INFLUENCE OF PRESCRIBED FIRE ON REPRODUCTIVE ECOLOGY OF FEMALE EASTERN WILD TURKEY (*MELEAGRIS GALLOPAVO SILVESTRIS*) IN WEST-CENTRAL LOUISIANA

by

NATHAN ANDREW YELDELL

(Under the Direction of Michael J. Chamberlain)

ABSTRACT

The eastern wild turkey (*Meleagris gallopavo silvestris*) inhabits fire-managed, pine-dominated ecosystems of the Southeastern United States. However, the influence of fire-induced disturbance on reproductive ecology of turkeys is poorly understood. Therefore, I investigated nest site selection, nest survival, habitat selection, and behavioral response to fire by female wild turkeys in a fire-managed pine ecosystem of Louisiana. Turkeys nested in forest stands with various fire histories, but nest survival was lowest where fire was absent for ≥3 years. Turkeys selected hardwood stands and avoided recently burned pine stands during winter, but selected pines burned zero and one years prior during the reproductive period. Turkeys used recently burned areas, but use peaked at 103 days post-fire before declining. Turkeys were more likely to use burned areas near the perimeter, but use of interior space increased with time-since-fire. I recommend managers in southeastern pine forests apply fire at 3-year intervals and maintain habitat diversity through retention of hardwood stands.

INDEX WORDS: habitat selection, nest survival, prescribed fire, wild turkey

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DEDICATION

I dedicate this work to my father, Ricky Yeldell, who instilled in me a love and respect for the outdoors at a young age. In good times and hard times, you always went out of your way to expose me to the wonders of the natural world. Some of my fondest childhood memories include playing with snakes you brought home from work, catching salamanders at night, and watching the sunrise from a deer stand. I am proud to follow in your footsteps as I begin my career as a professional wildlife biologist and hope to one day share my knowledge and passion for nature with my children the way that you did with me. Thank you for being an awesome dad.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

The wild turkey (*Meleagris gallopavo*) is North America's largest upland gamebird and its range extends across much of the United States. Wild turkey range now includes every state except for Alaska, as well as Mexico and some of the southern Canadian provinces. Hunting seasons are held in every state in which they occur. Approximately 2.5 million hunters pursued wild turkeys in 2006 (U.S. Fish and Wildlife Service 2010). Those hunters spent approximately $1.6 billion on direct expenditures related to turkey hunting, which generated an estimated $4.1 billion in total economic impact (U. S. Fish and Wildlife Service 2010). Given the social and economic value of wild turkeys, natural resource managers often include turkey population management and habitat provisions as objectives within forest management plans. To sustain healthy turkey populations, managers must understand how forest management practices influence the behavior, survival, and reproductive success of the wild turkey.

WILD TURKEY ECOLOGY AND PRESCRIBED FIRE

Turkeys are adapted to a variety of ecosystems and use diverse habitats within their environments. Two critical components of turkey habitat are suitable trees for overnight roosting and herbaceous ground cover for foraging and brood-rearing (Porter 1992). Habitat selection of turkeys changes seasonally and individuals may have distinct seasonal home ranges (Miller and Conner 2007). Seasonal variations in space and habitat use are linked to the progression of the annual cycle, which is significantly influenced by the reproductive period (March – July). Several studies have shown that females select nest sites with greater lateral cover provided by woody or herbaceous understory vegetation as compared to non-nest sites (e.g., Badyaev 1995, Kilburg et al. 2014), which has been correlated with increased nest survival (e.g., Lehman et al. 2008, Moore et al. 2010). Brooding habitat is typically characterized by less woody and more herbaceous understories of moderate density (Phalen et al. 1986). Ground cover is an important component of brooding areas (Campo et al. 1989, Peoples et al. 1995). Brood survival has been correlated with increased visual obstruction (Metzler and Speake 1985, Spears et al. 2007), although females are thought to require less cover for brooding than for nesting. Herbaceous ground cover is associated with increased invertebrate abundance which provides an important protein source for growing poults (Healy 1985, Hurst 1992).

The eastern wild turkey (*M. g. silvestris*) is the most abundant and widespread of the 7 wild turkey subspecies and its range extends across much of the eastern United States (Eriksen et al. 2015). In the southeastern U.S., eastern wild turkeys inhabit a variety of forest types, including oak-pine (*Quercus-Pinus*), loblolly-shortleaf pine (*P. taeda-P. echinata*), and longleaf-slash pine (*P. palustris- P. elliottii*) ecosystems (Hurst and Dickson 1992). Southern pine forests have traditionally been managed using prescribed fire (Fowler and Konopik 2007). Fire alters understory vegetative structure and communities and maintains sub-climax plant communities (Hodgkins 1958, Waldrop et al. 1992, Haywood et al. 2001, Glitzenstein et al. 2012), which in turn influences habitat conditions (Bendell 1974, DeBano et al. 1998, Van Lear and Harlow 2000). Fire has influenced landscapes of the southeastern United States for millennia, which has resulted in fire-dependent ecosystems, including the longleaf pine savanna (Garren 1943, Van Lear et al. 2005). Many wildlife species have adapted to and now depend upon fire-dependent ecosystems, such as the endangered red-cockaded woodpecker (*Picoides borealis*, hereafter RCW). Red-cockaded woodpeckers inhabit mature pine forests with low timber stocking, few midstory trees, and herbaceous understory plant communities maintained by frequent, low-intensity fires (U.S. Fish and Wildlife Service 2003). The United States Forest Service now actively manages for RCW habitat on national forests inhabited by the species by applying prescribed fire in those areas. This means that many other wildlife species, including wild turkeys, experience the effects of fire in those areas.

The effects of prescribed fire on the resulting plant communities depend on several factors, including frequency of fire disturbance, severity of fire, seasonal timing of application, and the spatial scale of burn patches (Turner et al. 2001). Thus, resource managers can manipulate one or more of these variables to achieve their desired management objectives. For example, Glitzenstein et al. (2012) found that understory plant species richness declined along a gradient of fire return interval of 1-3 years, with the highest diversity associated with annual burning. That same study showed a shift in herbaceous plant dominance along that gradient with greatest herbaceous cover found in areas burned every 1-2 years. Along with frequency of disturbance, timing of fire application also plays an important role in driving plant communities. Growing season burns (late spring-early summer) are more effective at killing and controlling understory hardwood growth compared to dormant season burns (Waldrop et al. 1992, Barlow et al. 2015), and may be used when hardwood control is desired. The spatial scale of fire application can affect interspersion and juxtaposition of patches at differing stages of plant succession, thereby influencing post-disturbance landscape heterogeneity (Turner et al. 2001). This may be an important factor when managing for wildlife species dependent on habitat diversity, such as the wild turkey.

Prescribed fire can provide multiple benefits to wild turkeys. The creation of an herbaceous understory provides a diversity of seeds, legumes, and insects important in spring and summer diets of turkeys in all age classes (Dalke et al. 1942, Healy 1985, Hurst 1992, Baughman and Guynn 1993). Additionally, fire may increase availability of suitable nesting and brood-rearing habitat for females by altering structure and species composition of ground level vegetation. In pine forests managed with fire, turkeys frequently nest in stands burned 2 to 3 years prior (Sisson et al. 1990, Still and Baughman 1990) where dense vegetation provides concealment. Alternatively, suitable brood-rearing habitat is typically less dense and composed of primarily herbaceous plants (Campo et al. 1989); these conditions may be found in forest openings (Peoples et al. 1995), hardwood stands (Phalen et al. 1986, Williams et al. 1997), pine forests burned 1 year prior (Hon et al. 1970), or immature pine forests with moderate canopy closure (Jones et al. 2005).

Despite benefits that fire may provide to turkey populations, there is also potential for negative impacts. Of particular concern are growing season fires that coincide with the nesting and brood-rearing period (April-July). Biologists have long been concerned that growing season burns could destroy turkey nests and kill poults, and some have advised against burning during that time of year (Stoddard 1935, Sisson and Speake 1994). However, recent studies have found that growing season fires in pine ecosystems had minimal impact on nest and brood survival. In southern Georgia, Little et al. (2014) examined nest survival in a longleaf pine savanna burned on a 3-year rotation and observed only 3 of 78 (3.8%) nests destroyed by fire and 1 of 34 (2.9%) broods lost to fire. Similarly, Kilburg et al. (2014) examined nest survival in the Sandhills region of North Carolina where pine forests were also burned on a 3-year rotation and observed only 1 of 30 (3.3%) nests destroyed by fire. Kilburg et al. (2014) attributed the low impact of fire to female selection of nest sites in lowland mesic areas and transitional habitats that did not burn as thoroughly as xeric upland areas, thus reducing susceptibility of those nests to destruction by fire. These findings suggest that growing season prescribed fire may have little direct negative impacts on turkey reproduction in similar southern pine forests on 3-year burn rotations.

Fire may influence turkey reproduction indirectly by affecting female movements and habitat availability during the reproductive period. Turkeys may be temporarily displaced if a fire is conducted within their area of use, and data have been collected supporting this hypothesis. In a longleaf pine savanna in southern Georgia, female turkeys were located 114 m farther from burn units in the 10-day period following a fire than they were in the 10-day period prior to the fire (Perez 2013). However, Martin et al. (2012) noted that turkeys returned to recently burned areas almost immediately, although a specific time frame was not specified. On a longer time scale, Martin et al. (2012) found that females used areas burned <500 days prior and avoided stands burned >2 years prior. This suggests that even at relatively short burn rotations (1-3 years), turkey habitat selection relative to fire application is time-sensitive and can change in a matter of months or even days. Shifts in space use following fire disturbance are likely related to changes in habitat suitability via alterations to vegetation structure or distribution of food resources. Such changes in habitat suitability could influence reproductive success, particularly when fires are applied immediately prior to or during the reproductive period. Therefore, examining potential influence of fire on wild turkey reproductive ecology is warranted.

Most past research on turkey reproductive ecology in landscapes managed with prescribed fire was conducted in areas where fire was applied at relatively small (<200 ha) spatial scales (e.g., Martin et al. 2012, Perez 2013, Little et al. 2014). The effects of fire on turkey movement, space use, and reproduction may be dependent on the scale at which fire is applied, and little research has been conducted in areas where fire is applied at larger, landscape scales (>500 ha). Pittman (2014) recently conducted a study on turkey nest site selection and nest success in the Ozark Highlands of Arkansas where large-scale (500 to 2500 ha) prescribed fire was applied for forest restoration purposes, and found that nest success was positively related to increased visual concealment and that concealment was correlated with time since fire. These findings suggested that availability of suitable nesting habitat increased with time since fire. The estimated mean home range size of adult females in the pre-incubation period was 4750 ha, which was considerably larger than an earlier estimate of 1414 ha reported by Badyaev et al. (1996) in the same landscape prior to implementation of large-scale burning (Pittman 2014). This suggests that large-scale burning may result in significantly greater travel distances and larger home ranges as compared to smaller burns. Clearly, there is a need for further research on turkey space use and reproductive ecology in the presence of large-scale fire disturbance.

Despite past research on long-term response of wild turkeys to prescribed fire, little has been done to examine the direct, short-term response to fire. This is largely because past studies have relied on very-high frequency (VHF) radio-transmitters to monitor individuals and record location data. While VHF telemetry has been an invaluable tool for conducting research on many wildlife species (Dickson 1992), it has its drawbacks. These include the potential for relatively high spatial inaccuracy and the inability/cost-ineffectiveness of gathering large datasets with fine temporal resolution (Rodgers 2001). Recently, a Global Positioning System (GPS)-equipped transmitter was developed for use with wild turkeys, and is capable of collecting and storing fix locations onboard (Model Minitrack Backpack L, Lotek Wireless, Newmarket, Ontario, Canada). This micro-GPS (μGPS) transmitter is more accurate in its location estimates and more cost-effective than traditional VHF transmitters. Furthermore, the μGPS transmitter can be programmed to collect fix locations according to the researcher’s needs (Guthrie et al. 2011). The use of GPS transmitters in turkey research will allow scientists to closely examine individual space use, habitat selection, and movements in much greater detail than was previously possible with VHF technology; this will allow for rigorous analyses and strong inferences of behavioral patterns of turkeys (Collier and Chamberlain 2011).

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CHAPTER 2

REPRODUCTIVE ECOLOGY, NEST SITE SELECTION, AND NEST SURVIVAL OF FEMALE EASTERN WILD TURKEYS IN A PYRIC LANDSCAPE

[1] Yeldell, N. A., B. S. Cohen, A. R. Little, B. A. Collier, and M. J. Chamberlain. To be submitted to the *Journal of Wildlife Management*.

ABSTRACT

Prescribed fire is commonly used on public land in the Southeastern United States to reduce fuel loads, maintain diverse plant communities, and increase habitat quality for many wildlife species. Prescribed fire alters understory vegetation, which is a key component of nesting habitat for ground-nesting birds. To examine roles of habitat selection and fire disturbance on reproductive ecology of female eastern wild turkeys *(Meleagris gallopavo silvestris*), we assessed the relative influence of habitat types, landscape features, fire history, and vegetative characteristics on wild turkey nest site selection and nest survival in a pine-dominated forest managed with prescribed fire in west-central Louisiana. We radio-marked 55 female wild turkeys and evaluated habitat characteristics associated with 69 nests during the 2014 and 2015 reproductive periods. Nests were 1.35 times less likely to occur for every 100 m farther from roads and 1.28 times more likely to occur for every 100 m farther from transitions between forest types. Nests were positively associated with ground cover vegetation within 15 m of the nest. Nests were located in stands of all time-since-fire categories, ranging from 0 to ≥3 years since fire application. However, comparison of time-since-fire at actual nest sites and random locations within pre-nesting ranges suggested that stands burned 2 years prior were favored for nesting, and stands burned ≥3 years prior were least favorable. Nest survival was positively associated with percent ground cover and negatively associated with time-since-fire, with nests in stands burned ≥3 years prior having significantly higher predation risk than nests in stands burned the current year. Vegetative cover in forest stands burned within 2 years provides more suitable nesting habitat in pine-dominated ecosystems in the Southeastern United States. Managers should apply prescribed fire in pyric southern pine systems in a mosaic fashion to

intersperse nesting habitat and should avoid burn rotations longer than 3 years where turkey management is an objective.

INTRODUCTION

Wild turkey population dynamics are influenced by adult survival, nest success, and recruitment of poults into the breeding age class (Vangilder 1992). Nest success of wild turkeys is influenced by predator-prey interactions (Miller et al. 1998), environmental conditions (Vangilder et al. 1987, Schwertner et al. 2005), and availability of suitable nesting habitat (Lazarus and Porter 1985). Provision of suitable nesting habitat may affect reproductive effort (Byrne and Chamberlain 2013) or nesting success by decreasing interactions between nesting female wild turkeys and their predators (Bowman and Harris 1980). Vegetative conditions at small spatial scales (i.e., at or close to the nest site) influence probability of nest site selection by wild turkeys, and habitat characteristics at larger spatial scales may play a role as well (Thogmartin 1999, Byrne and Chamberlain 2013). In particular, overhead cover (Lehman et al. 2003), visual obstruction of the nest (Badyaev 1995, Streich et al. 2015), and herbaceous ground cover (Chamberlain and Leopold 1998) are positively associated with nest site selection. Conversely, overstory canopy cover has been shown to be negatively associated with nest site selection (Streich et al. 2015). Greater nest concealment (Badyaev 1995, Nguyen et al. 2004, Lehman et al. 2008, Fuller et al. 2013) and woody stem density (Moore et al. 2010) positively influence nest success.

In pine-dominated forests, eastern wild turkeys (*Meleagris gallopavo silvestris*; hereafter, turkey) nest in a wide variety of habitat types (Moore et al. 2010), but nests are often located in mature pine stands (Miller et al. 1999, Thogmartin 1999). However, in longleaf pine-wiregrass (*P. palustris-Aristida stricta*) savanna managed intensively with frequent (1- to 3-year interval) fire, turkeys avoided nesting in mature pine (Streich et al. 2015) or located nests in ecotones between mature pine and bottomlands (Kilburg et al. 2014). Previous studies have noted that turkeys nest close to edges (Thogmartin 1999, Byrne and Chamberlain 2013), whereas others have found proximity to edges to be insignificant in nest site selection (Miller et al. 1999). Likewise, several studies have found turkeys to nest near roads, but that proximity to roads negatively influenced nest survival (Badyaev 1995, Thogmartin 1999, Moore et al. 2010). The affinity for nesting near forest edges has been attributed to quality of brood-rearing habitat found along roads (Sisson et al. 1991*a*), but roads may simply facilitate travel to and from the nest. Locating nests near roads and edges may influence nest survival by increasing predation risk. Roads and habitat edges are used by several nest predators for travel and hunting, including coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and rat snakes (*Elaphe obsoletus*; Weatherhead and Charland 1985, Bradley and Fagre 1988, Durner and Gates 1993, Chalfoun et al. 2002, Hinton et al. 2015). Therefore, predator encounter rates may be more likely at nests located near roads and edges.

Similarly, predation risk may differ by forest type. In a bottomland hardwood forest, raccoons (*Procyon lotor*), a common predator of turkey nests, focused foraging efforts in lowland areas, thereby increasing probability of encountering nests located in those areas (Byrne and Chamberlain 2015). Hence, risk of nest predation by raccoons may be lower in upland pine habitat than hardwood or mixed pine-hardwood stands at lower elevation. Turkeys have used forest openings (Healy 1985), pastures (Hillestad and Speake 1970), or oldfields (Hon et al. 1978, Sisson et al. 1991*a*) as brood-rearing habitat; therefore, locating nests near forest edges and suitable brood-rearing habitat may be an adaptive strategy to increase brood survival. While structural diversity at the nest site may influence nest site selection (Badyaev 1995) and lead to increased nest survival (Bowman and Harris 1980), diversity at the landscape scale has not been linked to nest site selection (Byrne and Chamberlain 2013, Little 2015). Although there is consensus among turkey biologists and researchers that understory vegetative conditions play a strong role in nest site selection, management practices that result in desirable turkey nesting habitat likely vary regionally. Hence, habitat management plans that influence understory vegetation should be tailored to specific areas.

Pine-dominated forest systems, including the longleaf pine (*Pinus palustris*) ecosystem, comprise a large portion of the landscape in the southeastern United States. Currently, efforts are underway to maintain and restore this biologically diverse system (Alavalapati et al. 2002, Van Lear et al. 2005). Longleaf pine savannas and forests are characterized by mature pine trees, relatively open canopies, diverse understory vegetation, and are maintained with frequent (1-3 year) prescribed fire return intervals (Brockway and Lewis 1997, Glitzenstein et al. 2012). Prescribed burning has been recognized for its potential to increase habitat suitability for turkeys and other upland game species (Stoddard 1935), although some have expressed concern that spring burning coinciding with turkey nesting and brood-rearing may pose a threat to nest and brood survival (Sisson and Speake 1994). In pyric pine forests, nesting cover can be found in areas burned 2-4 years prior (Burk et al. 1990, Sisson et al. 1990, Still and Bauman 1990), although females have shown tolerance to a wider range of time-since-fire (Hon et al. 1978, Exum et al. 1987) and others have found fire history to have no significant effect on nest site selection (Seiss et al. 1990). In Southeastern forests, prescribed fire is typically applied to upland, pine-dominated sites where burning increases ground level vegetation (Garren 1943, Brockway and Lewis 1997, Haywood et al. 2001) that may be used as nesting cover. However, the effect of fire on understory vegetation depends on many factors and likely varies regionally.

Application of prescribed fire can have profound effects on habitat suitability for nesting turkeys, which may affect nest success and productivity at the population level. A thorough understanding of the relationships between habitat, fire events, and turkey reproductive ecology in pine-dominated forest systems is necessary for resource managers to balance objectives of ecosystem restoration and game management.

Our objectives were to evaluate influences of prescribed fire history, macro-habitat type, landscape features, and vegetative characteristics on nest site selection and nest survival in a pine-dominated forest managed with prescribed fire. We also investigated reproductive parameters including nesting rates, nest success, and brood survival. We hypothesized that female turkeys would 1) select nest sites with greater ground cover and visual obstruction than surrounding areas, 2) locate nests in mature pine stands, 3) nest near forest edges and roads, 4) nest near open, non-forested habitats, and 5) locate nests in areas burned 2 to 3 years prior. With respect to nest survival, we hypothesized that survival would be positively associated with greater visual concealment and ground cover, distance to hardwoods, and distance to roads.

