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Research Article

Wild Turkey Nest Survival and Nest-Site Selection in the Presence of Growing-Season Prescribed Fire

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ABSTRACT Concerns about destruction of wild turkey (*Meleagris gallopavo*) nests traditionally restricted the application of prescribed-fire to the dormant season in the southeastern United States. Periodic dormant-season burns were used to open forest understories and increase forage and nesting cover for wild turkeys. However, much of the Southeast historically burned during late spring and early summer (i.e., growing season), which tended to decrease understory woody vegetation and promote grasses and forbs, an important spring and summer food for wild turkeys. Despite the potential benefits of growing-season burns, landscape-scale application coincident with turkey nesting may destroy nests and reduce or redistribute woody nesting cover. We determined turkey nest-site selection and nest survival in a landscape managed with frequent growing-season burns. We monitored radio-tagged female wild turkeys to locate nests and determine nest survival. We compared vegetation composition and structure at nest sites to random sites within dominant cover types and calculated the probability of nest destruction as the product of the proportion of wild turkey nests active and the proportion of the landscape burned. Females selected shrub-dominated lowland ecotones (a transitional vegetation community between upland pine and bottomland hardwoods) for nesting and avoided upland pine. Ecotones had greater cover than upland pine and estimated nest survival in lowlands (60%) was greater than in uplands (10%). Although approximately 20% of the study area was burned concurrent with nesting activity, only 3.3% of monitored nests were destroyed by fire, and we calculated that no more than 6% of all turkey nests were exposed to fire annually on our study site. We suggest that growing-season burns have a minimal direct effect on turkey nest survival but may reduce nesting cover and structural and compositional heterogeneity in uplands, especially on poor quality soils. A combination of dormant and growing-season burns may increase nesting cover in uplands, while maintaining open stand conditions.

KEY WORDS growing-season fire, longleaf pine, *Meleagris gallopavo*, nest-site selection, nest survival, prescribed fire, wild turkey.

Prescribed fires traditionally were applied during the dormant season in southeastern United States forests to improve habitat conditions for wild turkeys (*Meleagris gallopavo*) and avoid fire-related nest destruction and poult mortality (Stoddard 1936, Brennan et al. 1998, Knapp et al. 2009). Periodic dormant-season burns top-kill woody stems, stimulate early green-up, and increase the availability of arthropods selected by presenting female wild turkeys (Sisson et al. 1990, Palmer et al. 1996, Palmer and Hurst 1998). Further, dormant-season burns stimulate sprouting of understory woody stems, which provides nesting cover in subsequent years (Seiss et al. 1990, Waldrop et al. 1992, Palmer and Hurst 1998).

Much of the southeastern United States historically burned primarily during spring and summer, and experimentation with growing-season fire has produced vegetation conditions that may benefit wild turkeys (Cox and Widener 2008, Knapp et al. 2009). Periodic application of early growing-season fire (May–Jun) in longleaf pine (*Pinus palustris*) forests suppresses understory and midstory woody growth and promotes a more open grass- and forb-dominated understory than dormant season fire, especially on short (1–3 years) return intervals (Waldrop et al. 1992, Knapp et al. 2009). Competitive release of herbaceous vegetation may increase abundance of grass seeds, forbs, and arthropods important for broods, and increased sight distances may reduce predation on adults (Hurst 1992, Moore 2006).

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Although use of early growing-season fire for management of longleaf pine forests has become common, traditional concerns about the extent of nest destruction have not been adequately assessed. Because nest success is commonly the most influential factor of population growth, it is important to understand the influence of fire on nest success (Vanguilder 1992, Roberts and Porter 1996). In one of the few studies that address fire effects on turkeys, only 9% of nests over 3 years were destroyed by growing-season fire in South Carolina, USA. However, the fire return interval (4–5 years) was longer than many longleaf pine forests managed with prescribed fire, the extent of the site subjected to growing-season fire was limited (<3%), and the transition to greater emphasis on growing-season burns had occurred only recently (Moore et al. 2010). Additionally, because female wild turkeys often nest in pine stands unburned for more than 2 years, nesting activity may be focused in fire management units scheduled to burn, especially under short fire return intervals (Burk et al. 1990, Sisson et al. 1990).

