MOVEMENT AND REPRODUCTIVE ECOLOGY OF FEMALE EASTERN WILD TURKEYS IN A MANAGED LONGLEAF PINE FOREST

by

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(Under the Direction of MICHAEL J. CHAMBERLAIN)

ABSTRACT

Longleaf pine (*Pinus palustris*) forests rely on frequent prescribed fire, but how prescribed fire influences habitat selection, and nest and brood survival of eastern wild turkeys (*Meleagris gallopavo silvestris*; turkeys) is poorly understood. I captured 63 female turkeys during 2015-2016 and used GPS transmitters to document reproductive chronology, movement, and habitat selection during the reproductive period. I found that increased patch diversity increased nest survival, whereas proximity to stands burned 3 growing seasons prior reduced brood survival. Females selected hardwood stands during pre-nesting and post-nesting phases, open vegetation communities during all phases except pre-nesting, and used pine stands regardless of fire return interval throughout the reproductive period. I suggest managers focus on creating a mosaic of pine seral stages, intermixed with open and hardwood vegetation communities, while applying frequent prescribed fire (1-3 years) to create understory conditions selected by turkeys for foraging and concealment year-round.

INDEX WORDS: longleaf pine forest, prescribed fire, wild turkeys, nest survival, brood survival, habitat selection, Georgia

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DEDICATION

This thesis is dedicated to my grandfather, Charlie Wood, who taught me at a young age to always be aware of my surroundings and to learn from my experiences. I'd like to think I've come a long way from thinking I knew it all about the outdoors because that was what "Channel 9" said, to realizing there is so much more to know, and that is owed in no small part to the lessons he taught me in my youth. His passion for all things turkey and the outdoors helped guide me down this path, and I'll be forever grateful for the time we've had to experience them both together.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

In the Southeast, longleaf pine (*Pinus palustris*) forests once covered upwards of 37 million ha (Landers et al. 1995, Brockway et al. 2005, Van Lear et al. 2005), the largest expanse dominated by a single overstory species (Chapman 1932). Due to changing land use practices, and managing for shorter rotation pines (e.g. loblolly [*Pinus taeda*] and slash [*Pinus elliottii*]), roughly 3% of longleaf forests remain (Frost 1993, Van Lear et al. 2005). Longleaf pine forests are one of the most diverse ecosystems outside of the tropics (Alavalapati et al. 2002) and managers have been charged with reestablishing and restoring these ecosystems. Efforts to restore longleaf forests rely primarily on the use of frequent (1-3 yrs) prescribed fire, which controls competing hardwoods (Waldrop et al. 1992, Brockway and Lewis 1997, Glitzenstein et al. 2012), and promotes early successional vegetation communities favored by threatened and endangered species (e.g., red-cockaded woodpecker [*Picoides borealis*], and gopher tortoise [*Gopherus polyphemus*]) and popular game species (e.g. northern bobwhite [*Colinus virginianus*]). Recent efforts to understand the role of prescribed fire on the reproductive ecology of eastern wild turkeys (*Meleagris gallopavo silvestris;* turkeys) in the Southeast have focused on how vegetation structure, time-since-fire, and season of fire affect nest site selection and survival (Kilburg et al. 2014, Streich et al. 2015, Little et al. 2016, Yeldell et al. 2017), but little is known about how turkeys relate to vegetation communities as a result of time-since-fire on the landscape. Research is needed to further our understanding of reproductive ecology of wild turkeys in longleaf pine forests, and in particular how prescribed fire influences reproductive chronology, brooding ecology, and movements of reproductively active females.

WILD TURKEY ECOLOGY

The Eastern wild turkey (*Meleagris gallopavo silvestris*; turkey) is the most abundant and widely distributed subspecies of turkey (Eriksen et al. 2016), and is often associated with early successional habitats, including those resulting from frequent fire in longleaf savannas. Declines in wild turkey populations occurred concurrently with declines in longleaf pine forests, primarily due to overhunting and widespread deforestation resulting in habitat loss (Kennamer et al. 1992). By the late 19th century, wild turkeys became extirpated across much of North America, surviving in only the most remote and isolated portions of their range (Kennamer et al. 1992). Hunters and natural resource managers noticed these declines, and recovery efforts were implemented to restore wild turkey populations. Initial recovery efforts that focused on releasing captive bred birds failed, but in the 1940s and 1950s, with the help of cannon-nets to capture wild birds, translocation programs conducted by state game agencies began to reestablish wild turkeys across their former range (Kennamer et al. 1992).

Restoration of wild turkeys is considered one of North America's greatest conservation success stories, and populations peaked near 7 million between 2000 and 2009 (Tapley et al. 2011). However, turkey populations in the Southeast have recently begun to show declines, and populations in Georgia declined 14% from 2005-2009 (Tapley et al. 2011). Although the ultimate reasons for these declines are speculative (Bond et al. 2012, Byrne et al. 2016), proximate causes appear related to adult survival and reproductive success (i.e. nest survival, and poult survival). In addition, how restoration and management efforts (e.g. prescribed fire) in longleaf pine forests affect turkey populations are poorly understood. Recent research suggests that prescribed fire has minimal impact on nest success (Jones et al. 2005, Little et al. 2014), but the relationship between use of fire and reproductive ecology are not well documented.

Population growth in wild turkeys is limited by reproductive success (i.e. nest and poult survival; Vangilder 1992, Palmer et al. 1993, Roberts et al. 1995, Thogmartin and Johnson 1999), hence nest and brood site selection may strongly influence reproductive success (Badyaev 1995, Thogmartin 1999). Turkeys nest in a variety of habitats, ranging from open fields to dense pine stands, and tend to select nest sites closer to ecotones (Mosby and Handley 1943, Exum et al. 1987, Holbrook et al. 1987, Thogmartin 1999, Byrne and Chamberlain 2013) and in areas with greater vegetation density and visual obstruction (Holbrook et al. 1987, Porter 1992, Badyaev 1995). Nest survival has been positively associated with increased cover (Badyaev 1995, Fuller et al. 2013, Streich et al. 2015) and woody stem density (Moore et al. 2010, Streich et al. 2015). Initial nest initiation rates have been documented as high as 100% in adult females (Vander Haegen et al. 1988), and as low as 34.4% in juveniles (Pollentier et al. 2014), but long-term trends suggest >75% of females nest each year (Table 1.1).

Reduced nesting rates can result in loss of production (Norman et al. 2001); however, nest predation has the greatest impact on production in ground nesting birds (Ricklefs 1969). Many mammalian predators have been documented to depredate turkey nests [e.g., raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), and gray foxes (*Urocyon cinereoargenteus*)]. Nests with greater vegetation density tend to be more successful than depredated nests (Thogmartin 1999), suggesting that as vegetation density increases, predation risk decreases. Nesting near roads or ecotones may increase predation risk, therefore influencing nest survival. Several nest predators such as coyotes and bobcats use these habitats as travel corridors and for foraging (Godbois et al. 2003, Hinton et al.

2015), and nests found closer to natural edges or roads may be less successful than nests located farther from these habitats (Thogmartin 1999).

Poult mortality is greatest during the flightless period [≤ 2 weeks post hatch; (Vangilder 1992)] and predation accounts for most poult loss (Speake et al. 1985). Precipitation may also account for poult loss depending upon the duration and intensity of the event (Healy and Nenno 1985). Habitat selection during brood rearing also has potential to affect brood survival, thus limiting reproductive potential and population growth. Quality brood habitat is generally described as a mixture of forested area and herbaceous vegetation (Porter 1992), and brood survival may increase in areas with increased visual obstruction (Metzler and Speake 1985, Spears et al. 2007). Invertebrate abundance is an important component of quality brood habitat as insects provide important food sources for developing poults (Hurst 1978), and has been documented to increase with increasing amounts of herbaceous vegetation (Healy 1985). Across wild turkey range, brood survival at 4 weeks (i.e. transition from poult to juvenile) averages ~34% (range: 24-47; Vangilder 1992). Notably, previous work in longleaf savannas of south Georgia reported brood survival (20.6%) among the lowest documented (see Little et al. 2014), but the causes and mechanisms for this remain unclear.

HOME RANGE

Understanding how an animal selects for and occupies habitat across the landscape is central to understanding its ecological niche (Johnson 1980). Within a given species range, individuals occupy home ranges to satisfy basic needs (i.e. food, cover, and reproduction; Burt 1943). Current methods to estimate home range size rely on quantifying areas of use based on estimates of an individual’s location across the landscape over a specified period of time (Laver and Kelly 2008). Individuals do not use space within a home range evenly, therefore space use is often reported as a utilization distribution, which reflects an individual's probability of occurrence at a random time (Powell and Mitchell 2012). Home range size is influenced by a myriad of factors, including population density, social structure, habitat quality, age, and distribution of resources (McNab 1963, Hixon 1980, Lindstedt et al. 1986, Lucherini and Lovari 1996).

Home range estimates for wild turkeys are highly variable across the species range (Badyaev et al. 1996, Miller et al. 1997, Thogmartin 2001, Miller and Conner 2005, Kiss et al. 2016). In a pine and mixed pine-hardwood forest in Mississippi, Miller and Conner (2005) estimated mean annual range for females to be 796 ± 46.0 ha, with ranges during fall/winter (524 ± 43.5 ha) greater than those during pre-incubation (326 ± 23.2 ha) and summer (392 ± 32.5 ha). In contrast, Badyaev et al. (1996) found that home ranges during spring (309.6 ha) and summer (265.8 ha) in the Arkansas Ozarks were greater than home ranges during fall (167.8 ha) and winter (255.3 ha).

WILD TURKEYS AND PRESCRIBED FIRE

Wild turkeys are generalists, occupying a variety of habitats across their range. In the southeast, pine forest types dominate much of the landscape, and particularly the southeastern coastal plain. Of these forests, longleaf savannas are one of the most biologically diverse (Van Lear et al. 2005), and home to many species considered threatened, endangered, or candidates for listing (Landers et al. 1995). Longleaf savannas require frequent fire events to maintain open, herbaceous understories. Managers use prescribed fire during the dormant season (October-March) to reduce accumulating fuels and stimulate herbaceous growth, but these fires fail to adequately control hardwood species (Brockway and Lewis 1997). Hence, in pine savannas prescribed fire is applied specifically during the growing season from April through September to control hardwood regeneration, maintain open herbaceous understories (Waldrop et al. 1992, Brockway and Lewis 1997, Glitzenstein et al. 2012), and stimulate wiregrass to flower (Mulligan and Kirkman 2002, Fill et al. 2012). Regardless of the season, fire has the potential to positively influence the structure and composition of habitats used by wild turkeys by reducing vegetation height, increasing herbaceous ground cover, and increasing forage (Exum et al. 1987, Waldrop et al. 1992, Brockway and Lewis 1997, Provencher et al. 2001). Wild turkeys are inextricably linked to the ground, taking flight typically only to avoid predation, or to roost. Therefore, prescribed fire has the potential to influence wild turkeys both directly (i.e. nest loss) and indirectly (i.e. home range size, habitat selection).

Wild turkey habitat use in pine savannas is not random. Females on private plantations in south Georgia showed a preference for freshly burned pinelands during spring and chose 1-3 year old roughs for nesting (Sisson et al. 1990). A study in the same region showed that habitat selection was sensitive to time since fire, and that females used stands burned in the previous 18 months, and began to avoid stands not burned in the previous 2 years (Martin et al. 2012). Prescribed fires applied during the reproductive period (March-July) have long been thought to negatively impact ground nesting birds (Sisson and Speake 1994). However, recent studies suggest that nest and brood loss due to growing season fire is low. Moore et al. (2010) observed minimal nest loss (5%) due to growing season fire, and Kilburg et al. (2014) found that despite a larger portion (20%) of the study area being burned during the reproductive period, < 6% of active nests were exposed to or failed due to fire. In pine savannas in southwest Georgia, ≤ 7% of nests were exposed to fire, and of these 60% successfully hatched (Little et al. 2014).

In addition to using prescribed fire to restore longleaf savannas, managers are now tasked with removal of off-site hardwood species to promote more desirable upland hardwoods including southern red oak (*Q. falcata*) and post oak (*Q. stellata*) (Georgia Department of Natural Resources; hereafter; GADNR, unpublished report). Removal of off-site hardwoods may influence wild turkey habitat selection by reducing hard mast, removing suitable roost trees, and reducing vertical escape cover. Previous research in longleaf savannas has identified the importance of hardwoods as roosting sites for brooding wild turkeys (Streich et al. 2015). However, hardwoods are also selected by raccoons (Chamberlain et al. 2002) and bobcats (Godbois et al. 2003) which are primary predators of nests and adult wild turkeys in upland pine habitats. Movements of successful and unsuccessful broods have been reported to be similar (Peoples et al. 1996, Godfrey and Norman 1999), suggesting habitat selection of brooding females may be more important than movements alone. Brood habitat of wild turkeys has been studied across their range; however, due to limitations of previous technology, fine scale analysis of brood habitat was impossible or required numerous assumptions. Previous studies in forests managed with fire noted that females nest and brood in stands subjected to prescribed fires on a 2 to 3 year rotation, although Exum et al. (1987) found that brooding females avoided areas burned ≥ 2 years prior.

Until recently, studying wild turkeys relied on triangulating individuals equipped with very high frequency (hereafter; VHF) transmitters. Recent development of a global positioning system (hereafter; GPS) transmitter suitable for wild turkeys now allows improvement to studies of wild turkey behavior (Guthrie et al. 2011). Previous research relied on a small number of locations to identify home range and habitat relationships. However, with the increasingly frequent locations that GPS transmitters can record, these relationships can be more accurately described (Collier and Chamberlain 2010). Many of the downfalls of previous wild turkey research using VHF technology such as triangulation error, observer induced biases to nesting, and misidentifying selected habitats can now be reduced. Thogmartin (2001) estimated triangulation error up to 485m, but with newer µGPS transmitters these error estimates have been reduced to ≤ 30m ($\overline{X}$ = 15.5m) (Guthrie et al. 2011).

My objectives were to equip female wild turkeys with µGPS transmitters to document reproductive chronology and success, and to evaluate fine-scale movements and habitat selection throughout the reproductive period, with an emphasis on movement and habitat selection during nesting and brood rearing. My research was conducted on an area subjected to frequent prescribed burning, and prescribed fire events occurred concomitantly with turkey reproductive seasons (Kilburg et al. 2014, Little et al. 2014, Yeldell et al. 2017a). In addition, management efforts to restore longleaf pine forests on my study area resulted in a mosaic of pine seral stages that influenced understory vegetation thought to be important to turkeys during reproductive phases. However, managers don’t fully understand how the interaction between pine seral stage and time-since-fire affects habitat selection by turkeys. Therefore, my goal was to assess how vegetation and landscape characteristics influence nest and brood site selection, success, and survival. Likewise, I sought to determine how time-since-fire influences habitat selection by female turkeys throughout their reproductive cycle.

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Table 1.1. Reproductive parameter estimates of female eastern wild turkeys (*Meleagris gallopavo silvestris*) in North America across multiple study sites from 1988-2014.

Citation	Location	Nesting Rate[a]	Nest Success[b]	Renesting Rate[c]	Renest Success[d]	Pooled Nest Success[e]
Vander Haegen et al. 1988	Massachusetts	0.92	0.39	0.50[f]	0.40	0.39
Roberts et al. 1995	New York	0.90	0.36	0.45	0.44	0.40
Thogmartin and Johnson 1999	Arkansas	0.62	0.17	.35 (.14[g])	0.04	0.14
Godfrey and Norman 2001	West Virginia	0.71	-	0.29	-	0.52
Bryne and Chamberlain 2013	Louisiana	0.60	0.39	0.27	0.25	0.35
Little et al. 2014	Georgia	0.70	0.42	0.37[f]	0.43	0.43
Pollentier et al. 2014	Wisconsin	0.77	-	0.37	-	0.26
	Pooled	0.74	0.35	0.34	0.31	0.36

[a] Percentage of females observed incubating at least one nest.

[b] Percentage of nests that successfully hatched a brood during an initial nest attempt.

[c] Percentage of females observed incubating a 2nd nest following a failed attempt.

[d] Percentage of renesting attempts that successfully hatched a brood.

[e] Pooled nest success estimate across all nesting attempts.

[f] Renesting rate includes multiple renest attempts (i.e. 3rd nest attempts).