STUDY AREA

We conducted research on Kisatchie National Forest (KNF) and Fort Polk Wildlife Management Area (WMA) in west-central Louisiana. The KNF is owned and managed by the United States Forest Service (USFS) and is divided into 5 Ranger Districts. We conducted research on the Kisatchie Ranger District, Winn Ranger District, and the Vernon Unit of the Calcasieu Ranger District located in Natchitoches, Winn, and Vernon Parishes, respectively. Fort Polk WMA was jointly owned by the USFS and the United States Army. The northern portion of Fort Polk WMA owned by the US Army lied within the Fort Polk Joint Readiness Training Center, whereas the southern portion lied within the Vernon Unit of KNF. Environmental conditions and forest management practices were similar on the Vernon Unit and Fort Polk WMA, hence we considered these areas as a single study site. The Kisatchie Ranger District, Winn Ranger District, and the Vernon/Fort Polk area were comprised of approximately 41,453-ha, 67,408-ha, and 61,202-ha, respectively. The area was composed of pine dominated forests, hardwood riparian zones, and forested wetlands, with forest openings, utility right-of-ways, and forest roads distributed throughout. Overstory trees included loblolly pine (*P. taeda*), longleaf pine, shortleaf pine (*P. echinata*), slash pine (*P. elliottii*), sweetgum (*Liquidambar styraciflua*), oaks (*Quercus* spp.), hickories (*Carya* spp.) and red maple (*Acer rubrum*). Understory plants included yaupon (*Ilex vomitoria*), American beautyberry (*Callicarpa americana*), blackberry (*Rubus* spp.), greenbrier (*Smilax* spp.), wild grape (*Vitis* spp.), broomsedge (*Andropogon virginicus*), woodoats (*Chasmanthium* spp.), and panic grasses (*Panicum* spp. and *Dichanthelium* spp.). Privately owned land within and surrounding KNF were also available to turkeys. Much of this land was used for industrial timber production and was comprised of even-aged stands of loblolly pine and recent clearcuts ≤4 years old. Pine stands on private lands were typically not managed with frequent prescribed burns (see below), hence forest conditions on these lands generally differed from those on KNF. Forest stands on private lands typically had lower diversity of overstory tree species, higher stem densities, greater canopy cover, and less dense understory growth. Other private lands in the area consisted of small rural settlements, agricultural fields, pastures, and hardwood-dominated forested wetlands.

To promote the growth of longleaf pine, inhibit the growth of undesirable hardwood species, and reduce fuel loads, land managers on KNF used prescribed fire and mechanical hardwood removal. Fire was primarily applied to upland sites containing mature pine, young pine, and mixed pine-hardwood stands. Prescribed fire was applied in both dormant season

(December-March) and growing season (April-July), with most fires (71.3% of total area burned) applied in the dormant season (Table 2.1). Burn patch sizes averaged 484.93 ha (SD = 295.33; Table 2.2) and ranged from 7.28 to 1567.35 ha. The proportion of public land within the study area burned annually was 23.2% and 19.2% in 2014 and 2015, respectively (Table 2.2). Land managers occasionally used mechanical hardwood removal to remove undesirable hardwood trees from the midstory, particularly near active colonies of red-cockaded woodpeckers (*Picoides borealis*). Most upland pine stands were burned on a 3-5 year rotation, although some areas had no recent burn history at the time of this study. Prescribed burning was uncommon on private lands within the boundary of and surrounding KNF.

METHODS

We captured female turkeys using rocket nets during January-March of 2014 and 2015. We classified each turkey as adult or subadult based on presence of barring on the ninth and tenth primary feathers (Pelham and Dickson 1992). We fitted all turkeys with a serially numbered, butt-end style or riveted aluminum tarsal band. We also fitted each turkey with a backpack-style GPS transmitter equipped with a VHF beacon and mortality sensor weighing approximately 88 g (Lotek Minitrack Backpack L; Lotek Wireless Inc., Newmarket, Ontario, Canada). We programmed GPS transmitters to record hourly locations from 0600 to 2000 each day and one nightly roost location at midnight, with the exception that in 2014 only roost locations were collected prior to 15 February. All birds were released on site immediately after processing. Turkey capture, handling, and marking procedures were approved by the Institutional Animal Care and Use Committee at the University of Georgia (protocol #A3437-01).

We used a hand-held, 3-element Yagi antenna and R2000 receiver (Advanced Telemetry Systems, Inc., Isanti, MN) to locate and monitor status of radio-marked turkeys ≥1 time per week from mid-February to mid-August. We downloaded GPS locations from each turkey ≥1 time per week during the nesting period (April-July) to monitor nesting activity. We viewed GPS locations and considered a female to be incubating a nest when recorded locations did not significantly deviate from a central location for several days. Once a female was determined to be laying or incubating a nest, we monitored its location via VHF telemetry and GPS data interpretation until nest termination. After nest termination, we located nest sites using GPS locations to determine nest fate, clutch size (number of eggs incubated), brood size (number of eggs hatched), and to confirm the estimated nest location (via GPS locations) for future analysis. Wild turkey nests require approximately 27 days of continuous incubation before hatching (Williams et al. 1971), but incubation time in pen-raised turkeys has ranged from 25 to 29 days (Healy and Nenno 1985). Therefore, we considered a nest abandoned if the female left the nest before 30 days of incubation and only intact eggs were found at the nest bowl. We assumed if a nest was incubated for ≤25 days and the nest bowl was found with no eggs or egg shell remains nearby, the nest had been predated. If a nest was incubated for >25 days, we located the female after nest termination via VHF signal homing and used visual and auditory cues to confirm the presence or absence of poults. We considered a nest successful if ≥1 live poult hatched and failed if no poults hatched. If the exact nest location could not be determined, we estimated its location as the center of the cluster of GPS locations recorded during incubation. If location data indicated a female restricted movement to area ≤30 m radius, we assumed the female was incubating a nest based on typical behavior and movement patterns associated with incubation (Conley et al. 2015). We defined nesting rate as the proportion of females that initiated at least 1 nest, the second nest rate as the proportion of females that initiated a second nest following the loss of the first nest or brood, and so on for all subsequent nest attempts. We defined nest success rate as the proportion of nests that were successful, and overall reproductive success as the proportion of females that attempted ≥1 nest and hatched ≥1 egg.

After nest termination, we evaluated vegetative conditions at nest sites by conducting vegetation surveys within a 15-m radius circular plot (Streich et al. 2015). We recorded tree density, percent canopy cover, percent total ground cover, average understory vegetation height (cm), and visual obstruction (cm). We measured tree density by counting all trees ≥10.16 cm DBH within 15 m of the nest bowl. We measured percent canopy cover using a convex spherical densiometer (Lemmon 1956) at a distance of 15 m in each of the cardinal directions, then calculated a mean of the 4 readings. We measured percent ground cover using a 1-m^2 Daubenmire frame (Daubenmire 1959) at the center of the nest bowl and 15 m in each cardinal direction from the nest bowl. We divided ground cover vegetation into 5 types: fern, forb, graminoid (grasses, sedges, and rushes), vine, and woody. We then summed percentages of each category into a single variable (percent total ground cover) and used the mean value from all 5 frames at each nest site. To evaluate height of understory vegetation and quantify visual obstruction, we used a 2-m Robel pole (Robel et al. 1970). We placed the Robel pole in the nest bowl and took readings from 15 m in each cardinal direction. We measured visual obstruction as the lowest point of the Robel pole we could see when viewing from a height of 1 m above the ground, and estimated average height of understory vegetation along our line of sight between the nest bowl and a point 15 m from the nest in each cardinal direction. We averaged Robel pole readings from all 4 readings to estimate mean vegetation height and visual obstruction. To test for non-random resource use, we also surveyed one random location per nest in an identical manner. We traveled between 100 to 200 m from each nest site in a randomly chosen azimuth and conducted surveys identical to those at nest sites. We chose distances of 100 to 200 m between paired nest and random plots to compare nest sites to available sites in the surrounding landscape, presumably at which a female could have selected as an alternative nest site.

To delineate major habitat types within our study area, we obtained forest inventory data from the US Forest Service, the US Army Environmental and Natural Resources Division, and local timber companies. In areas where stand data were not available, we estimated stand conditions via photo interpretation using Landsat 8 multi-spectral satellite imagery (data available from the U.S. Geological Survey) and 30 cm aerial imagery (Digital Globe, Inc.; available in ArcGIS Version 10.3.1 [Environmental Systems Research Institute, Redlands, CA]). We used satellite and aerial imagery to develop a land cover map of major habitat types throughout our study area. We classified forest stands as pine if they consisted of ≥ 70% loblolly, longleaf, slash, or shortleaf pine in the overstory. We classified pine stands as mature if they were ≥20 years old and consisted primarily of trees in the pulpwood and sawtimber classes (≥20.4 cm diameter at breast height [DBH]). We classified pine stands as immature if they were <20 years old and consisted of trees in the seedling, sapling, and pulpwood classes (range: 0 to 20.3 cm DBH). Mixed pine-hardwood stands consisted of a variety of tree species, including loblolly pine, longleaf pine, slash pine, sweetgum, white oak (*Quercus alba*), swamp chestnut oak (*Q. michauxii*), sassafras (*Sassafras albidum*), hickories, and Southern magnolia (*Magnolia grandiflora*). We classified stands as mixed pine-hardwood if they were 50 to 70% pine or hardwood and trees ranged in size from seedling and sapling to mature sawtimber. Hardwood stands were confined to streamside management zones (SMZs), river bottoms, and forested wetlands. Hardwood stands were comprised of oaks, cypress (*Taxodium distichum*), American sycamore (*Platanus occidentalis*) and river birch (*Betula nigra*), with trees ranging in size from seedling and sapling to mature sawtimber. We classified wildlife food plots, pastures, agricultural fields, and clearcuts (≤4 years old) as open habitat. Wetland areas were herbaceous or non-forested. Developed areas included human structures and settlements or barren land not suitable as turkey habitat.

To enumerate habitats available to our marked sample of turkeys, we first divided our sample population into 5 distinct groups based on spatial distribution (1 group at the Kisatchie RD, 1 at the Vernon/Fort Polk site, and 3 at the Winn RD). We then created a 100% minimum convex polygon (MCP) around each of the 5 groups that encompassed all recorded locations of turkeys monitored throughout the study period and buffered the MCPs by 500 m. The area within the 5 MCPs was comprised of approximately 83,930 ha and was composed of 59% mature pine, 18% mixed pine-hardwood, 11% hardwood, 6% young pine, 5% open, 1% developed, and <1% open water.

To evaluate influence of habitat type and proximity to landscape features on nest site selection, we used Euclidean distance analysis (EDA; Conner and Plowman 2001, Conner et al. 2003) to compare used nest sites to available nest sites. We defined available nesting areas as the space used by each individual turkey prior to the initiation of its first nesting attempt of the reproductive season. The pre-nesting period precedes the laying sequence during which females typically deposit no more than 1 egg per day in the nest and may not deposit an egg on 1-3 days during the sequence (Williams et al. 1971). Based on an average clutch size of approximately 10 eggs (Vangilder 1992), we estimated that the laying sequence would occur during the 12 days prior to onset of continuous nest incubation. We estimated pre-nesting ranges using a dynamic Brownian bridge movement model (dBBMM) to calculate 95% utilization distributions (UDs) using each turkey's locations collected from time of capture until beginning of the laying sequence for the first nest of the season. The dBBMM incorporates the temporal structure and location error of spatial data and produces utilization distributions that estimate animal use areas based on their movement paths (Kranstauber et al. 2012). We used a window size of 15, a margin of 5, and a location error of 21 m as input parameters for the dBBMM. We used the software program GME (Geospatial Modelling Environment Version 0.7.4) to generate random locations within each individual turkey's pre-nesting range at a ratio of 5 random locations to 1 nest location. For example, if a turkey attempted 2 nests during the reproductive season, we generated 10 random locations within its pre-nesting range. We used ArcGIS 10.3.1 to measure distances to the nearest mature pine, young pine, mixed pine-hardwood, hardwood, open habitat, road, forest to non-forest edge, and edge between forest types by generating distance raster grids as described by Benson (2013). We then intersected all known nest locations and random locations with distance maps and extracted the distance to the nearest specified habitat type, road, and edge.

To evaluate influence of time-since-fire on nest site selection, we obtained spatial data displaying history of prescribed fire application throughout our study area from public land management agencies and private timber companies, and classified each nest site based on history of prescribed fire at that location. Time-since-fire categories included: not burned for ≥3 years (BURN3), burned 2 years prior (BURN2), burned the previous year (BURN1), or burned less than one year prior, but after the previous growing season (BURN0). As noted previously, we estimated that nest initiation occurred 12 days prior to onset of continuous incubation, and used the estimated nest initiation date as the reference date to calculate time-since-fire at each nest site. We then calculated time-since-fire at each random location generated within pre-nesting areas of use described above.

We developed 14 models that predicted nest site locations as a function of proximity to habitat types and landscape features (Table 2.7). These models were based on results of our study and represented predictions regarding proximity to habitat types known to be used as turkey nesting habitat, and proximity to landscape features found to be attractive to nesting turkeys. Five models were based on predictions that nest site selection was influenced by proximity to individual habitat types. One model was based on the prediction that females selected nest sites in proximity to roads and another was based on the prediction that females selected nests sites based on proximity to edges between 2 different forest types (soft edge). Five models were based on predictions that nest site selection was influenced by a combination of proximity to multiple habitat types and landscape features. A global model predicted nest site selection based on proximity to all habitat types, roads, and habitat edges, whereas a null model included no landscape scale predictor variables.

We developed 7 models that predicted nest site selection as a function of vegetative structure within 15 m of the nest (Table 2.10). These models also were based on results of our study and represented predictions regarding vegetative characteristics previously found to influence nest site selection. Four models were based on predictions that nest site selection was influenced by tree density, canopy closure, density of ground cover vegetation, or visual obstruction provided by understory vegetation. One model included density of ground cover vegetation and visual obstruction as predictors of nest site selection. A global model predicted nest site selection based on all vegetative characteristics measured, whereas a null model included no vegetative scale predictor variables.

To examine collinearity, we calculated Pearson correlations (r) for all pairs of vegetative and landscape-scale predictor variables. To reduce variables used in modeling and avoid inflation of variance, we eliminated highly correlated ($|r| \geq 0.7$) variables from model development (Dormann et al. 2013). We developed resource selection functions (RSF; Manly et al. 2002) to evaluate non-random nest site selection by comparing used (nest sites) to available (random locations) in a logistic regression framework where nests were represented as a binary response (1 = actual nest site; 0 = potential nest site). We evaluated each RSF using generalized linear modelling (GLM) within the package lme4 (Bates et al. 2004) implemented in R (R Core Team 2013).

We used second-order Akaike's Information Criteria (AIC_c) to determine the weight of evidence in support of landscape and vegetative-scale models (Akaike 1973, Burnham and Anderson 2002). We calculated adjusted Akaike's weights (w_i) for each model as an estimate of the probability of that model being the most parsimonious of the candidate model set. We calculated weight of evidence for the top model by dividing Akaike's weight of the top model by that of the second best candidate model. We then selected the most parsimonious model at each scale based on AIC_c values and examined parameter estimates of fixed effects from that model. For easier interpretation, we calculated scaled odds ratios for all parameter estimates using scalers believed to be biologically relevant. We scaled all distance-based predictor variables by dividing by 100 m and calculated scaled odds ratios for all model parameter estimates (Hosmer et al. 2003). We scaled percent total ground cover and percent canopy cover by 5%, height of visual obstruction by 10 centimeters (cm), and tree density by 10 trees per hectare (tph). We only considered parameter estimates to be informative if 85% confidence intervals around their odds ratio excluded one (Arnold 2010).

After examining the relative influence of landscape-scale habitat metrics and vegetative-scale characteristics on nest site selection, we examined the relative influence of variables at each spatial scale on nest survival using an information-theoretic approach and Cox proportional hazards modeling (Cox 1972). We used package ‘survival’ (Therneau 2015) implemented in R version 3.1.1 (R Core Team 2013) to evaluate risk of nest failure based on habitat characteristics at each scale. The Cox proportional hazards model provides hazard ratios for each covariate term included in the model. Hazard ratios >1.0 indicate increasing risk of an event (e.g., nest failure) with increasing values for the covariate, whereas hazard ratios <1.0 indicate decreasing risk of an event with increasing values for the covariate. Prior to data analysis, we assessed the proportional hazards assumption for our models. At the vegetative scale, we developed a Cox proportional hazards model based on statistically informative predictive variables from the most parsimonious model used to predict nest site selection at the vegetative scale. At the landscape scale, we developed Cox proportional hazards models based on time-since-fire (categorical variable with 3 levels: 0, 1, 2, and ≥3 years since fire), Julian day of the onset of continuous nest incubation, and statistically informative predictive variables from the most parsimonious model used to predict nest site selection at the landscape scale. Before data analysis, we scaled all distance variables by dividing the linear distance by 100 m. We evaluated pairwise correlations between explanatory variables using Pearson correlation. We considered any variables that were correlated ($|r| > 0.7$) and retained the variable that provided the simplest biological interpretation (Dormann et al. 2013). We developed 6 models to evaluate nest survival as a function of landscape-scale variables and used AIC*c* to compare models (Akaike 1973, Burnham and Anderson 2002). We considered the model with the lowest AIC*c* value to be the best model. We calculated the Akaike weight (w_i) for each model as an estimate of the probability of the model being the most parsimonious of the candidate models.

RESULTS

We captured and radio-marked 55 female turkeys (45 adults and 10 subadults) during winters of 2014 and 2015. We monitored 69 nests from 40 individuals during the 2014 and 2015 nesting seasons. Two nests were discovered following the reproductive season via examination of turkey location data collected by GPS transmitters. Location data of the 2 aforementioned females indicated that the turkeys were either stationary or moved very short distances for several days, which is characteristic of incubation behavior. Nesting rates were 87.0%, 65.6%, and 50% for first, second, and third nest attempts, respectively (Table 2.4). In 2014, one female attempted 4 nests, none of which were successful. Onset of initial nest incubation ranged from 5 April to 3 June ($\bar{x}$ = 28 April; n = 39; Table 2.3). Onset of incubation of second nest attempts ranged from 26 April to 24 June ($\bar{x}$ = 23 May; n = 21), third attempts ranged from 3 June to 12 July ($\bar{x}$ = 27 June; n = 7) and one fourth nest attempt was incubated on 4 July (Figure 2.1). We observed egg-laying behavior from approximately 25 March to 12 July, a span of 109 days (Figure 2.2), and date of onset of continuous incubation ranged from 4 April to 19 July.

We censored 3 nests from estimates of nest success because we believed they were abandoned due to observer influence. Of the remaining 66 nests, 10 (15.2%) were successful, 36 (54.5%) were destroyed by predators, 3 (4.5%) failed due to predation of the female, 5 (7.6%) were abandoned, 1 (1.5%) was destroyed by a vehicle, and 11 (16.7%) failed due to unknown causes. Nest success rates were 15.8%, 20.0%, and 0.0% for first, second, and third nest attempts, respectively (Table 2.4). Overall, female reproductive success was 15.2%. In 2015, one female successfully hatched 2 broods within the same reproductive period. No nests were exposed to prescribed fire during incubation, although one nest would have been exposed had it not been predated prior to a fire. One nest was exposed to fire 1 day after initiation, but the female returned to the nest the following day to continue egg deposition and later successfully hatched the clutch. Of 56 failed nests, predation accounted for 69.6% of nest failures. We found 12 predated nests (33.3%) with no remaining egg or egg shell fragments nearby, which is indicative of predation by rat snakes; a live rat snake was at the nest site in 2 of these cases. We found egg shell remains with tooth punctures at 8 nests, indicative of predation by a mammalian predator. One nest was likely destroyed by feral pigs (*Sus scrofa*) as evidenced by sign surrounding the nest. The remaining 15 predated nests were destroyed by unknown predators. Overall female reproductive success was 8.3% and 44.4% in 2014 and 2015, respectively.

In 2014, of 24 females that nested 2 hatched broods. In 2015, of 16 females that nested 8 hatched broods. Six broods were lost within 14 days of hatching and 1 brood was lost between days 15-28 (Table 2.5). Of the 3 surviving broods, we estimated that in 2014 2 poults from 1 brood survived to 28 days, and in 2015 8 poults from 1 brood and 1 poult from another brood survived to 28 days.

Females located nests in mature pine (n = 55; 78%), open habitat (n = 5; 7%), young pine (n = 4; 6%), hardwood (n = 3; 4%), and mixed pine-hardwood (n = 2; 2.9%). Of 5 nests located in open habitat types, 4 were located in clearcuts and 1 was located in a utility right-of-way dominated by dense grass and herbaceous ground cover. The 5 nests located in open habitats and 3 nests located in hardwood habitats were not in areas to which prescribed fire was likely to be applied, whereas the remaining 61 nests located in mature pine, young pine or mixed pine-hardwood habitats were in areas to which fire may have been applied. Nests in these habitats were located in areas burned ≤1 year prior (n = 13; 21.3%), 1 year prior (n = 19; 31.1%), 2 years prior (n = 13; 21.3%), and ≥3 years prior (n = 16; 26.2%; Table 2.6). We excluded 1 nest from our analysis of site selection at the landscape-scale because transmitter malfunction prevented us from estimating the female's space use during the pre-nesting period. Therefore, we developed our predictive models of nest site selection relative to landscape variables based on 68 observed nests from 39 individuals. Distance to forest edge was correlated with distance to open habitat (r = 0.828), so we excluded distance to forest edge from our analysis. The global model was the most parsimonious model (w_i = 0.341; Table 2.7) and had a weight of evidence of 1.58 when compared to the second-ranked model. Confidence intervals around odds ratios indicated that distance to nearest road and distance to nearest edge between 2 different forested habitats were informative predictors of nest site selection (Table 2.8). Odds ratios suggested that nests were 1.35 times less likely to occur for every 100 m farther from roads, and 1.28 times more likely to occur for every 100 m farther from edges between 2 different forest types (Table 2.8). Mean distance from nest sites to the nearest road and edge between 2 different forested habitats was 145 m and 235 m, respectively, whereas mean distance from random sites to the nearest road and edge between forested habitats was 224 m and 158 m, respectively (Table 2.9).