Because repeated growing-season burns reduce understory shrubs commonly used by wild turkeys for nest concealment and promote homogeneous coverage of grasses and forbs, nest success may be indirectly reduced. Successful nests often have greater shrub cover, nest concealment, and structural heterogeneity than unsuccessful nests because these attributes tend to increase predator search time and slow the development of search images (Bowman and Harris 1980, Badyaev 1995, Moore et al. 2010). Additionally, limited shrub cover in uplands that are burned repeatedly during the growing season may cause females to nest near riparian areas isolated from fire. We assessed wild turkey nest survival and nest-site selection in a longleaf pine ecosystem managed primarily with growing-season burns implemented on a 3-year return interval. We hypothesized that landscape-scale application of fire during the wild turkey nesting season would destroy nests and that females would nest in vegetation types with greater concealment than randomly available, primarily in riparian areas isolated from frequent fire.

STUDY AREA

We studied wild turkey nesting ecology on a 20,000-ha portion of Fort Bragg Military Reservation in the Sandhills physiographic region of North Carolina, USA. The Sandhills region is characterized by variably deep, well-drained, sandy soils (dunes; Sorrie et al. 2006), and uplands were xeric despite an average 120 cm of annual rainfall. Hillside seeps feed numerous blackwater streams. Forest stands were burned using prescribed fire every 3 years from January to September, but primarily during March–June. Since 1989, growing-season fire was applied on a 3-year return interval to control woody stem encroachment into the forest midstory in accordance with management objectives for the endangered red-cockaded woodpecker (*Picoides borealis*). Firebreaks and streams divided the study area into 34-ha (SE = 0.98) fire management units. Frequent fire and variable soil moisture produced many unique vegetation types at Fort Bragg (Sorrie et al. 2006). Generalized types included bottomland hardwood (8% land area), ecotone (6%), upland pine (74%), and non-forested (11%). Bottomland hardwood included red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), yellow-poplar (*Liriodendron tulipifera*), and blackgum (*Nyssa sylvatica*) forming closed canopy stands with sparse understories along permanently flowing streams. Dense thickets of gallberry (*Ilex coriacea*), fetterbush (*Lyonia* spp.), and greenbrier (*Smilax* spp.) were common in canopy gaps and along edges.

Ecotones were lowland pine vegetation located along ephemeral streams and as a transitional edge between bottomland hardwood and upland pine types. Ecotones were associated with hillside seeps, and the width was variable depending on hydrology and fire history. We estimated land coverage by ecotone by placing a 20-m buffer (typical ecotone width) around ephemeral streams and around delineated bottomland hardwood stands. Longleaf, loblolly (*Pinus taeda*), and pond pine (*Pinus serotina*) were common overstory species. Understory vegetation was dominated by giant cane (*Arundinaria gigantea*), sweet pepperbush (*Clethra alnifolia*), huckleberry (*Gaylussacia frondosa*), gallberry (*Ilex glabra*), cinnamon fern (*Osmunda cinnamomea*), swamp redbay (*Persea palustris*), bracken fern (*Pteridium aquilinum*), and blueberry (*Vaccinium* spp.).

Longleaf pine was the dominant overstory species in the upland pine type with open canopy and an understory of sparse wiregrass (*Aristida stricta*), dwarf huckleberry (*Gaylussacia dumosa*), turkey oak (*Quercus laevis*), and blackjack oak (*Quercus marilandica*).

Non-forested vegetation occurred in artillery firing points and aerial drop zones. Artillery firing points (10–20 ha) were sparsely vegetated, and 6 aerial drop zones (100–450 ha) were dominated by a variety of grasses and forbs including weeping lovegrass (*Eragrostis curvula*), sericea lespedeza (*Lespedeza cuneata*), and blackberry (*Rubus* spp.). Drop zones were burned and mowed annually or biennially to reduce woody vegetation.

Wild turkey abundance increased on Fort Bragg following restocking efforts between 1998 and 2000. Turkeys were uncommon on the study area prior to restocking but were considered abundant during the study (J. Jones, Fort Bragg Wildlife Division, personal communication). Spring gobbler harvest increased rapidly from 1 in 1994 to 66 in 2011. Potential predators of wild turkey nests and adults at Fort Bragg included American crow (*Corvus brachyrhynchos*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), raccoon (*Procyon lotor*), and gray fox (*Urocyon cinereoargenteus*).

METHODS

Capture and Monitoring

We captured wild turkeys by rocket net from February to April 2011 and January to March 2012 (Grubb 1988). In 2011, we fitted 85-g micro global positioning system (GPS) data loggers (Model G1H271; Sirtrack LTD, Havelock North, New Zealand) programmed to obtain 4 fixes daily (every 6 hr) to females. We set the fix rate to optimize relocation frequency with data logger battery life to ensure the devices could collect data for >1 year. Data loggers were equipped with radio transmitters and stored location coordinates onboard (Guthrie et al. 2011). In 2012, we fitted females with a combination of micro GPS data loggers and 80-g very high frequency transmitters (Model A1540; Advanced Telemetry Systems, Isanti, MN). We aged females as juveniles or adults by the contour of the rectrices and molt condition (Pelham and Dickson 1992). We censored mortalities that occurred within 7 days post-capture. All capture and handling protocols were approved by North Carolina State University Animal Care and Use Committee (#10-149-A).