[g] Percentage of females observed incubating a third nest.

CHAPTER 2

NESTING AND BROODING ECOLOGY OF EASTERN WILD TURKEYS IN A LONGLEAF PINE FOREST

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ABSTRACT

Management of longleaf pine (*Pinus palustris*) forests relies on use of frequent prescribed fire to limit encroachment of hardwoods and maintain understory communities dominated by early successional species. Prescribed fire is often applied during nesting and brooding phases of female wild turkeys and may immediately affect habitat availability and demographic outcomes. Therefore, we identified covariates affecting selection of areas used by nesting and brooding females and determined if these covariates influenced nest and brood survival in a longleaf pine ecosystem managed on a 1 - 3 year fire return interval. We captured 63 female wild turkeys and calculated vegetation and landscape characteristics surrounding nest, brood roosts, and brood daytime use locations. We used conditional logistic regression to determine what vegetation and landscape-scale (e.g., distance to stands exposed to prescribed fire, metrics of landscape heterogeneity, etc.) characteristics influenced nest, brood roost or brood daytime site selection. We then generated Cox proportional hazard models at both spatial scales to estimate effects of vegetation and landscape covariates on nest and brood survival. Females selected nest sites with greater visual obstruction and increased ground cover, while also selecting nest sites closer to stands burned during the previous 6 months, stands burned ≥ 3 years prior, roads, and areas with increased patch diversity. Females roosted broods at sites with increased ground cover and patch diversity. Likewise, during daytime females took broods to sites with increased ground cover, lower basal area, and decreased visual obstruction. We found that our measure of patch diversity (Shannon Diversity Index) positively influenced nest survival at the landscape-scale, while negatively impacting brood survival. Our results suggest managers should continue to use prescribed fire at frequent return intervals (1-3 years), applied in a mosaic fashion to create a

diversity of understory successional stages, which provides adequate cover and forage for nesting and brooding females.

INTRODUCTION

Managers of longleaf pine (*Pinus palustris*) forests rely on frequent fire return intervals (1-3 yrs) to reduce hardwood competition (Waldrop et al. 1992, Brockway and Lewis 1997, Glitzenstein et al. 2012) and promote vegetation communities favored by threatened and endangered species [e.g., red-cockaded woodpecker (*Picoides borealis*) and gopher tortoise (*Gopherus polyphemus*)] and popular game species [e.g. northern bobwhite (*Colinus virginianus*)]. Prescribed fire immediately alters vegetation succession, with post-fire vegetation responses determined by fire return interval, severity, and timing of application (Thaxton and Platt 2006, Ellair and Platt 2013, Wiggers et al. 2013, Robertson and Hmielowski 2014). Prescribed fire increases understory plant diversity, promotes germination of legumes and grasses, and alters vertical and horizontal structure (Brockway and Lewis 1997, Thaxton and Platt 2006, Grady and Hoffmann 2012). However, frequent fire return intervals are necessary because decreasing fire frequency facilitates hardwood competition, reducing diversity and structural heterogeneity in understory communities (Kush et al. 2000, Varner et al. 2000, Provencher et al. 2001, Beckage et al. 2009).

Application of prescribed fire in longleaf pine dominated ecosystems occurs prior to and during the reproductive period of eastern wild turkeys (*Meleagris gallpavo silvestris*; hereafter: turkeys) and may immediately affect habitat availability. Turkeys primarily consume herbaceous vegetation (Dalke et al. 1942, Glover and Bailey 1949, Schemnitz 1956, Exum et al. 1987) and new growth following recent fire may increase attractiveness of these stands to turkeys (Martin et al. 2012, Kilburg et al. 2014). As stands recover immediately post-fire, increasing availability of ground cover vegetation (Lemon 1949, Wiggers et al. 2013), herbaceous plants (Ellair and Platt 2013), and invertebrates (New 2014, Chitwood et al. 2017) may improve concealment of nests and increase foraging efficiency (Campo et al. 1989, Burk et al. 1990, Sisson et al. 1990, Still and Baumann 1990). However, fires may destroy turkey nests when applied during nesting (Moore et al. 2010, Kilburg et al. 2014, Little et al. 2014). Hence, turkey reproductive success has the potential to be negatively impacted by prescribed fire (Sisson and Speake 1994).

Vegetation cover surrounding nest sites may be the most important queue to turkeys when selecting nest sites (Conley et al. 2016, Little et al. 2016). Turkeys select nests in areas with relatively dense vegetation and visual obstruction (Holbrook et al. 1987, Badyaev 1995, Streich et al. 2015, Little et al. 2016, Yeldell et al. 2017*a*). Cover provided by hardwood stems surrounding the nest site may also positively influence nest site selection (Streich et al. 2015), but has been negatively associated with nest survival (Fuller et al. 2013, Morris and Conner 2016). Similarly, turkeys tend to nest close to roads (Holbrook et al. 1987, Badyaev 1995), but nest survival may be negatively correlated with distance to roads (Thogmartin 1999). Prescribed fire immediately affects vegetation structure, and therefore may influence selection of nest sites. For example, in pine landscapes managed with fire, turkeys selected to nest within mature pine stands burned 2 years prior (Yeldell et al. 2017a). Collectively, this suggests that characteristics at the nest site, and characteristics of the landscape surrounding it, influence nest site selection and can be affected by prescribed fire.

Brood habitat is generally described as a mixture of forested area and herbaceous vegetation that provide foraging opportunities and cover (Healy 1985, Metzler and Speake 1985, Porter 1992, Spears et al. 2007), and areas with increased visual obstruction may be associated with increased brood survival (Metzler and Speake 1985, Spears et al. 2007). The influences of fire on brood habitat selection in longleaf ecosystems are poorly understood. In southwest Georgia, Streich et al. (2015) found that brooding females selected roost sites closer to mixed pine-hardwood stands and water; however, vegetation characteristics did not appear to affect selection of locations where females ground roosted with their brood. Insects provide a primary food source for developing poults (Hurst 1978), and fire initially reduces insects populations by eliminating vegetation and litter (Siemann et al. 1997, Swengel 2001, Panzer 2002, Chitwood et al. 2017). Conversely, as plant communities regenerate post-fire, insects recolonize and abundance in the weeks and months following fire is similar to pre-fire levels (Siemann et al. 1997, Chitwood et al. 2017). Therefore, fire applied in a mosaic fashion, which increases landscape heterogeneity and diversity of understory successional communities, could have a positive impact on foraging success during brood-rearing.

Predation is the primary cause of turkey nest (Byrne and Chamberlain 2013, Kilburg et al. 2014, Little et al. 2014, Yeldell et al. 2017a) and brood loss (Speake et al. 1985, Palmer et al. 1993). Risk of predation likely operates across multiple spatial scales. For instance, percent ground cover may influence nest survival at local scales, whereas increasing edge density or patch shape complexity may influence nest survival at the landscape scale (Fleming and Porter 2004). Risk of predation on broods and hence, brood survival, are most likely influenced by multi-scale processes as well. Furthermore, because fire reduces available nesting substrate initially, it could influence predation rates and nest survival. Conversely, fire is also known to temporarily alter space use and habitat selection of common nest predators including raccoons (*Procyon lotor* ; Chamberlain et al. 2003, Jones et al. 2004) which could increase nest survival in patches burned since the previous growing season. Collectively, this suggests fire affects vegetation and landscape composition in ways that could affect nest and brood survival.

Because prescribed fire events occur concurrent with turkey reproductive seasons (Kilburg et al. 2014, Little et al. 2014, Yeldell et al. 2017a), understanding how vegetation and landscape characteristics influence nest and brood site selection, success and survival is necessary to manage turkey populations in ecosystems managed with fire. Our goals were to identify vegetation and landscape covariates influencing selection of nest sites, brood ground roost sites (hereafter ground roosts), and sites used by brooding females during daytime (hereafter daytime use sites), and determine if these covariates affected nest and brood survival. We hypothesized that females would select nests and ground roost sites closer to stands burned ≥ 2 years prior due to increased concealment cover from predators, while also selecting nest and ground roosts and daytime use sites (collectively, brood sites) closer to stands burned < 2 years previously for access to forage and potential brooding areas. We also hypothesized that females with broods would select sites closer to stands burned < 2 years previous during daytime due to increased foraging opportunities, and open vegetation that poults could navigate easily. We hypothesized that brooding females would select ground roost sites in areas burned ≥ 2 years prior due to increased concealment cover needed while roosting on the ground. In addition, we hypothesized that covariates females selected for during nesting and brood-rearing would influence nest and brood survival.

STUDY AREA

We conducted research on the Silver Lake Wildlife Management Area (hereafter, SLWMA) owned and managed by the Georgia Department of Natural Resources-Wildlife Resources Division (GADNR), and the Lake Seminole Wildlife Management Area owned by the U.S. Army Corps of Engineers (USACE) and managed by GADNR in southwest Georgia. Due to similarity in management and vegetation communities, and because these properties were adjacent to each other, the collective 4,700 ha area is hereafter referred to as SLWMA. In addition, research was conducted on private lands surrounding SLWMA as necessary, and management of these lands differed from SLWMA.

The SLWMA was dominated by mature pine (*Pinus* spp.) forests, and forested wetlands, with clear-cuts, young pine plantations and forest openings scattered throughout. Overstory trees were predominately longleaf pine, but also loblolly pine (*P. taeda*), shortleaf pine (*P. echinata*), slash pine (*P. elliottii*), oaks (*Quercus* spp.), and sweetgum (*Liquidambar styraciflua*). Understory plants included wiregrass (*Aristida stricta*), broomsedge (*Andropogon* spp.), bracken fern (*Pteridium* spp.), runner oak (*Q. pumilla*), blackberry (*Rubus* spp.), blueberry (*Vaccinium* spp.), muscadine (*Vitis rotundifolia*), American beautyberry (*Callicarpa americana*), common ragweed (*Ambrosia artemisiifolia*), and greenbrier (*Smilax* spp.). Private lands surrounding SLWMA were primarily a mixture of agricultural fields, managed timber lands, and hunting plantations managed for northern bobwhite. Other private lands in the area consisted of rural dwellings, cattle pastures, poultry farms, and hardwood-dominated forested wetlands.

The SLWMA was managed for both nongame (i.e. RCWs) and game (i.e. northern bobwhite) species. In particular, SLWMA is managed by GADNR as a bobwhite focal area. In some areas of SLWMA, managers trapped and removed mesomammals during late February and early March of 2015 and 2016 prior to the onset of incubation behavior. Additionally, to create a mosaic of vegetation communities available to quail and other game species, land managers on SLWMA used prescribed fire to maintain herbaceous understory vegetation communities and promote growth of longleaf pine, while inhibiting undesirable hardwood regeneration and reducing fuel loads (GADNR, unpublished report). Burn units were divided by a mixture of gravel roads, disked fire lines, and natural fire breaks. Prescribed fire was primarily applied using ATV-mounted drip torches, although some burn units on USACE owned properties were burned using a helicopter due to lack of access. Prescribed fire was applied throughout the year, but most fires occurred during the dormant season in 2015 (63.3%) and growing season in 2016 (92.3%). In 2015, 1060 ha were burned, whereas 1211 ha were burned in 2016. Average size of prescribed burns on SLWMA was 26.02 ± 3.72 ha (range: 3.30 ha to 72.41 ha) in 2015 and 19.84 ± 2.45 ha (range: 1.13 ha to 73.18 ha) in 2016. Prescribed fire was sparsely applied on private lands surrounding SLWMA, but records were unavailable to determine the frequency or extent of these fires, and therefore analyses including fire were confined to the SLWMA boundary.

METHODS

Capture and Monitoring

We captured turkeys using rocket nets from January-March 2015 and 2016. Turkeys were sexed, aged (Pelham and Dickson 1992) and fitted with serially numbered butt-end aluminum leg bands. All females were fitted with a backpack style, remotely downloadable, micro-Global-Positioning-System (µGPS) transmitter (Minitrack L, Sirtrack, Havelock North, New Zealand) with very high frequency (VHF) capabilities, and released at the capture site. We programmed µGPS transmitters to record locations 2 times per day (1200-hrs and 2359-hrs) from date of capture until 1 March. From 1 March to 15 August, transmitters recorded GPS locations once per hour from 0500-hrs to 2000-hrs, and a single roost location at 2359-hrs. All turkey capture, handling, and marking procedures were approved by the Institutional Animal Care and Use Committee at the University of Georgia (Protocol #A2014 06-008-Y1-A0).

Nest Monitoring

We located turkeys ≥ 1 time per week using a 3-element handheld Yagi antenna and R4000 receiver (Advanced Telemetry Systems, Inc., Isanti, MN) to monitor survival and nesting activity. We downloaded GPS locations from each turkey ≥ 1 time per week. We viewed GPS locations and considered a female to be incubating a nest when female locations became concentrated around a single point (Yeldell et al. 2017*a*, *b*). Once females were laying or incubating, we monitored them daily to determine nest survival. After nest termination, we located the nest site to determine nest fate and conduct vegetation sampling. Because turkey nests require continuous incubation approximately 25 to 29 days before hatching (Williams Jr. et al. 1971, 1976), we considered nests abandoned if a female left the nest prior to 30 days and only intact eggs were found in the nest bowl. We considered nests depredated if the nest was found empty or with only eggshell fragments prior to 25 days. We considered nests successful if ≥ 1 poult hatched, and the large end of eggshells were neatly chipped away (Healy 1992).

To better understand nesting ecology, we measured nesting rate and nest success. We defined the initial nesting rate as the percentage of females that initiated ≥1 nest, second nest attempt rate as the percentage of females that initiated a second nest attempt following the loss of the first nest or brood, and third nest attempt rate as the percentage of females that initiated a third nest attempt following the loss of their second nest or brood. We defined nest success rates for each nesting attempt as the percentage of nests that were successful, and overall reproductive success as the percentage of females that attempted ≥1 nest and hatched ≥1 egg.

Brood Monitoring

After nests hatched, we monitored the brooding female up to 28 days post-hatch to estimate brood survival and aid in locating ground roosts for vegetation sampling. This 28 day period represents the time a young wild turkey is known as a poult, after which they are considered juveniles (Hurst 1992). Similar to Ruttinger et al. (2014), we located each female after nest termination on the roost via VHF signal homing and used a Raytheon Infrared-Palm IR

250 Digital thermal camera (Raytheon Commercial Infrared, Dallas, TX) to confirm presence of poults, as poults < 18 days post-hatch are difficult to detect during flush counts (Glidden and Austin 1975). We considered a brood to be present if ≥ 1 poult was seen or heard with the female. In the event a female flushed, we also considered a brood present if the adult female displayed brood protective behavior, whereby the female did not fly away, feigned a broken wing, and/or repeatedly emitted calls while circling the observer. If we detected a brooding female on the ground prior to 14 days, we assumed she was still with a brood as brooding females typically begin tree roosting with poults around 14 days post-hatch (Barwick et al. 1971, Spears et al. 2007). Likewise, if we detected a brooding female roosted in a tree prior to 14 days post-hatch and could not detect poults, we assumed the brood was lost. After females began tree roosting with poults, we relied on visual and auditory detection of poults to confirm brood presence. We performed brood surveys every 3 days up to 28 days post-hatch or until we failed to detect poults during 2 consecutive attempts, at which point we assumed the brood to be lost. After broods begin roosting in trees, survival tends to increase (Everett et al. 1980) and ground level vegetation becomes less relevant at roosts. Hence, we did not measure vegetation characteristics at roost sites past 14 days post-hatch. We defined brood success as the proportion of broods with ≥ 1 poult surviving to 28 days post-hatch (Little et al. 2014, Yeldell et al. 2017a).

Vegetation Sampling

To understand vegetation covariates influencing selection of nest and brood sites, we sampled vegetation characteristics within a 15 m radius circle at nest sites, daytime use sites (0800 – 1900 hrs) and ground roost sites, following established protocols (Little et al. 2014, Streich et al. 2015, Conley et al. 2016, Yeldell et al. 2017a) to enable comparisons to previous studies. At each site, we recorded percent total ground cover, percent canopy cover, height of visual obstruction (cm), average vegetation height (cm), and basal area. To approximate tree density, we recorded a single basal area estimate using a 10 B.A.F. prism centered on the use site. We measured percent total ground cover of understory vegetation using a 1-m^2 frame (Daubenmire 1959) placed on the ground at the use sites and at 15 m in each cardinal direction. We estimated percent canopy cover of vegetation using a convex spherical densiometer (Lemmon 1956) from a height of approximately 1 m at the use site and 15 m in each cardinal direction. To estimate density of understory vegetation, we placed a 2 m tall Robel pole (Robel et al. 1970) at the use point and 15 m in each cardinal direction to estimate visual obstruction and average height of vegetation.