We did not conduct vegetation surveys at sites of 2 nests discovered via examination of turkey location data. To maintain equal sample sizes in our analyses of nest site selection at both spatial scales, we calculated mean values of vegetation metrics recorded at 66 nest sites and imputed the mean values at 2 nest sites not surveyed. Therefore, we used 68 nests from 39 individuals to develop 9 predictive models of nest site selection relative to vegetative characteristics at the nest site. Average vegetation height was correlated with visual obstruction (r = 0.854), so we excluded average vegetation height from our analysis. The groundcover model was the most parsimonious model (w_i = 0.61; Table 2.10) and had an evidence ratio of 2.51 when compared to the second-ranked model. Confidence intervals around odds ratio indicated that percent total ground cover was informative and odds ratios suggested that nests were 1.14 times more likely to occur for every 5% increase in ground cover. Mean percentage of ground cover was 58.4% at nest sites and 49.1% at random sites (Table 2.11).

To evaluate the influence of habitat variables on nest survival, we first excluded from our analysis 3 nests that failed due to observer influence and 2 nests that were predated either prior to or on the day of the onset of continuous incubation. Our final dataset for both the vegetative and landscape scale analyses consisted of 64 nests. Because percent ground cover was the only predictor variable in our top model of nest site selection at the vegetative scale, we developed a Cox proportional hazards model to examine the influence of ground cover on nest survival. At the vegetative scale, percent ground cover influenced nest survival ($\beta = -0.127$; Hazard ratio = 0.881; SE = 0.077; $P = 0.020$). For every 10% increase in percent ground cover, turkey nests were 11.8% more likely to not be predated (Figure 2.3). At the landscape scale, the time-since-fire model was the most parsimonious model followed by the time-since-fire + Julian day model (Table 2.12). Our results suggest that if a turkey nested in a stand burned ≥3 years prior, the nest was 3.4 times more likely to be at risk of predation relative to a stand burned the current year ($P = 0.007$; Table 2.13).

DISCUSSION

Mean incubation dates for initial nest attempts occurred on average 15 days later in 2014. We believe this variation was due to increased precipitation and lower than average temperatures during early spring 2014. Vangilder et al. (1987) found mean initial nest incubation dates in Missouri occurred approximately 2 weeks later in a year of lower than average March temperatures. We observed higher nesting rates relative to other populations in the southeastern United States (see Burk et al. 1990, Palmer et al. 1993, Miller et al. 1998, Thogmartin and Johnson 1999, Moore et al. 2010), and rates of second and third nest attempts were noticeably higher than in the aforementioned studies. Likewise, we observed 1 instance of a fourth nest attempt, which to our knowledge has only been reported once in the literature (Exum et al. 1987). We also observed a female hatching a second brood following loss of the first brood; to our knowledge this has only been documented once in the literature (Sisson et al. 1991*b*). A high propensity to re-nest following nest loss may be an adaptation to life in an ecosystem characterized by frequent disturbance events such as fire. High reproductive effort, in the form of re-nesting, could also result from good physiological condition attributable to quality habitat on site (Miller et al. 1998). Conversely, our findings could be an artifact of our increased ability to monitor movements and reproductive behaviors of females via the use of GPS transmitters (Collier and Chamberlain 2011). Regardless, the turkey population at KNF exhibits a strong reproductive effort throughout a reproductive season extending from late March to as late as August. Although nest success in 2015 was within the range of other studies, nest success in 2014 was among the lowest reported for the eastern subspecies (Vangilder 1992). Annual variability in nest success may be inherent in turkey populations, as Moore et al. (2010) also found that over a span of 4 years, both nesting rates and nest success varied greatly. Predation was the primary cause of nest failure and most brood loss occurred within 2 weeks of hatching when young poults are flightless and most vulnerable to predation (Glidden and Austin 1975, Everett et al. 1980, Speake et al. 1985). High nest predation may have been a result of relatively high predator densities in the area. Although reliable population estimates of nest predators at KNF do not exist, populations of meso-carnivores are believed to have increased during the past few decades (Laliberte and Ripple 2004, Roberts and Crimmins 2010), and increasing abundance of raccoons has been correlated with declines in nest success of low-nesting birds (Gehrt et al. 2002, Schmidt 2003). Although KNF is comprised of relatively large areas of contiguous forest,

forest management practices (i.e., timber thinning) and construction of road networks and firebreaks may promote population increases of, and facilitate effective hunting by, turkey nest predators. Further research on predator communities, and how they influence wild turkey reproductive success, in managed forests of the southeastern U.S. is warranted.

Ground level vegetation was the most important predictor of nest site selection at the vegetative scale. This is not surprising, as most previous studies evaluating vegetative conditions have found nests to be positively associated with density of ground story vegetation (Chamberlain and Leopold 1998, Byrne and Chamberlain 2013, Kilburg et al. 2014, Streich et al. 2015, but see Fuller et al. 2013). However, we did not find visual obstruction at the nest to be an important predictor of nest site selection, contrary to several recent studies (Byrne and Chamberlain 2013, Streich et al. 2015). The importance of visual obstruction as measured at nest sites likely varies across forest types. In the closed canopy bottomland forests studied by Byrne and Chamberlain (2013), understory vegetation was sparse and believed to limit availability of nesting habitat. Similarly, the longleaf pine savanna studied by Streich et al. (2015) featured a more open canopy and was treated with prescribed fire on shorter return intervals (1 to 3 years) than what occurred on KNF. This resulted in a relatively homogenous layer of low, herbaceous vegetation in the understory of pine stands that failed to provide quality nesting cover. Streich et al. (2015) noted that most nests were located outside of pine stands, and that females selected nest sites farther from mature pine stands and closer to shrub/scrub habitats than expected.

We found that proximity to roads most influenced nest site selection at the landscape scale. Previous studies have noted the propensity for turkeys to nest near roads and firebreaks (Hon et al. 1978, Badyaev 1995, Thogmartin 1999, Moore et al. 2010). Although roads through forested areas do not always provide juxtaposition between 2 distinct habitat types, they do typically represent a defined edge. Hence, roads may represent one of several potential resources to reproductively active females. Badyaev (1995) stated that females used roads to travel to and from nests during incubation, which may have reduced noise as compared to travelling through understory vegetation. We offer that roadsides may provide females quality foraging resources as they are typically dominated by herbaceous plant species capable of providing seeds and insects (Hurst and Stringer 1975). Further research is needed to examine the role that roads and travel corridors play in nest site selection. Notably, road networks alter landscapes (Trombulak and Frissell 2000) and can influence movement patterns of predators known to affect turkeys. Coyotes and bobcats are known to travel along roads and other linear landscape features (Bradley and Fagre 1988, Hinton et al. 2015), and black rat snakes have been shown to prefer forest edges, particularly in spring which coincides with avian breeding seasons (Weatherhead and Charland 1985). Indeed, nesting near roads has negatively influenced reproductive success in some turkey populations (Badyaev 1995, Thogmartin 1999). If turkeys select to nest near the habitat edge provided by roads, yet experience higher nest predation in these areas, then roads could represent an ecological trap (Flaspohler et al. 2001, Schlaepfer et al. 2002). Although we found prescribed fire history to be the most important predictor of nest survival at KNF, influences of roads on predator-prey interactions could have relatively greater significance at sites where prescribed fire is not the primary forest management practice.

Females on KNF located nests in forest stands of all burn history categories. However, we observed nearly half the percentage of nests located in stands burned ≥3 years prior as compared to random locations. Conversely, the percentage of nest sites in areas burned 2 years prior was 3 times greater than percentage of random locations in the same areas. The proportion of nest sites in areas burned within the same year or 1 year prior was approximately equal to the proportion of random sites located in those areas. Similarly, both Sisson et al. (1990) and Still and Bauman (1990) found most turkey nests located in stands burned within 2 years. In an insular turkey population of coastal Georgia, females nested in stands burned the current or previous year and avoided nesting in an areas not burned for 15 years (Hon et al. 1978). In Southern pine forests, shrubs and woody vines are prominent 2 years following prescribed fire applications (Hodgkins 1958), whereas in the absence of fire shade-tolerant trees reach the midstory and ground-level vegetation becomes sparse (Lewis and Harshbarger 1976), resulting in poor quality nesting habitat. Our findings corroborate previous research noting that turkeys select nest sites in areas burned 0 to 2 years prior, while avoiding nesting in areas where fire has been excluded for longer periods.

Nest survival was positively correlated with percentage of vegetative ground cover. Previous studies have also noted the link between ground level vegetation and nest survival (e.g. Badyaev 1995, Lehman et al. 2008, Moore et al. 2010) and have attributed the correlation to concealment from nest predators. Similarly, female turkeys at KNF exhibited selection of nest sites with vegetative conditions which resulted in increased nest survival. This observation suggests that female turkeys behaved in a manner which is evolutionarily adaptive.

Time-since-fire application had greater influence on nest survival than habitat type or landscape features, with nests located in stands burned the current year having lowest predation risk and nests in stands burned ≥3 years prior having significantly greater risk of predation. These findings may seem counter-intuitive, as fire disturbance typically reduces ground level vegetation for weeks or months following disturbance. However, effects of prescribed fire are often spatially heterogeneous and areas remain where vegetation is less severely affected. Furthermore, effects of fire on vegetation beyond the nest site may influence predator-prey interactions. For example, raccoons have been shown to forage for artificial nests more efficiently in structurally complex habitat (Bowman and Harris 1980). If fire reduces understory vegetation and creates more homogenous habitat patches, then raccoons and other mammalian carnivores may select unburned stands to forage in. However, fire severity is likely not homogenous throughout burn compartments, which may result in variation in understory species composition and physical structure of residual plants following fire. Because prescribed fires are initiated along firebreaks and move to the interior of burn compartments, fire intensity is typically lower near firebreaks. At KNF, most firebreaks were formed by the network of roads throughout the study site, and an increased density and height of woody vegetation in the understory was noticeable along forest edges bordering roads at KNF. Increased woody cover along roadsides may have been attractive to female turkeys seeking nesting cover, but may also have led to increased nest predation by providing a concentrated search area for predators. Alternatively, increased woody cover along roadsides may have been due to increased light penetration. In either case, the end results on nest site selection and nest predator interactions are the same; negative influences on nest success for females selecting nests near roads. Further research is warranted on predator-prey interactions in landscapes featuring extensive road networks.

MANAGEMENT IMPLICATIONS

Our findings suggest that ground cover vegetation immediately surrounding the nest is an important factor influencing nest site selection by wild turkeys, and that ground level vegetative cover contributes to nest survival. Female turkeys at KNF also selected nest sites near roads, but it is unclear how proximity to roads may influence predator-prey interactions and nest survival.

Our findings also suggest that turkeys would benefit from provision of pine stands burned 2 years prior dispersed throughout the landscape during the nesting period. At KNF, most fires were applied in the late dormant season prior to the nesting period. Therefore, applying fire primarily during the late dormant season at 3-year intervals would result in forests stands burned 0, 1, and 2 years prior available to nesting females. Our findings also suggest that nest survival is lowest in stands not burned for ≥3 years, such that burn rotations of ≥4 years would be detrimental to turkey reproduction Therefore, burning on a 3 year rotation in southeastern pine-dominated forest such as KNF is compatible with turkey reproduction.

We also recommend that future researchers recognize the duration of nesting behaviors in wild turkeys, and hence, the likelihood that females will attempt multiple nests well into summer months. Studies focused on understanding reproductive ecology in wild turkeys should use GPS transmitters to intensively monitor females throughout spring and summer, so that all nesting attempts can be documented and reproductive parameters accurately described.

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Table 2.1. Timing of prescribed fire application at Kisatchie Ranger District (KRD), Winn Ranger District (Winn), and Vernon Ranger District/Fort Polk Wildlife Management Area (V/FP) in west-central Louisiana, USA, 2014 and 2015.

Year[a]	Site	Date range	Mean date
2013-2014	KRD	Jan 16 - May 6	March 7
	Winn	Jan 20 - May 23	March 28
	V/FP	Dec 2 – June 21	Feb 24
	pooled	Dec 2 – June 21	March 7
2014-2015	KRD	Jan 19 – May 7	March 10
	Winn	Jan 19 – May 6	March 7
	V/FP	Oct 17 – May 8	Jan 30
	pooled	Oct 17 – May 8	Feb 15

a. Refers to the annual period of prescribed fire application beginning in late October and extending through early October of the following year. Coincides with the beginning of the dormant period for deciduous forest plants in the southeastern United States and extends through the end of the growing period of the following year.

Table 2.2. Descriptive statistics associated with the prescribed fire regime at Kisatchie Ranger District (KRD), Winn Ranger District (Winn), and Vernon Ranger District/Fort Polk Wildlife Management Area (V/FP) in west-central Louisiana, USA, 2014 and 2015.

Year	Site	Number of burn patches[a]	Total area burned (ha)	Mean burn patch size ± SD (ha)	Minimum burn patch size (ha)	Maximum burn patch size (ha)	Proportion of site burned[b]
2013-2014	KRD	16	8,725	545 ± 414	16	1,567	21.05
	Winn	23	9,532	415 ± 293	7	1,056	14.14
	V/FP	47	21,254	452 ± 260	40	1,085	34.73
	pooled	86	39, 511	459 ± 302	7	1,567	23.23
2014-2015	KRD	17	6,523	383 ± 253	23	868	15.74
	Winn	16	7,969	491 ± 201	221	942	11.82
	V/FP	44	18,110	412 ± 265	13	1,180	29.59
	pooled	77	32, 602	423 ± 250	13	1,180	19.17

a. Adjacent burns conducted on the same day were combined and considered to be a single burn patch.

b. Proportion of public land burned annually at each site (does not account for private lands within proclamation boundary of Kisatchie National Forest).

Table 2.3. Mean date and range of onset of incubation of initial nesting attempts by female eastern wild turkeys at Kisatchie Ranger District (KRD), Winn Ranger District (Winn), and Vernon Unit/Fort Polk WMA (V/FP) in west-central Louisiana, USA, 2014 and 2015.

Year	Site	n[a]	Mean Date	Date Range
2014	KRD	17	7 May	12 April – 3 June
	Winn	6	27 April	20 April – 8 May
2015	Kisatchie	10	16 April	5 April – 24 May
	V/FP	5	26 April	10 April – 14 May
	Winn	2	17 April	11 April – 24 May

a. Number of initial nesting attempts.

Table 2.4. Nesting ecology of female eastern wild turkeys at Kisatchie Ranger District (KRD), Winn Ranger District (Winn), and Vernon Unit/Fort Polk WMA (V/FP) in west-central Louisiana, USA, 2014 and 2015.

Year	Site	n[a]	% Initial nesting (n)[b]	% Initial nest success (n)[c]	% Renest (n)[d]	% Renest success (n)[e]	% Third nest (n)[f]	% Third nest success (n)[g]	% Fourth nest (n)[h]	% Fourth nest success
2014	KRD	21	85.7 (18)	5.9 (1)	60.0 (9)	0	33.3 (2)	0	0.0 (0)	n/a
	Winn	7	85.7 (6)	16.7 (1)	80.0 (4)	0	100.0 (2)	0	50.0 (1)	0
2015	KRD	10	100.0 (10)	33.3 (3)	75.0 (6)	50.0 (3)	60.0 (3)	0	0.0 (0)	n/a
	Vernon	6	66.7 (4)	25.0 (1)	33.3 (1)	0.0 (0)	0	n/a	n/a	n/a
	Winn	2	100.0 (2)	0	100.0 (1)	100.0 (1)	n/a	n/a	n/a	n/a
Pooled sites and years		46	87.0 (40)	15.8 (6)	65.6 (21)	20.0 (4)	50.0 (7)	0.0 (0)	14.3 (1)	0

a. Number of radio-marked females monitored from the earliest known nesting attempt (2014: 12 April; 2015: 5 April).

b. Number of females initiating ≥1 nest.

c. Number of first nest attempts hatching ≥ 1 live poult. Nests suspected of abandonment due to observer influence were censored from success estimates.

d. Number of females initiating a second nest following the loss of a first nest or first brood within 30 days following hatch.

e. Number of second nest attempts hatching ≥ 1 live poult. Nests suspected of abandonment due to observer influence were censored from success estimates.

f. Number of females initiating a third nest following the loss of a second nest or brood within 30 days following hatch.

g. Number of third nest attempts hatching ≥ 1 live poult.

h. Number of females initiating a fourth nest following the loss of a third nest or brood within 30 days following hatch.

Table 2.5. Survival rates of eastern wild turkey broods at Kisatchie Ranger District (KRD), Winn Ranger District (Winn), and Vernon Unit/Fort Polk Wildlife Management Area (V/FP) in west-central Louisiana, USA, 2014 and 2015. Numbers in parentheses correspond to the number of broods (≥ 1 poult) that survived during the time period.

Year	Site	n^a	% Survival days 1-14[b] (*n*)	% Survival Day 15-28[c] (*n*)	% Survival Day 1-28[d] (*n*)
2014	KRD	1	100.0 (1)	100.0 (1)	100.0 (1)
	Winn	1	0.0	---	0.0
2015	KRD	6	16.7 (1)	0.0	0.0
	V/FP	1	100.0 (1)	100.0 (1)	100.0 (1)
	Winn	1	100.0 (1)	100.0 (1)	100.0 (1)
Pooled sites and years		10	40.0 (4)	75.0 (3)	30.0 (3)

a. Number of broods successfully hatched

b. Percentage of broods that survived to 14 days post-hatch.

c. Percentage of broods alive at 14 days post-hatch that survived to 28 days post-hatch.

d. Percentage of broods that survived to 28 days post-hatch.

Table 2.6. Time-since-fire at nest sites selected by female eastern wild turkeys and at random sites at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Fire history[a]	% Nest sites (n^b)	% Random sites (n^b)
Burn 0	21.3 (13)	20.6 (70)
Burn 1	31.1 (19)	28.5 (97)
Burn 2	21.3 (13)	6.8 (23)
Burn 3	26.2 (16)	44.1 (150)

a. Fire history categorized as burned within the current annual prescribed fire application period (October – May; Burn 0), 1 year prior (Burn 1), 2 years prior (Burn 2), and ≥3 years prior (Burn 3).

b. Number of nest and random sites in each burn category. Random locations were generated at a ratio of 5 random to 1 nest site.

Table 2.7. Landscape-level models associated with nest site selection of female eastern wild turkeys at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Model[a]	K^b	$AICc^c$	$\Delta AICc^d$	Adjusted[e] w_i	LL[f]
GLOBAL	8	356.98	0.00	0.341	-170.31
HW+MPH+ROAD	4	357.87	0.89	0.219	-174.89
ROAD+MPH	3	359.04	2.05	0.122	176.49
SOFT EDGE	2	359.72	2.74	0.087	-177.85
OPEN+ROAD	3	359.84	2.86	0.082	-176.89
ROAD	2	360.11	3.12	0.071	-178.04
MP+MPH+ROAD	4	360.97	3.99	0.046	-176.44
MP+ROAD	3	361.88	4.89	0.030	-177.91
HW	2	369.07	12.09	0.001	-182.52
MPH	2	369.19	12.21	0.001	-182.58
NULL	1	369.67	12.68	0.001	-183.83
OPEN	2	369.94	12.95	0.001	-182.95
MP	2	370.04	13.05	0.001	-183.00
YP	2	371.59	14.60	0.000	-183.78

a. Landscape level variables within models include distances to hardwood (HW), mature pine (MP), mixed pine-hardwood (MPH), open habitat (OPEN), nearest road (ROAD), edge between forested habitats (SOFT EDGE), and young pine (YP).

b. Number of variables (K).

c. Second-order Akaike's Information Criterion (AIC*c*).

d. Distance from the second-order AIC*c* of the top-performing model.

e. Adjusted Akaike weight of evidence (w_i) in support of model.

f. Log-likelihood (LL).