We located females ≥3 times weekly by homing (1 Apr–1 Jul). During the nesting season, we flagged sites at a distance of 30–50 m from the incubating females and monitored the female's presence on the nest from outside the flagged perimeter until the nesting attempt was terminated. We determined nest fate (the nest was considered successful if ≥1 egg hatched) from eggshell condition and duration of incubation (Healy 1992).

Vegetation Sampling

We quantified vegetation characteristics within 20-m-diameter circular plots centered at the nests and stratified random points in bottomland hardwood ($n = 60$), ecotone ($n = 60$), and upland pine ($n = 75$) vegetation types. Access to aerial drop zones was restricted, so we did not assess micro-site features within non-forested areas. We randomly positioned sampling plots within riparian areas at a random distance from the stream or bottomland hardwood edge to sample within the ecotone. We delimited the upland edge of the ecotone as the transition from mesic- to xeric-dominated understory plant species (Sorrie et al. 2006). Ecotone width varied greatly but averaged approximately 20 m. We estimated percent ground cover below 1.2 m with a 20- × 50-cm quadrat (Daubenmire 1959) within each plot at 4 positions along each of 3 transects radiating from plot center (0°, 120°, 240°). We identified vegetation within the quadrat to genus and grouped vegetation as grass, forb, woody, and total cover. We measured pine and hardwood basal area within the plot using a diameter at breast height (dbh) tape. We estimated percent horizontal cover from 0 to 2 m in 50-cm height categories using a vegetation profile board (Nudds 1977). We estimated percent horizontal cover (0–20%, 21–40%, 41–60%, 61–80%, or 81–100%) at each height category from plot center out to 15 m at 0° and 180° in 2011 and in all 4 cardinal directions in 2012 to reduce variation. We viewed the vegetation profile board from a 1-m height. We determined distance to nearest stream and firebreak, the number of years since last burn, and the number of times burned since 1991 for each nest and random point using ArcMap 10 (Environmental Systems Research Institute, Inc., Redlands, CA). Although fire has been applied in the growing season since 1989, burning activity was not recorded until 1991, so we used the number of times burned since 1991.

Data Analysis

We modeled weekly rates at which nests in the study area were exposed to fire as the product of the proportion of nests active and the proportion of the study area burned each week. For example, if 30% of nests were active from 8 to 14 April (week 2) and 5% of the study area was prescribed burned during week 2, then 1.5% ($0.30 \times 0.05 = 0.015$) of all nests would be exposed to fire that week. The model assumed nests were distributed randomly across fire management units (i.e., this model assumed time since burn did not influence nest-site selection) and that forest stands were burned completely. Because we used the nest monitoring component of the project to document actual rates of nest destruction from prescribed fire over 2 nesting seasons, we considered this landscape-scale modeling approach as a measure of the potential for fire-induced wild turkey nest mortality where prescribed burning occurs on frequent intervals (i.e., every 2–3 years) and during the nesting season (i.e., growing-season fire). We calculated total nest exposure during the nesting season for both years as the sum of weekly exposure rates.

We used a geographic information system (GIS) to determine the percent of each vegetation type on the study area burned during the nesting season and during the entire growing season each year of the study (Table 1). We used these values to demonstrate whether nests located in specific vegetation types may have been at relatively greater or lesser risk to fire-induced mortality.

We compared percent horizontal cover and percent ground cover at random locations among bottomland hardwood, ecotone, and upland pine vegetation types using analysis of variance (ANOVA), and we determined pairwise differences with Tukey's honestly significant difference test ($\alpha = 0.05$). We could not make comparisons to the non-forested vegetation type because of restricted access to some non-forested areas.

We modeled landscape-level nest site selection using logistic regression (R, version 2.15.1, www.r-project.org, accessed 22 Jun 2012) to obtain the parameters of an exponential predicting relative nest selection (Manly et al.

Table 1. Overall land cover (%) of bottomland hardwood, ecotone, upland pine, and non-forested vegetation types at Fort Bragg, and percent and average patch size (ha) of each vegetation type exposed to fire during the wild turkey nesting season (1 Apr–4 Jul) and the vegetation growing season (15 Mar–30 Sep), Fort Bragg, North Carolina, USA, 2011–2012.

