ABSTRACT

KILBURG, ERIC LEE. Wild Turkey Nesting Ecology and Nest Survival in the Presence of Frequent Growing-season Fire. (Under the direction of Dr. Christopher Moorman and Dr. Christopher DePerno).

Prescribed fire traditionally has been applied during the dormant season in southeastern pine forests, partly out of concern for destruction of nests of ground nesting birds such as the wild turkey (*Meleagris gallopavo*). However, burning during late spring and early summer promotes grasses and forbs in the forest stand understory which may benefit forage quantity and quality, nesting cover and survival, and recruitment for wild turkeys. The effects of frequent, long-term application of growing-season fire on wild turkey prenesting resource selection, nesting cover availability, and nest destruction have not been determined. We used GPS and VHF-telemetry to assess female prenesting resource selection and locate and monitor wild turkey nests. Additionally, we calculated the risk of nest destruction by prescribed fire as the proportion of nests active times the proportion of the study area burned each week of the nesting season. Growing-season fire history did not influence female resource selection prior to nesting. Rather, females selected locations burned the preceding dormant season, drop zone (managed opening) edges, and riparian areas. Females selected the upland-lowland transitional vegetation community (ecotone) for nesting and avoided upland pine forest. Ecotones had greater cover than upland pine, attributable to abundant ericaceous shrubs. Likewise, estimated nest survival was greater in lowland vegetation types (60%) than uplands (10%). Although approximately 20% of the study area was burned annually during the nesting season, only 1 of 30 wild turkey nests we monitored was destroyed by fire. We estimated that no more than 6% of nests annually were active in a fire management unit when a burn was applied to the same unit. We suggest that prescribed burning forest stands during the wild turkey prenesing and nesting seasons does not negatively influence prenesting resource selection or considerably reduce nest survival. However, dormant-season burns may increase green forage availability for prenesting females and woody cover for nesting in uplands. Including dormant-season burns in fire prescriptions may improve wild turkey spring forage, nesting cover availability, and nest survival. Because females used forest stands managed with growing-season fire as available for prenesting and nesting activities, and because the probability of direct nest failure from fire was low, growing-season burning does not conflict with wild turkey habitat management.

Wild Turkey Nesting Ecology and Nest Survival in the
Presence of Frequent Growing-season Fire

by
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DEDICATION

To my parents whose encouragement, optimism, and work ethic inspired me to live the way life moved me.

BIOGRAPHY

Eric Kilburg grew up in rural eastern Iowa on a small acreage surrounded by woodlands and fallow fields where he learned to hunt morel mushrooms, squirrels, turkeys, and deer. He explored deeper into the forests as he grew older, discovering rocky bluffs, hidden groves, and abundant wildlife. In an attempt to learn more and increase his time afield, Eric enrolled at Iowa State University where he studied Animal Ecology and Forestry and assisted graduate students with forest and wildlife research across Iowa. In the fall of 2010 he moved to North Carolina to study wild turkey nesting ecology. New experiences in North Carolina opened numerous opportunities for learning, and helped Eric develop an attitude of questioning and investigation. His experiences at Iowa State and North Carolina have increased his appreciation for the natural world and his ability to understand and interpret the joys of his youth.

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Wild Turkey Prenesting Resource Selection in a Landscape Managed with Frequent Prescribed Burns

ABSTRACT

Prescribed burning during the wild turkey (*Meleagris gallopavo*) prenesting season may affect the availability of forage and nesting cover and influence nest success. Although long-term application of fire during the early growing season may increase herbaceous forage and nutrition for egg production, growing-season burns may temporarily reduce nesting cover in burned forest stands causing females to disperse and decrease time spent searching potential nest sites, a behavior correlated with nest survival. We assessed female wild turkey resource selection during the prenesting period in a landscape managed with frequent growing-season prescribed fire. We attached GPS data loggers that collected multiple daily fixes to female turkeys and compared percent cover of major vegetation types, stream density, non-forested edge density, and time since burn between used and simulated ranges. Further, we modeled the effects of the nest location, distance to stream, distance to non-forested edge, time since burn, frequency of fire since 1991, overstory basal area, and midstory density on intensity of use within prenesting ranges. Growing-season fire history was not predictive of resource selection. However, females selected forest stands burned during the preceding dormant season and selected the edges of non-forested cover and creek drainages within prenesting ranges. On our study area, ericaceous shrubs along creek drainages provided nesting cover, and greater probability of use near creeks likely reflected females searching for potential nest sites. Recent dormant-season burns may provide an important source of nutrition for pre-nesting females and should be used in addition to growing-season burns when managing for wild turkeys.