We sampled vegetation characteristics at all sites within 3 days of the projected hatch date or date of use to reduce biases associated with changes in vegetation growth and standardize sampling among sites (McConnell et al. 2017). To quantify vegetation associated with areas females used while brooding during the daytime, we downloaded GPS locations from each female every 3 days and randomly selected 1 GPS location from the day of our most recent brood survey to visit and sample. We used handheld GPS units to navigate to the brooding female’s location, and conducted the same vegetation sampling we used for nest and brood roost sites. As stated earlier, vegetation sampling at roost sites was limited to 14 days, whereas sampling occurred at daytime use sites up to 28 days post-hatch. For each site (i.e., nest, ground roost, or daytime use), we randomly selected a site 100 – 200 m away from the used site and conducted surveys identical to those at used sites. This location was presumably a site that a female could have selected, and acted as a paired random location in our analyses.

Landscape Characteristics

To identify landscape characteristics affecting selection of nest and brood sites, we obtained forest inventory data from GADNR for stands located within SLWMA. Stand data were unavailable for surrounding private lands, so we estimated stand conditions via photo interpretation for these areas. We obtained data from the National Agriculture Imagery Program, Landsat 8 multi-spectral satellite imagery (Roy et al. 2014), and the National Land Cover Database (Homer et al. 2015). We then hand-digitized a 30 m resolution landcover dataset, and classified vegetation communities into 5 cover types. We classified pixels as pine stands if they consisted of > 50% longleaf, loblolly, slash, or shortleaf pine in the overstory. We subsequently classified pine stands as mature if they were ≥ 20 years old, and young if they were 4 - 19 years old. Mature pine stands primarily were identified by lower stocking levels and increased DBH classes. Young pine stands were identified by increased stocking levels and included planted pines 4 years post-establishment and plantations with little to no understory. We classified pixels as hardwood stands if they consisted of > 50% hardwood species, which were typically confined to lowland areas bordering lakes and ponds, upland depressional wetlands, or planted sawtooth oak (*Quercus acutissima*) groves. We classified wildlife food plots, fallow fields, cattle pastures, and clear-cuts planted in pine (≤ 3 years old) as open. We classified fields planted in row crops as agriculture. Pixels that contained houses, or other man-made structures were classified as developed, but not considered turkey habitat, and were excluded from analysis. To ensure the accuracy of our landcover data, we ground-truthed each landcover type by visiting a random sample of 20 - 30 pixels of each vegetation community and assessing dominant vegetation. We found that we correctly classified vegetation communities 96% of the time.

Turkeys are generalists, and nest in a wide-range of vegetation communities across their range (Badyaev 1995, Roberts et al. 1995, Chamberlain and Leopold 1998, Thogmartin 1999, Yeldell et al. 2017a). For instance, turkeys use diverse overstory communities for nesting such as bottomland hardwoods in Louisiana (Byrne et al. 2011), areas of dense cover in open vegetation communities in Florida (Giuliano et al. 2016), and pine forests in Arkansas (Thogmartin 1999). However, nest sites are often similar at the vegetation scale and are often found in areas with increased ground cover and vegetation density (Streich et al. 2015, Little et al. 2016, Yeldell et al. 2017a). Therefore, managing for specific overstory species may not influence selection of nests, and instead, the composition of features across a landscape may best predict nest site selection (Pollentier et al. 2017, Yeldell et al. 2017a). As such, we were less interested in associations to specific overstory vegetation communities, and instead used these vegetation communities to generate landscape composition metrics (i.e. patch diversity).

Features surrounding nest and brood sites (i.e. food resources, predation risk) may influence nest (Martin and Roper 1988) and brood site selection, hence we calculated distance to landscape characteristics (i.e. roads and edges). We obtained road data (e.g. two-tracks, firebreaks, primary roads; collectively, roads) within SLWMA from GADNR, and used TIGER (U.S. Census Bureau 2017) data to identify roads outside the SLWMA boundary. If needed, we hand digitized roads, trails, or firebreaks not included in the above datasets. We used the 5 vegetation community types delineated above, along with roads, to identify edges on the landscape. We used a circular moving window analysis in FRAGSTATS (McGarigal et al. 2012) with a radius of 94.6 m to generate raster values for Shannon's Diversity Index and Contagion Index, and extracted values at known use and random sites. We used this radius as it equates to a circular area of 2.81 ha, which was the average incubation range of females in our study (see

Chapter 3). Contagion index (CONTAG) relates to the dispersion and interspersion of patch types on the landscape, and habitat suitability for turkeys has been shown to increase where vegetation communities are more interspersed (Kurzejeski and Lewis 1990, Pollentier et al. 2017). Shannon's Diversity Index (SHDI) is a measure of patch diversity on the landscape, and diversity of patch types has been negatively associated with nest site suitability (Byrne and Chamberlain 2013).

To understand how prescribed fire influenced nest, ground roosts, and daytime use sites, we obtained burn data for each stand within SLWMA from GADNR, and combined fire history data with our landcover map to distinguish between areas that had and had not been burned within 6 years. Because fire on our study site tended to be applied to the same compartments within 3 years, stands that had no history of fire during the previous 6 years were assumed to never be burned. We categorized burned stands based on fire history at the time of laying for each nest attempt. We classified stands as being burned during the previous 6 months, burned 1 year previously, burned 2 years previously, burned 3 or more years previously, or never burned. Diversity in understory vegetation communities in longleaf pine forests declines with increasing time since fire, and stands ≥ 3 years post-burn are similar in appearance and structure (Glitzenstein et al. 2012). Thus, we combined all stands burned ≥ 3 years prior as vegetation communities were characterized by increased ground cover dominated by woody plants. Because we were interested in how turkeys selected nest and brood sites relative to prescribed fire, we calculated distance to each burn type and extracted the values at known use sites and random sites.

Before calculating landscape characteristics around known nest sites, we generated random sites within each female's pre-nesting area. We defined the pre-nesting area as the space used from 1 March until the onset of laying behavior for first attempts. We estimated space use using the dynamic Brownian Bridge movement model (dBBmm) to calculate 95% utilization distributions (UDs) around individual turkey locations, using a window size of 15, margin of 5, and location error of 15 m (Kranstauber et al. 2012, Byrne et al. 2014). We calculated UDs during all pre-nesting, laying, and incubation periods detected for each female. We assumed laying occurred during the 12 days prior to continuous incubation based on an average clutch size of 12 eggs (Vangilder 1992, Yeldell et al. 2017a). If a turkey had > 1 nest, we considered the pre-nesting area for each female as the merged UDs for each reproductive period prior to laying for any given nest attempt. We did this to create a more conservative estimate of space use, as a new UD would be overly biased and collapsed by locations during the previous incubation period. Based on Yeldell et al. (2017*a*), we generated 5 paired random locations within each pre-nesting range for each individual female across each nest attempt. To calculate landscape characteristics at ground roosts and brood daytime use sites, we constructed daily ranges by creating 100% minimum convex polygons around the GPS locations for the day prior to roost sampling, and around the GPS locations for the day of the daytime site sampling. Similar to nest sites, we generated 5 paired random points within each daily range.

Data Analysis

To understand factors influencing nest, ground roost and brood daytime use site selection at vegetation and landscape-scales, we used conditional logistic regression analysis with case-controlled sampling in package ‘survival’ (Therneau and Lumley 2016) in program R v.3.1.1 (R Core Team 2014), where cases were known use sites and controls were random sites. We treated nest sites as independent samples regardless if a turkey nested multiple times in a season. We treated individual brooding sites as independent samples because samples were taken from locations 3 days apart. Because highly correlated covariates included in the same model inflate estimates of variance and hinder biologically relevant interpretation of data (Dormann et al. 2013), we calculated Pearson correlations (*r*) between pairs of explanatory covariates at each scale prior to building our models. If any pairs of covariates were found to be highly correlated (|*r*| ≥ 0.7; Dormann et al. 2013), we only retained the covariate that provided the simplest biological interpretation.

Nest, Brood Roost, and Brood Daytime Site Selection

Similar biological and ecological cues likely affect how turkeys perceive predation risk and select nest and brood sites. Therefore, we used the same candidate set of models to test which vegetation covariates influenced nest and brood site selection. We developed 7 predictive models to identify how vegetation covariates influenced nest, brood roost and brood daytime sites (Table 2.1). Our first 4 models were based on the prediction that selection was influenced by percent total ground cover, visual obstruction, percent canopy closure, or basal area. Turkeys have been shown to select nest sites with greater percent total ground cover (Badyaev 1995, Fuller et al. 2013, Streich et al. 2015, Yeldell et al. 2017a), and increased visual obstruction (Holbrook et al. 1987, Streich et al. 2015, Little et al. 2016), and ideal habitat for brooding turkeys should provide adequate concealment for poults while providing a female unobstructed views to detect predators (Porter 1980). Therefore, our fifth model examined additive effects of total percent ground cover and visual obstruction on selection.

At the landscape-scale, we developed 10 predictive models to identify how proximity to fire-influenced vegetation communities, landscape characteristics, and landscape heterogeneity influenced nest, ground roost and brood daytime use sites (Table 2.2). Early successional communities resulting from prescribed fire provide abundant foraging opportunities in the form of herbaceous vegetation (Brockway and Lewis 1997) and insects (Chitwood et al. 2017) compared to other vegetation communities. Likewise, roads receive annual maintenance and can provide greater forage than nearby forested areas (Hurst and Dickson 1992). Therefore, our first model predicted selection would be based primarily on forage availability and stated the additive effects of distance to stands burned ≤ 1 year previously and distance to roads best explained site selection. Understory vegetation density increases with increasing time since fire, which provides increased concealment from predators and reduced thermal radiation (Taylor et al. 1999, Carroll et al. 2015, Kamps et al. 2017), but may decrease poult mobility and increase predation risk of broods. Therefore, our second model suggested site selection was most influenced by concealment cover offered by vegetation communities offered by stands burned ≥ 2 years. Predators are positively associated with linear landscape features and increased patch diversity (Oehler and Litvaitis 1996), areas where fire has been excluded (e.g. hardwoods; Godbois et al. 2003, Hinton et al. 2015), and may be reduced in areas burned within the previous calendar year (Jones et al. 2004). Hence, our third model examined whether site selection was most influenced by predation risk and examined additive effects of distance to roads and edges, SHDI, distance to stands burned during the previous 6 months, and stands that were never burned.

Nest and brood site selection may be influenced by both concealment cover and foraging opportunities. So, our fourth model predicted selection would be influenced by concealment cover and foraging opportunity, and examined additive effects of distance to all burned stands, distance to roads, and SHDI. Turkeys may select vegetation communities in relation to nearby escape cover (Yeldell et al. 2017b), and this may be true both during nesting in areas with increased vegetation cover and during brood-rearing. Therefore, our fifth model investigated how turkeys select nest and brood sites while balancing concealment with the opportunity to escape predators, so we examined additive effects of distance to stands burned ≥ 2 years previously, distance to stands that were never burned, distance to edge, and CONTAG. Because nest and brood site selection may be influenced by both mitigating predation risk and providing adequate cover from thermal radiation, our sixth model predicted selection was primarily influenced by interspersion of vegetation communities, and vegetation communities that provide increased ground cover, and examined additive effects of distance to linear landscape features, distance to all burn classes, and percent CONTAG on nest site selection. Because habitat suitability has been shown to increase where vegetation communities are more interspersed (Kurzejeski and Lewis 1990, Pollentier et al. 2017), and because patch diversity has been negatively associated with nest site suitability (Byrne and Chamberlain 2013), we developed the next 2 models based on the prediction that SHDI and CONTAG alone influenced nest and brood site selection. Because we presumed *a priori* all covariates measured would be important to nest and brood site selection, we developed a global model at each scale examining additive effects of all explanatory covariates on selection of nests, ground roosts, and brood daytime use sites. Lastly, we compared all models at each scale to a null model, which predicted selection was not influenced by any landscape-scale covariates we measured.

Prior to running our models, we scaled covariates to simplify interpretation of selection. We scaled distance covariates by a distance of 100 m, and all other covariates except SHDI by a factor of 10. We did not scale SHDI because scaling would not benefit interpretation. We calculated second-order Akaike's Information Criteria (AIC_c) for all models to assess model support (Akaike 1973) and considered the most plausible model to have the lowest AIC_c score. We used a likelihood-ratio test (LRT) to compare the top performing models to the null model to assess how well the model fit the data (Hosmer and Lemeshow 2000). The *p*-value associated with LTR was set at 0.05. We rejected the null hypothesis and considered models biologically informative if $P \leq 0.05$. We calculated ΔAIC_c values and adjusted Akaike's weights (w_i) for each model, and considered all models within 2 units of the lowest ΔAIC_c value for explaining selection to be equally plausible (Burnham and Anderson 2002). We calculated parameter estimates (β), standard errors (SE), *P*-values (*P*), scaled odds ratios (*SOR*) and their associated confidence intervals (*CI*) for all covariates in the top-performing model(s) at each scale for nest and brood site selection (Table 2.3). Except for SHDI in which we calculated an odds ratio (*OR*) and associated confidence interval. In the event multiple models were within 2 units of the lowest AIC_c value, we calculated model-averaged parameter estimates, standard errors and *P*-values (Table 2.3). We considered covariates statistically significant if $P \leq 0.05$.

Nest and Brood Survival

We sought to assess if covariates included in model(s) best explaining site selection at each scale (Table 2.6) affected survival probability of nests or broods. To determine if selection decisions made by female wild turkeys influenced nest survival, we used Cox proportional hazards model (COXPH) in package 'survival' (Therneau and Lumley 2016). To assess how covariates in our top model(s) influenced brood survival, we used a cumulative exposure COXPH model because we hypothesized additional exposure to our covariates could affect risk. To assess the cumulative exposure for each brood, we calculated a running mean for each covariate sampled at each successive brood use site for each brooding female. The most vulnerable period for developing poults occurs during the first 2 weeks of life (Barwick et al. 1971, Speake 1980, Speake et al. 1985, Peoples et al. 1995) prior to roosting in trees, therefore we only examined the influence of ground roost selection on survival. Brood survival is greater following the first 2 weeks post-hatch; however, poults are still susceptible to multiple predator guilds during this period. Therefore, we examined how daytime use influenced survival across the entire 28 day brood-rearing period. Because we were unable to accurately count how many poults were with a female, our analysis only considered survival of the entire brood (e.g., at least 1 individual poult survived). To determine if covariates deviated significantly from proportionality, we tested the proportional hazards assumption. The COXPH model generates hazard ratios (*HR*) for each covariate within the model, where hazard ratios > 1 indicate increasing probability of nest or brood failure, and hazard ratios < 1 indicate a decreasing probability of failure.

Based on our top performing vegetation models (Table 2.2), we examined if ground cover and visual obstruction affected nest and brood survival. Vegetation covariates in our best performing models explaining brood daytime use included ground cover, basal area, canopy cover, and visual obstruction. Hence, we used an additive time-varying COXPH to determine if any of these covariates influenced brood survival. Our top performing models at the landscape-scale (Table 2.2) included all covariates except for CONTAG. Therefore, we examined whether covariates for time-since-fire, linear landscape features, and patch diversity influenced nest and brood survival.

RESULTS

Nest and Brood Success

We captured 63 female turkeys (58 adults and 5 juveniles) during 2015 and 2016; of which 3 (2 adults, 1 juvenile) died prior to nesting, 7 (5 adults, 2 juveniles) had transmitters that malfunctioned and precluded us from determining reproductive status, and 5 adults never nested. Therefore, we monitored 76 nests from 48 females (39 in 2015, 37 in 2016), only 2 of which were initiated by juveniles, so we included them with the sample of adults. Of 76 nests, 2 failed prior to the onset of incubation, leaving 74 nests from 46 females (51 initial nest attempts, 21 second attempts, and 2 third attempts). Nest initiation rates for initial, second and third nest attempts were 96.2%, 61.8%, and 13.3% respectively (Table 2.4). Earliest onset of incubation of initial nest attempts was 6 April (2015) and 30 March (2016), and mean date of incubation was 18 and 11 April, respectively (Figure 2.1). Mean onset of incubation for second attempts was 21 and 12 May, and 13 June for third attempts. Reproductive behaviors (i.e. laying, incubating, and brood-rearing) were documented from mid-March to mid-July (Figure 2.1).