		Nesting season (%)		Growing season (%)		Patch size (ha) (mean ± SE)	
	Land cover (%)	2011	2012	2011	2012	2011	2012
Bottomland hardwood	8	12	25	14	25	12.4 ± 4.9	25.0 ± 9.8
Ecotone	6	14	24	17	24	0.7 ± 0.1	0.7 ± 0.1
Upland pine	74	18	27	20	27	11.4 ± 0.8	10.8 ± 0.7
Non-forested	11	2	14	11	51	4.8 ± 2.8	24.8 ± 44.1

2002). Using ArcMap, we generated 1,030 random locations across the study area in bottomland hardwood, ecotone, upland pine, and non-forested vegetation types. Random locations represented availability of each vegetation type for nesting. Nest sites were known use locations (Manly et al. 2002). We generated a 20-m buffer on both sides of ephemeral streams with a pine overstory and around all bottomland hardwood stands to estimate availability of ecotone on the study area. We included only indicator variables (0 = random point; 1 = known use location) for each vegetation type (bottomland hardwood, ecotone, and upland pine) as covariates in the landscape-level model of nest site selection using logistic regression. By default, the fourth vegetation type (non-forested) is indicted in the model by a 0 for each of the other vegetation types.

We developed 2 models to assess relative nest-site selection within individual vegetation types (i.e., 1 model to assess selection in ecotones and 1 to assess selection in upland pine) by comparing percent horizontal cover, percent total ground cover, distance to firebreak, distance to stream, time since burn, and the number of growing season burns since 1991 at nest sites and random locations. To limit the number of covariates in these models, we tested 1 height category from the vegetation profile board as the percent horizontal cover covariate in each model. We selected the height category at which the greatest difference in the mean between used and random sites occurred. Therefore, we tested percent horizontal cover at the 0–0.5-m height category in the upland pine model and at the 1–1.5-m height category in the ecotone model.

We calculated the probability of nest survival using the nest survival model in Program MARK (www.phidot.org, accessed 9 Jul 2012; Dinsmore et al. 2002). We exponentiated the daily survival rate by the number of incubation days for a successful female (i.e., 28 days) to calculate seasonal survival rates. To determine the most important predictors of nest survival, we compared 6 a priori models: 1) null; 2) year-effect; 3) vegetation type; 4) cover; 5) stream; and 6) fire. We predicted vegetation type would affect nest survival because understory structure and composition in each vegetation type largely reflected site hydrology and fire history. We developed a cover model because greater nest concealment may reduce detection by predators, and greater nest concealment is commonly correlated with increased nest survival (Badyaev 1995, Moore et al. 2010). The cover model included percent horizontal cover (1–1.5-m height category) and percent total ground cover. We developed a stream model because hydrology influences vegetation structure and composition and likely reflects availability of cover for nest concealment. The stream model included a single covariate for distance to stream. We assessed the effect of time since burn on the probability of nest survival with a fire model. Fire greatly influences understory vegetation structure and composition on the study area. We used second-order Akaike's Information Criterion (AIC_c) for model selection and accepted any model with a $\Delta AIC_c \leq 2$ (Burnham and Anderson 2002). We considered parameters in the above models significant if the 95% confidence interval of the estimate did not overlap 0.

RESULTS

We captured and radio-marked 65 female wild turkeys in 2011 (6 juveniles, 23 adults) and 2012 (1 juvenile, 35 adults). Nesting occurred 4 April–4 July in 2011 and 1 April–23 June in 2012. We located 18 nests in 2011 and 24 nests in 2012, including 4 renest attempts (1 in 2011 and 3 in 2012). We removed 12 nests from nest survival modeling because of observer-induced abandonment ($n = 5$) or because the nest was found opportunistically ($n = 7$) and the unmarked female could not be monitored. Therefore, we used 30 nests in nest survival modeling. However, we used all 42 nests in nest-site selection models.

In 2011 and 2012, 19% and 31% of the study area was burned during the growing-season and 16% and 22% during the 14-week nesting season, respectively. The proportion of the study area burned weekly during the nesting season ranged from 0% to 2.6% in 2011 and 0% to 6.9% in 2012. We estimated that 5.4% and 6.1% of wild turkey nests were exposed to fire during the 2011 and 2012 nesting seasons, respectively. However, only 1 of 30 (3.3%) monitored nests failed as a direct result of growing-season burning. The percentages of each vegetation type exposed to fire during the growing and nesting seasons were similar (Table 1). However, bottomland hardwoods often did not burn completely because of high moisture levels; hence, the estimated percent exposed, or the percent that was in a designated burn unit in GIS (Table 1), likely was greater than the percent that actually burned.