KEYWORDS GPS transmitters, growing-season fire, *Meleagris gallopavo*, prenesting, prescribed fire, resource selection, wild turkey

INTRODUCTION

Wild turkey (*Meleagris gallopavo*) resource selection during the prenesting season (i.e., flock breakup until onset of incubation) can influence nest success and population growth (Chamberlain and Leopold 2000). Prior to nesting, females selectively forage in non-forested areas and open forest stands with grass-forb dominated understories (Hurst and Dickson 1992, Palmer et al. 1996, Chamberlain and Leopold 2000). Often, arthropod availability is correlated positively with herbaceous cover and along with grass seeds and forbs, provides protein and calcium for egg production (Hurst and Dickson 1992, Harper et al 2000). Additionally, females search potential nest sites during prenesting, a behavior correlated with nest success (Badyaev 1995, Miller et al. 1999, Chamberlain and Leopold 2000).

Prescribed fire helps create and maintain vegetation conditions that provide forage and nesting cover for prenesting females. Forest stands burned during the dormant season green-up earlier in the spring and often are selected by prenesting females (Sisson et al. 1990, Palmer et al. 1996). Additionally, periodic dormant-season burns stimulate shrub and hardwood sprouting, which provides nesting cover in subsequent years (Waldop et al. 1992, Palmer and Hurst 1998, McCord and Harper 2011). Alternatively, repeated, short (1 – 2 year) dormant-season fire return intervals may decrease understory shrub cover and favor herbaceous species (Waldrop et al. 1992, Brockway and Lewis 1997).

Management of southeastern pine forests with frequent growing-season (15 March – 15 October) burns may produce understory vegetation conditions more beneficial for prenesting females than periodic applications of dormant-season fire. Burning shrubs and hardwoods during the early growing season reduces energy stores more than burning during the dormant season, when carbohydrates are amassed in roots (Drewa 2002). Hence, early growing-season burns, especially when applied on short (1 – 3 year) return intervals, can produce a more open forest understory dominated by grasses and forbs than similar application of dormant season burns (Waldrop et al. 1992, Glitzenstein et al 1995). Greater sight distance in the understory as a result of woody stem reduction may decrease predation risk (Thogmartin and Shaeffer 2000). Additionally, herbaceous vegetation and associated arthropods promoted by growing-season fire could increase protein and calcium availability for egg production.

However, fire applied during the early growing season may coincide with the primary timing of prenesting activities in some wild turkey populations and reduce potential nesting cover. Although prenesting females commonly forage in forest stands burned during the preceding dormant season, stands burned early in the growing season may not re-establish green vegetation until after the nesting season (Sisson et al. 1990, Palmer et al. 1996). Additionally, the application of fire during the prenesting season may temporarily reduce available nesting cover, and force females to disperse in search of alternate nest sites which may negatively affect nest success (Badyaev 1995).

Frequent early growing-season burns may increase forest understory openness and forage availability for wild turkeys, although burning during the prenesting season may reduce nesting cover. Therefore, we hypothesized that prenesting females would select forest stands with more frequent application of growing-season fire and stands burned within the preceding 2 years because those stands likely would have a greater composition of grasses and forbs in the understory. Additionally, we hypothesized that females would avoid forest stands burned during the same prenesting season because those stands may not provide suitable forage or nesting cover.

STUDY AREA

We assessed female wild turkey resource selection on a 10,000-ha portion of Fort Bragg Military Reservation, North Carolina, USA in the Sandhills physiographic region of the Atlantic Coastal Plain. Topography was rolling with xeric, sandy uplands interrupted by numerous blackwater streams. Firebreaks and streams divided the study area into 34-ha (SE = 0.98) fire management units that were prescribed burned during the growing season (mid March – August), primarily (April – June) on a 3-year return interval. Initiation of the growing season is determined by Fort Bragg Forestry Branch and typically is 15 March (± 3 days) (Jason Monroe, Fort Bragg Forestry Branch, personal communication). Additionally, large ordinance impact areas in the center of the study area were burned annually to biennially during the dormant or growing season. Fire and soil moisture interacted to produce numerous vegetation communities (Sorrie et al. 2006). Generalized communities included pine (85 %), non-forested (11 %), and lowland hardwood (4 %).