Of 74 nests incubated, we removed 4 from estimates of nest success due to suspected abandonment via observer influence. We documented 29 (41.4%) successful nests. We documented cause of nest failure for 39 nests, 35 (85.4%) of which failed due to predation. Nest success rates for first, second, and third nests were 34%, 65%, and 0% respectively (Table 2.4), which led to overall female reproductive success of 55%. No nests from radio-marked females were exposed to fire during incubation. Four nests (5.4%) would have been exposed to fire prior to the projected hatch date but were predated before fire application.

Of 29 successful nests, we monitored 25 broods from 24 females (12 in 2015, 13 in 2016), the fate of the remaining 4 broods was unknown due to transmitter malfunction. Three broods were lost immediately after hatching and prior to leaving the nest site, and each female subsequently renested. Of monitored broods in 2015, 7 (58.3%) survived the initial 14 days post hatch, and 5 (41.7%) survived to 28 days post-hatch. In 2016, 2 (15.4%) survived the initial 14 days post hatch, and 1 (7.7%) survived to 28 days post-hatch. Overall, 9 (36.0%) broods survived the initial 14 days post-hatch and 6 survived to 28 days, making overall brood success 24%.

Nest Site Selection and Survival

Average vegetation height and visual obstruction were correlated ($r = 0.81$), so we only included visual obstruction in our candidate models. Our top-performing nest site selection model (visual obstruction and ground cover model; $w_i = 0.76$; LRT = 33.41; $P = < 0.01$: Table 2.2) suggested turkeys were more likely to nest in areas with increased ground cover ($\beta = 0.30$; $SOR = 1.35$; 95% CI: 1.12 – 1.63; $P \leq 0.01$: Table 2.3) and increased visual obstruction ($\beta = 0.21$; $SOR = 1.23$; 95% CI: 1.04 – 1.46; $P = 0.02$: Table 2.3). Scaled odds ratios suggested that females were 1.35 times more likely to select nest sites for every 10% increase in ground cover, and 1.23 more likely to select nest sites for every 10 cm increase in visual obstruction.

Females located nests in mature pine ($n = 41$; 52.5%), open habitats ($n = 21$; 26.9%), young pine ($n = 14$; 17.9%), and hardwood dominated stands ($n = 2$; 2.5%). At the landscape scale no covariates were correlated, so we used all in our models. We removed 11 nests initiated off of SLWMA where burn histories were unknown, or when transmitter malfunction prevented us from determining known incubation dates. Our top model, the global model($w_i = .78$; LRT = 61.59; $P = < 0.01$: Table 2.2), suggested females selected nest sites closer to stands burned ≥ 3 years previous ($\beta = -0.46$; $SOR = 0.63$; 95% CI: 0.48 – 0.82; $P \leq 0.01$: Table 2.3), closer to stands never burned ($\beta = -0.51$; $SOR = 0.60$; 95% CI: 0.38 – 0.94; $P = 0.03$: Table 2.3), closer to roads ($\beta = -1.68$; $SOR = 0.19$; 95% CI: 0.05 – 0.66; $P = 0.01$: Table 2.3), and within areas with greater patch diversity (SHDI; $\beta = -3.25$: $OR = 0.04$; 95% CI: 0.01 – 0.14; $P \leq 0.01$; Table 2.3). Scaled odds ratios suggested that females were 1.38, 1.40, and 1.81 times less likely to choose a nest site for every 100 m increase in distance to stands burned ≥ 3 years previous, stands never burned, or roads respectively. In addition, odds ratios suggested females were 1.96 times more likely to choose a nest site as patch diversity increased.

We removed 6 nests from the survival analysis that failed prior to the initiation of continuous incubation (*n = 1*) or failed due to observer interference (*n* = 5). As a result, we used 63 nests to determine covariates that may influence nest survival. We found that percent ground cover (β = 0.16; *HR* = 1.17; 95% CI: 0.84 – 1.64; *P* = 0.35) and visual obstruction (β = -0.09; *HR* = 0.92; 95% CI: 0.81 – 1.04; *P* = 0.18) did not influence nest survival (Table 2.5). At the landscape-scale, only SHDI (β = -1.36; *HR* = 0.26; 95% CI: 0.07 – 0.90; *P* = 0.03) had a significant influence on nest survival (Table 2.5), with probability of nest survival increasing as patch diversity increased.

Brood Roost Site Selection and Survival

We analyzed vegetation data from 83 ground roosts from 21 broods. Our top model (VO and GC model; w_i = 0.58; LRT = 23.95; *P* = < 0.01: Table 2.2) and second best approximating model (GC model; w_i = 0.32; LRT = 20.7; *P* = < 0.01: Table 2.2) suggested females were more likely to select ground roost sites with increased ground cover (β = 0.26; *SOR* = 1.30; 95% CI: 1.14 – 1.48; P ≤ 0.01), but visual obstruction (β = -0.11; *SOR* = 0.93; 95% CI: 0.78 – 1.01; *P* = 0.08) was not an informative covariate for selection (Table 2.3). Females were 1.3 times more likely to choose brood roost sites for each 10% increase in ground cover.

We removed 19 ground roosts that were located off of SLWMA using logic previously discussed. Our top model (concealment and foraging model; w_i = 0.65; LRT = 158.1; *P* = 0.00: Table 2.2) suggested time-since-fire affected ground roost selection; females were more likely to choose ground roosts farther from stands burned during the preceding 6 months (β = 0.45; *SOR* = 1.58; 95% CI: 1.13 – 2.19; *P* = 0.01: Table 2.3) or burned ≥ 3 years previously (β = 0.45; *SOR* = 1.57; 95% CI: 1.07 – 2.30; *P* = 0.02: Table 2.3). Also, females were more likely to select ground roosts in areas with increased patch diversity (β = -1.10; *OR* = < 0.01; 95% CI: < 0.01 – < 0.01; *P* ≤ 0.01: Table 2.3).

Vegetation characteristics at roost sites did not influence brood survival (Table 2.5). However, we found brood survival at ground roosts was influenced by SHDI (β = 3.63; *HR* = 37.57; 95% CI: 2.37 – 595.15; *P* = 0.01: Table 2.5). Hazard ratios suggested that broods were 37.57 times more likely to fail as patch diversity (SHDI) increased.

Brood Daytime Site Selection and Survival

We analyzed vegetation data from 111 daytime use sites from 20 females. For daytime use sites, the global model was the best approximating model (w_i = 0.99; LRT = 43.27; *P* = < 0.01: Table 2.2), suggesting that females took broods to areas with increased ground cover (β = 0.18; *SOR* = 1.20; 95% CI: 1.08 – 1.34; *P* ≤ 0.01: Table 2.3), decreased basal area (β = -0.24; *SOR* = 0.78; 95% CI: 0.69 – 0.88; *P* ≤ 0.01: Table 2.3), and decreased visual obstruction (β = -0.17; *SOR* = 0.84; 95% CI: 0.75 – 0.94; *P* ≤ 0.01: Table 2.3); canopy cover was not informative (Table 2.3). Females were 1.2 times more likely to choose brood daytime use sites for each 10% increase in ground cover, and 1.22 and 1.16 times less likely to choose sites for every increase of 2.30 m^2/ha basal area and every 10 cm increase in visual obstruction.

Vegetation characteristics at daytime sites did not influence survival of broods (Table 2.5). We analyzed landscape scale covariates at 86 known brood daytime use sites; no landscape scale covariates measured were found to influence selection of daytime use sites (Table 2.3). Therefore, we did not examine how landscape-scale covariates at daytime use sites influenced brood survival.

DISCUSSION

Prescribed fire immediately alters vegetation communities and may influence habitat quality for reproductively active female wild turkeys. The turkey population at SLWMA was involved in nesting or brood-rearing activities for approximately 4 months, similar to the extent recently reported for turkeys in Louisiana, USA (Yeldell et al. 2017a). We observed initial nesting rates comparable to other sites across the species' range (Vander Haegen et al. 1988, Roberts et al. 1995, Yeldell et al. 2017a), but noticeably higher than previously reported rates in the southeastern United States (Palmer et al. 1993, Miller et al. 1998, Byrne and Chamberlain 2013) and southwest Georgia (Little et al. 2014). Renesting rates were similar to those found in west-central Louisiana (Yeldell et al. 2017a). Higher observed rates of nesting and renesting were most likely attributable to improved monitoring afforded by the use of GPS transmitters (Collier and Chamberlain 2010, Yeldell et al. 2017a), and we suggest may be more indicative of true nesting rates than works published prior to the advent of GPS transmitters for turkeys. Despite monitoring 74 nests, none were exposed to prescribed fire during incubation. Brood loss was greatest during the first 2 weeks post-hatch, after which few broods were lost.

Percent ground cover was consistently important to females when selecting nest and brood sites. Turkeys should select nesting and brood-rearing areas which minimize predation risk (Martin 1993), and our results agree with previous assertions that turkeys are more likely to select nest sites in areas with abundant ground cover (Hon et al. 1978, Holbrook et al. 1987, Badyaev 1995, Byrne and Chamberlain 2013, Streich et al. 2015). Similarly, females selected ground roosts and brood daytime use sites in areas with increased ground cover. Increased ground cover may reduce visual and olfactory cues at nest and brood sites, and reduce predator foraging efficiency (Bowman and Harris 1980). Nest survival has been shown to increase with increasing ground cover at the nest site and on the same site nest survival decreased with increasing vegetation density (Fuller et al. 2013). On our study site, females selected nest sites with increased visual obstruction and brood daytime sites with decreased visual obstruction. Conversely, visual obstruction has not been shown to be an important predictor of nest site selection in a fire-managed landscape in Louisiana (Yeldell et al. 2017a). Quality brooding habitat is generally considered to provide understory vegetation with enough cover to conceal poults while allowing brooding females an unobstructed view to detect predators (Porter 1992). Likewise, decreased visual obstruction at brood daytime use sites is likely preferred to increase foraging efficiency and increase mobility of poults. Despite females selecting for these areas, neither ground cover nor visual obstruction influenced nest survival. Predation risk on our study site may be operating at a larger scale, or a combination of scales, and we suggest future research attempt to address the scale at which to measure predation risk for wild turkeys.

Contrary to our hypothesis, no covariates influenced brood daytime use sites at the landscape level. In fact, our top model was the null model indicating that our metrics failed to explain any variability in selection of daytime use sites. Conversely, nest sites in our study tended to be closer to roads, which may be a strategy to minimize noise as females move to and from nests during recess periods (Badyaev 1995), or allows easy travel to brood habitats after hatching (Moore et al. 2010). Selecting nests near roads may be related to denser vegetation attributable to greater sunlight along roadsides (Holbrook et al. 1987) than roads themselves. Although some researchers have shown that nests closer to roads may be at increased risk of depredation (Thogmartin 1999, Yeldell et al. 2017a), roads did not affect nest survival on our study site. This could be due high road density on our study site (i.e. gravel roads, disced firebreaks), and some predators may avoid high road densities due to human disturbance and hunting pressure (Basille et al. 2013). Likewise, roads did not affect brood site selection, counter to previous work on female ruffed grouse (*Bonasa umbellus*) in the southern Appalachians, which likely selected roads during brood-rearing due to increased herbaceous cover on old logging roads than surrounding forested areas (Tirpak et al. 2008). We offer that herbaceous ground cover is not limiting on our study site, and likely explains why females showed no selection or avoidance of roads.

Time-since-fire affected nest and ground roost site selection. Nest sites were closer to stands burned ≥3 years previously and stands that were never burned. Vegetation cover increases with increasing time since fire (Lemon 1949), and stands burned ≥3 years provide increased woody cover and minimum vegetation height that turkeys select during nesting and ground roosting broods (Streich et al. 2015). Nesting closer to stands that are never burned seems counterintuitive as these areas are primarily dominated by hardwoods that provide suitable habitat and refugia for mesopredators (Chamberlain et al. 2002, Godbois et al. 2003, Kirby et al. 2016, 2017). However, in frequently-burned longleaf pine systems like our study area, hardwoods create fire-shadows where fire is excluded. These consistent landscape features may provide suitable vegetation for nesting (Moore et al. 2010) while decreasing the uncertainty of nest-failure from pine-stands where prescribed fire is often applied.

Nest and ground roost selection should be influenced by time-since-fire in a similar manner; sites should be selected to reduce predation risk while maximizing nearby foraging opportunities (Fretwell and Lucas 1969, Martin 1993). However, at the landscape-scale females selected to roost broods farther from recently burned stands, and stands burned ≥3 years previously. At the vegetation scale, females selected ground roosts in areas with increased ground cover, which is lacking in recently burned stands. Stands burned 3 or more years previously should provide increased woody cover and vegetation height turkeys prefer during nesting and ground roosting with broods (Streich et al. 2015). However, contrary to recent research in a fire-managed landscape in Louisiana, time since fire was not an important predictor of nest or brood survival (Yeldell et al. 2017a).

Patch diversity (SHDI) was the best predictor of nest and ground roost site selection and influenced both nest and brood survival. Animals should select habitats within their home range to provide resources for physiological processes (i.e. foraging, nest sites; Orians and Wittenberger 1991). Therefore, females may select to nest and brood in areas with increased patch diversity to provide needed resources in close proximity. In Louisiana, turkeys used edges between burned and unburned patches immediately after fire to maximize foraging opportunities while balancing the need for nearby escape cover (Yeldell et al. 2017b). We found that as patch diversity increased, nest survival also increased. Conversely, as patch diversity increased around ground roosts, brood survival decreased. Superficially, increasing patch diversity could lead to an increase in edges, which are attractive foraging areas for predators (Flaspohler et al. 2001, Batary and Baldi 2004, Sosa and Lopez de Casenave 2017). However, in a nearby longleaf pine savanna managed with frequent fire, coyote abundance was negatively associated with patch diversity (Cherry et al. 2016), potentially reducing predation risk of turkeys in these areas. Similarly, coyote predation of white-tailed deer (*Odocoileus virginianus*) fawns decreased in areas of higher patch diversity in a site managed with frequent prescribed fire in South Carolina (Gulsby et al. 2017). Therefore, applying prescribed fires in a mosaic fashion on the landscape may influence habitat selection of predators (Chamberlain et al. 2003), which could increase brood survival.

Turkeys select for areas with increased ground cover throughout nesting and brood-rearing which may influence reproductive success. Management using frequent prescribed fire (≤ 3 years) provides suitable understory conditions favored by turkeys during nesting and brood-rearing. In addition, females selected for areas with increased patch diversity during nesting and for ground roosting with broods. As patch diversity increased, nest survival increased but, brood survival decreased. However, our analysis of brood survival may have been influenced by extraneous covariates (i.e. predation risk) that were unaccounted for. Therefore, we offer that future research attempt to address the primary mechanisms that reduce nest and brood survival, by assessing the scale that predators affect nest and brood survival.

MANAGEMENT IMPLICATIONS

Application of prescribed fire did not directly influence nest or brood survival. However, females selected for understory vegetation characteristics during nesting and brood-rearing that result from succession following prescribed fire. Therefore, managers should continue to apply prescribed fire on a 1 - 3 year fire return interval in longleaf pine systems, which creates a mosaic of understory vegetation communities at the vegetation level that increase foraging opportunities, and create concealment cover suitable for nesting and brood-rearing. In addition, this fire regime will increase diversity at the landscape-scale, which may increase nest survival; however, managers should use caution as it may also reduce brood survival.

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Table 2.1. Conditional logistic regression models used to evaluate the effect of vegetation covariates on nest site, ground roost, and brood day time use selection of female eastern wild turkeys (*Meleagris gallopavo silvestris*) at Silver Lake Wildlife Management Area, southwest Georgia, USA, 2015 and 2016.