At random locations within vegetation types, percent cover was greater at all height categories in bottomland hardwood and ecotone than upland pine (Table 2). Additionally, percent total ground cover at random locations in ecotone was greater than bottomland hardwood and upland pine. Woody vegetation was the primary source of ground cover in all 3 vegetation types (Table 2). Grass and forb cover was greater in upland pine than bottomland hardwood and ecotone vegetation types.

We located wild turkey nests in ecotone (23 nests), upland pine (9 nests), bottomland hardwood (4 nests), and non-forested vegetation types (6 nests). Nests were not distributed randomly; turkeys selected ecotone and avoided upland pine for nest sites (Table 3). Within the ecotone vegetation type, nest sites had greater percent horizontal cover at 1–1.5 m (i.e., taller understory vegetation) and were closer to streams than random locations (Table 4). Within upland pine, nest sites had greater percent total ground cover, were nearer to firebreaks, and were farther from streams than random locations (Table 5). Because we had too few nests in bottomland hardwoods and because we did not measure vegetation structure at random locations in non-forested areas, we did not analyze nest site selection within those vegetation types.

Of 30 nests included in survival analyses ($n = 15$ ecotone, 10 upland pine, 3 bottomland hardwood, 2 non-forested), predation was the primary cause of nest failure ($n = 16$) followed by fire ($n = 1$) and abandonment ($n = 1$). All surviving nests ($n = 12$) were located in ecotone ($n = 9$) or

Table 2. Mean and standard error of percent horizontal cover and percent ground cover at random locations in bottomland hardwood, ecotone, and upland pine vegetation types at Fort Bragg, North Carolina, USA, 2011–2012.

	Bottomland hardwood	Ecotone	Upland pine
Feature	Mean ± SE	Mean ± SE	Mean ± SE
% Horizontal cover[a]			
0–0.5 m	80 ± 3 A[b]	86 ± 1 A	65 ± 3 B
0.5–1 m	73 ± 3 A	70 ± 3 A	46 ± 3 B
1–1.5 m	66 ± 3 A	55 ± 3 A	35 ± 3 B
1.5–2 m	58 ± 4 A	43 ± 3 B	28 ± 3 C
% Ground cover			
Total cover	41 ± 3 B	63 ± 2 A	29 ± 2 C
Woody cover	29 ± 3 B	48 ± 3 A	14 ± 1 C
Forb cover	0.4 ± 0.1 B	0.6 ± 0.1 B	1 ± 0.2 A
Grass cover	1 ± 0.4 B	4 ± 0.8 B	12 ± 1 A

[a] Horizontal cover was estimated at 4 height categories with a vegetation profile board from a 1-m height at plot center out to 15 m.
[b] Statistical difference among vegetation types for each feature (i.e., row) using Tukey's honestly significant difference test. Means with same letter within a row are not different ($\alpha = 0.05$).

bottomland hardwood ($n = 3$) vegetation types. The probability of nest survival given the nest reached incubation was 35% (SE = 7%) and was similar in 2011 (27%, SE = 9%) and 2012 (39%, SE = 9%). Because we located few nests in the bottomland hardwood and non-forested vegetation types, we grouped nests into upland (upland pine and non-forested) and lowland (bottomland hardwood and ecotone) classes in the vegetation type model. The vegetation type model had the greatest support and no other models were competitive (i.e., within 2 ΔAIC_c; Table 6). Nest survival was greater in lowlands (60%, SE = 10%) than uplands (10%, SE = 7%).

DISCUSSION

Prescribed burns increasingly are conducted during the early growing season (Apr–Jun) to promote herbaceous plants and to match the predominant historical fire season in the longleaf pine ecosystem (Fill et al. 2012). However, because these burns occur during the peak of the wild turkey nesting season, fire-induced nest mortality should be quantified. We showed that growing-season prescribed fire had minimal direct effect on wild turkey nest survival because the probability that a female was actively nesting in a fire management unit during the time of burning was low. Although approximately 20% of the study area was burned during the nesting season each year, only a small portion (~1.4%) of the study area was burned each week, and because nests are active for ≤6 weeks of the nesting season (approximate egg laying and incubation for a successful nest; Healy 1992), the probability that a nest was active and located in a burned area was low (<6%). Predation was the primary source of nest failure (53%) and reduced the duration of time many nests were active and exposed to fire. Additionally, predation was greatest in upland vegetation types that tended to burn thoroughly, so nests that are destroyed by fire in those areas very likely would otherwise fail because of predation, suggesting a compensatory effect. Additionally, nests on Fort Bragg were not located randomly, and in our study area and elsewhere turkeys may nest in mesic, lowland vegetation isolated from fire (Moore et al. 2010). Because bottomland hardwood and ecotone vegetation types at Fort Bragg often did not burn thoroughly, nests in those vegetation types (10% and 55%, respectively) may have been less susceptible to fire. However, none of the nests we observed in a bottomland hardwood type were active when fire was applied to the corresponding fire management unit. Additionally, females that lose a first nest to fire may renest (Vanguilder 1992). However, the 1 nest destroyed by fire in our study failed in Jun, near the end of the nesting season, and the female did not renest. Given the large extent (20%) of our study area that burned annually during the wild turkey nesting season, nests experienced a high fire-exposure risk relative to many areas in the Southeast where the percent of the land base burned is much less (e.g., Moore et al. 2010). Therefore, the low rate of nest failure from growing-season fire that we observed at Fort Bragg suggests that fire-induced mortality rates are as low or