The pine vegetation type included upland and lowland pine communities. Upland pine stands had an open longleaf pine (*Pinus palustris*) canopy with wiregrass (*Aristida stricta*), dwarf huckleberry (*Gaylussacia dumosa*), scrub turkey oak (*Quercus laevis*), and blackjack oak (*Quercus marilandica*) dominating the understory. Lowland pine communities were located along ephemeral streams and as ecotones between upland pine and lowland hardwood communities. Longleaf pine, loblolly pine (*Pinus taeda*), and pond pine (*Pinus serotina*) were common overstory species, and ericaceous shrubs dominated the understory. Non-forested areas included managed and unmanaged openings. Managed openings were mowed and burned annually during the dormant season. Vegetation was dominated by weeping lovegrass (*Eragrostis curvula*), sericea lespedeza (*Lespedeza cuneata*), and blackberry (*Rubus* spp.). Unmanaged openings located within impact areas burned frequently and unpredictably from artillery fire. Wiregrass, dwarf huckleberry, and poison oak (*Toxicodendron pubescens*) were dominant in uplands, and switchcane (*Arundinaria tecta*), *Dicanthelium* spp., ericaceous shrubs, *Eupatorium* spp., and *Smilax* spp. were dominant in lowlands. Closed canopy bottomland hardwood communities were located along permanently flowing streams. Overstory species included red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), yellow-poplar (*Liriodendron tulipifera*), and blackgum (*Nyssa sylvatica*). Dense thickets of gallberry (*Ilex coriacea*), fetterbush (*Lyonia* spp.), and greenbrier (*Smilax* spp.) were common in canopy gaps and along edges.

METHODS

We captured female wild turkeys by rocket-netting from February - April 2011 and January - March 2012 (Grubb 1988). We attached 85-g Micro global positioning system (GPS) data loggers (Model G1H271 Sirtrack LTD, Havelock North, New Zealand), programmed to obtain and store on board 4 fixes daily to each turkey. We set the fix rate to maximize sampling frequency while maintaining battery life > 1 year to allow potential recapture and recovery of data loggers. We recovered the backpack style data loggers as the harness wore naturally, when animals were depredated, and by recapture. We aged turkeys as juveniles and adults by the contour of the rectrices and censored mortalities that occurred within 7 days of capture (Pelham and Dickson, 1992). All capture and handling protocols were approved by North Carolina State University Institutional Animal Care and Use Committee (#10-149-A).

Data Analysis

We determined landscape-scale resource selection by comparing vegetation type, stream and drop zone edge density, and fire history attributes between wild turkey prenesting ranges and 30 circular simulation (i.e., random) ranges (Katnik and Weilgus 2005, Miller et al. 2007). We created a minimum convex polygon around all observed prenesting ranges to define availability, and simulation ranges were randomly placed inside the availability polygon using ArcMap 10 (Environmental Systems Research Institute, Inc., Redlands, CA). Simulation ranges had variable acreages between the minimum and maximum values of observed turkey prenesting ranges. In each prenesting and simulation range, we determined the percent of pine, bottomland hardwood, and non-forested cover types, stream density, drop zone edge density, and the percent of each range burned during the prenesting season, the previous dormant season, and the previous growing season, and the percent unburned for greater than 2 years (Table 1).

We developed a global model that included vegetative cover types, stream and drop zone edge densities, and fire history attributes. From the global model, we developed 9 additional logistic regression models to assess predicted habitat relationships and the relative influence of fire history (Table 2). The Landcover model compared proportions of pine, bottomland hardwood, and non-forested cover types in used and simulation ranges (Table 2). The

Landscape Features model included stream density (m/ha) and drop zone edge density (m/ha) (Table 2). The Fire History model compared the proportion of used and simulation ranges burned during the prenesting season, the preceding dormant season, the previous growing season, and unburned for greater than 2 years (Table 2). Finally, we assessed landscape feature and fire history variables individually (Table 2). We used Akaike's Information Criterion (AIC) for model selection and considered any model with a $\Delta AIC \leq 2$ as a candidate model (R, version 2.15.1, www.r-project.org, accessed 22 Jun 2012).