Model name	Hypothesis	Model
Vegetation models		
Global	All main effects will change selection.	y = GC[a] + VO[b] +CC[c] + BA[d]
Ground cover	Selection is dependent on percent ground cover.	y = GC
Visual obstruction	Selection is dependent on visual obstruction.	y = VO
Canopy cover	Selection is dependent on canopy cover.	y = CC
Basal area	Selection is dependent on basal area.	y = BA
Visual obstruction and ground cover	Selection is dependent on the additive effect of visual obstruction and percent ground cover.	y = VO + GC
Null	Selection is dependent on the random covariates turkey	y = 0
Landscape-scale models		
Global	All main effects will change selection.	y = 0yr + 1yr + 2yr + 3yr + No + Edge + Road + SHDI[e] + CONTAG[f]
Foraging	Selection is dependent on the additive effect of distance to a 0yr and 1y burn and distance to roads.	y = 0yr + 1yr + Road

Concealment	Selection is dependent on the additive effect of distance to 2yr burn and 3yr burns.	y = 2yr + 3 yr
Predation Risk	Selection is dependent on the additive effect of distance to edge and road and 0yr burn and no burn and SHDI.	y = Edge + Road + 0yr + No + SHDI
Concealment and foraging	Selection is dependent on the additive effect of distance to 0yr burn and 1yr burn and 2yr burn and 3yr burn and road and SHDI.	y = 0yr + 1yr + 2yr + 3yr + ROAD + SHDI
Predation risk and concealment	Selection is dependent on the additive effect of distance to edge, roads, burn age and CONTAG.	y = Edge + Road + 0yr + 1yr + 2yr + 3yr + No + CONTAG
Concealment and escape	Selection is dependent on the additive effect of distance to edge, 2yr burn, 3yr burn and no burn and CONTAG.	y = Edge + 2yr + 3yr + No + CONTAG
Diversity	Selection is dependent on the diversity of vegetation communities on the landscape.	y = SHDI
Contagion	Selection is dependent on the interspersion of vegetation communities on the landscape.	y = CONTAG
Null	Selection is dependent on the random covariate turkey.	y = 0

[a] Ground cover

[b] Visual obstruction

[c] Canopy cover

[d] Basal area

[e] Shannon’s Diversity Index

[f] Contagion Index

Table 2.2. Akaike's Information Criterion with small sample bias adjustment (AIC_c), number of parameters (K), ΔAIC_c, adjusted Akaike weight of evidence (w_i) in support of model, and log-likelihood (LL) for candidate models relating the selection of a nest, brood ground roost, and brood daytime sites used by female eastern wild turkeys (*Meleagris gallopavo silvestris*) at Silver Lake Wildlife Management Area, southwest Georgia, USA, 2015 and 2016. Models used a conditional logistic regression with matched-pairs case-control sampling, where cases were known use sites and controls were random sites.

Model	K	AIC_c	ΔAIC_c	Adjusted w_i	LL
Nest Selection					
Vegetation[a]					
Visual obstruction and ground cover	2	76.86	0.00	0.76	-36.38
Global	4	79.73	2.86	0.18	-35.70
Ground cover	1	81.90	5.04	0.06	-39.94
Visual obstruction	1	87.46	10.60	0.00	-42.71
Basal area	1	105.98	29.12	0.00	-51.98
Null	0	106.17	29.31	0.00	-53.09
Canopy closure	1	108.20	31.33	0.00	-53.08
Landscape-scale[b]					

		Global	9	220.30	0.00	0.78	-100.91
		Concealment and foraging	6	222.84	2.55	0.22	-105.31
		Predation risk	5	229.46	9.16	≤ 0.01	-109.65
		Predation risk and concealment	8	247.24	26.95	0.00	-115.44
		Concealment	2	249.14	28.84	0.00	-122.55
		Concealment and escape	5	251.59	31.29	0.00	-120.72
		Foraging	3	252.31	32.01	0.00	-123.12
		Diversity	1	261.68	41.38	0.00	-129.83
		Null	0	263.42	43.12	0.00	-131.71
		Contagion	1	264.54	44.24	0.00	-131.26
Ground Roost Site Selection							
	Vegetation[a]						
		Visual obstruction + Ground cover	2	161.12	0.00	0.58	-78.53
		Ground cover	1	162.32	1.20	0.32	-80.15
		Global	4	164.51	3.39	0.11	-78.13

Null	0	181.00	19.87	0.00	-90.50
Basal area	1	182.67	21.55	0.00	-90.32
Visual obstruction	1	182.89	21.76	0.00	-90.43
Canopy cover	1	182.93	21.81	0.00	-90.45
Landscape-scale[b]					
Concealment and foraging	6	150.53	0.00	0.65	-69.15
Global	9	153.55	3.02	0.14	-67.54
Diversity	1	153.62	3.09	0.14	-75.80
Predation risk	3	155.14	4.61	0.07	-72.49
Contagion	1	296.31	145.78	0.00	-147.15
Null	0	296.42	145.90	0.00	-148.21
Concealment and escape	5	298.60	148.07	0.00	-144.22
Concealment	2	300.33	149.80	0.00	-148.15
Foraging	3	301.30	150.77	0.00	-147.62
Predation risk and concealment	8	303.04	152.51	0.00	-143.33
Brood Daytime Selection					

Vegetation[a]					
Global	4	205.71	0.00	0.99	−98.76
Basal area	1	215.08	9.37	0.01	−106.53
Visual obstruction and ground cover	2	221.85	16.13	0.00	−108.89
Ground cover	1	228.55	22.84	0.00	−113.27
Canopy cover	1	233.67	27.95	0.00	−115.82
Null	0	240.79	35.07	0.00	−120.39
Visual obstruction	1	241.20	35.48	0.00	−119.59
Landscape-scale[b]					
Null	0	411.54	0.00	0.31	-205.77
Diversity	1	412.30	0.76	0.21	-205.14
Predation risk	5	413.05	1.51	0.15	-201.46
Contagion	1	413.55	2.01	0.11	-205.77
Foraging	3	413.74	2.21	0.10	-203.85
Concealment	2	415.53	3.99	0.04	-205.75
Concealment and escape	5	415.53	4.00	0.04	-202.71
Concealment and foraging	6	417.09	5.55	0.02	-202.46

Predation risk and concealment	8	419.12	7.59	0.01	-201.42
Global	9	419.28	7.74	0.01	-200.46

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[a] Models reflect vegetation characteristics surveyed at the nest site and include covariates percent canopy cover (CC), percent total ground cover (GC), basal area (BA), and lateral visual obstruction (VO).

[b] Models reflect covariates predicted to influence nest site selection at the landscape scale and include distance to roads, edges, burn age, in addition to landscape heterogeneity covariates SHDI and CONTAG.

Table 2.3. Parameter estimates from the best approximating models predicting nest, brood ground roost, and brood daytime use site selection of female eastern wild turkeys (*Meleagris gallopavo silvestris*) at Silver Lake Wildlife Management Area, southwest Georgia, USA, 2015 and 2016. Negative values for beta-estimates associated with distance covariates are interpreted as selection for these landscape features; positive values represent avoidance.

								Odds Ratio CI	
Model			β^a	SE	Z	*P*	Scaled odds ratio	Lower 95%	Upper 95%
Nest Selection									
	Vegetation								
		Ground cover	0.30	0.10	3.15	≤0.01	1.35	1.12	1.63
		Visual obstruction	0.21	0.09	2.39	0.02	1.23	1.04	1.46
	Landscape-scale								
		Distance to 0yr burn	-0.11	0.07	-1.56	0.12	0.89	0.77	1.03
		Distance to 1yr burn	-0.14	0.09	-1.62	0.11	0.87	0.74	1.03
		Distance to 2yr burn	-0.06	0.07	-0.96	0.34	0.94	0.82	1.07
		Distance to 3yr burn	-0.46	0.14	-3.42	≤0.01	0.63	0.48	0.82
		Distance to no burn	-0.51	0.23	-2.22	0.03	0.60	0.38	0.94
		Distance to edge	-0.51	0.90	-0.56	0.57	0.60	0.10	3.53
		Distance to road	-1.68	0.64	-2.60	0.01	0.19	0.05	0.66
		SHDI^b	-3.25	0.66	-4.90	≤0.01	0.04*	0.01	0.14
		CONTAG^c	-0.18	0.10	-1.82	0.07	0.83	0.69	1.01
Ground Roost Selection									

	Vegetation								
		Ground cover	0.26	0.07	4.02	≤0.01	1.30	1.14	1.48
		Visual obstruction	-0.12	0.07	1.76	0.08	0.93	0.78	1.01
	Landscape-scale								
		Distance to 0yr burn	0.45	0.17	2.71	0.01	1.58	1.13	2.19
		Distance to 1yr burn	0.17	0.15	1.16	0.25	1.18	0.89	1.57
		Distance to 2yr burn	0.11	0.13	0.83	0.41	1.11	0.86	1.45
		Distance to 3yr burn	0.45	0.19	2.33	0.02	1.57	1.07	2.30
		SHDI	-1.1	1.83	-6.02	≤0.01	≤0.01*	≤0.01	≤0.01
		Distance to road	-0.72	0.56	-1.28	0.20	0.49	0.16	1.47
Brood Daytime Selection									
	Vegetation								
		Ground cover	0.18	0.06	3.28	≤0.01	1.20	1.08	1.34
		Basal area	-0.24	0.06	-3.95	≤0.01	0.78	0.69	0.88
		Canopy cover	0.06	0.04	1.50	0.13	1.07	0.98	1.16
		Visual obstruction	-0.17	0.06	-2.94	≤0.01	0.84	0.75	0.94
	Landscape-scale								
		Distance to edge	-0.06	0.72	0.08	0.93	0.94	0.23	3.85
		Distance to road	-0.54	0.37	1.45	0.15	0.59	0.28	1.21
		Distance to 0yr burn	0.01	0.08	0.14	0.89	1.01	0.86	1.19
		Distance to no burn	-0.38	0.25	-1.56	0.12	0.68	0.42	1.10
		SHDI	-1.77	1.63	-1.10	0.28	0.16*	0.01	4.11

[*] Odds ratio not scaled

[a] Variables scaled by biologically relevant scalers. Distance variables scaled by 100m, all other variables scaled by a factor of 10, except SHDI as scaling would not benefit interpretation.

[b] Shannon's Diversity Index

[c] Contagion Index

Table 2.4. Nesting ecology of female eastern wild turkeys (*Meleagris gallopavo silvestris*) at the Silver Lake Wildlife Management Area and surrounding lands in southwest Georgia, USA, 2015 and 2016.

Year	*n*[a]	% Nest Initiation (*n*)[b]	% Incubation 1st attempt (*n*)[c]	% Initial nest success (*n*)[d]	% 2nd attempt (*n*)[e]	% 2nd attempt success (*n*)[f]	% 3rd attempt (*n*)[g]	% 3rd attempt success
2015	29	93.1 (27)	96.3 (26)	32.0 (8)	58.8 (10)	60.0 (6)	40.0 (2)	0
2016	29	89.7 (26)	96.2 (25)	36.4 (8)	64.7 (11)	70.0 (7)	0	0
Pooled	58	91.4 (53)	96.2 (51)	34.0 (16)	61.8 (21)	65.0 (13)	13.3 (2)	0

[a] Number of radio-marked females monitored from the earliest known nesting attempt (2015: 6 April; 2016: 30 March).

[b] Number of females detected initiating ≥1 nest.

[c] Number of females successfully laying a clutch, and establishing continuous incubation of ≥1 nest.

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

[e] Number of females initiating and incubating a second nest following the loss of a first nest or first brood within 30 days following hatch.

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

[g] Number of females initiating and incubating a third nest following the loss of a second nest or brood within 30 days following hatch.

Table 2.5. Results of Cox proportional hazards analysis modeling eastern wild turkey (*Meleagris gallopavo silvestris*) nest and brood survival based on covariates found to influence nest site, brood roost, and brood daytime selection at Silver Lake Wildlife Management Area, southwest Georgia, USA, 2015 and 2016.

						Hazard ratio CI	
Model		B[a]	SE	*P*	Hazard ratio	Lower 95%	Upper 95%
Nest Selection Covariates Influencing Survival							
Vegetation							
	Ground cover	0.16	0.17	0.35	1.17	0.84	1.64
	Visual obstruction	-0.09	0.06	0.18	0.92	0.81	1.04
Landscape-scale							
	Distance to 0yr burn	0.1	0.1	0.36	1.1	0.89	1.36
	Distance to 1yr burn	0.01	0.11	0.91	1.01	0.82	1.25
	Distance to 2yr burn	0.04	0.08	0.6	1.04	0.9	1.2
	Distance to 3yr burn	0.1	0.16	0.53	1.11	0.81	1.52
	Distance to No burn	0.33	0.28	0.19	1.4	0.84	2.31
	Distance to road	-0.69	1.07	0.52	0.5	0.06	4.07
	Distance to edge	-1.04	1.25	0.42	0.35	0.03	4.53
	SHDI[b]	-1.36	0.67	0.03	0.26	0.07	0.9
	CONTAG[c]	0.27	0.15	0.09	1.31	0.96	1.77
Ground Roost Selection Covariates Influencing Brood Survival							
Vegetation							

		Ground cover	0.32	0.34	0.35	1.38	0.71	2.70
		Visual obstruction	-0.09	0.30	0.77	0.92	0.50	1.66
	Landscape-scale							
		Distance to road	-0.69	0.98	0.48	0.50	0.07	3.44
		Distance to 0yr burn	-0.07	0.21	0.75	0.93	0.61	1.42
		Distance to 1yr burn	-0.22	0.22	0.32	0.80	0.52	1.23
		Distance to 2yr burn	-0.04	0.13	0.76	0.96	0.75	1.24
		Distance to 3yr burn	0.17	0.20	0.41	1.18	0.79	1.76
		SHDI	3.63	1.38	0.01	37.57	2.37	595.15
Daytime Use Selection Covariates Influencing Brood Survival								
	Vegetation							
		Ground cover	0.53	0.52	0.31	1.70	0.61	4.74
		Basal area	0.22	0.19	0.24	1.25	0.86	1.81
		Canopy cover	0.15	0.22	0.50	1.15	0.75	1.79
		Visual obstruction	-0.44	0.41	0.28	0.65	0.29	1.44

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[a] Variables scaled by biologically relevant scalers. Distance variables scaled by 100m, all other variables scaled by a factor of 10, except SHDI as scaling would not benefit interpretation.

[b] Shannon's Diversity Index

[c] Contagion Index

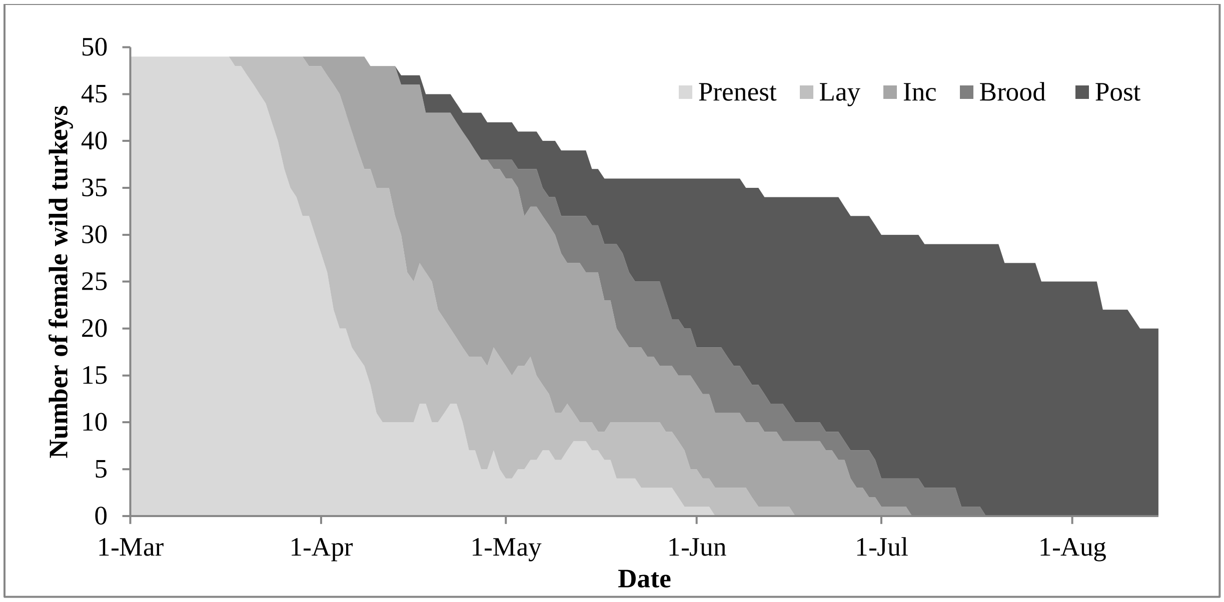

Figure 2.1. Reproductive chronology of female eastern wild turkeys (*Meleagris gallopavo silvestris*) at Silver Lake Wildlife Management Area, southwest Georgia, USA, 2015 and 2016. We classified reproductively active females by behavior across the reproductive period in the following categories: Pre-nesting (prior to initiation of an initial nest attempt, or period between a prior nest attempt and a subsequent laying sequence), Laying (the period during which females actively laid eggs), Incubating (the period during which females were actively sitting on the nest), Brooding (the period a female was actively raising young post-hatch), and Post-nesting (the period following the completion of nesting or brood rearing behaviors).