Table 2.8. Parameter estimates from the most parsimonious model used to predict nest site selection of female eastern wild turkeys relative to landscape variables at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Parameter[a]	Estimate[b]	SE[c]	Scaler[d]	Scaled odds ratio	Scaled lower 85% odds ratio	Scaled upper 85% odds ratio
ROAD[e]	-0.297	0.101	100	0.743	0.645	0.856
SOFT EDGE[e]	0.245	0.101	100	1.277	1.104	1.477
OPEN	-0.039	0.027	100	0.962	0.925	1.001
HW	0.020	0.018	100	1.020	0.994	1.047
MPH	0.014	0.058	100	1.014	0.933	1.102
YP	-0.005	0.013	100	0.995	0.977	1.014
MP	0.001	0.138	100	0.999	0.820	1.219

a. Landscape level variables within models include distances to hardwood (HW), mature pine (MP), mixed pine-hardwood (MPH), open habitat (OPEN), nearest road (ROAD), edge between forested habitats (SOFT EDGE), and young pine (YP).

b. Parameter estimate on logit scale.

c. Standard error (SE) of the estimate.

d. Biologically relevant scaler in meters (m).

e. Statistically informative predictor variable based on 85% confidence intervals around odds ratio.

Table 2.9. Distances (m) from eastern wild turkey nest sites and random sites to landscape features and habitat types at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Predictor variable[a]	Nest sites ($\bar{x}$ ± SE)	Random sites ($\bar{x}$ ± SE)
ROAD[b]	144.6 ± 20.0	224.2 ± 10.7
SOFT EDGE[b]	233.5 ± 21.0	158.2 ± 8.1
OPEN	847.5 ± 69.0	945.3 ± 30.3
HW	885.6 ± 130.0	702.3 ± 40.4
MPH	351.3 ± 27.9	284.8± 17.4
YP	1071.4 ± 152.6	1122.6 ± 66.9
MP	37.6 ± 12.7	59.8 ± 8.4

a. Landscape-level variables include distances to hardwood (HW), mature pine (MP), mixed pine-hardwood (MPH), open habitat (OPEN), nearest road (ROAD), edge between forested habitats (SOFT EDGE), and young pine (YP).

b. Statistically informative predictor variable based on 85% confidence intervals around odds ratio.

Table 2.10. Models using vegetative conditions associated with nest site selection of female eastern wild turkeys at Kisatchie National Forest, west-central Louisiana, 2014 and 2015.

Model[a]	K[b]	AICc[c]	ΔAICc[d]	Adjusted[e] w_i	LL[f]
GC	2	184.37	0.00	0.613	-90.14
GC+VO	3	186.20	1.84	0.244	-90.01
Global	5	188.83	4.46	0.066	-89.18
Null	1	190.57	6.20	0.028	-94.27
TPH	2	191.15	6.78	0.021	-93.53
VO	2	191.28	6.91	0.019	-93.59
CC	2	192.62	8.25	0.010	-94.26

a. Variables within models included percent canopy cover (CC), percent total ground cover vegetation (GC), trees per hectare (TPH), and lateral visual obstruction (VO).

b. Number of variables (K).

c. Second-order Akaike's Information Criterion (AICc).

d. Distance from the second-order AICc of the top-performing model.

e. Adjusted Akaike weight of evidence (w_i) in support of model.

f. Log-likelihood (LL).

Table 2.11. Mean values of vegetative characteristics of female eastern wild turkey nest sites (*n* = 68) and random sites (*n* = 68) at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Predictor variable[a]	Nest sites ($\bar{x}$ ± SE)	Random sites ($\bar{x}$ ± SE)
GC[b]	58.8 ± 2.2	49.3 ± 2.4
VO	95.9 ± 5.7	86.0 ± 6.5
TPH	333.7 ± 26.4	385.0 ± 33.7
CC	76.9 ± 2.3	76.6 ± 2.3

a. Micro-habitat scale predictors include percent total ground cover vegetation (GC), lateral visual obstruction (VO), trees per hectare (TPH), and percent canopy cover (CC).

b. Statistically informative predictor variable based on 85% confidence intervals around odds ratio.

Table 2.12. Time-since-fire, distance to nearest road and soft edge, and Julian day models associated with eastern wild turkey nest survival at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Model	*K*[a]	AICc[b]	ΔAIC_c	Adjusted w_i[d]	LL[e]	Relative Likelihood
Time-since-fire[f]	3	226.73	0.00	0.45	-110.13	1.00
Null	0	228.85	2.12	0.16	-114.42	0.35
Julian day	1	228.93	2.20	0.15	-113.43	0.33
Distance to soft edge (m)[g]	1	229.55	2.82	0.11	-113.74	0.24
Distance to roads (m)	1	230.17	3.44	0.08	-114.05	0.18
Global model[h]	4	230.78	4.05	0.06	-108.50	0.13

a. Number of variables (*K*).

b. Second-order Akaike's Information Criterion (AIC*c*).

c. Distance from the second-order AIC_c of the top-performing model.

d. Akaike weight of evidence (w_i) in support of model.

e. Log-likelihood (LL).

f. Time since fire application at nest site measured as a categorical variable with 4 levels: 0, 1, 2, and ≥3 years.

g. Linear distance to nearest boundary between 2 distinct forest types

h. Global model: Time-since-fire + Julian day + Distance to nearest road + Distance to soft edge

Table 2.13. Results of Cox proportional hazards models of risk of eastern wild turkey nest failure at Kisatchie National Forest in west-central Louisiana, USA, 2014 and 2015. Models are listed in order of rank from AIC*c* model selection.

Model	β	SE	*P*	Hazard ratio	Hazard ratio CI	
					Lower 95%	Upper 95%
Time-since-fire						
1 year	0.486	0.382	0.204	1.626	0.768	3.344
2 years	0.529	0.489	0.279	1.698	0.651	4.428
≥3 years	1.233	0.459	0.007	3.431	1.396	8.433
Julian day	0.028	0.020	0.164	1.029	0.989	1.070
Distance to soft edge (m)	-0.103	0.106	0.331	0.902	0.733	1.111
Distance to roads (m)	0.072	0.067	0.285	1.075	0.942	1.226
Global model						
Time-since-fire						
1 year	0.685	0.441	0.121	1.983	0.836	4.706
2 years	0.855	0.533	0.108	2.353	0.828	6.681
3 years	1.302	0.489	0.007	3.678	1.408	9.609
Julian day	0.019	0.021	0.378	1.019	0.978	1.062
Distance to nearest road	0.137	0.081	0.091	1.147	0.978	1.345
Distance to soft edge	-0.037	0.106	0.731	0.964	0.783	1.188

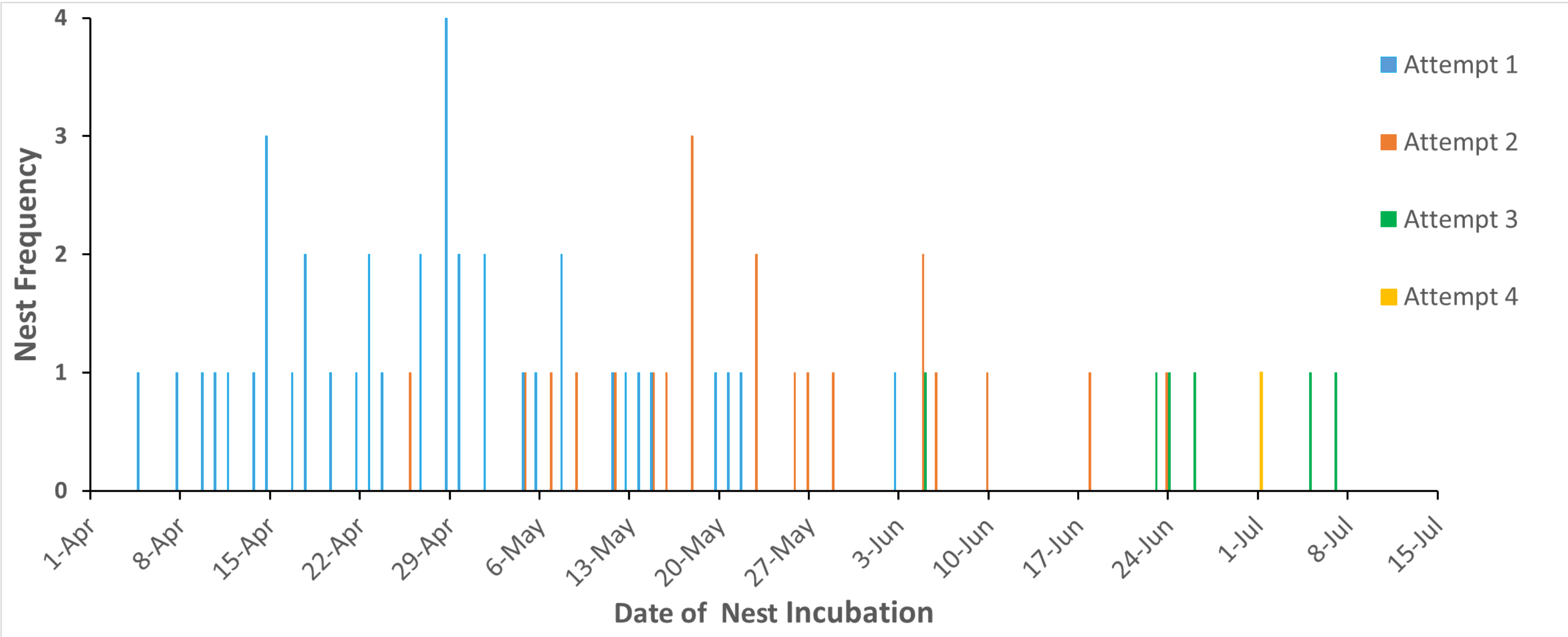

Figure 2.1. Chronology of onset of nest incubation for female eastern wild turkeys at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015. Nests classified as first nest attempt (Attempt 1), second nest attempt (Attempt 2), third nest attempt (Attempt 3), or fourth nest attempt (Attempt 4).

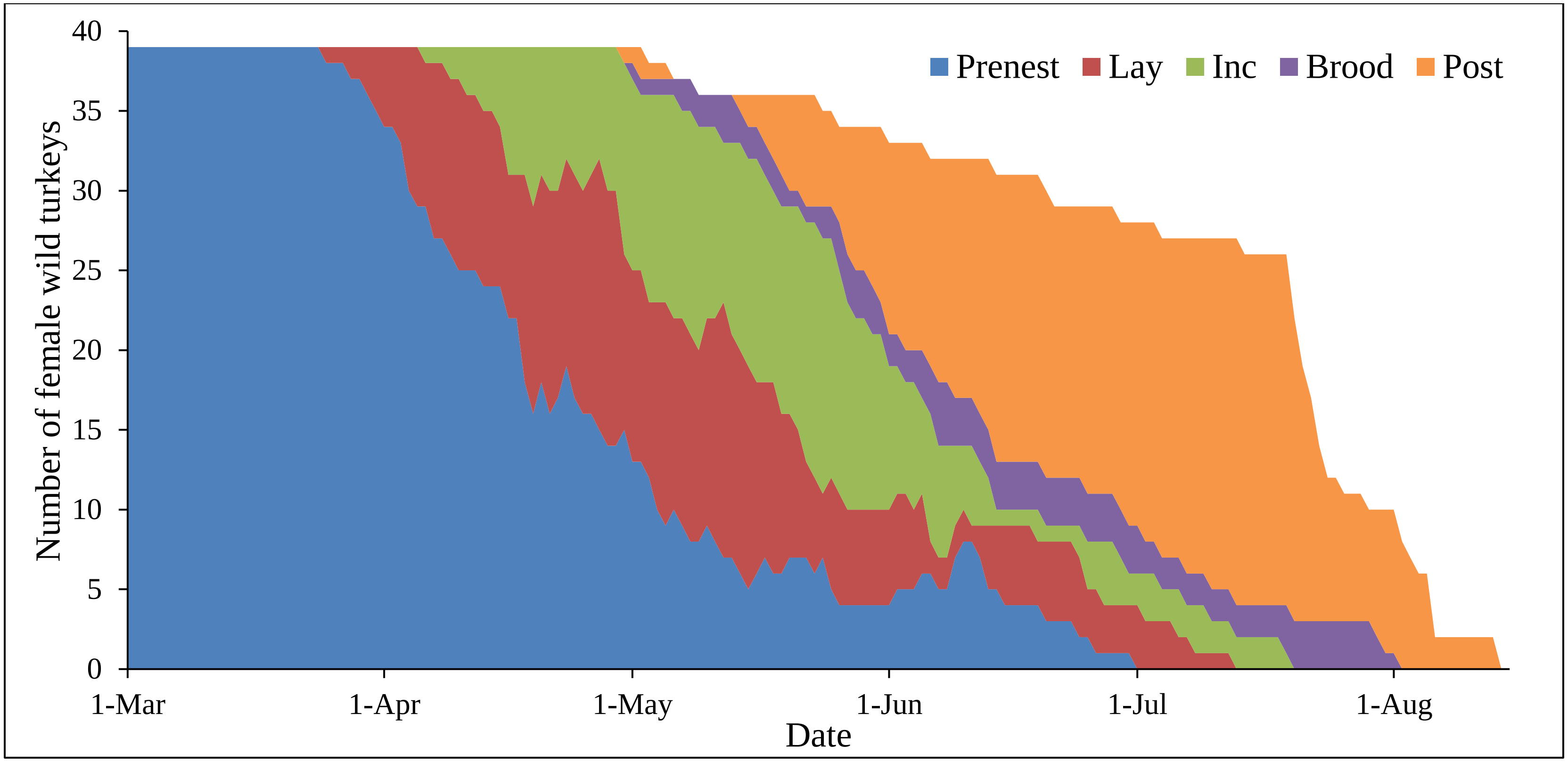

Figure 2.2. Chronology of female eastern wild turkey reproductive activity at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015. Reproductively active females were grouped into the following categories based on reproductive phenology: prior to initiating first nest attempt (Prenest), following nest failure or brood loss and prior to a subsequent nest attempt (Prenest), laying a clutch associated with any nest attempt (Lay), incubating a nest (Inc), brood-rearing (Brood), and following all nest attempts or after surviving poults reach 56 days old (Post).

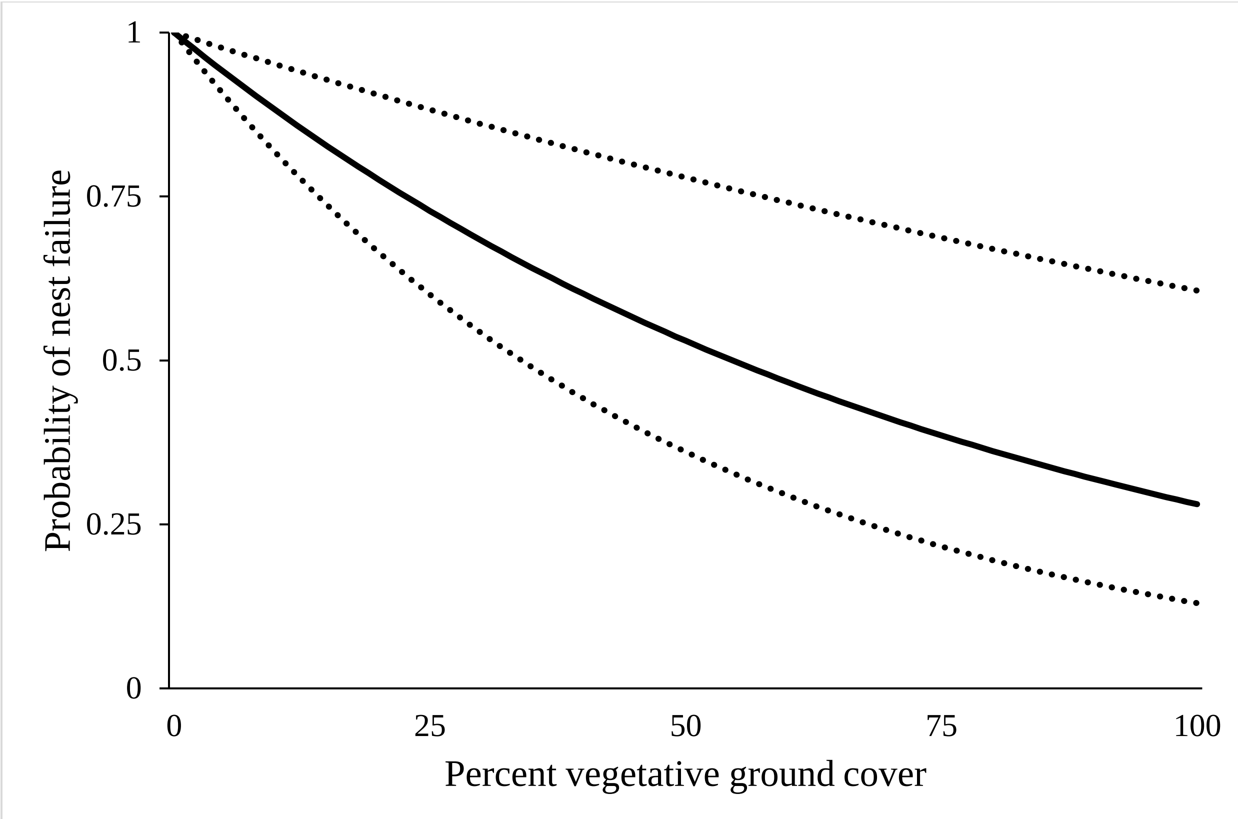

Figure 2.3. Predicted probability of female turkey nest failure as a function of the overall percent of vegetative ground cover at the nest site. Female turkeys were captured at sites within the Kisatchie National Forest in west-central Louisiana, USA, and each of their nesting attempts was monitored for failure or successful hatch in 2014 and 2015. Solid line represents predicted probability of nest failure based on parameter estimates from Cox proportional hazards model of nest failure as a function of ground cover. Dashed lines represent 95% confidence intervals around the estimate.

CHAPTER 3

SPACE USE AND HABITAT SELECTION OF FEMALE EASTERN WILD TURKEYS DURING THE REPRODUCTIVE PERIOD

[1] Yeldell, N. A., B. S. Cohen, T. J. Prebyl, B. A. Collier, and M. J. Chamberlain. To be submitted to the *Journal of Wildlife Management*.

ABSTRACT

Prescribed fire is widely used in southeastern pine forests to maintain desirable forest conditions and provide early successional habitat. However, it is unclear how fires applied prior to and during the reproductive cycle of upland birds influences resource use throughout reproductive cycles. We examined the influence of prescribed fire on habitat selection of female eastern wild turkeys (*Meleagris gallopavo silvestris*) throughout the reproductive cycle at Kisatchie National Forest in west-central Louisiana, USA. Kisatchie was dominated by pine stands managed with prescribed fire on a 3-5 year rotation. We used distance-based analysis to calculate habitat selection ratios relative to reproductive phenology of individual females. Prior to initiating first nests, females selected hardwoods and avoided mature pines burned 2 years prior. Females selected mature pines burned within the same year while laying their first clutch, and mixed pine-hardwoods and open habitats when laying their second clutch and after all reproductive activity ended. Females with broods avoided hardwoods. Our findings suggest that turkeys use pine stands burned both during the current year, and in years prior, but that selection varies throughout the reproductive cycle. We recommend maintaining landscape diversity through retention of hardwoods, maintenance of forest openings, and application of prescribed fire at 3-year intervals to benefit turkeys in southeastern pine forests.

INTRODUCTION

The eastern wild turkey (*Meleagris gallopavo silvestris*; hereafter, turkey) is a socially and economically valuable game species found throughout the eastern United States (U.S. Fish and Wildlife Service 2010, Eriksen et al. 2015). Wild turkeys occupy a variety of habitats within their range (Porter 1992), including Southeastern pine-dominated forests (Hurst and Dickson 1992). Pine ecosystems are often managed with prescribed fire, and therefore are characterized by frequent disturbance events. Fire disturbance increases landscape heterogeneity by creating a mosaic of seral stages (Sousa 1984, Turner et al. 2001) which in turn provides diverse wildlife habitat (Van Lear and Harlow 2000). Fire events alter vegetation structure by removing standing biomass of grasses, herbaceous plants, and woody shrubs and tree saplings in the lower forest strata (Bendell 1974). Prescribed fire in Southeastern pine forests is applied to upland pine stands during the dormant season (October – March) and growing season (April – September) to reduce fuel loads (DeBano et al. 1998), promote the establishment and growth of longleaf pine (*Pinus palustris*; Garren 1943), inhibit growth of undesirable hardwood trees (Lotti 1955, Hodgkins 1958), and improve wildlife habitat (Stoddard 1935; Lay 1956, 1967). Dormant season fires often occur immediately prior to the reproductive period of wild turkeys (April – July) and therefore may influence the distribution of suitable habitat when females are nesting and brooding. Prescribed fire in pine forests typically benefits female turkeys by increasing suitability of nesting habitat for up to 3 years post-fire (Hon et al. 1970, Burk et al. 1990, Sisson et al. 1990, Still and Bauman 1990) and promoting herbaceous plant communities used by broods (Hurst and Stringer 1975, Hurst 1978, Metzler and Speake 1985, Campo et al. 1989). Frequency of fire disturbance influences brood habitat quality, as brood hens select pine stands burned within 4 years (Hon et al. 1970, Burk et al. 1990, Jones et al. 2005). Conversely, in pine forests burned on 4-7 year rotations, brooding females avoided pine stands and selected hardwood habitat with moderate understory vegetation density (Phalen et al. 1986, Miller et al. 1999, Jones et al. 2005).