To assess resource selection at the prenesting range scale, we plotted diurnal GPS locations from 20 March (determined with camera surveys) until the onset of incubation using GIS. We assessed resources selected prior to first nesting attempts only because resource availability may have changed significantly between first and subsequent nesting attempts. We created 95% utilization distributions for each turkey from GPS fix locations and sampled the intensity of use (i.e., the height of the utilization distribution) at 200 randomly generated points in each utilization distribution (Marzluff et al. 2004, Millspaugh et al. 2006). Using multiple regression (R, version 2.15.1), we regressed distance to nest, stream, and drop zone edge, pine and hardwood basal area, hardwood midstory density, time since burn, and the number of times a location was burned on the height of the utilization distribution for each turkey (Marzluff et al. 2004, Millspaugh et al. 2006). The number of times a site was burned produced a better model fit than either the number of growing or dormant-season burns. Therefore, the total number of burns was used in the model. We log-transformed the response variable to normalize residuals. We included distance to nest as a variable in the model because the prenesting season included egg-laying, and the location of the nest likely influenced resource selection during that period. Because hardwood midstory density and overstory basal area often are inversely correlated with herbaceous cover and spring forage availability, we included these forest attributes in the model. We standardized model coefficients by multiplying the unstandardized coefficients from individual turkey models by a ratio of the standard deviation of the parameter in each turkey's prenesting range to the standard deviation of the log-transformed heights of the utilization distribution (Marzluff 2004). We averaged standardized coefficients from individual turkey models to calculate a population-level model and compared the relative influence of each parameter on the response. We determined parameter significance from the overlap of the 95% confidence interval with zero (Marzluff et al. 2004, Millspaugh et al. 2006).

RESULTS

In 2011 and 2012, we captured and attached GPS data loggers to 29 (6 juveniles, 23 adults) and 5 (0 juveniles, 5 adults) female wild turkeys, respectively. Of the 34 data loggers deployed, 11 were recovered with suitable data for analysis. The remaining 23 data loggers were either unrecovered (n = 12), contained an insufficient number of data points (n = 7), or were attached to females that did not nest (n = 4).

Prenesting ranges averaged 761 ha (range = 255 to 1571 ha), and a greater proportion of female wild turkey prenesting ranges were burned during the preceding dormant season (i.e., 2 - 6 months) than was observed in simulated ranges (Table 2). The proportion of ranges burned during the prenesting season, 20 March – 26 April (average onset of incubation), was similar for used and simulation ranges (Table 2). That is, we did not observe selection or avoidance of forest stands within approximately one month of burning. Likewise, the proportion of prenesting ranges burned the preceding growing-season and unburned for greater than 2 years was similar to simulation ranges (Table 2). No fire management units within our study area were unburned for greater than 4 years.

Intensity of use was greater nearer to streams, drop zone edges, and the nest location within prenesting ranges (Table 3). Neither time since burn nor the number of times a site was burned since 1991, regardless of season, were significant predictors of intensity of use. Likewise, pine and hardwood overstory basal area and hardwood midstory density were not significant predictors of prenesting resource selection.

DISCUSSION

Vegetation conditions immediately following a growing-season burn, 1 year after a burn, and > 2 years post burn did not influence prenesting resource selection, but burns the preceding dormant season attracted hens, likely because of forage resources made available following the fire. Consistent fire management, in combination with low productivity soils, produced open vegetation conditions across uplands in fire management units, regardless of time since burn. Wild turkeys use forest stands with open understories for travel potentially to increase predator detection, so females likely used forest stands as available (with the exception of stands burned the previous dormant season) while traveling to feeding areas and sampling potential nest sites (Palmer et al. 1996, Palmer and Hurst 1998). However, in forest stands burned during the previous dormant season, litter reduction may increase light transmittance to the understory and soil temperature. Early vegetation production in the warmer soils may increase the availability of protein-rich shoots (Hobbs and Schimel 1984, Knapp 1985, Stys et al. 1992).