Table 3. Parameter estimates from a landscape-scale logistic regression model of wild turkey nest-site selection for 42 nests at Fort Bragg, North Carolina, USA, 2011–2012.

Parameter[a]	β_i	SE	P
Intercept	−3.09	0.42	≤0.001
Bottomland hardwood ($n = 4$)	0.29	0.66	0.66
Ecotone ($n = 23$)	2.15	0.54	≤0.001
Upland pine ($n = 9$)	−1.36	0.48	0.01

[a] For selection of the non-forested vegetation type ($n = 6$ nests), coefficients for bottomland hardwood, ecotone, and upland pine are 0 in the model. Non-forested vegetation type was used as available relative to all other vegetation types.

Table 4. Parameter estimates for a model of wild turkey nest-site selection within the ecotone vegetation type for 23 nests at Fort Bragg, North Carolina, USA, 2011–2012.

Parameter	β_i	SE	P
Intercept	−0.44	1.92	0.82
% Horizontal cover (1–1.5 m)	2.80	1.45	0.05
% Total ground cover	1.53	2.20	0.49
Distance to firebreak	−0.01	0.01	0.16
Distance to stream	−0.02	0.01	0.02
Time since burned	−0.33	0.25	0.20
Growing-season burns	−0.26	0.19	0.17

Table 5. Parameter estimates for a model of wild turkey nest-site selection in the upland pine vegetation type for 9 nests at Fort Bragg, North Carolina, USA, 2011–2012.

Parameter	β_i	SE	P
Intercept	−6.23	3.48	0.07
% Horizontal cover (0.5–1 m)	−3.00	2.40	0.20
% Total ground cover	14.54	4.97	0.003
Distance to firebreak	−0.04	0.02	0.04
Distance to stream	0.01	0.003	0.03
Time since burned	0.24	0.42	0.57
Growing-season burns	−0.13	0.37	0.72

Table 6. Number of parameters (*K*), second-order Akaike's information criterion (AIC_c) and Akaike weights (w_i) of 6 models of wild turkey nest survival at Fort Bragg, North Carolina, USA, 2011–2012.

Model	*K*	AIC_c	ΔAIC_c	w_i
Vegetation type[a]	2	131.33	0.00	0.91
Stream[b]	2	137.66	6.34	0.04
Fire[c]	2	138.30	6.97	0.03
Null	1	139.18	7.85	0.02
Year-effect[d]	2	140.78	9.46	0.01
Cover[e]	3	142.55	11.23	0.00

[a] Single binomial indicator covariate for nest position: upland (pine or non-forested) or lowland (ecotone or bottomland hardwood) vegetation types.
[b] Single covariate: distance to nearest stream or lake.
[c] Single covariate: time since burn.
[d] Single binomial indicator covariate for year: 2011 or 2012.
[e] Two covariates: percent ground cover and percent horizontal cover from 1 to 1.5 m.

lower elsewhere in the region where growing-season fire is applied.