Female turkeys select nest sites with abundant visual cover provided by understory vegetation (Byrne and Chamberlain 2013, Streich et al 2015) which is positively associated with higher nest success (Badyaev 1995, Nguyen et al. 2004, Lehman et al. 2008). Therefore, a temporary reduction in nesting cover resulting from fire disturbance has potential to influence reproductive success in the days or weeks following fire. Further, growing season fires may coincide with turkey nesting and have both direct and indirect effects on reproductive success. Concerns have been raised over the potential destruction of turkey nests by growing season fires (Stoddard 1935, Sisson and Speake 1994). However, recent research in fire-managed pine ecosystems found minimal turkey nest loss due to fire (Moore et al. 2010, Kilburg et al. 2014, Little et al. 2014), suggesting that growing season fire application is compatible with turkey management.

The influence of prescribed fire on turkey habitat use prior to and during the reproductive period is not fully understood, and use of fire-influenced habitats may vary among distinctive phases of the reproductive period. Female turkeys in frequently-burned pine savannas used burned areas immediately after fire application and avoided areas burned ≥2 years prior throughout the entire reproductive period (March – October; Martin et al. 2012), whereas turkeys are known to avoid recently burned pine stands during winter (Sisson et al. 1990). However, fire frequency, timing of application, fire behavior, pre-fire plant communities, and fuel characteristics influence post-fire vegetation dynamics (Bendell 1974, DeBano et al. 1998). Hence, wildlife responses to fire disturbance may be site-specific and influenced by unique characteristics of individual fires.

The recent development of GPS-equipped transmitters for use with wild turkeys has enhanced our ability to describe behavior, particularly space use and movement ecology (Collier and Chamberlain 2010; Kie et al. 2010; Guthrie et al. 2011; Byrne et al. 2014, 2015). Because refinements in estimates of space use incorporate temporal information to create utilization distributions, researchers can now calculate more accurate estimates of habitat use (Walter et al.

2015). Specifically, estimators such as dynamic Brownian bridge movement models (Kranstauber et al. 2012) and movement-based kernel density estimators (Benhamou and Cornélis 2010) provide more reliable estimates of area used by individual animals. Hence researchers can better assess preference and avoidance of different habitats. However, previous studies of resource selection by turkeys have often used minimum convex polygons or kernel density methods (e.g., Holbrook et al. 1987, Bidwell et al. 1989, Palmer et al. 1996). These estimates of space use tend to overflow into never-visited areas and possibly bias estimates of habitat selection (Benhamou and Cornélis 2010). Furthermore, past studies have analyzed habitat use across relatively coarse temporal seasons relative to the reproductive phenology of individuals (e.g., Holbrook et al. 1985, 1987; Stys et al. 1992, Miller and Conner 2007). In contrast, high temporal resolution GPS data allows researchers to more accurately describe reproductive behaviors of individual turkeys. The importance of recognizing individual phenology is evident when considering the significant variation in reproductive effort by individual female turkeys (see Chapter 2). By incorporating individual variation in reproductive phenology into an assessment of space and resource use, we can improve our understanding of habitat selection and potential influences of fire disturbance on wild turkey behavior.

Our objective was to examine space use and habitat selection by female wild turkeys on a landscape managed with prescribed fire. We sought to examine habitat selection during specific phases of the reproductive cycle for each female. We predicted that during pre-nesting, females would select hardwoods and mixed pine-hardwood habitats, while avoiding recently burned areas. Similarly, we predicted that females in the laying phase would avoid recently burned areas and select pine habitats burned 2 to 3 years prior because of availability of dense understory vegetation in these habitats. Finally, we predicted that brooding females would select hardwood stands and mature pine stands burned ≤2 years prior.

STUDY AREA

We conducted research on Kisatchie National Forest (KNF) and Fort Polk Wildlife Management Area (WMA) in west-central Louisiana. Both sites were characterized by pine-dominated forest, with some mixed pine-hardwood stands, hardwood-dominated stands, and smaller non-forested habitats interspersed throughout. Prescribed fire was a primary forest management practice, as well as timber thinning and timber stand improvement. See Chapter 2 for a more detailed description of the study area.

METHODS

We captured female turkeys using rocket nets during January – March of 2014 and 2015. We fitted each female with a GPS transmitter equipped with a VHF beacon. Turkey capture, handling, and marking procedures were approved by the Institutional Animal Care and Use Committee at the University of Georgia (protocol #A3437-01). See Chapter 2 for a more detailed description of methods of turkey capture and monitoring throughout the study period.

Reproductive Phases

We examined GPS locations of each female to determine reproductive status. We defined nest initiation as the first day a female began laying eggs in a nest and considered females that initiated ≥1 nest as reproductively active, whereas females that did not appear to initiate a nest were reproductively inactive. We delineated up to 8 reproductive phases for each reproductively active female based on individual phenology. The PRENEST1 phase began on the date of capture (range: 16 Jan to 3 March) and ended upon initiation of the first nest, PRENEST2 phase began upon failure of the first nest or loss of brood and ended upon initiation of the second attempted nest, and PRENEST3 phase began upon failure of the second attempted nest or loss of brood and ended upon initiation of a third attempted nest. The LAY1, LAY2, and LAY3 phases referred to females laying eggs in the first, second, and third attempted nest, respectively. Because turkeys lay approximately 1 egg per day (Williams et al. 1971) and the eastern wild turkey lays an average clutch size of 12 eggs (Vangilder 1992), we estimated that the laying sequence began 12 days prior to the onset of nest incubation. Thus, the laying period for each attempted nest was 12 days long. The incubation phase began the day following the onset of nest incubation and lasted until nest termination. For any female that was successful in hatching a brood, we defined the brood-rearing phase as extending from the day of hatch to 56 days post-hatch as long as ≥1 surviving poult was present. The post-nesting phase began following the last day of nest incubation or brood-rearing. Following a nest failure, a female either entered the post-nesting phase or another pre-nesting phase if a subsequent nest was attempted.

Habitat Delineation

We delineated major habitat types using forest inventory data from the US Forest Service, the US Army Environmental and Natural Resources Division, and local timber companies. We used this data to develop a map of major habitat types, including mature pine, young pine, mixed pine-hardwood, hardwood, open habitat, wetlands, and developed areas. See Chapter 2 for a more detailed description of methods of delineating habitat types.

We obtained spatial data displaying history of prescribed fire application throughout our study area from public land management agencies and private timber companies. We used these data to create a map of fire events which occurred during the study period and 4 years prior to the beginning of each year of our study. We combined fire history data with our land cover map to distinguish between areas that had and had not been burned in recent years. Because prescribed fires affect drier, upland pine stands more severely than mesic, hardwood lowlands and mixed pine-hardwood drainages, we only incorporated fire history into our delineation of mature pine stands. We categorized mature pine stands as burned within 1 year but after the previous growing season (MP0), burned approximately 1 year prior (MP1), burned 2 years prior (MP2), or burned ≥3 years prior or having no known recent fire application (MP3).

*Habitat Availability and Us*e

We examined third-order habitat selection (Johnson 1980) in a use vs. availability framework similar to Manly et al. (2002) study design III. Because fire disturbance alters vegetation structure and may affect availability of suitable habitat, we estimated daily habitat selection by calculating daily utilization distributions and comparing them to each individual turkey's home range. Specifically, we defined available habitats as those within each turkey's home range and defined used habitats as those within each core area of use. We estimated 95% (home range) and 50% (core area) utilization distributions using dynamic Brownian bridge movement models (dBBMM). We used a window size of 15, a margin of 5, and a location error of 21 m as input parameters for the dBBMM. We calculated each home range as the 95% dBBMM utilization distribution (UD) built around locations collected from the time of capture throughout the lifetime of the transmitter. We then calculated daily core areas of use as 50% dBBMM UDs built around locations collected from 0000 to 2359 each day.

To calculate habitat selection ratios, we used Euclidean distance analysis with a systematic sampling of habitats within each area of use as described by Benson (2013) to produce raster grids of distances to each habitat class with a pixel size of 10 m. For each day of the study period, we updated our map of fire history according to application of prescribed fires. We then measured habitat use within each daily core area and measured habitat availability within each home range. We calculated the mean for these daily habitat use and availability values, as measured by distances to each habitat class, to produce a mean use and availability measurement for each reproductive phase or season for each turkey. To draw inference about habitat use at the population level, we then pooled selection ratios of each turkey during each reproductive phase and calculated a mean selection ratio respective to each phase. We estimated 95% confidence intervals around population level selection ratios and considered ratios with confidence intervals excluding one to be statistically informative. We chose not to analyze habitat selection of incubating females because we had already examined the influence of habitat type, landscape features, and vegetative characteristics on nest site selection previously (see Chapter 2).

To test for non-random habitat use, we created distance ratios (mean observed distance/mean expected distance) relative to each habitat type for each turkey during each reproductive phase or season. Within this framework, a selection ratio approximately equal to 1.0 indicated use proportional to availability (i.e. random use), whereas a ratio <1.0 indicated selection of habitats and a ratio >1.0 indicated avoidance of habitats (Conner et al. 2003). In the event that a female raised 2 broods from 2 separate nest attempts within the same year, we pooled data from the 2 brood-rearing periods and calculated a temporally weighted average estimate of core area space use and a mean habitat selection ratio during the brood-rearing phases. To make inferences of habitat selection at the population level, we calculated the mean selection ratio relative to each habitat type during all reproductive phases. We considered any estimated selection ratios with 95% confidence intervals excluding one to be informative.

RESULTS

We based our results on data collected from 46 female turkeys captured and radio-marked in the winters of 2014 and 2015. We observed 87.0% (*n* = 40) of females initiate ≥1 nest whereas 13.0% (*n* = 6; 3 adult and 3 juvenile) did not initiate a nest (see Chapter 2 for detailed reproductive data). We observed 40 initial nesting attempts, 21 second nest attempts, 7 third nest attempts, and 1 fourth nest attempt. In 2015, we observed 1 female initiate a second nest and successfully hatch a second brood following the loss of her first brood.

Due to transmitter malfunctions, we were unable to estimate 50% core areas of 1 reproductively active female during the PRENEST1 phase; thus, we estimated core areas used during the PRENEST1 and LAY1 phases for 39 of 40 individuals that initiated a first nest. Likewise, transmitter failure prevented estimation of core areas used by 1 female during the LAY2 phase; thus, we estimated core areas used during the LAY2 phase for 20 of the 21 individuals that initiated a second nest. We estimated core areas used during the PRENEST3 and LAY3 phases for 7 individuals that initiated a third nest. Mean core area sizes during pre-nesting phases were 62.9 ha, 54.1 ha, and 78.0 ha for PRENEST1, PRENEST2, and PRENEST3 phases, respectively (Table 3.1). Mean core area sizes during laying phases were 31.5 ha, 34.0 ha, and 45.2 ha for LAY1, LAY2, and LAY3 phases, respectively (Table 3.1). We excluded the fourth nest attempt from the single bird that initiated 4 nests from our analysis. Because we did not expect space use to vary significantly by nest attempt, we pooled all nest attempts to estimate space use during the incubation phases. Four females initiated nests but never began continuous incubation due to predation or nest abandonment. Transmitter malfunctions prevented us from estimating space use during the incubation phase associated with 4 nest attempts. Thus, we estimated core areas used during the incubation phases associated with 61 nests. Mean core area size during incubation was 0.25 ha (0.03 SE). We estimated core areas used during the brood-rearing periods associated with 10 broods from 9 individual females. Mean size of core areas used during brood-rearing periods was 11.6 ha, whereas mean size of core areas used by reproductively active females after cessation of reproductive activity was 52.4 ha (n = 31; Table 3.1).

During PRENEST1 (15 February – 22 May), females selected hardwoods and avoided mature pines burned 2 years prior (Figure 3.1; Table 3.2). We did not detect significant habitat selection during the PRENEST2 (12 April – 12 June) or PRENEST3 (17 May – 30 June) phases. During LAY1 (25 March – 3 June), females selected mature pines burned the previous winter (Figure 3.2). While laying eggs of a second nest attempt (LAY2; 18 April – 24 June), females selected mixed pine-hardwood habitat and open habitats (Figure 3.2). We did not detect significant habitat selection during the LAY3 (25 May – 12 July) phase. During the brood-rearing phase (1 May – 1 August), females avoided hardwood habitats (Figure 3.3). Selection ratios suggested that brooding females avoided mature pine burned ≥3 years prior, but effects were marginally insignificant (Figure 3.3). Following the cessation of all reproductive activity (28 April – 13 August), females selected mixed pine-hardwood habitat and open habitats (Figure 3.4).

DISCUSSION

Our findings suggest that prescribed burning, and the associated fire history, influences resource selection seasonally. Moreover, we observed that use of mature pine stands managed with prescribed fire varied relative to reproductive phenology of individual birds. However, selection ratios relative to pine stands with various burn histories were not significant in all reproductive phases, suggesting that selection is not uniform throughout the reproductive period.

Alternatively, insignificant selection ratios during reproductive phases which occurred later in the reproductive period (i.e. PRENEST2, PRENEST3, LAY2, and LAY3) may have resulted from smaller sample sizes of females in those phases.

Wild turkeys generally benefit from a diversity of habitats capable of fulfilling needs throughout their annual cycle (Holbrook 1973, Hurst and Dickson 1992), and our results show a similar pattern. We found that females selected hardwoods prior to initiating first nest attempts, which coincided with late winter and early spring. Use of hardwood habitats during this time was likely due to availability of residual hard mast, an important component in turkey diets in winter (Schemnitz 1956; Kennamer et al. 1980*a*, b; Kurzejeski and Lewis 1990) and spring (Exum et al. 1987). Conversely, females avoided mature pine stands burned 2 years prior to initiating first nests, which may be related to density of woody understory vegetation in these areas. Previous research in fire-influenced pine forests also noted an avoidance of pine habitats left unburned for 1 to 3 years (Sisson et al. 1990). Dense understory vegetation in 2 year roughs may impede or deter movement of turkeys. Alternatively, dense vegetation may increase predation risk by ambush predators (e.g. bobcat) which select habitats with dense understory vegetation (Rolley and Ward 1985, Kolowski and Woolf 2002).

Contrary to our prediction that females would select pine habitats burned ≥2 years prior while laying eggs, females laying their first clutch selected pine stands burned within the current year, which was 0 to 5 months prior to the laying period. Our prediction was based on the assumption that females laying eggs would be located closer to habitats that provided adequate nesting cover and that nesting cover would be found in mature pine stands burned ≥2 years prior. However, females typically spend <1 hour at the nest site when depositing individual eggs early in the laying sequence (Williams et al. 1971). Therefore, females may travel to adjacent habitats to meet nutritional and social needs while not depositing eggs. This may explain why we observed females selecting recently burned pine habitat while laying eggs despite the fact that only 19.1% of nests were located in recently burned stands (see Chapter 2). We suspect the selection of recently burned pines during the initial laying period was related to forage availability. Most females laid their first clutch during spring green-up, when herbaceous vegetation had begun growing in areas burned during late winter and early spring. Herbaceous vegetation, particularly grasses, comprise a substantial component of turkey diets (Dalke et al. 1942, Glover and Bailey 1949, Schemnitz 1956, Exum et al. 1987) and turkeys likely feed on young shoots of grasses that emerge following prescribed fires. Furthermore, improved access to food items remaining in forest stands after fire disturbance may increase attractiveness of burned stands to turkeys (Martin et al. 2012). Conversely, we noted that females laying their second clutch (which occurred during 18 April – 24 June) selected mixed pine-hardwood stands and open habitats. Wild turkey use of open habitats in spring and summer has been widely documented (Lewis 1964, Kurzejeski and Lewis 1990, Sisson et al. 1990) and is likely attributable to presence of quality food resources (Dalke et al. 1942, Glover and Bailey 1949, Schemnitz 1956). Resource use while laying first and second clutches may have both been influenced by food availability, but variation in resources used may have been related to plant phenology. Alternatively, mixed pine-hardwood stands on our study area were primarily found along creek drainages, which are known to provide roosting sites in pine-dominated landscapes (Chamberlain et al. 2000) as well as travel routes (Palmer et al. 1996).

Females with broods avoided hardwoods, which was surprising given previous work in pine-dominated systems which noted selection of hardwoods by females following nest incubation (Phalen et al. 1986, Miller et al. 1999, Jones et al. 2005). The differences in findings are likely attributable to differences in analytical methods used to examine habitat selection. Phalen et al. (1986) considered the entire study area as available habitat to brooding hens, whereas we considered only habitats within individual female home ranges as available. Similarly, Miller et al. (1999) found females selected mature hardwood habitat at all spatial scales following cessation of nest incubation, but did not distinguish between females with and without broods. Furthermore, Miller et al. (1999) relied on VHF location data and used 95% minimum convex polygons as home range estimates. By comparison, we defined our reproductive phases based on known periods for each individual and not using calendar dates. Also, we estimated use via a mechanistic model which incorporated temporal structure of GPS data to more precisely estimate probability of use, enabling us to more accurately assess preference and avoidance of habitats (Horne et al. 2007). Importantly, pine stands in the aforementioned studies were managed with relatively infrequent fire (4-7 year return intervals) and generally characterized by a dense understory. Hardwoods on our study site were primarily located in lowland areas, and were characterized by closed canopies, a prominent midstory, and a lack of understory vegetation found in upland pine stands managed with fire. The lack of herbaceous plants in hardwood habitats likely influenced the observed avoidance by females with broods, as herbaceous plants are important to brooding females (Metzler and Speake 1985, Peoples et al. 1995). However, it is worth noting that our results of brood habitat selection were based on a relatively small sample size of 10 broods. Furthermore, we observed low brood survival (see Chapter 2), such that brooding females may not have had sufficient time to shift from nesting habitat to brood-rearing habitat.

Following the cessation of all reproductive activity, females selected mixed pine-hardwood and open habitats. Open habitats provide important food resources in the form of insects, green foliage, soft mast, and grass seeds (Baughman and Guynn 1993). We speculate that selection of mixed pine-hardwood stands during this time is also attributable to favorable roost locations (Chamberlain et al. 2000) and preferred travel corridors (Palmer et al. 1996), but it may also be related to lower ambient temperatures present under the more closed canopies found in mixed pine-hardwood stands compared to other forested habitats.

Our findings suggest that turkeys in pine-dominated forest ecosystems managed with fire use a diversity of habitat types during the reproductive cycle. Across most habitats, and specific to the time since fire, selection and avoidance changed depending on reproductive phenology of individual females. A notable exception to this generalization was that pines in the 5-19 year age class and mature pines burned ≥2 years prior were not selected. Our results support the long-standing recommendation that turkeys benefit from habitat diversity within forested landscapes, and that habitat quality in upland pine forests is improved by application of prescribed fire.

MANAGEMENT IMPLICATIONS

Our findings suggest that female eastern wild turkeys in Southeastern pine forests select a variety of habitat types throughout the reproductive period. We recommend managers retain hardwood and mixed pine-hardwood stands in pine-dominated landscapes to provide habitats during winter and throughout portions of the reproductive cycle. Mature pine stands burned within the current year were not selected prior to first nest initiation, which generally coincided with late winter and early spring (February and March). However, selection increased during subsequent periods of reproductive activity, which generally occurred later in spring and summer (April – July). Therefore, dormant season prescribed fire should be applied in March, rather than early winter, to avoid creating undesirable winter habitat. Our findings suggest that turkeys will avoid pine stands with a burn rotation longer than 3 years, hence managers in systems such as those we studied should recognize that shorter burn rotations are necessary if turkey use of burned stands is desired. Our findings suggest that maintaining open habitats is important for turkeys existing in primarily forested landscapes, particularly during late spring and summer.

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Table 3.1. Core area space used by reproductively active female eastern wild turkeys during reproductive phases at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Phase	Number of 50% UD core areas[a]	Date range[b]	Temporal extent (mean days ± SE)[c,d]	Area (mean ha ± SE)[e]
PRENEST 1	39	15 Feb – 22 May	55.8 ± 3.0	62.9 ± 5.3
LAY 1	39	25 March – 3 June	12	31.5 ± 2.3
PRENEST 2	21	12 April – 12 June	10.5 ± 1.4	54.1 ± 6.2
LAY 2	20	18 April – 24 June	12	34.0 ±3.2
PRENEST 3	7	17 May – 30 June	15.9 ± 2.1	78.0 ± 6.1
LAY 3	7	25 May – 12 July	12	45.2 ± 6.7
BROOD	9[e]	1 May – 1 Aug	23.1 ± 8.4	11.6 ± 3.7
POST	31	1 May – 13 Aug	36.2 ± 4.5	52.4 ± 5.2

a. Sample size (n) of dynamic Brownian bridge 50% utilization distributions from which core area space use was estimated.

b. Date range from first date of earliest phase initiation to last date of latest phase termination.

c. Temporal extent (days) of turkey location data used to estimate space use.

d. Temporal extent of egg-laying phases was not calculated, but estimated from previous literature.

e. Size (ha) of core area of use.

f. Brood-rearing core area of use pooled for 1 female turkey that raised 2 broods in 1 year.