Female turkeys selected resources proximal to non-forested vegetation and streams, suggesting these landscape features provided nutrition and nesting cover. Grass and forb cover was abundant in drop zones and females likely selected the perimeter where forested escape cover was immediately adjacent. Additionally, arthropods typically are abundant on non-forested sites and commonly are selected by hens prior to nesting (Speak et al. 1975, Hurst and Dickson 1992, Harper et al. 2000). Greater intensity of use near streams reflected cover availability for potential nest sites (Badyaev et al. 1995, Chamberlain and Leopold 2000). Low ericaceous shrubs and ferns along stream corridors provided nesting cover that was selected by females on our study area, and 7 of the 11 GPS-telemetered females nested within 25 m of a stream (Kilburg 2013).

MANAGEMENT IMPLICATIONS

The application of fire during the prenesting season did not attract female wild turkeys or cause them to shift prenesting ranges. Therefore, we suggest prescribed burning can be conducted during the prenesting season without considerable negative effects on forage and nesting cover availability or reductions in nest success (Kilburg 2013). Alternatively, frequent (1 – 2 year) application of dormant-season fire can be used to produce similar understory conditions with abundant grass and forb cover. Additionally, female wild turkeys commonly select forest stands burned the preceding dormant season suggesting understory conditions produced by these fires are beneficial to prenesting activities and potentially nest success. Therefore, we recommend dormant-season burns should be incorporated into fire management prescriptions to increase early season forage, especially in large continuous forest stands where non-forested cover is unavailable.

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Table 1. Mean and standard error of resources in female wild turkey prenesting ranges and circular simulation ranges at Fort Bragg, North Carolina, USA, 2011 – 2012.

	Prenesting Range	Simulation Range
Feature	Mean ± SE	Mean ± SE
% pine	85 ± 4	85 ± 2
% bottomland hardwood	3 ± 1	4 ± 1
% non-forested	12 ± 4	11 ± 2
Stream density (m / ha)	12.3 ± 1.6	14.5 ± 1
Drop zone edge density (m / ha)	2.3 ± 0.9	2.1 ± 0.4
Non-forested edge density (m / ha)	6.9 ± 1.3	6.5 ± 0.5
% burned prenesting	4 ± 2	8 ± 2
% burned dormant season	40 ± 8	22 ± 4
% burned growing season	21 ± 4	25 ± 2
% burned 1 – 2 years previously	12 ± 3	15 ± 1
% unburned > 2 yrs	23 ± 5	30 ± 3

Table 2. Number of parameters (K), Second-order Akaike's Information Criterion (AIC_c), difference from lowest AIC_c (ΔAIC_c), and Akaike weights (w_i) from logistic regression models of wild turkey prenesting resource selection at the landscape scale at Fort Bragg, North Carolina, USA, 2011-2012.

Model	K	AIC_c	ΔAIC_c	w_i
% burned dormant season[a]	2	47.60	0.00	0.43
% burned growing season[b]	2	50.21	2.61	0.12
% unburned > 2 years	2	50.25	2.65	0.19
% burned prenesting[c]	2	50.42	2.82	0.11
Stream density (m/ ha)	2	50.71	3.11	0.09
Drop zone edge density (m/ha)	2	51.97	4.37	0.05
Landscape Features[d]	3	53.02	5.42	0.03
Fire History[e]	5	53.38	5.78	0.03
Landcover[f]	4	55.45	7.85	0.01
Global[g]	10	58.20	10.60	0.00

[a]% of prenesting range burned during the preceding dormant season (i.e., 1 – 6 months previously)

Table 2 Continued

[b]% of prenesting range burned during the preceding growing season (i.e., 6 – 12 months previously)

[c]% of prenesting range burned during concurrent with prenesting activities

[e]Landscape Features = stream density (m/ ha) + drop zone edge density (m/ ha)

[e]Fire History = % burned prenesting + % burned dormant season + % burned growing season + % unburned > 2 years

[f]Landcover = % pine + % bottomland hardwood + % non-forested

[g]Global = Landcover + Landscape + Fire History

Table 3. Model coefficients (β_i) and upper (UCL) and lower (LCL) confidence limits from a multiple regression model of wild turkey resource selection within prenesting ranges at Fort Bragg, North Carolina, USA, 2011-2012.

