white-tailed deer and wild turkeys with forest stand improvement and prescribed fire. Thesis. Auburn University, Alabama, USA.
U.S. Department of the Interior, U.S. Fish and Wildlife Service, U.S. Department of Commerce, and U.S. Census Bureau. 2017. 2016 National survey of fishing, hunting, and wildlife-associated recreation. Washington, D.C., USA.
Vander Haegen, W. M., W. E. Dodge, and M. W. Sayre. 1988. Factors affecting productivity in a northern wild turkey population. Journal of Wildlife Management 52:127–133.
Verme, L. 1969. Reproductive patterns of white-tailed deer related to nutritional plane. Journal of Wildlife Management 33:881–887.
Wentworth, J. M., A. S. Johnson, P. E. Hale, and K. E. Kammermeyer. 1992. Relationship of acorn abundance and deer herd characteristics in the southern Appalachians. Southern Journal of Applied Forestry 16:5–8.
Wood, J. D., B. S. Cohen, L. M. Conner, B. A. Collier, and M. S. Chamberlain. 2018. Nest and brood site selection of eastern wild turkeys. Journal of Wildlife Management 83:192–204.

Associate Editor: Grado/Haukos.