Table 3.2. Habitat rankings (most preferred [1] to least preferred [8]) as determined by Euclidean distance analysis of habitat selection of reproductively active female eastern wild turkeys during phases of the reproductive period at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Reproductive phase	*n*[b]	Habitat ranking[a]							
		1	2	3	4	5	6	7	8
PRENEST1	39	HW*	MPH	MP3	MP1	OPEN	YP	MP0	MP2*
LAY1	39	MP0*	YP	OPEN	MP2	MPH	MP1	HW	MP3
PRENEST2	21	MP0	OPEN	HW	YP	MP2	MPH	MP3	MP1
LAY2	20	MP0	OPEN*	MPH*	MP2	MP1	YP	HW	MP3
PRENEST3	7	OPEN	MP0	YP	MPH	HW	MP2	MP1	MP3
LAY3	7	MP1	YP	MP3	OPEN	MP0	MPH	HW	MP2
BROOD	9[c]	MP1	MP2	OPEN	MPH	MP0	YP	HW*	MP3
POST	31	MPH*	OPEN*	YP	MP1	HW	MP0	MP3	MP2

a. An asterisk (*) indicates significant non-random habitat use as determined by 95% confidence intervals around point estimate of selection ratio.

b. Sample size (*n*) of female turkeys for which habitat selection was analyzed.

c. Brood-rearing habitat selection ratios pooled for 1 female turkey that raised 2 broods in 1 year.

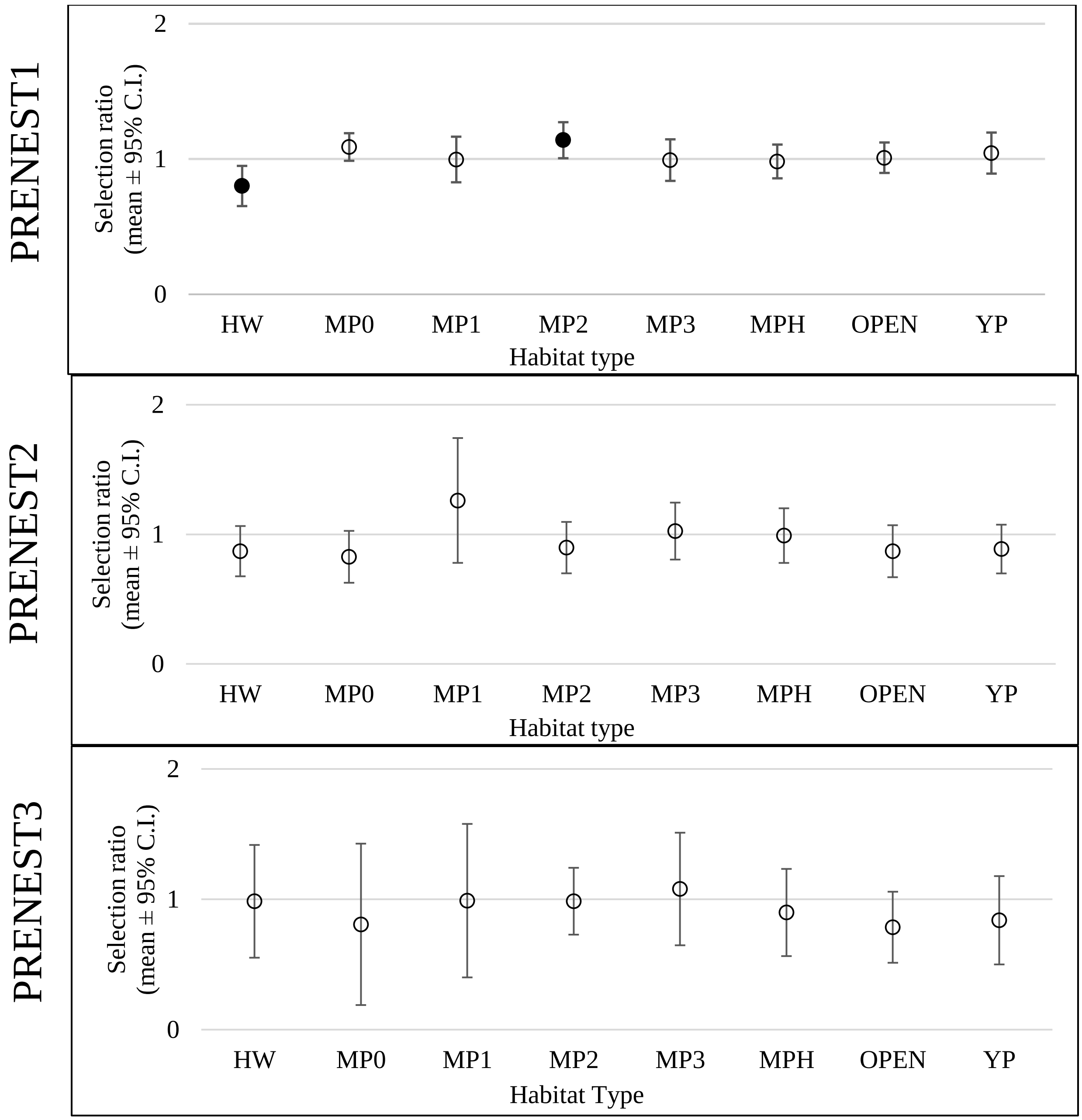

Figure 3.1. Habitat selection ratios of reproductively active female eastern wild turkeys during PRENEST1 (prior to initial nest attempt; 15 February – 22 May; *n* = 39), PRENEST 2 (following loss of first nest or brood and before initiation of second nest; 12 April – 12 June; *n* = 21), and PRENEST3 (following loss of second nest or brood and before initiation of third nest; 17 May – 30 June; *n* = 7) reproductive phases at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015. Estimates >1 indicate avoidance and estimates <1 indicate

selection, with deviation from 1 indicative of effect size. Error bars show 95% confidence intervals. Black-filled estimate markers indicate statistically significant selection or avoidance as indicated by 95% confidence intervals. Habitat types included hardwood (HW), mature pine (≥20 years old) burned within the within the same annual prescribed fire application period (October – September; MP0), mature pine burned 1 year prior (MP1), mature pine burned 2 years prior (MP2), mature pine burned ≥3 years prior (MP3), mixed pine-hardwood (MPH), open habitats (OPEN), and young pine (5 to 19 years old; YP).

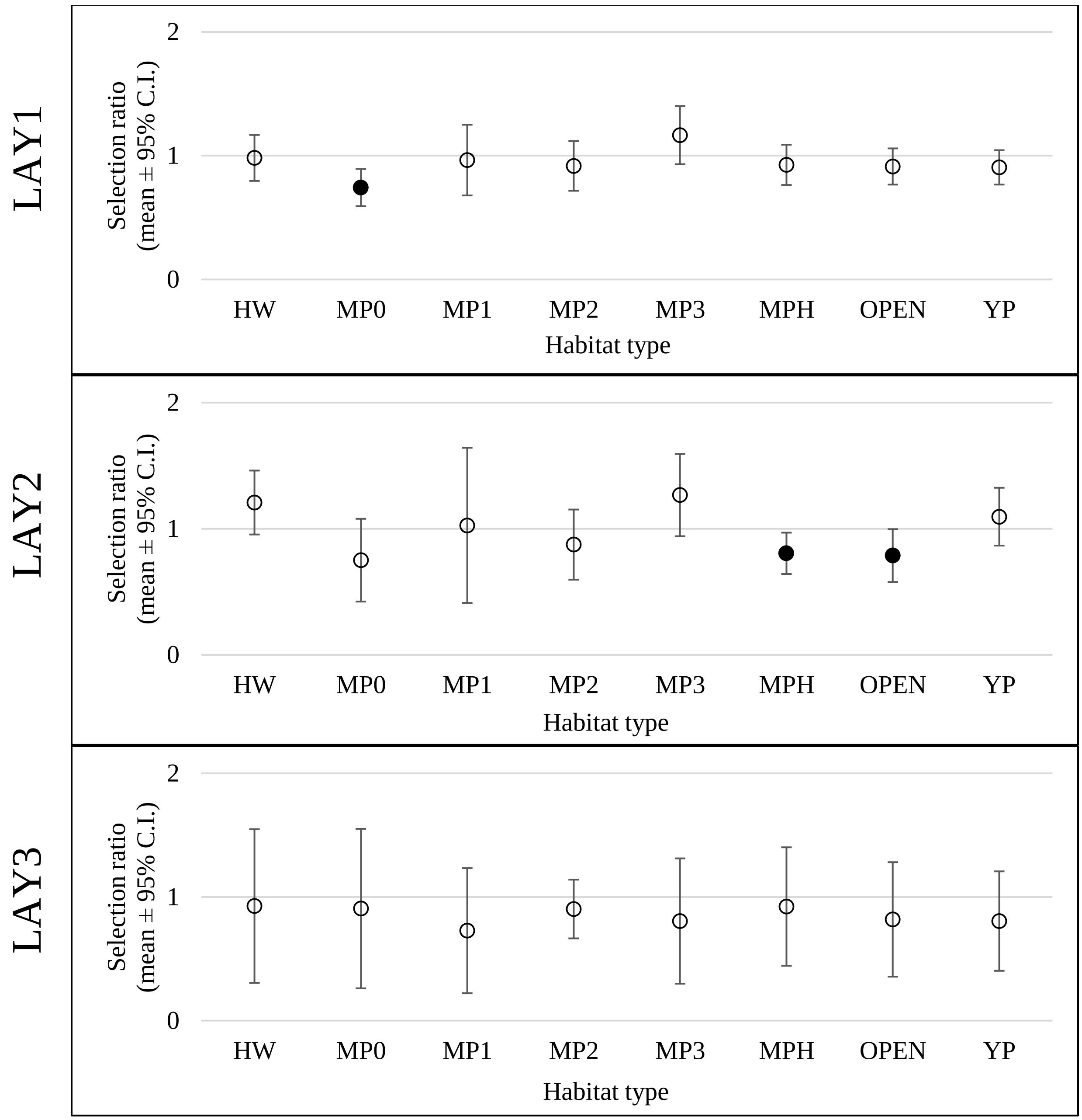

Figure 3.2. Habitat selection ratios of reproductively active female eastern wild turkeys during LAY1 (laying first clutch; 25 March – 3 June; *n* = 39), LAY 2 (laying second clutch; 18 April – 24 June; *n* = 20), and LAY3 (laying third clutch; 17 May – 30 June; *n* = 7) reproductive phases at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015. Estimates >1 indicate avoidance and estimates <1 indicate selection, with deviation from 1 indicative of effect size. Error bars show 95% confidence intervals. Black-filled estimate markers indicate statistical

significance. Habitat types included hardwood (HW), mature pine (≥20 years old) burned within the within the same annual prescribed fire application period (October – September; MP0), mature pine burned 1 year prior (MP1), mature pine burned 2 years prior (MP2), mature pine burned ≥3 years prior (MP3), mixed pine- hardwood (MPH), open habitats (OPEN), and young pine (5 to 19 years old; YP).

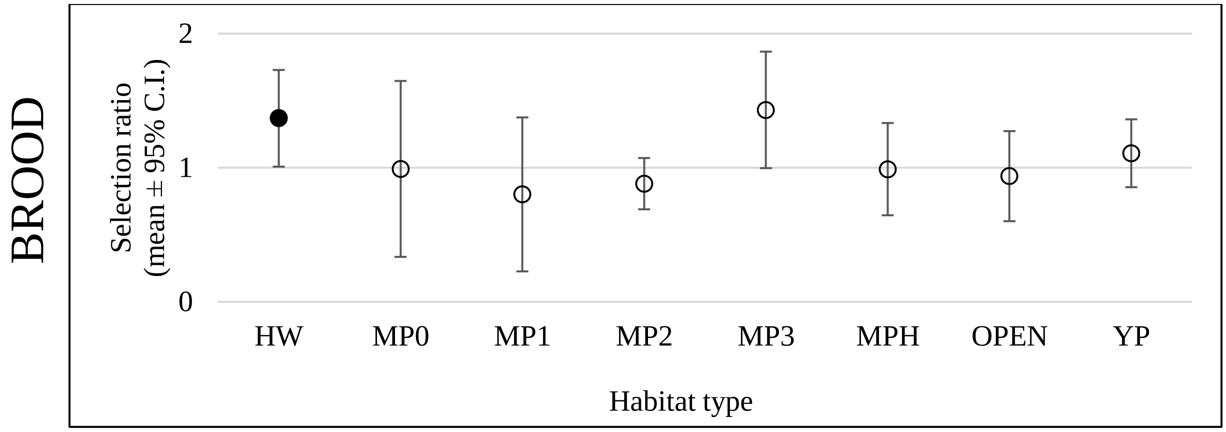

Figure 3.3. Habitat selection ratios of reproductively active female eastern wild turkeys during the brood-rearing phase (beginning on date of nest hatch and extending 56 days or until brood is lost to predation or other mortality; 1 May – 1 August; n = 9) at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015. Estimates >1 indicate avoidance and estimates <1 indicate selection, with deviation from 1 indicative of effect size. Error bars show 95% confidence intervals. Black-filled estimate markers indicate statistically significant selection or avoidance as indicated by 95% confidence intervals. Habitat types included hardwood (HW), mature pine (≥20 years old) burned within the within the same annual prescribed fire application period (October – September; MP0), mature pine burned 1 year prior (MP1), mature pine burned 2 years prior (MP2), mature pine burned ≥3 years prior (MP3), mixed pine-hardwood (MPH), open habitats (OPEN), and young pine (5 to 19 years old; YP).

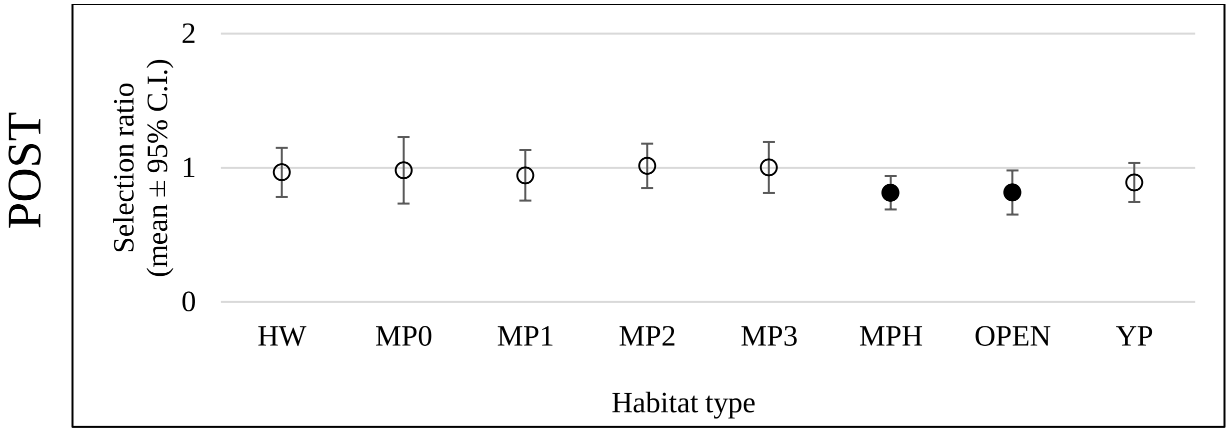

Figure 3.4. Habitat selection ratios of reproductively active female eastern wild turkeys during the post-nesting phase (following all nesting attempts, loss of brood, or after broods reach 56 days old; 28 April – 13 August; $n = 31$) at Kisatchie National Forest in west-central Louisiana, USA, 2014 and 2015. Estimates >1 indicate avoidance and estimates <1 indicate selection, with deviation from 1 indicative of effect size. Error bars show 95% confidence intervals. Black-filled estimate markers indicate statistically significant selection or avoidance as indicated by 95% confidence intervals. Habitat types included hardwood (HW), mature pine (≥20 years old) burned within the within the same annual prescribed fire application period (October – September; MP0), mature pine burned 1 year prior (MP1), mature pine burned 2 years prior (MP2), mature pine burned ≥3 years prior (MP3), mixed pine-hardwood (MPH), open habitats (OPEN), and young pine (5 to 19 years old; YP).

CHAPTER 4

USE OF PINE-DOMINATED FORESTS IMMEDIATELY AFTER PRESCRIBED FIRE BY FEMALE EASTERN WILD TURKEYS

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ABSTRACT

Prescribed fire is used in Southeastern pine forests to maintain desirable forest conditions and provide herbaceous understory plant communities for wildlife. However, it is unclear how time since fire affects short-term wildlife response to prescribed fire. We examined use of recently burned pine stands by female eastern wild turkeys (*Meleagris gallopavo silvestris*) up to 250 days following prescribed fire at Kisatchie National Forest in west-central Louisiana, USA. Kisatchie was dominated by pine forests managed with prescribed fire on a 3 to 5 year rotation. We developed resource selection functions to examine influence of time-since-fire and month of fire application on turkey use of burned areas. We also assessed influence of distance to the perimeter of burned stands and days since fire application on turkey use of space within burned areas. Female turkeys used burned areas non-randomly with respect to time since fire application. Probability of use increased until 106 days post-fire, then began to decline. Use of burned areas increased as month of burn application advanced from December to May, with the exception that use declined when fire was applied in March. Turkey use of space within burned areas declined as distance to surrounding unburned habitat increased, suggesting that turkeys favor the edge of burned and unburned habitat. However, effect of distance to the perimeter of burned stand decreased as time-since-fire increased. Our findings suggest that turkeys are less likely to use areas burned in early winter (e.g., December) than early spring (February), and are more likely to use space near edges of burned areas than the interior. We recommend managers in Southeastern pine-dominated ecosystems apply dormant season fires in late winter and apply early spring growing season fires as needed to meet forest management objectives. We recommend applying prescribed fire to patches smaller than those burned at Kisatchie National Forest to increase usable space suitable to female turkeys throughout the reproductive period.

INTRODUCTION

Fire alters landscape heterogeneity (Sousa 1984, Turner et al. 2001) and habitat suitability for wildlife (DeBano et al. 1998). Fire affects ecosystem components by modifying soil composition, plant growth and succession, and soil fauna (Ahlgren and Ahlgren 1960). Fire can have direct lethal effects on wildlife via exposure to high temperature, tissue damage resulting from direct contact with flames, and suffocation due to smoke inhalation (Howard et al. 1959, Whelan 1995). However, studies have reported very little direct mortality in avian species resulting from fire exposure, as various species have been observed avoiding flames or taking refuge in fire shadows (Howard et al. 1959, Lawrence 1966, Komarek 1969). Equally important are indirect and less immediate effects of fire on wildlife, which include alterations to vegetation structure, shifts in food availability, and changes to microclimate (Bendell 1974). Fire disturbance and the subsequent creation of early successional habitat may increase diversity of birds and small mammals in the following years (Hagar 1960, Bock and Lynch 1970, Hein 1978).

The eastern wild turkey (*Meleagris gallopavo silvestris*; hereafter, turkey) inhabits pine-dominated (*Pinus* spp.) ecosystems in the Southeastern United States that are frequently managed with prescribed fire. Previous research on habitat use of turkeys in this region has indicated that fire can improve habitat quality for turkeys by reducing height and basal area of woody shrubs and small trees (Lotti 1955, Hodgkins 1958, Lewis and Harshbarger 1976, Elliott et al. 1999), stimulating growth of herbaceous plants which provide food (Stoddard 1935) and brooding habitat (Hurst 1978, Healy 1985, Burk et al. 1990), and creating suitable nesting cover (Sisson et al. 1990, Still and Bauman 1990). However, there have been concerns about potential for fire applied during the reproductive period (March – July) to reduce reproductive success through nest destruction (Stoddard 1935, Sisson and Speake 1994). Recent studies have assessed the potential impact of fire-related nest loss on reproductive success of turkeys in frequently burned pine forests and found losses to be minimal (Moore et al. 2010, Kilburg et al. 2014, Little et al. 2014). Furthermore, the ability of female turkeys to re-nest may offset any nest losses due to fire disturbance. Collectively, these data suggest that turkeys are well-adapted to fire disturbance in pine-dominated ecosystems.

Although prescribed fire may improve habitat structure for turkeys (Stoddard 1935), it is unclear how turkeys respond to fire disturbance immediately after fires. Researchers have reported observations of other upland game birds (mourning dove [*Zenaida macroura*], northern bobwhite [*Colinus virginianus*], and American woodcock [*Scolopax minor*]) returning to burned areas immediately following the passing of flame fronts (Edwards and Ellis 1969), but few studies have examined the direct influence of fire on behavior of turkeys immediately following fire. In longleaf pine savannas, Perez (2013) noted that female turkeys were farther from burned areas in the 10-day period following fire than before, and Martin et al. (2012) found that probability of use of burned areas seemed to peak at approximately 250 days after fire. The physical effects of fire on the environment may alter habitat suitability for turkeys and potentially displace them from their normal activity areas. Turkeys operating in a recently modified environment may behave sub-optimally and experience reduced fitness (Reinert and Rupert 1999, Roe et al. 2010, Cohen et al. 2015). Such negative consequences are of particular concern for female turkeys since females bear the responsibility of nest site selection, incubation, and brood-rearing. Therefore, understanding immediate effects of prescribed fire on habitat suitability for turkeys is prudent.