Parameter	β_i	LCL	UCL
Nest	-0.71	-1.49	0.07
Stream[a]	-0.33	-0.63	-0.02 *
Drop zone edge[b]	-1.00	-1.73	-0.28 *
Times burned	-0.11	-0.39	0.18
Time since burn	-0.09	-0.38	0.19
Pine basal area	0.06	-0.24	0.37
Hardwood basal area	0.21	-0.11	0.52
Hardwood midstory density[c]	-0.14	-0.53	0.25

[a]Probability of use significantly increased as distance to stream decreased

[b]Distance to nearest drop zone edge

[c]Index values (1 – 9). 1 = short and sparse, 9 = tall and dense

CHAPTER 2

Wild Turkey Nest Survival and Nest-site Selection in the Presence of Growing-season Prescribed Fire

ABSTRACT

In the Southeast, concerns about destruction of wild turkey (*Meleagris gallopavo*) nests traditionally restricted the application of prescribed-fire to the dormant season. Periodic dormant-season burns were used to open forest understories and increase forage and nesting cover for wild turkeys. However, much of the southeastern United States historically burned during late spring and early summer (i.e., growing season), which tended to decrease understory woody vegetation and promote grasses and forbs, and 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 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 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 ~20% of the study area was burned concurrent with nesting activity, only 3.3% of monitored nests were destroyed by fire, and 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 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

INTRODUCTION

Traditionally, in southeastern U.S. forests, prescribed fires were applied during the dormant to improve habitat conditions for wild turkeys (*Meleagris gallopavo*) and to 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 prenesting 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 U.S. 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 – June) 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 year) 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).

Although use of early growing-season fire for longleaf pine forest management has become common, traditional concerns about the extent of wild turkey nest destruction have not been adequately assessed. Because nest success is commonly the most influential factor of population growth, an insufficient understanding of the impact of fire on nest success could lead to population declines (Vanguilder 1992, Roberts and Porter 1996). Although only 9% of wild turkey nests over 3 years were destroyed by growing-season fire in South Carolina, USA, the fire return interval (4 – 5 years) was longer than at many sites, the extent of the site subjected to growing-season fire was limited (<1,000 ha), and the transition to greater emphasis on growing-season burns had occurred only recently (Moore et al. 2005). 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. 2005). Although small, patchy growing-season burns can maintain pockets of low shrubs for nesting, landscape-scale application may reduce nesting cover or 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 plant communities with greater concealment than randomly available, or 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 was 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 fed numerous blackwater streams. Forest stands were burned using prescribed fire every 3 years from January – August, 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 communities at Fort Bragg (Sorrie et al. 2006). Generalized communities were:

Bottomland Hardwood (8% land area) - Red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), yellow-poplar (*Liriodendron tulipifera*), and blackgum *(Nyssa sylvatica*) formed 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.

Ecotone (6% land area) – Ecotones were lowland pine communities located along ephemeral streams and as a transitional edge between bottomland hardwood and upland pine communities. Ecotones were associated with hillside seeps, and the community width was variable depending on hydrology and fire history. We estimated land coverage by ecotone by placing a 20-m buffer (typical ecotone community width) around ephemeral streams and around delineated bottomland hardwood communities. 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 palustrus*), bracken fern (*Pteridium aquilinum*), and blueberry (*Vaccinium* spp.).

Upland Pine (74% land area) – Longleaf pine was the dominant overstory species in open canopy stands with sparse wiregrass (*Aristida stricta*), dwarf huckleberry (*Gaylussacia dumosa*), turkey oak (*Quercus laevis*), and blackjack oak (*Quercus marilandica*) in the understory.

Non-forested (11% land area) – Non-forested communities 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. Drop zones were burned and mowed annually or biennially to reduce woody vegetation.

METHODS

Capture and Monitoring

We captured wild turkeys by rocket net from February - April 2011 and January - March 2012 (Grubb 1988). In 2011, we fitted 85-g Micro GPS data loggers (Model G1H271 Sirtrack LTD, Havelock North, New Zealand) programmed to obtain 4 fixes daily (every 6 hours) 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 (Gutherie et al. 2011). In 2012, we fitted females with a combination of Micro GPS data loggers and 80-g VHF 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 incubating females at a distance of 30 - 50 m and monitored the female's presence on the nest from the flagged perimeter until the nesting attempt was terminated. We determined nest fate from egg shell condition and duration of incubation (Healy 1992).