Despite the low risk of fire-induced nest mortality, growing-season fire may greatly influence nest-site selection through effects on the distribution of suitable nesting cover. Female wild turkeys commonly select nest sites with greater concealment, and understory woody vegetation is often a component of nesting cover (Hurst and Dickson 1992, Badyaev 1995, Moore et al. 2010). On our study area, females selected ecotones and avoided upland pine for nesting. Ecotones had roughly 20% greater horizontal cover attributable to greater understory woody vegetation than the upland pine vegetation type. Repeated growing-season burns may suppress hardwood midstory and overstory encroachment from bottomlands into ecotone, and moisture in ecotones may decrease fire intensity and allow understory woody vegetation to persist (Glasgow and Matlack 2007, Knapp et al. 2009). Alternatively, in more xeric uplands, growing-season burns reduce woody stem densities (Waldrop et al. 1992, Brockway and Lewis 1997). Although females selected nest sites in upland pine that had greater percent total ground cover than was randomly available in the same vegetation type, total ground cover available in upland pine was much less than in ecotones. On sites more productive than the Sandhills, grass and forb cover promoted by growing-season fire in uplands may provide sufficient nesting cover (Hurst and Dickson 1992, Palmer et al. 1996). Because periodic dormant-season burns typically do not reduce understory woody vegetation as thoroughly as growing-season burns applied on the same return interval and can stimulate woody stem sprouting, a combination of dormant and growing-season prescribed fire may increase suitable nesting cover in uplands, while maintaining low shrubs along riparian corridors (Waldrop et al. 1992, Brockway and Lewis 1997, Drewa et al. 2002). Alternatively, increasing growing-season fire return intervals (to a 4–5-year interval) in some upland stands would allow woody vegetation to develop and provide more cover for nesting females.

Changes in vegetation structure resulting from growing-season fire that affect turkey nest-site selection may influence nest survival. All nests that hatched were located in lowland vegetation types, particularly ecotone, where abundant low shrubs provided greater concealment than understory vegetation in upland pine. Nest concealment and vegetation structural heterogeneity around the nest may have decreased predator search efficiency and reduced predation risk in the ecotone (Bowman and Harris 1980). However, concealing cover at the nest was not predictive of nest survival. Rather, nest survival was most strongly associated with vegetation type, being greater in lowlands than uplands. Although concealment parameters were not significant at the microsite level, cover at the nest-patch scale may have been predictive of nest survival. In Arkansas, females selected large (80-m diameter) patches of cover for nesting (Badyaev 1995). Although females selected greater nest concealment in ecotone and upland pine than was randomly available in each vegetation type, respectively, patches of nesting cover in upland pine may have been more easily searched by predators because understory vegetation was more open and homogeneous as a result of growing-season fire (Bowman and Harris 1980, Waldrop et al. 1992). Establishing greater structural heterogeneity with periodic dormant-season burns or by increasing fire return intervals in some upland forest stands may benefit turkey nest survival.

MANAGEMENT IMPLICATIONS

Growing-season prescribed burning likely is a minor source of wild turkey nest failure in pine forests of the southeastern United States where prescribed fire is a commonly used management tool because the probability that a nest is active and located in a fire management unit that gets burned is low. Fires were applied frequently and on fairly large burn units on Fort Bragg, so we suggest risk of nest destruction from prescribed burning may be even less elsewhere across the region where fires are implemented less frequently and on smaller burn units. Additionally, growing-season fire may increase nesting cover on the edges of mesic lowlands (i.e., ecotones) by suppressing dense thickets of midstory shrubs and hardwoods and promoting low woody and herbaceous cover. Conversely, in xeric uplands, growing-season fire may reduce low woody vegetation often important for nest concealment and promote a homogeneous groundcover of grasses and forbs. However, on sites with greater productivity than the Sandhills, herbaceous vegetation in uplands may provide sufficient nesting cover. We suggest including dormant-season fire or longer (4–5-year) growing-season fire return intervals in some upland forest stands to increase woody nesting cover and potentially reduce nest predation. Alternatively, we suggest short (2–3-year) growing-season fire return intervals may be applied to dense lowland midstory thickets to establish low shrub conditions consistent with nest sites selected by females and attributed to greater nest survival.

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LITERATURE CITED

Badyaev, A. V. 1995. Nesting habitat and nesting success of eastern wild turkeys in the Arkansas Ozark Highlands. Condor 97:221–232.

Bowman, G. B., and L. D. Harris 1980. Effect of spatial heterogeneity on ground nest depredation. Journal of Wildlife Management 44:806–813.

Brennan, L. A., R. T. Engstrom, W. E. Palmer, S. M. Hermann, G. A. Hurst, L. W. Burger, and C. L. Hardy. 1998. Whither wildlife without fire? Transactions of the North American Wildlife and Natural Resources Conference 63:402–414.

Brockway, D. G., and C. E. Lewis 1997. Long-term effects of dormant-season prescribed fire on plant community diversity, structure and productivity in a longleaf pine wiregrass ecosystem. Forest Ecology and Management 96:167–183.

Burk, J. D., D. R. Smith, G. A. Hurst, B. D. Leopold, and M. A. Melchiors. 1990. Wild turkey use of loblolly pine plantations for nesting and brood rearing. Proceedings Annual Conference of Southeastern Association of Fish and Wildlife Agencies 44:163–170.