Although previous research has demonstrated turkey use of fire-influenced habitat, little research has examined patterns of space use within recently burned areas. Because vegetative cover is reduced by fire disturbance (Bendell 1974), use may be confined to outer portions of burned areas so as to remain close to escape cover and reduce predation risk (Elton 1939). Alternatively, reduced visual obstruction in burned areas may facilitate scanning behavior and reduce perceived predation risk (Metcalfe 1984, Lazarus and Symonds 1992). Such effects may vary with time-since-fire, as vegetative growth following fire disturbance will result in increased cover. Therefore, an interactive effect of distance to surrounding unburned vegetation and time-since-fire may exist. Such an effect would have important implications for managers applying prescribed fire to landscapes where turkey management is an objective.

Because dynamic shifts in landscape suitability may alter fitness of turkey populations in fire-influenced pine forests, we sought to examine turkey use of burned forest stands following prescribed fire application. Our objectives were to examine female turkey use of forest stands treated with prescribed fire and describe patterns of use within 1 year following fire application. Because turkeys are a highly mobile species capable of flight, we hypothesized that prescribed fire would not directly cause mortality. We also hypothesized that turkey use of burned areas would be non-random. Specifically, we predicted that 1) use of burned areas would be low immediately following fire, but would increase to an apex before beginning to decline, and 2) space use within burned areas would be influenced by distance to escape cover in the surrounding unburned landscape.

STUDY AREA

We conducted research on Kisatchie National Forest (KNF) and Fort Polk Wildlife Management Area (WMA) in west-central Louisiana. Both sites were characterized by pine-dominated forest, with some mixed pine-hardwood stands, hardwood-dominated stands, and smaller non-forested habitats interspersed throughout. Prescribed fire was a primary forest management practice, as well as timber thinning and timber stand improvement. See Chapter 2 for a more detailed description of the study area.

METHODS

We captured female turkeys using rocket nets during January – March of 2014 and 2015. We fitted each female with a GPS transmitter equipped with a VHF beacon. Turkey capture, handling, and marking procedures were approved by the Institutional Animal Care and Use Committee at the University of Georgia (protocol #A3437-01). See Chapter 2 for a more detailed description of methods of turkey capture and monitoring throughout the study period.

We obtained spatial data from USFS, US Army, and private industrial timber managers which detailed areas and dates of prescribed fire applications within the study area during the study period. We defined a recently burned area as an area burned between October prior to turkey capture and June following turkey capture. In cases in which adjacent management units were burned on the same day, we considered the units as a single unique burn compartment. To determine availability of burned areas to radio-marked turkeys, we generated a 100% minimum convex polygon (MCP) around all recorded GPS locations of each turkey and identified all turkeys whose MCP intersected ≥1 burned area. We assumed that any recently burned area that intersected a turkey MCP was available to that individual. We considered a turkey to have used a burned area if ≥1 used location fell within the burn compartment following fire application. To assess use of available burned areas, we generated 3 random locations to 1 used location within the MCP of each turkey with ≥1 used location in a recently burned area. Each random location was associated with a single used location and therefore shared the same timestamp. We selected only the used and random locations that fell within areas burned the current year and calculated days-since-fire for all used and random locations as the time (days) lapsed between the date of prescribed fire application and the associated timestamp. By excluding used and random locations outside of recently burned areas, our final data set was no longer structured in a 3:1 ratio. This allowed us to analyze the influence of time-since-fire on probability of use based on time stamps associated with used and random locations. Because we were interested in the response of turkeys following fire, we excluded any used or random location with a negative days-since-fire value.

We used generalized linear mixed-effects modeling (GLMM) within the package lme4 (Bates et al. 2004) implemented in R version 3.1.1 (R Core Team 2013) to evaluate influence of time-since-fire on probability of turkey use of recently burned areas. We modeled probability of use by selecting time-since-fire as a continuous predictor variable and used (known turkey locations) and available (random locations) locations as a binary response variable. We assumed a binomial distribution and treated known turkey locations as a 1 and random locations as a 0. Our only fixed-effect predictor variable was days-since-fire for each location. To account for individual variability in response to fire among turkeys, each model included unique turkey identifier (ID) as a random effect. To account for variation in vigor of plant growth following fire, which is dependent on timing of fire application, each model treated month of fire application as a random effect. We scaled our days-since-fire predictor variable by a factor of 50 to improve model convergence. We developed 3 models to predict probability of use of burned areas as a function of days since the fire occurred and used an information-theoretic approach to select the most parsimonious model. Our first model predicted turkey use of burned areas would increase linearly as time-since-fire increased. Our second model assumed a quadratic relationship such that turkey use of burned areas would increase with time-since-fire to a certain day, at which probability of use would begin to decline. Our third model was a null model and included only the random effects of turkey ID and burn month. Both random effects were assumed to be normally distributed with a mean of zero. We used second-order Akaike's Information Criteria (AIC_c) to determine the weight of evidence in support of each model (Burnham and Anderson 2002). We calculated adjusted Akaike's weights (w_i) for each model to select the most parsimonious model from the candidate set. We selected the most parsimonious model based on the lowest AIC_c value and examined parameter estimates of fixed and random effects from that model. We then predicted effect of days since fire on probability of use from beta estimates.

After identifying which turkeys used recently burned areas, we examined the influence of distance to surrounding unburned habitat on the spatial distribution of turkey locations within burned areas. For each turkey that used a burned area following fire application, we counted the number of used locations within the burn compartment following fire application and generated random locations within the burn compartment at a ratio of 3 random locations to 1 used location. Each random location was associated with a single used location and therefore shared the same turkey identifier and days-since-fire value. For turkeys that used multiple burned areas, we generated separate sets of random locations within each unique burn compartment used. Within each burned area used by a turkey, we used ArcGIS 10.3.1 (Environmental Systems Research Institute, Redlands, CA) to measure distance to the nearest point along the perimeter of the burn compartment by generating distance raster grids as described by Benson (2013). We then intersected all used and random locations with distance maps and extracted the distance to the nearest point along the burn compartment perimeter.

Similar to our analysis above, we used GLMM to evaluate influence of distance to unburned habitat on probability of turkey space use within recently burned areas. Because we hypothesized that time-since-fire would influence the spatial distribution of turkey locations within burns, we also included an interaction between distance to perimeter and days-since-fire in our analysis. We modeled probability of use by selecting distance to perimeter and time-since-fire as continuous predictor variables and used (known turkey locations) and available (random locations) locations as a binary response variable. We assumed a binomial distribution and treated known turkey locations as a 1 and random locations as a 0. All models included individual turkey identifier as a random effect. We scaled our distance to burn perimeter and days-since-fire predictor variables by a factor of 100 to improve model convergence. We developed 3 models to predict the probability of use within burned areas as a function of distance to perimeter of burned area and days since the fire occurred, and then used an information-theoretic approach to select the most parsimonious model. Our first model predicted turkey use within burned areas would decrease as distance to burn perimeter increased. Our second model assumed an interaction between distance to burn perimeter and days-since-fire, such that as days-since-fire increased, the effect of distance to perimeter on probability of turkey use would decrease. Our third model was a null model which included no predictor variables. We used AIC_c to determine the weight of evidence in support of each model (Burnham and Anderson 2002) and calculated adjusted Akaike's weights (w_i) for each model as an estimate of the probability of that model being the most parsimonious. We selected the most parsimonious model based on the lowest AIC_c value and examined parameter estimates of fixed and random effects from that model.

RESULTS

We based our results on 48 female turkeys captured and radio-marked during the winters of 2014 and 2015. We observed no direct mortalities of turkeys attributable to fires. Forty-two females had MCPs that intersected a recent burn, whereas 6 females did not. Of these 42 females, 4 had no locations within a recent burn. Turkey use of recent burns was associated with 23 unique burns applied from 08 December to 30 April ($\bar{x}$ = 09 March) and ranged in size from 32.3 to 1668.5 ha ($\bar{x}$ = 618.8, SD = 412.0). Nineteen females maintained an area of use that included 1 unique recent burn, 16 maintained areas of use that included 2 burns, and 3 maintained areas of use that contained 3 burns. We recorded locations of 10 females inside a burn compartment on the day of fire application. Two females had all daily locations within a burn compartment the day it was burned. Female #60274 remained within a burn compartment as it was burned and continued to use the area for at least 1 week after, at which time we lost contact with the transmitter (Figure 4.1). Similarly, Female #60343 remained within a burn compartment as it was burned, then returned to a nest location within the burn compartment the following day and resumed nesting activity (Figure 4.2).

Three females were located within burn compartments during peak times of fuel consumption, but left the area later in the day. For example, Female #52 was located within a burn compartment as it was ignited and left the area at approximately 1700, but continued to use the area during daylight hours in the following weeks (Figure 4.3). Two females were outside of burn compartments during ignition, but entered the burned areas immediately afterward. For example, Female #64 was not located inside a burn compartment in the 13 days prior to fire, but entered the burn compartment only hours after ignition and continued to use the area for approximately 1 month (Figure 4.4). Two females exited a burn compartment the morning fire was applied, then returned later in the day (presumably after most fuel consumption). One female exited a burn compartment on the morning of fire application (04 May) and did not return to use the area, but instead used another area burned on 03 May throughout May and early June.

We developed probability of use models relative to time-since-fire using locations from 42 females whose MCP intersected a recent burn. Our findings indicated that the quadratic model, in which the regression line of probability of use formed a downward concave curve, was the most parsimonious model (w_i = 1.00; Table 4.1). We noted that variance estimates of random effects for individual females ranged from -2.67 to 2.87, suggesting large inter-individual variation in response to fire. Likewise, logit parameter estimates for the main effect of burn month on probability of use by females ranged from 0.94 to 3.98, suggesting that timing of a burn has considerable influence on turkey response to fire (Figure 4.5). A quadratic equation built from parameter estimates of main effects from our most parsimonious candidate model predicted that probability of turkey use of recently burned areas peaked at approximately 103 days post-fire application (Figure 4.5).

We developed models of probability of use within burn compartments relative to distance to perimeter and days-since-fire based on locations from 38 females. We found that the interaction model, in which distance to perimeter interacted with days-since-fire, was the most parsimonious (w_i = 1.00; Table 4.3). Parameter estimates from the interaction model suggested a negative relationship between distance to perimeters of burn compartments and probability of use, but that effect of distance to perimeter decreased as time-since-fire increased (Table 4.4). We observed variance estimates of the random effect for individual turkey ranging from -0.103 to 0.243.

DISCUSSION

We observed females using recently burned areas in the days and weeks following fire disturbance, suggesting that low intensity fires do not completely displace turkeys from treated areas. Our modeling efforts suggest that female turkeys increase use of burned areas up to 103 days after a fire, at which point use decreases. We noted that predicted probability of use differed depending on month of fire application, with probability generally increasing as burn month advanced from winter to spring. Predicted probability of using burned areas varied among individual turkeys, suggesting that other factors influence individual decisions relative to using burned areas. Predicted probability of using space within burned areas decreased as distance to surrounding unburned habitat increased, but the negative effect of distance to perimeter was dampened as time-since-fire increased.

We detected no lethal effects of fire on female turkeys, supporting our hypothesis that prescribed fire as applied at KNF was not an immediate threat to females. The probability of mortality events due to fire has been reported to be directly related to severity of fire (Buech et al. 1977, Whelan 1995), and prescribed fires in Southeastern pine forests are typically of low intensity. The probability of fire-induced mortality also varies among wildlife species and is related to the mobility of the species (DeBano et al. 1998). Turkeys are highly mobile and capable of seeking refuge from flames in treetops or leaving the affected area. This was evidenced by 5 females we observed within burn compartments during peak hours of fuel combustion. Furthermore, Female #60343 initiated a nest in an area which was then burned before completion of the egg-laying cycle. Female #60343 remained within the burn compartment the day of fire application, but did not visit the nest to deposit eggs that day (Figure 4.2). However, Female #60343 returned to the nest the day after fire application and continued egg deposition, eventually incubating and successfully hatching the clutch. Fire intensity and severity are spatially heterogeneous, providing refugia within burned areas (Howard et al. 1959, DeBano et al. 1995, Brennan et al. 2011). The nest of Female #60343 exposed to fire was located alongside an ephemeral drainage featuring moist soils and hardwood shrubs, conditions which likely contributed to nest survival. Little et al. (2015) reported 3 of 5 nests exposed to growing season fire were unsuccessful, and that fire severity was greater at the unsuccessful nests (A. Little, personal communication).

Prescribed fires are often applied prior to and during the turkey reproductive period, hence influence of fire on space use could affect distribution of usable space for nesting and brood-rearing. Therefore, residual effects of fire on space use throughout the nesting and brood-rearing period should be carefully considered when developing and implementing a prescribed fire management plan. We found that female turkey use of burned areas was sensitive to time since fire, with use increasing following fire and peaking at 103 days before declining. We suspect this resulted from changing availability of food resources in burned areas. Various species are attracted to burned or otherwise disturbed areas because new food resources are made available (Hagar 1960, Bock and Lynch 1970). Turkeys feed on a variety of foods found in leaf litter, including hard mast, grass and forb seeds, and insects (Hurst 1992), all of which may be exposed after a fire removes litter from the ground. Use of recently burned areas may increase foraging efficiency of turkeys and provide more optimal feeding areas (Macarthur and Pianka 1966, Schoener 1971). The observed decline in use of burned areas after several months may have resulted from the depletion of easily accessible food resources. Alternatively, the probability of use may have been more strongly influenced by changing vegetation structure. Fire removes herbaceous vegetation and foliage of woody plants from the understory, thereby reducing cover for both turkeys and potential predators. Effects of visual obstruction on behavior of prey species varies and may be site- and species-specific (Metcalfe 1984, Lima 1987). We offer that reduction in understory vegetation following fire increases the ability of turkeys to scan their environment for predators. However, as understory vegetation regenerates, cover increases and understory structure becomes more similar to that in surrounding habitats. Hence, probability of use of burned areas by turkeys may be a function of both a temporary increase in food availability and a gradual restoration of understory cover.

Female turkeys were least likely to use areas burned in December and January, and recently burned areas were avoided in the pre-nesting period (see Chapter 3). Similarly, Sisson et al. (1990) found that turkeys avoided recently burned pine stands in winter. Lower use of areas burned in December and January may have been related to the time elapsed between fire application and collection of turkey locations, which began mid-January to early March. Alternatively, reduction of understory cover may have reduced suitability of burned areas as nesting habitat throughout the reproductive period. Some females at KNF located nests within recently burned areas, but relatively greater effort was put into nesting in unburned areas (see Chapter 2). Conversely, areas burned in April and May were most likely to be used. We suspect that greater use of April and May burns was related to timing of first nest initiation, which occurred in late April and early May (see Chapter2). Females selected recently burned mature pine habitat during the egg-laying phase of first nests (see Chapter 3), and greater use may have been related to food consumption associated with increased energy demands of egg production and nest incubation (Drobney 1980, Parker and Holm 1990). Our results suggest that applying fire to pine forests in late winter and spring (February – May) results in more turkey use than applying fires in early winter (December and January). However, we caution against managers applying fire entirely within the growing season, which coincides with the nesting period of turkeys and other ground nesting upland birds. Fires applied in April and early May did not coincide with most nesting activity at KNF (see Chapter 2). However, had managers at KNF applied fires in late May – July, there would have been greater potential for nest disturbance. Managers should be mindful of the timing of nesting activity at specific sites and apply growing season fires with caution.

Turkeys were less likely to use space within burned areas as distance to surrounding unburned habitat increased. We offer that this finding was related to limited cover available to turkeys within recently burned areas. Northern bobwhites (*Colinus virginianus*) typically fly <75 m to escape cover, and researchers have advocated for provision of woody escape cover within 100 m to promote predator avoidance (Kassinis and Guthery 1996). Likewise, a trade-off between high quality foraging opportunities and predation risk influences habitat use by Himalayan snowcock (*Tetraogallus himalayensis*; Bland and Temple 1990). Similarly, turkeys may use the interface between burned and unburned habit in a similar way to balance food availability and proximity to escape cover. Further, remaining closer to unburned habitat may reflect the availability of other resources outside the burned area such as loafing sites and potential nest sites. Woody cover is an important component of summer covert sites used by northern bobwhites to avoid hyperthermia (Miller and Guthery 2005), and such cover is more abundant in unburned areas compared to recently burned areas. If turkeys rely on resources found exclusively in burned and unburned patches, then remaining near the edge may reduce energy expenditures associated with travelling between habitats, thereby optimizing use of a patchy environment (MacArthur and Pianka 1966). Regardless, our findings suggest that burn patch sizes at KNF were larger than optimal for turkey use. Mean size of burn patches used by females was 618.8 ha (max = 1668.5), which seemed to create interior space less suitable than space near the perimeter. We recognize that our study was observational in nature and did not explicitly link size of burned patches to size of annual or seasonal home ranges of turkeys. Hence, our work is not capable of determining the optimal size of burn patches that would increase useable space for turkeys. Further research is needed to assess influences of highly variable burn patch sizes on use by turkeys.

MANAGEMENT IMPLICATIONS

To increase likelihood of use by turkeys, we recommend dormant season fires be applied in late winter (February). Stands treated with fire in late spring (April and May) were most likely to be used, suggesting that spring burning is compatible with wild turkey management. Female turkeys readily used recently burned areas, but were more likely to remain near the perimeter than use interior space. This suggests that patches burned at KNF were likely too large to maximize useable space for turkeys. Managers may want to consider separating burn compartments into smaller units to balance objectives of turkey population management and efficiency of prescribed fire program implementation. We recommend applying prescribed fire at smaller spatial scales than applied at KNF to maximize useable space for female turkeys. Future research should assess the optimal burn patch size for turkeys in pine-dominated ecosystems.

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Table 4.1. Predictive models of use of recently burned forested areas by female eastern wild turkeys at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Model[a]	K[b]	AICc[c]	ΔAICc[d]	Adjusted w_i[e]	LL[f]
DSF (polynomial) + month	9	91856.6	0.00	1.0	-45919.31
DSF (linear) + month	8	92059.6	203.00	0.0	-46021.81
Month	7	92116.5	259.90	0.0	-46051.26
Null	2	93795.2	1938.56	0.0	-46895.59

a. Predictor variable within models included days-since-fire (DSF) and month of burn application (month).

b. Number of variables (K).

c. Second-order Akaike's Information Criterion (AICc).

d. Distance from the second-order AICc of the top-performing model.

e. Adjusted Akaike weight of evidence (w_i) in support of model.

f. Log-likelihood (LL).

Table 4.2. Parameter estimates from the most parsimonious model used to predict use of recently burned forested areas by female eastern wild turkeys at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Parameter[a]	Estimate[b]	SE[c]	Scaler[d]
DSF	0.4321	0.0270	50
DSF^2	-0.1048	0.0074	50
December (Intercept)[e]	-3.3887	0.2234	--
January	0.9362	0.0627	--
February	2.0396	0.0979	--
March	1.3995	0.0956	--
April	2.7890	0.1075	--
May	3.9777	0.1348	--
Turkey ID[e]	1.615	--	--

a. Predictor variable in predictive model included days-since-fire (DSF) and month of burn application (6 levels: December – May).

b. Parameter estimate on logit scale.

c. Standard error (SE) of the estimate on logit scale.

d. Scaler in meters (m).

e. Turkey ID was considered a random effect in this model. Thus, a variance estimate is reported.

Table 4.3. Predictive models of use within recently burned forested areas by female eastern wild turkeys at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Model[a]	K^b	$AICc^c$	$\Delta AICc^d$	Adjusted w_i^e	LL[f]
Distance to edge*DSF	4	105995.9	0.00	1.0	-52993.93
Distance to edge	3	106039.3	43.41	0.0	-53016.63
Null	2	106308.1	312.23	0.0	-53152.04

a. Predictor variables within models included distance to perimeter of burn compartment and days-since-fire (DSF).

b. Number of variables (K).

c. Second-order Akaike's Information Criterion (AIC*c*).

d. Distance from the second-order AIC*c* of the top-performing model.

e. Adjusted Akaike weight of evidence (w_i) in support of model.

f. Log-likelihood (LL).