Vegetation Sampling

We quantified vegetation characteristics within 20-m-diameter circular plots at nests and stratified random points in bottomland hardwood (n = 60), ecotone (n = 60), and upland pine (n = 75) communities. Access to aerial drop zones was restricted, so micro-site features within non-forested communities were not assessed. To sample within ecotone we randomly positioned sampling plots within riparian areas at a random distance from the stream or bottomland hardwood edge. We delimited the upland edge of the ecotone as the transition from mesic- to xeric- dominated understory plant species (Sorrie et al 2006). 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°). Vegetation within the quadrat was identified to genus and grouped 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 – 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 (oldest burn records available) for each nest and random point using ArcMap 10 (Environmental Systems Research Institute, Inc., Redlands, CA).

Data Analysis

We modeled weekly fire exposure rates 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 April – 14 April (week 2) and 5% of the study area was prescribed burned during week 2, then (0.30 × 0.05 = 0.015) of all nests would be exposed to fire that week. We calculated total nest exposure during the nesting season for both years as the sum of weekly exposure rates. This approach assumed nests were distributed randomly across the study site; therefore, the resulting risk value would be a maximum, as many nests would be located in areas likely protected from prescribed fires (e.g., bottomlands and portions of ecotone) but still included in burn units.

We compared percent horizontal cover and percent ground cover between random locations in bottomland hardwood, ecotone, and upland pine vegetation types using ANOVA, and we determined differences with Turkey's HSD ($\alpha = 0.05$). We could not make comparisons to the non-forested vegetation type because of restricted access to some non-forested areas.

We generated 1,030 random points using ArcMap and determined the proportion of points classified as bottomland hardwood, ecotone, upland pine, and non-forested as the availability of each vegetation type on the study area and compared to the distribution of nests among vegetation types. 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 the vegetation type covariate in the landscape-level model of nest site selection using logistic regression (R, version 2.15.1, www.r-project.org, accessed 22 Jun 2012).

We determined nest-site selection within individual vegetation types 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 using logistic regression.

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). To calculate the nest survival rate given the nest reaches incubation, 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 tested 6 a priori models. 1) We calculated the nest survival rate during the study with a Null model (i.e., s(.)). 2) We compared nest survival rates between 2011 and 2012 with a Year-effect model. Years were coded binomially (i.e., 0 = 2011 and 1 = 2012 in the model). 3) We compared nest survival rates among vegetation types with a Vegetation Type model. We tested the effect of vegetation type because understory structure and composition in each vegetation type largely reflected site hydrology and fire history. Therefore, we were able to condense several covariates into a single, comprehensive parameter. 4) We developed the Cover model because greater nest concealment may reduce detection by predators, and greater nest concealment is commonly correlated with increased nest survival. The Cover model included percent horizontal cover (1 – 1.5 m height category) and percent total ground cover. 5) We developed the Stream model because hydrology influences vegetation structure and composition and reflected availability of cover for nest concealment. The Stream model included a single covariate for distance to stream. 6) We assessed the effect of time since burn on the probability of nest survival with the Fire model because fire influences understory vegetation structure and composition on the study area. We used Akaike's Information Criterion (AIC) for model selection and accepted any model with a $\Delta AIC \leq 2$ as a candidate model (Burnham and Anderson 2002).

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. We censored 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. 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. Assuming nests were located randomly across the study site, we estimated a maximum of 5.4% and 6.1% of wild turkey nests were exposed to fire during the 2011 and 2012 nesting seasons, respectively.

At random locations within vegetation types, percent horizontal cover was greater at all height categories in bottomland hardwood and ecotone than upland pine (Table 1). 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 1). Grass and forb cover was greater in upland pine than bottomland hardwood and ecotone communities.

Female wild turkeys selected ecotone (23 nests) and avoided upland pine communities (9 nests) for nesting (Table 2). Bottomland hardwood (4 nests) and non-forested communities (6 nests) were used similar to availability. Within the ecotone vegetation type, females selected locations with greater percent horizontal cover at 1 – 1.5m (i.e., taller vegetation) and locations nearer to streams for nesting (Table 3). Within upland pine, nest sites had greater percent total ground cover, were nearer to firebreaks, and were farther from streams than random locations (Table 4). Because we had too few nests in bottomland hardwoods and because we did not measure vegetation structure at random locations in non-forested communities, we did not model selection within those vegetation types.