CHAPTER 3

SPACE USE AND HABITAT SELECTION OF FEMALE EASTERN WILD TURKEYS IN A FREQUENTLY BURNED LONGLEAF PINE FOREST

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ABSTRACT

Longleaf pine (*Pinus palustris*) forests rely on frequent prescribed fire to limit encroachment of hardwoods and maintain early successional understory communities. Prescribed fire may affect habitat selection of reproductively active female wild turkeys by immediately altering habitat availability. Managers must balance meeting management goals for longleaf pine forests with having quality habitat for turkeys throughout their reproductive period. Our objective was to describe habitat selection of female wild turkeys during their reproductive cycle in a longleaf pine forest managed with frequent prescribed fire. The Silver Lake Wildlife Management Area and surrounding private lands in southwest Georgia were primarily composed of young pine (4-19 years) and mature pine stands (≥ 20 years), open vegetation communities (i.e. clear-cuts, wildlife openings), hardwood stands, and agricultural fields. We captured 63 female wild turkeys during 2015-2016, and recorded hourly locations from 1 March to 15 August. We used locations to construct 50 and 95% utilization distributions to compare habitat selection in a use versus availability framework. Females selected for hardwood stands during pre-nesting and post-nesting phases, but avoided them during incubation. Females used open vegetation communities during all phases of reproduction following pre-nesting. Females used pine stands regardless of seral stage and fire return interval during periods where females were actively participating in reproductive activities, but selection varied by reproductive phase. We suggest management focus on creating a mosaic of pine seral stages, intermixed with open and hardwood vegetation communities, while applying frequent prescribed fire (1-3 years) to create understory conditions selected by turkeys for foraging and concealment throughout the year.

INTRODUCTION

Management of longleaf pine (*Pinus palustris*) forests relies on frequent application of prescribed fire (e.g. 1-3 years) to mimic natural and historic burn frequencies (Brockway et al. 2005*a*, Oswalt et al. 2012). This frequent fire-return interval reduces fuel loads, limits encroachment of hardwoods into the midstory, and promotes early successional vegetation communities (Waldrop et al. 1992, Brockway and Lewis 1997, Glitzenstein et al. 2012). The degree of change immediately after fire disturbance can be heterogeneous across a burned area; vegetation responses are affected by differences in fire intensity, fuel loading, and timing of application (Thaxton and Platt 2006, Ellair and Platt 2013, Wiggers et al. 2013). These differences lead to increased understory diversity and structural heterogeneity in longleaf pine forests (Thaxton and Platt 2006, Grady and Hoffmann 2012). However, as time-since-fire increases, understory diversity decreases due to successful encroachment and establishment of woody species (Grady and Hoffmann 2012, Robertson and Hmielowski 2014).

Longleaf pine forests historically covered ≥ 36 million ha in the southeastern United States (Landers et al. 1995, Brockway et al. 2005*a*, Van Lear et al. 2005). Through intensive logging and conversion of sites to agriculture or faster growing species (i.e. loblolly pine [*Pinus taeda*] and slash pine [*Pinus elliottii*]), many longleaf pine forests were lost (Frost 1993, Landers et al. 1995, Brockway et al. 2005*a*, Van Lear et al. 2005, Oswalt et al. 2012). Currently, longleaf pine forests occupy < 5% of their historic range. However, restoring and reestablishing longleaf pine forests has become a management priority throughout the southeastern United States (Alavalapati et al. 2002). Mature longleaf pine forests are characterized by open, park-like conditions with extensive herbaceous understories that result from frequent prescribed fire (Kirkman et al. 2004, Outcalt 2008), and are representative of long-term management objectives.

Restoration efforts are primarily centered on reintroducing fire to stands where it has been excluded, and reestablishment of longleaf pine which necessitates mechanical removal of overstory trees, and replanting longleaf pine seedlings (Brockway et al. 2005*a*, *b*, Van Lear et al. 2005).

Reestablishment of longleaf pine forests can result in a mosaic of pine seral stages across the landscape. After mechanical removal of the overstory, managers apply prescribed fire to remove logging slash to prep sites for planting (Brockway et al. 2005*a*, *b*). Managers plant longleaf pine seedlings wherever conditions are appropriate, whereas poorer quality sites are planted in loblolly pine (GADNR-unpublished report). After replanting sites in longleaf pine seedlings, understory vegetation is similar to that of the understory in mature pine stands. Longleaf pine seedlings spend time in a grass stage devoting resources to root growth and when conditions are right, grow quickly thus outcompeting other understory vegetation and escaping harm from fire (Platt et al. 1988). When young longleaf pines reach the period of stem exclusion (i.e. canopy closure), resulting understory vegetation is sparse, similar to conditions in southern pine plantations (Harrington 2006). After thinning, understory communities respond to reduced canopy cover and applications of prescribed fire, and plant diversity increases (Harrington and Edwards 1999, Harrington 2006). These communities are dominated by grasses and herbaceous vegetation that with the application of frequent fire are maintained indefinitely (Kirkman et al. 2004). If attempting to mimic natural disturbance, mature pines are then managed by occasional single tree selection cuts designed to create canopy gaps that facilitate natural regeneration (McGuire et al. 2001, Outcalt 2008).

Prescribed fire immediately alters vegetation communities, and is applied prior to and during the reproductive period of eastern wild turkeys (*Meleagris gallopavo silvestris*; hereafter:

turkeys). Therefore, it has potential to alter habitat selection of reproductively active females (Little et al. 2016*a*, Yeldell et al. 2017*b*). Diverse understory vegetation in longleaf pine forests resulting from frequent prescribed fire may provide turkeys with resources needed for nesting and brood rearing (Streich et al. 2015, Little et al. 2016*b*, Yeldell et al. 2017*a*). Adult turkeys primarily consume herbaceous vegetation, and to a lesser degree, insects (Glover and Bailey 1949, Exum et al. 1987), which may be more readily accessible and in similar abundance shortly following fire (Martin et al. 2012). Regenerating clear-cuts dominated by early successional communities intermixed within older longleaf forests can provide similar resources to turkeys (Dalke et al. 1942, Kennamer et al. 1980). Hardwood stands intermixed in these systems may also provide forage and roosting cover for wild turkeys (Miller et al. 1999, Jones et al. 2005); however, these areas are also preferred by species known to prey on turkeys and their nests [e.g. bobcats (*Lynx rufus*), raccoons (*Procyon lotor*); Chamberlain et al. 2002, 2003, Godbois et al. 2003].

In landscapes managed with frequent fire, turkeys may use vegetation communities differently during different reproductive phases (i.e. pre-nesting, laying; Yeldell et al. 2017*b*). Similarly, habitat selection may be influenced by pine seral stage. For example, in managed pine stands in Mississippi, females were more likely to select stands that were thinned and burned (Miller and Conner 2007). These stands resulted in open, herbaceous understories preferred by turkeys. Similarly, in pine-dominated forests in Louisiana, females selected mature pine stands burned during the previous 5 months during laying, but not during any other reproductive period, probably because of foraging opportunities which met the physiological demands associated with egg laying (Yeldell et al. 2017*b*). In southwest Georgia, females avoided mature pine stands during nesting, in favor of shrub/scrub communities (Streich et al. 2015), whereas females used young pine stands in Mississippi burned on 2 - 3 year rotations during brood-rearing (Jones et al. 2005). Therefore, both pine seral stage and time-since-fire may interact to influence turkey habitat selection throughout their reproductive season, but the extent of this interaction is unknown.

Management efforts to restore longleaf pine forests result in a mosaic of pine seral stages on the landscape that influence understory vegetation important during reproductive phases, but managers do not fully understand how the interaction between pine seral stage and time-since-fire affect habitat selection by turkeys. Therefore, our objective was to determine how time-since-fire affected selection of different seral stages of pine by female turkeys during their reproductive cycle. We hypothesized that females would not select any pine-dominated stands during pre-nesting, but instead select hardwood stands as these stands provide roosting habitat and hard mast. Females require substantial nutrient uptake due to the high physiological stress during egg laying and brood-rearing, therefore we hypothesized females would select stands more recently burned (i.e. <6 months previous) due to increased foraging opportunities for protein-rich invertebrates (Lemon 1949, Wiggers et al. 2013, New 2014, Chitwood et al. 2017) during laying and brood-rearing. We hypothesized that females would select pine stands farther along in their burn rotation (i.e. ≥ 2 growing seasons post-burn), regardless of pine seral stage, during incubation due to increased vegetation density and nest concealment. Lastly, during post-nesting, we hypothesized that females would select vegetation communities similar to selection during pre-nesting.

STUDY AREA

We conducted research on the Silver Lake Wildlife Management Area (hereafter, SLWMA) and surrounding private lands in southwest Georgia. The SLWMA was formerly part of the 6,475-ha Southland Experimental Forest used by International Paper Company to conduct silvicultural research, and was purchased by the state of Georgia in 2008. The SLWMA was managed by the Georgia Department of Natural Resources-Wildlife Resources Division (GADNR) for hunting and other outdoor recreation. The SLWMA encompassed approximately 3,900-ha, of which 3,392 ha (88%) was dominated by pine (*Pinus* spp.) forests. Of these, 83% (2814.77 ha) were mature pine forests (≥ 20 years old), 14% (478.21 ha) were young pine plantations (4 - 19 years old). Other plant communities included clear-cuts planted in pine (0 - 3 years old), hardwood forests, forested wetlands, agricultural fields, and wildlife openings scattered throughout.

Dominant overstory species included longleaf pine and loblolly pine, and to a lesser extent slash pine, shortleaf pine (*P. echinata*), oaks (*Quercus* spp.), and sweetgum (*Liquidambar styraciflua*). Understory vegetation was dominated by wiregrass (*Aristida stricta*), broomsedge (*Andropogon* spp.), bracken fern (*Pteridium* spp.), runner oak (*Q. pumilla*), blackberry (*Rubus* spp.), blueberry (*Vaccinium* spp.), muscadine (*Vitis rotundifolia*), American beautyberry (*Callicarpa americana*), common ragweed (*Ambrosia artemisiifolia*), and greenbrier (*Smilax* spp.). Surrounding private lands were primarily managed for agriculture and timber production, and hunting opportunities for northern bobwhite. Other private lands in the area consisted of rural dwellings, cattle pastures, poultry farms and hardwood-dominated forested wetlands.

Land managers on SLWMA used prescribed fire to maintain herbaceous understory vegetation communities and promote growth of longleaf pine, while inhibiting undesirable hardwood regeneration and reducing fuel loads. Burn units were divided by a mixture of gravel roads, disked fire lines, and natural fire breaks. Prescribed fire was primarily applied using ATV-mounted drip torches, although some burn units on United States Army Corps. Of Engineers owned properties leased by GADNR were burned using a helicopter due to lack of access. Prescribed fire was applied throughout the year, but most fires occurred during the dormant season in 2015 (63.3%), and during the growing season in 2016 (92.3%). In 2015, 1060 ha were burned, whereas 1211 ha were burned in 2016. Average size of prescribed burns on SLWMA was 26.02 ± 3.72 ha (range: 3.30 ha to 72.41 ha) in 2015 and 19.84 ± 2.45 ha (range: 1.13 ha to 73.18 ha) in 2016. Prescribed fire was applied on private lands surrounding SLWMA, but records were unavailable to determine frequency or extent, and therefore our analysis was confined to the SLWMA boundary.

METHODS

Capture and monitoring

We captured turkeys using rocket nets from January-March 2015 and 2016. Turkeys were sexed, aged (Pelham and Dickson 1992) and fitted with serially numbered, butt-end aluminum leg bands. We fitted female turkeys with a backpack style, remotely downloadable, micro-global positioning system transmitter (µGPS; Minitrack L, Sirtrack, Havelock North, New Zealand) with very high frequency (VHF) capabilities, and released them immediately after handling. We programmed transmitters to record locations 2 times per day (1200-hrs and 2359-hrs) from date of capture until 1 March. Locations were recorded once per hour from 0500-hrs to 2000-hrs, and a single roost location at 2359-hrs from 1 March to 15 August. All turkey capture, handling, and marking procedures were approved by the Institutional Animal Care and Use Committee at the University of Georgia (Protocol #A2014 06-008-Y1-A0).

We located turkeys ≥ 1 time per week using a 3-element handheld Yagi antenna and R4000 receiver (Advanced Telemetry Systems, Inc., Isanti, MN) to monitor survival and reproductive status. We examined GPS locations for each female, and assumed a female was incubating an initial nest or successive renesting attempt when locations began to cluster around a single point, and the female restricted movements to ≤ 100m (Conley et al. 2016). We then located nesting females daily to ensure they were still nesting, and if a female was no longer at the nest site, we located the nest site to determine nest fate. After nest termination, a female either began a successive pre-nesting, brooding, or if reproductive activity ceased, a post-nesting period. Because turkey nests require continuous incubation approximately 25 to 29 days before hatching (Williams Jr. et al. 1971, 1976), we considered nests abandoned if a female left the nest prior to 30 days and only intact eggs were found in the nest bowl. We considered nests depredated if the nest was found empty or with only eggshell fragments prior to 25 days. We considered nests successful if ≥ 1 poult hatched, and the large end of eggshells were neatly chipped away (Healy 1992). If a nest hatched, we monitored the brooding female every 3 days up to 28 days post-hatch to confirm brood presence. This 28 day period represents the time a young wild turkey is known as a poult, after which they are considered juveniles (Hurst 1992). We considered females to be brooding if ≥ 1 poult was detected. We defined the post-nesting phase as the time of completion of nest or brood rearing activities for each female until 15 August.

Because habitat selection may be dependent on reproductive activity (Yeldell et al. 2017*b*), we delineated 5 phases relating to the reproductive status of females (pre-nesting, laying, incubation, brooding, and post-nesting). We defined the pre-nesting phase as the period from 1 March until the onset of egg laying for each female. We defined the 12 day period prior to the onset of continuous incubation for each nesting attempt for each female as the laying phase, based on the reported average clutch size of 12 eggs for female eastern wild turkeys (Vangilder 1992). We defined the incubation phase as the start of continuous incubation until either nest failure, or success. At 28 days, poults are considered juveniles and are assumed to be recruited into the fall flock (Hurst 1992), therefore, we defined the brooding phase as the day a female left the nest site with poults until brood failure, or a brood was successfully raised to 28 days post-hatch.

Because we believed habitat selection may change as the reproductive season progresses and females initiate successive nesting attempts, we also defined 2 sub-phases for each phase of pre-nesting, laying, and incubation. Due to low sample size (*n* = 2) we did not estimate habitat selection for females initiating a third nest attempt in a single season. We defined the prenest-1 phase as 1 March through the onset of egg laying for an initial nest attempt. We defined the time of initial nest or brood failure until the onset of egg laying for a second nest attempt as the prenest-2 phase. We defined the 12 day period prior to continuous incubation of first and second nest attempts as the lay-1 and lay-2 phases. We defined the nest-1 and nest-2 phases as the period of continuous incubation during first and second nest attempts, respectively.