Burnham, K. P., and D. R. Anderson 2002. Model selection and multimodel inference. Second edition. Springer-Verlag, New York, New York, USA.

Cox, J., and B. Widener 2008. Lightning-season burning: friend or foe of breeding birds? Tall Timbers Research Station Miscellaneous Publication 17. Tall Timbers Research Station and Land Conservancy, Tallahassee, Florida, USA.

Daubenmire, R. 1959. A canopy-coverage method of vegetation analysis. Northwest Science 33:43–64.

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476–3488.

Drewa, P. B., W. J. Platt, and E. B. Moser. 2002. Fire effects on resprouting of shrubs in headwaters of southeastern longleaf pine savannas. Ecology 83:755–767.

Fill, J. M., S. M. Welch, J. L. Waldron, and T. A. Mousseau. 2012. The reproductive response of an endemic bunchgrass indicates historical timing of a keystone process. Ecosphere 3:1–12.

Glasgow, L. S., and G. R. Matlack 2007. Prescribed burning and understory composition in a temperate deciduous forest, Ohio, USA. Forest Ecology and Management 238:54–64.

Grubb, T. G. 1988. Modifications of the portable rocket-net capture system to improve performance. USDA Forest Service Rocky Mountain Forest and, Range Experiment Station, Fort Collins, Colorado, USA.

Guthrie, J. D., M. E. Byrne, J. B. Hardin, C. O. Kochanny, K. L. Skow, R. T. Snelgrove, M. J. Butler, M. J. Peterson, M. J. Chamberlain, and B. A. Collier. 2011. Evaluation of a GPS backpack transmitter for wild turkey research. Journal of Wildlife Management 75:539–547.

Healy, W. M. 1992. Chapter 5. Behavior. Pages 46–65 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Hurst, G. A. 1992. Foods and feeding. Pages 66–83 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Hurst, G. A., and J. G. Dickson 1992. Eastern turkey in southern pine-oak forests. Pages 265–285 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Knapp, E., B. Estes, and C. Skinner. 2009. Ecological effects of prescribed fire season: a literature review and synthesis for managers. General Technical Report PSW-GTR-224. U.S. Department of Agriculture Forest Service, Pacific Southwest Research Station, Albany, California, USA.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Kluwer Academic, Norwell, Massachusetts, USA.

Moore, W. F. 2006. Survival, nesting success, and habitat selection of wild turkey populations in the upper Coastal Plain of South Carolina. Dissertation, Clemson University, Clemson, South Carolina, USA.

Moore, W. F., J. C. Kilgo, W. D. Carlisle, D. C. Guynn, Jr, and J. R. Davis. 2010. Nesting success, nest site characteristics, and survival or wild turkey hens in South Carolina. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 64:24–29.

Nudds, T. D. 1977. Quantifying the vegetation structure of wildlife cover. Wildlife Society Bulletin 5:113–117.

Palmer, W. E., and G. A. Hurst 1998. Prescribed burning effects on wild turkey hens during preincubation. Tall Timbers Fire Ecology Proceedings 20:102–106.

Palmer, W. E., G. A. Hurst, and B. D. Leopold. 1996. Pre-incubation habitat use by wild turkey hens in central Mississippi. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 50:417–427.

Pelham, PH., and J. G. Dickson. 1992. Chapter 4. Physical characteristics. Pages 32–45 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Roberts, S. D., and W. F. Porter 1996. Importance of demographic parameters to annual changes in wild turkey abundance. Proceedings National Wild Turkey Symposium 7:15–20.

Seiss, R. S., P. S. Phalen, and G. A. Hurst. 1990. Wild turkey nesting habitat and success rates. Proceedings National Wild Turkey Symposium 6:18–24.

Sisson, D. C., D. W. Speake, J. L. Landers, and J. L. Buckner. 1990. Effects of prescribed burning on wild turkey habitat preference and nest site selection in South Georgia. Proceedings National Wild Turkey Symposium 6:44–50.

Sorrie, B. A., J. B. Gray, and P. J. Crutchfield. 2006. The vascular flora of the longleaf pine ecosystem of Fort Bragg and Weymouth Woods, North Carolina. Castanea 71:129–161.

Stoddard, H. L. 1936. Relation of burning to timber and wildlife. Proceedings North American Wildlife Conference 1:399–403.

Vanguilder, L. D. 1992. Population dynamics. Pages 144–164 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Waldrop, T. A., D. L. White, and S. M. Jones. 1992. Fire regimes for pine-grassland communities in the southeastern United States. Forest Ecology and Management 47:195–210.

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