Table 4.4. Parameter estimates from the most parsimonious model used to predict space use within recently burned forested areas by female eastern wild turkeys at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

Parameter[a]	Estimate[b]	SE[c]	Scaler
Intercept	-0.909	0.018	--
Distance to edge	-0.082	0.005	100[d]
Distance to edge*DSF	0.033	0.005	--
Turkey ID[f]	0.005	--	--

a. Predictor variables in models included distance from used and random locations within burned areas to the perimeter of the burned area and days-since-fire (DSF).

b. Parameter estimate on logit scale.

c. Standard error (SE) of the estimate on logit scale.

d. Biologically relevant scaler in meters (m).

e. Scaler in days.

f. Turkey ID was considered a random effect in this model. Thus, a variance estimate is reported.

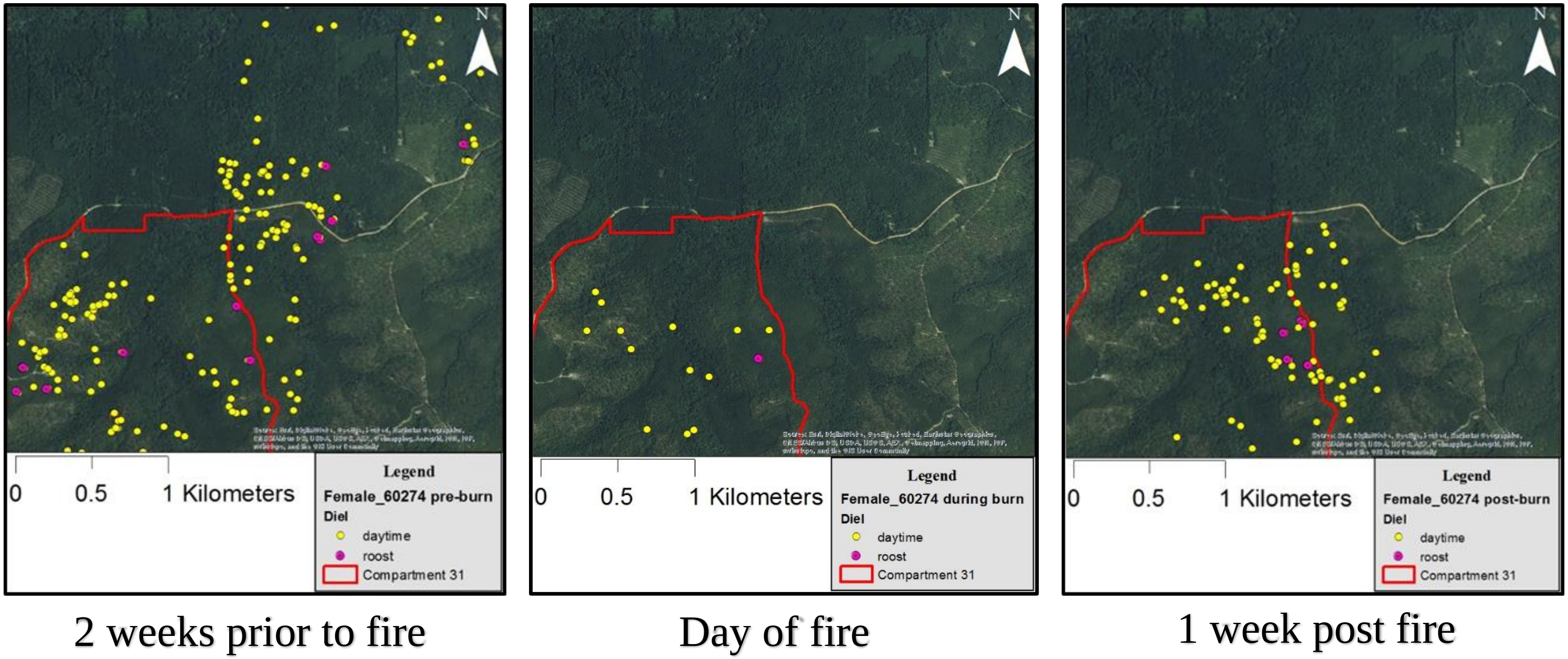


Figure 4.1. Locations of adult female eastern wild turkey #60274 relative to an area treated with prescribed fire on 3 May 2015 at Kisatchie National Forest, west-central Louisiana. Red outline depicts outer boundary of burned area. Locations shown depict diurnal activity as yellow circles and nocturnal roost locations as pink circles 2 weeks prior to prescribed fire application, on the day of fire application, and 1 week following fire application.

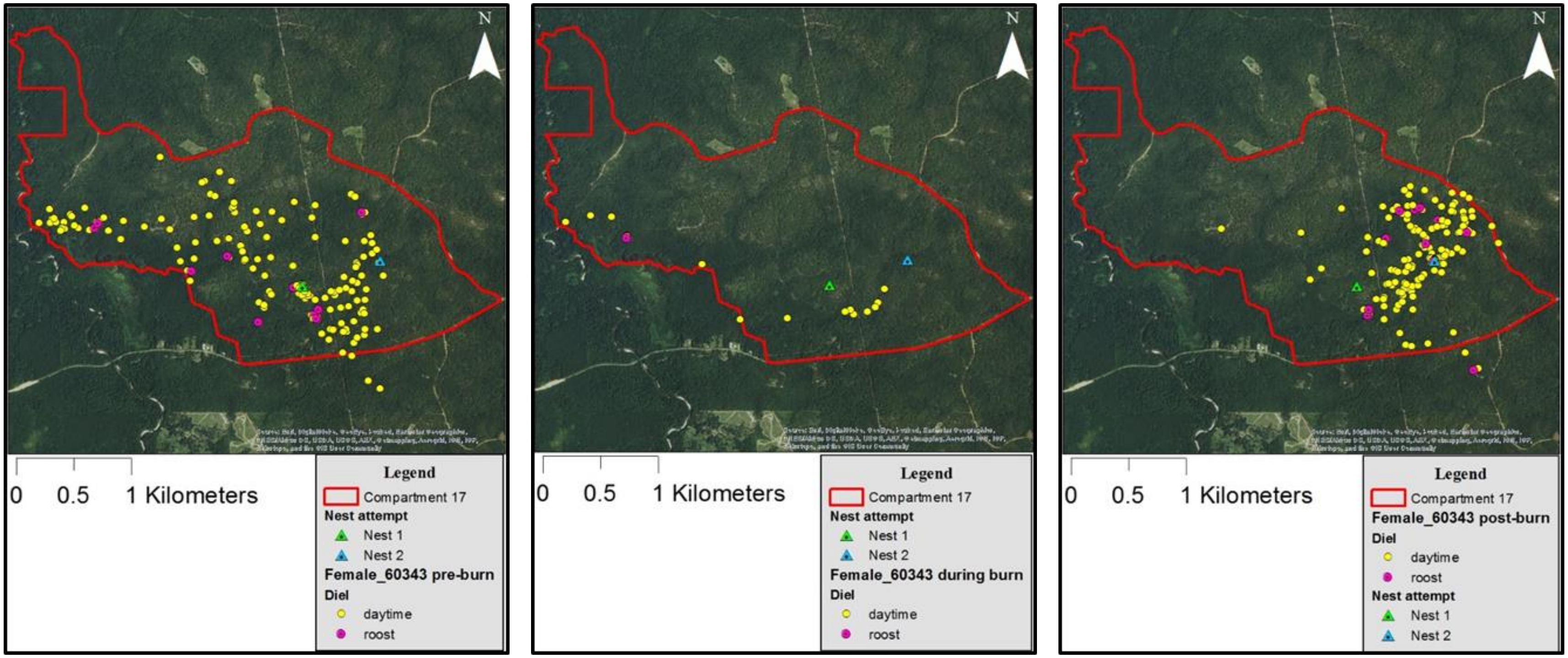
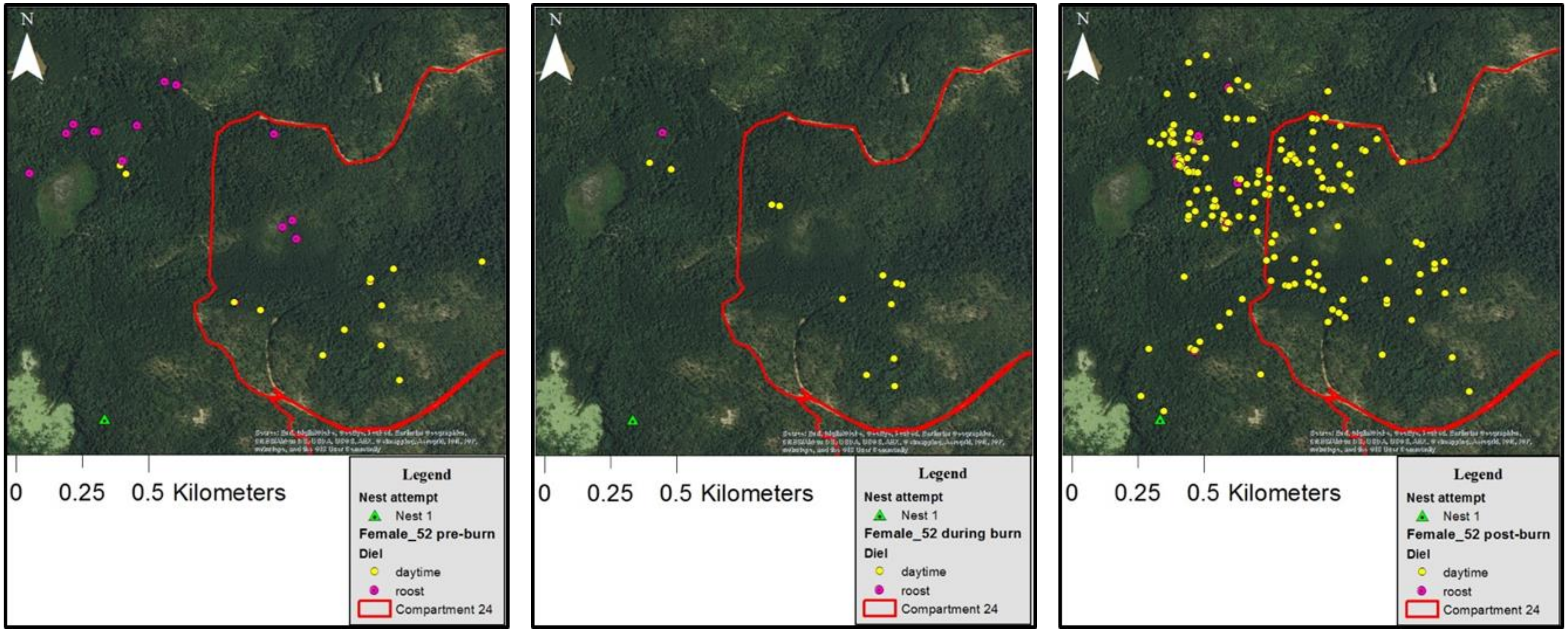
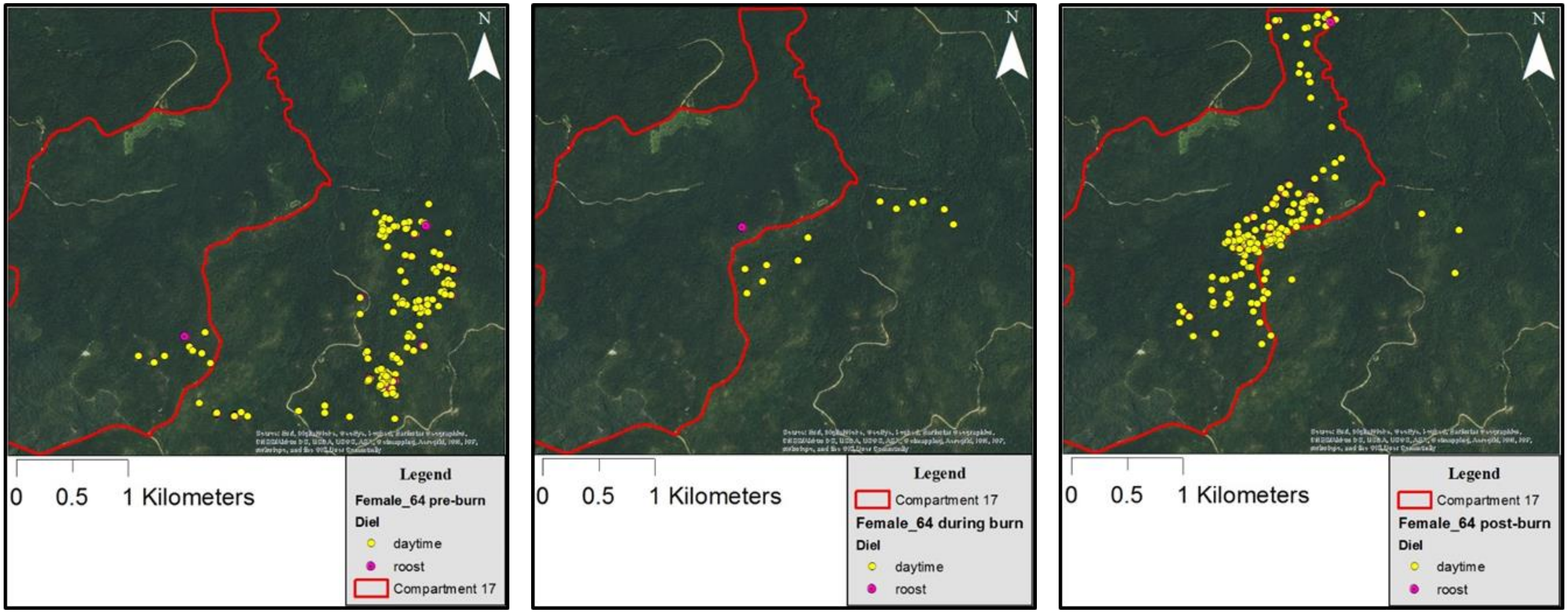


Figure 4.2. Locations of subadult female eastern wild turkey #60343 relative to an area treated with prescribed fire on 15 May 2015 at Kisatchie National Forest, west-central Louisiana. Red outline depicts outer boundary of burned area. Locations shown depict diurnal activity (daytime) and nocturnal roost locations (roost) 2 weeks prior to prescribed fire application, on the day of fire application, and 2 weeks following fire application. First nest attempt (green triangle) incubated from 14 April to 26 April. Second nest attempt (blue triangle) initiated on 5 May and incubated from 18 May until hatching on 14 June.



2 weeks prior to fire | Day of fire | 2 weeks post fire

Figure 4.3. Locations of adult female eastern wild turkey #52 relative to an area treated with prescribed fire on 16 February 2014 at Kisatchie National Forest, west-central Louisiana. Red outline depicts outer boundary of burned area. Locations shown depict diurnal activity (daytime) and nocturnal roost locations (roost) 2 weeks prior to prescribed fire application), on the day of fire application, and 2 weeks following fire application. First nest attempt (green triangle) incubated from 22 May to 24 May 2014.



2 weeks prior to fire　　Day of fire　　2 weeks post fire

Figure 4.4. Locations of adult female eastern wild turkey #64 relative to an area treated with prescribed fire on 28 February 2014 at Kisatchie National Forest, west-central Louisiana. Red outline depicts outer boundary of burned area. Locations shown depict diurnal activity (daytime) and nocturnal roost locations (roost) 2 weeks prior to prescribed fire application, on the day of fire application, and 2 weeks following fire application.

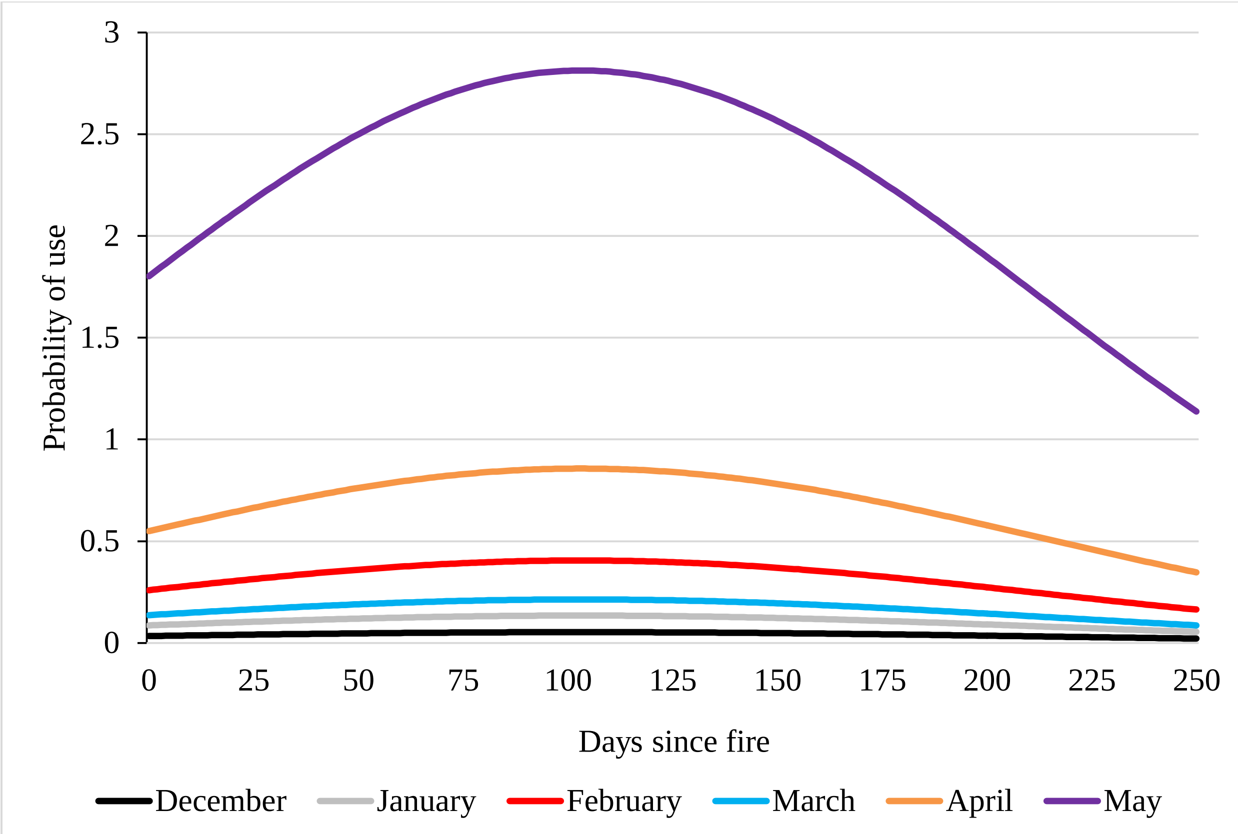


Figure 4.5. Predicted probability of use of recently burned forested areas by female eastern wild turkeys as a function of time since fire and month of fire application at Kisatchie National Forest, west-central Louisiana, USA, 2014 and 2015.

CHAPTER 5

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

My findings suggest that of the vegetation metrics I measured, ground cover vegetation immediately surrounding the nest was the most important factor influencing nest site selection by wild turkeys and that percent vegetative ground cover was positively associated with nest survival. Nest survival was also highest in stands burned immediately prior to or during the nesting period and lowest in stands not burned for ≥3 years. I recommend a burn rotation of 3 years to avoid low nest survival for female turkeys in Southeastern pine forests. I recommend land managers apply prescribed fire in a mosaic fashion to create interspersion of nesting cover across the landscape. I also recommend that future researchers recognize the duration of nesting behavior in wild turkeys, and hence, the likelihood that females will attempt multiple nests on into summer months. Studies focused on understanding reproductive ecology in wild turkeys should use GPS transmitters to intensively monitor females throughout spring and summer, so that all nesting attempts can be documented and reproductive parameters accurately described.

My findings suggest that female eastern wild turkeys in Southeastern pine forests select a variety of habitat types throughout the reproductive period. I recommend managers retain hardwood and mixed pine-hardwood stands in pine-dominated landscapes to provide habitats during winter and throughout portions of the reproductive cycle. Mature pine stands burned within the current year were not selected prior to first nest initiation, which generally coincided with late winter and early spring (February and March). However, selection increased during subsequent periods of reproductive activity, which generally occurred later in spring and summer

(April – July). Therefore, dormant season prescribed fire should be applied in March, rather than early winter, to avoid creating undesirable winter habitat. My findings suggest that turkeys will avoid pine stands with a burn rotation longer than 3 years, hence managers in systems such as those I studied should recognize that shorter burn rotations are necessary if turkey use of burned stands is desired. My findings suggest that maintaining open habitats is important for turkeys existing in primarily forested landscapes, particularly during late spring and summer.

To increase likelihood of use by turkeys, I recommend dormant season fires be applied in February. Stands treated with fire in late spring (April and May) were most likely to be used, suggesting that spring burning is compatible with wild turkey management. Female turkeys readily used recently burned areas, but were more likely to remain near the perimeter than use interior space. This suggests that patches burned at KNF were likely too large to maximize useable space for turkeys. Managers may want to consider separating burn compartments into smaller units to balance objectives of turkey population management and efficiency of prescribed fire program implementation. I recommend applying prescribed fire at smaller spatial scales than applied at KNF to maximize useable space for female turkeys. Future research should assess the optimal burn patch size for turkeys in pine-dominated ecosystems.