Of 30 nests included in survival analyses, 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 bottomland hardwood (n = 3) communities. 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 AIC) (Table 5). Nest survival was greater in lowlands (60%, SE = 10%) than uplands (10%, SE 7%). Similarly, nest survival increased as distance to stream decreased in the Stream model. Effects of time since burn and cover were not significant in the Fire and Cover model, respectively.

DISCUSSION

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%). Additionally, nests on Fort Bragg were not located randomly, as turkeys commonly nest in mesic, lowland vegetation isolated from fire (Moore et al 2005). Because bottomland hardwood communities at Fort Bragg often did not burn thoroughly, nests in that vegetation type (10%) may have been less susceptible to fire. However, none of the nests we observed in a bottomland hardwood community 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 one nest destroyed by fire in our study failed in June, near the end of the nesting season, and the female did not renest.

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. 2005). On our study area, females selected ecotones and avoided upland pine for nesting. Ecotones had greater percent 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 communities, 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 woody cover available in ecotones. However, 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 impact turkey nest-site selection may influence nest survival. All surviving nests 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 increased predator search time 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, as cover was greater in lowlands than uplands. Similarly, the distribution of vegetation types on our study area were largely determined by hydrology, and distance to stream was predictive of nest survival. 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 at the landscape scale because the probability that a nest is active and located in a fire management unit that is burned is low. 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 higher 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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Table 1. 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 – 0.5m	80 ± 3	A[b]	86 ± 1	A	65 ± 3	B
0.5 – 1m	73 ± 3	A	70 ± 3	A	46 ± 3	B
1 – 1.5m	66 ± 3	A	55 ± 3	A	35 ± 3	B
1.5 – 2m	58 ± 4	A	43 ± 3	B	28 ± 3	C
% Ground Cover						
Total cover	41 ± 3	B	63 ± 2	A	29 ± 2	C

Table 1 Continued

Woody	29 ± 3	B	48 ± 3	A	14 ± 1	C
Forb	0.4 ± 0.1	B	0.6 ± 0.1	B	1 ± 0.2	A
Grass	1 ± 0.4	B	4 ± 0.8	B	12 ± 1	A

[a]Horizontal cover was estimated at four height categories with a vegetation profile board from a 1-m height at plot center out to 15m.

[a]Statistical difference between vegetation types for each feature (i.e., row) using Tukey's HSD. Differences in letter across a row correspond to statistical significance at $\alpha = 0.05$.

Table 2. Parameter estimates and P-values from a logistic regression model of landscape-scale wild turkey nest-site selection at Fort Bragg, North Carolina, USA, 2011-2012.

Parameter[a]	β_i	SE	*P*
Intercept	-3.09	0.42	<0.001
Bottomland Hardwood	0.29	0.66	0.66
Ecotone	2.15	0.54	<0.001 *
Upland Pine	-1.36	0.48	0.01 *

[a]For non-forested vegetation type, effects of bottomland hardwood, ecotone, and upland pine go to zero in the model. Non-forested vegetation type was used as available relative to all other vegetation types.

Table 3. Parameter estimates and P-values from a logistic regression model of wild turkey nest site selection within the ecotone vegetation type 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[a]	-0.02	0.01	0.02 *
Time since burned	-0.33	0.25	0.20
Growing-season burns	-0.26	0.19	0.17

[a]Probability of use for nesting increased as distance to stream decreased in ecotone

Table 4. Parameter estimates and P-values from a logistic regression model of wild turkey nest-site selection in the upland pine vegetation type 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[a]	-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

[a]Probability of use for nesting increased as distance to firebreak decreased in upland pine

Table 5. 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]Vegetation Type model: single binomial indicator covariate for nest position, Upland (pine or non-forested) or Lowland (ecotone or bottomland hardwood) communities

[b]Stream model: single covariate, distance to nearest stream or lake

[c]Fire model: single covariate, time since burn

[d]Year-effect model: single binomial indicator covariate for year, 2011 or 2012

[e]Cover model: two covariates, percent ground cover and percent horizontal cover from 1 – 1.5 m