Delineating Vegetation Communities

To identify vegetation communities within our study area available to turkeys, we obtained forest inventory data from GADNR for stands located within SLWMA. We estimated stand conditions via photo interpretation for private lands where stand data were unavailable. We obtained imagery and landcover data from the National Agriculture Imagery Program, Landsat 8 multi-spectral satellite imagery (Roy et al. 2014), and the National Land Cover Database (Homer et al. 2015). We then hand-digitized and ground-truthed a 30 m resolution landcover dataset, and classified vegetation communities into 5 cover types. We classified pixels as pine if they consisted of ≥ 50% longleaf, loblolly, slash, or shortleaf pine in the overstory. We further classified pine stands into 2 seral stages based on age of pine within the stand: young pine (YP; 4

- 19 years), and mature pine (MP; ≥ 20 years). Young pine stands were characterized by increased stocking levels and diameter at breast height (DBH) classes ≤ 20.3 cm (Yeldell et al. 2017*a*, *b*). Mature pine stands were characterized by lower stocking levels, DBH classes > 20.3 cm, and open, park-like conditions (Yeldell et al. 2017*b*). We classified pixels as hardwood if they consisted of > 50% hardwoods. Hardwoods were often associated with lowland areas bordering lakes and ponds, and upland depressional wetlands, or planted sawtooth oak (*Quercus acutissima*) groves. Turkeys readily consume agricultural crops (Hurst 1992), and on private lands, historic longleaf pine forests on xeric soils were often harvested and converted to irrigated agricultural fields. Due to their potential importance for turkeys in some systems (Pollentier et al. 2017), we classified fields managed for row crops as agriculture. We classified wildlife openings and clear-cuts planted in pine (0 - 3 years old) as open. We included clear-cuts in this classification as managers often used fire to reduce logging slash and prepare stands for replanting in longleaf or loblolly pine (Brockway et al. 2005*a*), and thus vegetation during the first 3 years after planting is similar to old field communities and managed wildlife openings.

We were interested in how prescribed fire influenced female turkey selection of pine seral stages. Therefore, we obtained burn data for each stand within SLWMA from GADNR, and combined fire history data with our landcover map to distinguish between pine stands that had and had not been burned within 6 years. After ≥ 3 growing seasons post-burn, understory vegetation in longleaf pine forests becomes similar (Buckner and Landers 1979, Glitzenstein et al. 2012). On our study site, herbaceous plant density was greatest in the first year post-burn, and steadily declined as time-since-fire increased (Buckner and Landers 1979). Plant diversity peaked at 3 growing seasons post-burn, but as woody species became more prevalent the density of herbaceous plants declined (Buckner and Landers 1979). Therefore, we considered all stands where prescribed fire was excluded for ≥ 3 growing seasons as having no recent burn history (NRB). We identified 4 burn classes within each seral stage. We classified pine stands as being recently burned and having experienced no previous growing seasons (YP^0; MP^0), having experienced 1 growing season post-burn (YP^1; MP^1), having experienced 2 growing seasons post-burn (YP^2; MP^2), or having no recent burn history (≥ 3 growing seasons post-burn; YP^{NRB}; MP^{NRB}).

Habitat Selection

We examined habitat selection within turkey home ranges using a use versus availability framework (Johnson 1980). Because fire history is dynamic, and time-since-fire can change from one day to the next, we estimated selection daily for each female. We used a dynamic Brownian Bridge movement model (dBBMM; Kranstauber et al. 2012) to calculate daily utilization distributions (UDs) for each turkey and compared them to each individual female's home range (Yeldell et al. 2017*b*). To calculate home ranges we calculated the 95% dBBMM UD that encompassed all locations from 1 March to 15 August and used a window size of 15, margin of 5, and a location error of 15 (Kranstauber et al. 2012). We defined used vegetation communities as those within each daily core area. We calculated daily core area as the 50% dBBMM UD built around locations collected between 0000 and 2359 each day. In this daily UD calculation, we manually specified the Brownian motion variance for each step to be equal to that calculated in the overall home range dBBMM, rather than recalculate the values for each day which would have been compromised by our window and margin sizes. To estimate space use during each reproductive phase, we calculated home range and core area estimates for each female and used these estimates to calculate mean home range and core area size for each reproductive phase. We performed all dBBMM calculations using the move package (version 2.1.0) in R version 3.3.2.

To calculate selection ratios (*SR*), we used a Euclidean distance analysis to generate distance raster grids with a 30 m pixel size for each vegetation type (Yeldell et al. 2017*b*). Fire history was updated daily to account for prescribed fire application throughout the study period. This allowed the landscape an individual selected from to change daily in our analysis as we incorporated application of prescribed fire onto the landscape. Therefore, the proportional area that was burned and unburned changed daily for each individual. To estimate daily use and availability of vegetation communities, we calculated the distance of each pixel to each vegetation community within each daily core area and range (Yeldell et al. 2017*b*). Using the distance raster grids generated, we calculated a mean distance to each vegetation community within the daily core area and home range. We used the mean distance to each vegetation community within the daily core area and home range to generate daily selection ratios for each female. For each female, we then averaged daily selection ratios across each reproductive phase. Finally, to generate a population level estimate of selection, we pooled daily selection ratios from individual turkeys and generated a mean selection ratio for each reproductive phase. We calculated 95% confidence intervals (*CI*) around these selection ratios, and considered selection ratios to be informative if intervals did not include 1.0 (Conner et al. 2003, Yeldell et al. 2017*b*). Selection ratios < 1.0 indicated selection and > 1.0 indicated avoidance of vegetation communities. We treated all broods as independent samples regardless if a female was known to have 2 broods within a single nesting season.

Results

We captured and monitored 63 female turkeys (58 adults and 5 juveniles) during 2015 and 2016, of which 3 (2 adults, 1 juvenile) died prior to nesting, 7 (5 adults, 2 juveniles) had transmitters that malfunctioned and precluded us from determining reproductive status, and 5 adults never nested. We detected and monitored 76 nests from 48 females (39 in 2015, 37 in 2016), of which 2 were initiated by juveniles, so we included them with the sample of adults. Of 76 nests, 2 failed during egg laying. Therefore, we monitored 74 incubated nests (51 initial nest attempts, 21 second attempts, and 2 third attempts) from 46 females (see Chapter 2).

Home range size during pre-nesting was 390.72 ± 36.73 ha and for core areas was 50.21 ± 3.52 ha (Table 3.1), whereas during laying, home ranges and core areas were 185.80 ± 9.43 ha and 33.27 ± 1.59 ha respectively. During incubation, home ranges and core areas were 2.81 ± 0.43 ha and 0.13 ± 0.01 ha, whereas during brood-rearing, home ranges were 69.28 ± 14.31 ha and core areas were 8.43 ± 1.75 ha. During post-nesting females maintained home ranges of 347.86 ± 45.53 ha and core areas of 48.02 ± 5.10 ha. The 95% and 50% core area estimates for home range size throughout the spring/summer study period (1 March – 15 August) were 529.98 ± 49.51 ha and 57.30 ± 5.26 ha, respectively (Table 3.1).

During pre-nesting, females (n = 66) selected for hardwood stands (HW: SR = 0.82; 95% CI = 0.75 – 0.90: Figure 3.1, Table 3.2), and avoided young pine stands burned during the previous 6 months (YP^0: SR = 1.10, 95% CI = 1.01 – 1.19: Figure 3.2, Table 3.2), as well as young and mature pine stands burned 2 growing seasons prior (YP^2: SR = 1.07, 95% CI = 1.00 – 1.14; MP^2: SR = 1.11, 95% CI = 1.01 – 1.22: Figure 3.2, Table 3.2). This selection was more pronounced during the first pre-nesting period; females (n = 46) selected for hardwoods (HW: SR = 0.82, 95% CI = 0.74 – 0.89: Table 3.3), and avoided young pine stands burned < 6 months previous (YP^0: SR = 1.14, 95% CI = 1.03 – 1.26: Figure 3.3, Table 3.3), and young pine and mature pine stands 2 growing seasons post-burn (YP^2: SR = 1.09, 95% CI = 1.01 – 1.17; MP^2 :SR = 1.13, 95% CI = 1.02 – 1.25: Figure 3.3, Table 3.3). However, females (n = 19) in their second pre-nesting period used all vegetation communities in proportion to their availability (Figure 3.3, Table 3.3).

During laying, females (*n* = 65) selected for open vegetation communities (OP: *SR* = 0.77, 95% *CI* = 0.70 – 0.93), mature pine stands regardless of burn history (MP^{0}: *SR* = 0.83, 95% *CI* = 0.69 – 0.97; MP^{1}: *SR* = 0.85, 95% *CI* = 0.74 – 0.96; MP^{2}: *SR* = 0.88, 95% *CI* = 0.77 – 1.00; MP^{3}: *SR* = 0.82, 95% *CI* = 0.72 – 0.92), and young pine stands recently burned and those with 2 growing seasons post-burn (YP^{0}: *SR* = 0.86, 95% *CI* = 0.74 – 0.98; YP^{2}: *SR* = 0.91, 95% *CI* = 0.82 – 1.00: Figure 3.1, Table 3.2). Females generally selected for pine stands regardless of seral stage and burn history during their first laying period, except they used young pine stands burned ≥3 growing seasons prior (YP^{3}: *SR* = 0.90, 95% *CI* = 0.77 – 1.02), hardwood (HW: *SR* = 0.91, 95% *CI* = 0.79 – 1.02) and agricultural fields (AG: *SR* = 0.98, 95% *CI* = 0.87 – 1.07) in proportion to their availability (Figure 3.4, Table 3.3). Selection was more distinct during the second laying period as females selected mature pine stands burned during the previous 6 months (*SR* = 0.69, 95% *CI* = 0.53 – 0.85: Figure 3.4, Table 3.3).

During incubation, females (*n* = 62) avoided hardwood stands (HW: *SR* = 1.27, 95% *CI* = 1.07 – 1.46: Figure 3.1, Table 3.2), selected for open (OP: *SR* = 0.71, 95% *CI* = 0.55 – 0.87) vegetation communities, young pine (YP^{0}: *SR* = 0.84, 95% *CI* = 0.70 – 0.97) stands burned during the previous 6 months and mature pine (MP$^{1:}$ *SR* = 0.77, 95% *CI* = 0.61 – 0.94; MP^{2}: *SR* = 0.76 , 95% *CI* = 0.60 – 0.92) stands 1 to 2 growing seasons post-burn (Figure 3.2, Table 3.2). Selection varied by nest attempt. During the first incubation period, females selected for mature pine (MP^{1}: *SR* = 0.60, 95% *CI* = 0.45 – 0.76; MP^{2}: *SR* = 0.71, 95% *CI* = 0.56 – 0.86) stands 1 to 2 growing seasons post-burn, young pine (YP^{2}: *SR* = 0.88, 95% *CI* = 0.78 – 0.99) stands 2 growing seasons post-burn, and avoided hardwood (HW: *SR* = 1.43, 95% *CI* = 1.19 – 1.66) stands (Figure 3.5, Table 3.3). Females that incubated a second nest selected for mature (MP^0: *SR* = 0.65, 95% *CI* = 0.47 – 0.82) and young pine stands burned during the previous 6 months (YP^0: *SR* = 0.71, 95% *CI* = 0.47 – 0.96: Figure 3.5, Table 3.3).

During brood rearing, females (*n* = 21) used open vegetation communities (OP: *SR* = 0.53, 95% *CI*: 0.43 – 0.62: Figure 3.1, Table 3.2). Similarly, females selected young pine stands recently burned (YP^0: *SR* = 0.79, 95% *CI*: 0.62 – 0.96), and young and mature pine stands 2 growing seasons post-burn (YP^2: *SR* = 0.83, 95% *CI*: 0.66 – 0.99; MP^2: *SR* = 0.75, 95% *CI*: 0.56 – 0.93: Figure 3.2, Table 3.2). All other vegetation communities were selected in proportion to their availability (Table 3.2). Post-nesting, females (*n* = 32) selected for hardwood and open vegetation communities (HW: *SR* = 0.68, 95% *CI*: 0.60 – 0.77; OP: *SR* = 0.83, 95% *CI*: 0.72 – 0.93: Figure 3.1, Table 3.2), and selected all other stands in proportion to their availability (Figure 3.2, Table 3.2). Agricultural areas were used in proportion to their availability during all phases (Figure 3.1, Table 3.2).

Discussion

Prescribed fire is applied in longleaf pine forests to reset succession and control competing hardwoods (Brockway and Lewis 1997, Glitzenstein et al. 2012). Prescribed fire consumes understory vegetation, and is often applied during nesting and brood rearing periods for turkeys, and may influence habitat selection during these periods (Kilburg et al. 2014, Little et al. 2014, Streich et al. 2015, Yeldell et al. 2017*c*). Similarly, restoration and management of longleaf pine forests necessitates applying prescribed fire to different seral stages of pine on the landscape. However, how application of prescribed fire in these stands influences turkey selection is poorly understood. We found turkeys selected vegetation communities differently throughout the reproductive season, and pine seral stage and time-since-fire both influenced selection (Yeldell et al. 2017*b*).

Females selected for agricultural fields in proportion to their availability during all phases. During April and May, which encompassed most of the laying and nesting periods (see Chapter 2), most agricultural fields in our study area were planted in cotton (*Gossypium* sp.) or peanuts (*Arachis hypogaea*). Sprouting plants and green vegetation likely available soon following planting, are readily consumed by turkeys (Dalke et al. 1942, Hurst 1992). However, herbaceous understory communities in longleaf pine forests and open vegetation communities likely provide adequate forage and cover for turkeys during the reproductive cycle and throughout the year. Therefore, agricultural fields in systems dominated by longleaf may be less important to turkeys than in other portions of their range.

Open vegetation communities were important to turkeys during all phases except during pre-nesting, where they were used in proportion to their availability. Conversely, females in a landscape managed with frequent fire in Louisiana selected open vegetation communities during second laying attempts and post-nesting (Yeldell et al. 2017*b*). Turkeys primarily consume green vegetation and ground dwelling insects (Glover and Bailey 1949, Schemnitz 1956, Healy 1985, Exum et al. 1987), and open vegetation communities provide increased access and improved foraging efficiency that can provide resources needed due to the physiological demand of egg laying, and for development of poults (Hurst 1992). Vegetation cover increases with increasing time since disturbance or fire (Lemon 1949, Buckner and Landers 1979), and females on our study site selected nest sites with increased ground cover and visual obstruction (see Chapter 2; Streich et al. 2015, Little et al. 2016*b*). Likewise, females on our study site selected for areas with increased ground cover during brood rearing (see Chapter 2). Therefore, it is not surprising that females selected open vegetation communities during most phases associated with reproduction.

We found that females selected for hardwood stands during pre-nesting and post-nesting. This pattern is consistent with other research in the southeastern United States, where turkeys use hardwood stands during fall and winter before transitioning to pine-dominated uplands during spring and summer (Miller et al. 1999, Little et al. 2016*a*). Acorns are a preferred food source for turkeys (Hurst 1992), and on our study area water oaks provided ample forage during winter into early spring. After the onset of reproductive behavior, females began to shift their selection towards upland pines, and avoided hardwoods during nest incubation, likely due to increased predation risk (Chamberlain et al. 2003). Hardwoods provide daytime refugia for known nest predators (i.e. raccoons and bobcats; Godbois et al. 2003, Jones et al. 2004), therefore the costs associated with predation risk likely outweigh benefits provided by these stands during reproduction. We suggest future management focus on maintaining a hardwood component within longleaf pine forests (Hiers et al. 2014) as these stands are selected by turkeys during much of the year.

Young pine stands are generally stocked at high densities and have canopy closure which reduces light available to support extensive herbaceous communities more common in clear-cuts and mature pine stands (Harrington 2006). Females avoided young pine stands recently burned and those burned 2 growing seasons prior during pre-nesting, whereas they selected stands burned ≤ 2 growing seasons prior during laying, incubation, and brood-rearing. Application of prescribed fire has been shown to reduce predator populations during the first year following application (Chamberlain et al. 2003, Jones et al. 2004), hence an association with these stands during laying, incubation, and brood-rearing may be a strategy to reduce predation risk. When initiating egg laying for first nest attempts, females selected for young pine stands burned < 3 growing seasons prior, whereas they used young pine stands in proportion to their availability during second laying attempts. Use during initial laying attempts was likely due to a documented shift in space use during spring and summer, when turkeys transition from hardwood communities that provide hard mast used during fall and winter into upland pine dominated stands that provide increasing herbaceous cover during spring and summer (Stys et al. 1992, Miller and Conner 2007). During brood-rearing, females also selected for young pine stands that had been recently burned and had been burned 2 growing seasons prior, perhaps due to increased foraging opportunities and concealment cover provided for broods respectively.

Females selected for mature pine stands during phases when they were actively involved in nesting and brood rearing activities, but avoided mature pine stands 2 growing seasons post-burn during pre-nesting. During laying, females selected mature pine stands regardless of burn history. During incubation, females selected mature pine stands burned 1 – 2 growing seasons previous, and during brood-rearing selected for stands 2 years post burn. Turkey use of recently burned pine stands regardless of seral stage has been shown to increase through approximately 150 - 250 days post-fire and turkeys continue to select pine stands through the first 18 months post-fire, at which point use declines likely due to reduced access to forage (Buckner and Landers 1979, Martin et al. 2012, Yeldell et al. 2017*c*). This may explain why females avoided mature pine stands burned 2 growing seasons prior during pre-nesting. We can only speculate why females selected mature pine stands during the reproductive period, but it seems likely that females are associating with these stands due to reduced canopy cover and open park-like conditions, which similar to open vegetation communities, results in increased understory vegetation preferred by turkeys (see Chapter 2).

Throughout the reproductive period females selected for stands with variable fire return intervals and burn histories, while selection varied within reproductive phases. This is likely due to understory vegetation communities therein, suggesting that prescribed fire return intervals of 1 - 3 years are compatible with management for wild turkeys. Likewise, areas where prescribed fire was excluded (i.e. hardwoods) also provided resources used by turkeys outside of reproduction. In addition, management focused on creating a mosaic of burn histories at relatively small scales (~25ha) increases patch diversity, which likely increases proximity to foraging opportunities and concealment cover, all of which were important to turkeys when selecting nest sites and areas to forage broods (see Chapter 2).

Management Implications

Turkeys selected for pine stands across seral stages, providing evidence that managers should focus on creating a diversity of pine seral stages that may be important to reproductively active turkeys. Prescribed fire on our study area was applied to relatively small patches, and may allow turkeys to be more selective in their habitat use compared to turkeys in landscapes where fire is applied at larger spatial scales (Yeldell et al. 2017*c*). We suggest that this management scheme results in herbaceous understory communities preferred by turkeys during the reproductive period. Quality turkey habitat is thought to include open vegetation communities as a portion of the landscape, and females on our study site selected these habitats throughout the reproductive period. Likewise, hardwood stands in longleaf pine systems provide important resources for turkeys outside of the reproductive season. In addition, agricultural fields were not selected or avoided during most phases which likely limits the importance of these areas in an area dominated by early successional vegetation maintained by frequent prescribed fire. Therefore, if management objectives are to benefit wild turkeys, managers should continue to use prescribed fire in longleaf pine forests with frequent fire return intervals (1-3 years), while maintaining open and hardwood vegetation communities to create a mosaic of vegetation communities that provide resources needed by turkeys throughout the year.

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Table 3.1. Mean area (ha) of 95% and 50% core utilization distributions for reproductively active female wild turkeys (*Meleagris gallopavo silvestris*) during each reproductive phase on Silver Lake Wildlife Management Area, southwest Georgia, USA, 2015 and 2016.

Reproductive Phase	*n*	Range	95% (ha ± SE)	50% (ha ± SE)
Pre-nesting	66	1 March – 3 June	390.72 ± 36.73	50.21 ± 3.52
Laying	65	18 March – 16 June	185.80 ± 9.43	33.27 ± 1.59
Incubating	62	30 March – 5 July	2.81 ± 0.43	0.13 ± 0.01
Brooding	21	29 April – 17 July	69.28 ± 14.31	8.43 ± 1.75
Post-nesting	32	14 April – 15 August	347.86 ± 45.53	48.02 ± 5.10
Spring/Summer	46	1 March – 15 August	529.98 ± 49.51	57.30 ± 5.26

Table 3.2. Ranked selection of vegetation communities (where 1 is most selected and 14 is least selected) using a Euclidean distance approach in a use vs. availability framework for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) during pooled reproductive phases during the breeding season on Silver Lake Wildlife Management Area, southwest Georgia, USA, 2015 and 2016.

Reproductive phase	*n*[b]	Vegetation Community Ranking[a]										
		1	2	3	4	5	6	7	8	9	10	11
Prenesting	46	HW*	YP^{NRB}	AG	YP^{1}	OP	MP^{1}	MP^{0}	YP^{2}**	MP^{NRB}	YP^{0}**	MP^{2}**
Laying	46	OP*	MP^{NRB}*	MP^{0}*	MP^{1}*	YP^{0}*	MP^{2}*	HW	YP^{2}*	YP^{NRB}	YP^{1}	AG
Incubating	46	OP*	MP^{2}*	MP^{1}*	MP^{NRB}	YP^{0}*	MP^{0}	AG	YP^{2}	YP^{NRB}	YP^{1}	HW**
Brooding	23	OP*	MP^{2}*	YP^{0}*	YP^{NRB}	YP^{2}*	MP^{1}	YP^{1}	MP^{0}	AG	MP^{NRB}	HW
Post-nesting	34	HW*	OP*	YP^{NRB}	AG	YP^{2}	YP^{1}	YP^{0}	MP^{NRB}	MP^{1}	MP^{2}	MP^{0}

[*] Indicates significant use of vegetation community, where 95% confidence intervals did not include 1.

[**] Indicates significant avoidance of vegetation community, where 95% confidence intervals did not include 1.

[a] Vegetation communities included open (clear-cuts 0-3 years old, wildlife openings; OP), young pine (4-19 years old; YP), mature pine (≥ 20 years old; MP), agricultural fields (AG), and hardwoods (HW).

[b] Sample size *n* included in selection analysis during each reproductive phase.

[0] Recently burned (≤6 months)

[1] Experienced 1 growing season post-burn

[2] Experienced 2 growing seasons post-burn

[NRB] Experienced ≥3 growing seasons post-burn

Table 3.3. Ranked selection of vegetation communities (where 1 is most selected and 14 is least selected) using a Euclidean distance approach in a use vs. availability framework for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) during multiple reproductive phases during the breeding season on Silver Lake Wildlife Management Area, southwest Georgia, USA, 2015 and 2016.

Reproductive phase	n[b]	Vegetation Community Ranking[a]										
		1	2	3	4	5	6	7	8	9	10	11
Prenest-1	46	HW*	AG	YP^{NRB}	YP^{1}	OP	MP^{1}	MP^{0}	MP^{NRB}	YP^{2}**	MP^{2}**	YP^{0}**
Prenest-2	19	OP*	HW	YP^{0}	MP^{2}	MP^{0}	MP^{1}	YP^{2}	MP^{NRB}	YP^{1}	AG	YP^{NRB}
Lay-1	46	OP*	MP^{1}*	MP^{NRB}*	MP^{0}*	MP^{2}*	YP^{0}*	YP^{1}*	YP^{NRB}	YP^{2}*	HW	AG
Lay-2	19	MP^{0}*	YP^{0}	OP*	MP^{NRB}	HW	MP^{1}	MP^{2}	YP^{2}	YP^{1}	YP^{NRB}	AG
Nest-1	46	MP^{1}*	MP^{2}*	OP*	MP^{NRB}	YP^{2}*	YP^{0}	YP^{NRB}	AG	MP^{0}	YP^{1}	HW**
Nest-2	19	MP^{0}*	YP^{0}*	MP^{2}	OP	MP^{NRB}	YP^{1}	MP^{1}	YP^{2}	AG	YP^{NRB}	HW

[*] Indicates significant use of vegetation community, where 95% confidence intervals did not include 1.

[**] Indicates significant avoidance of vegetation community, where 95% confidence intervals did not include 1.

[a] Vegetation communities included open (clear-cuts 0-3 years old, wildlife openings; OP), young pine (4-19 years old; YP), mature pine (≥ 20 years old; MP), agricultural fields (AG), and hardwoods (HW).

[b] Sample size *n* included in selection analysis during each reproductive phase.

[0] Recently burned (≤6 months)

[1] One growing season post-burn

[2] Two 2 growing seasons post-burn

[NRB] Three or more growing seasons post-burn.

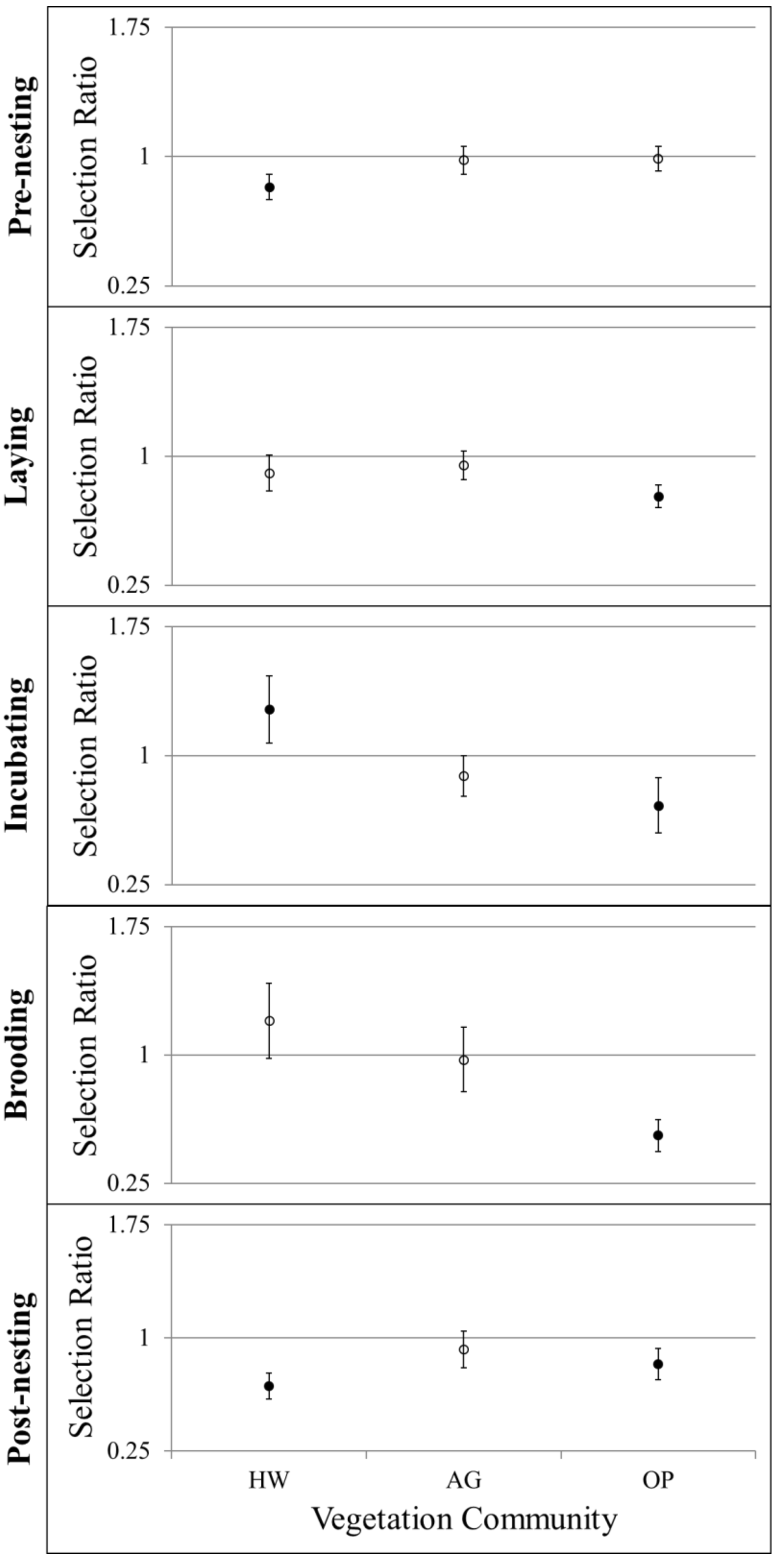

Figure 3.1. Selection ratios for hardwood, agriculture fields, and open (i.e. fallow fields, clearcuts planted in pine [*Pinus* spp.; 0-3 years old]) vegetation communities during the

reproductive period for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) on Silver Lake Wildlife Management Area, southwest Georgia, USA, during 2015 and 2016. Where selection ratios and confidence intervals > 1 indicate avoidance, < 1 indicate selection, and a selection ratio and confidence interval that includes 1 is considered to be used in proportion to availability.

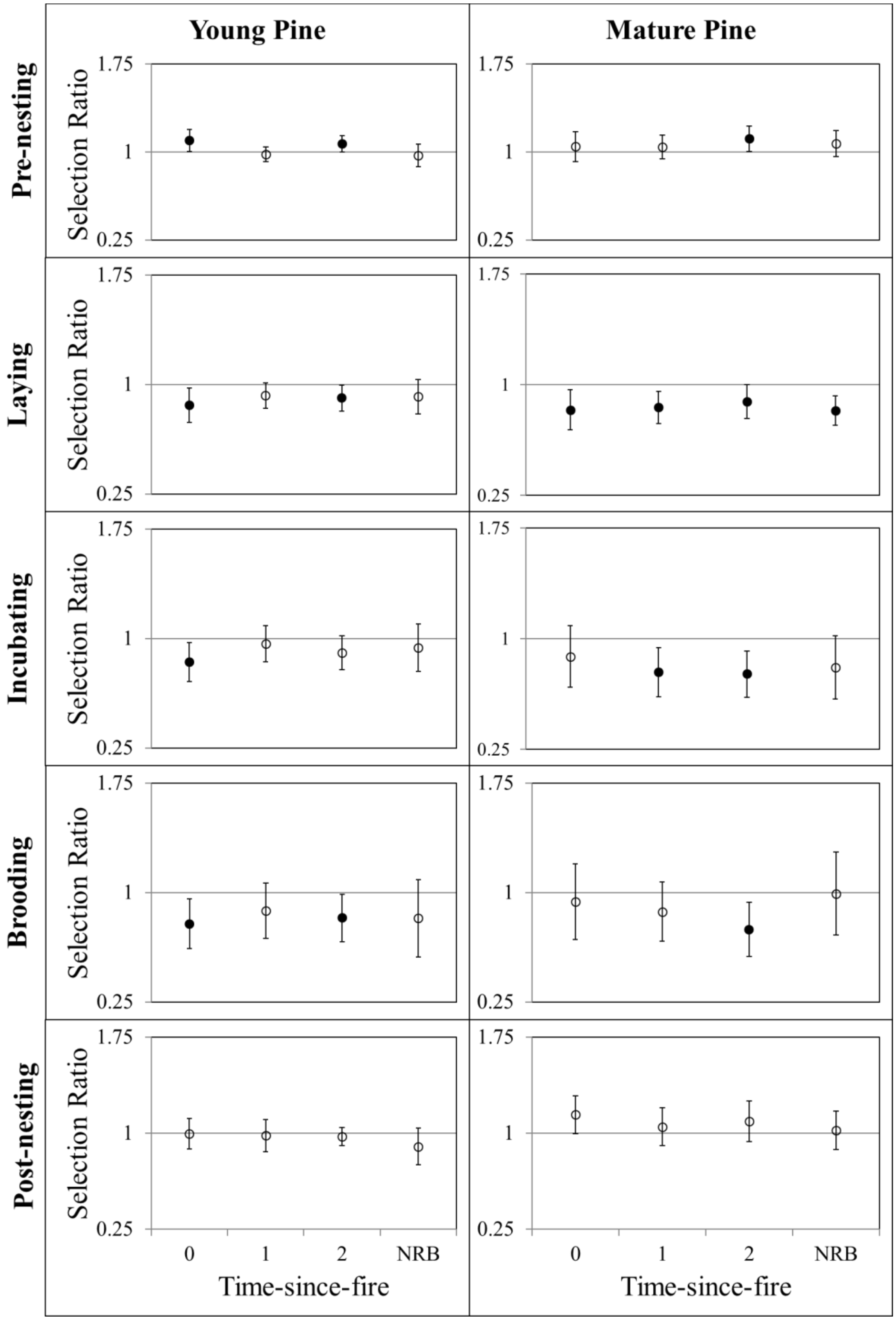

Figure 3.2. Selection ratios for young pine (4-19 years old) and mature pine (≥20 years old) communities throughout the reproductive period for reproductively active female eastern wild

turkeys (*Meleagris gallopavo silvestris*) on Silver Lake Wildlife Management Area, southwest Georgia, USA, 2015 and 2016. Where selection ratios and confidence intervals > 1 indicate avoidance, < 1 indicate selection, and a selection ratio and confidence interval that includes 1 is considered to be used in proportion to availability.

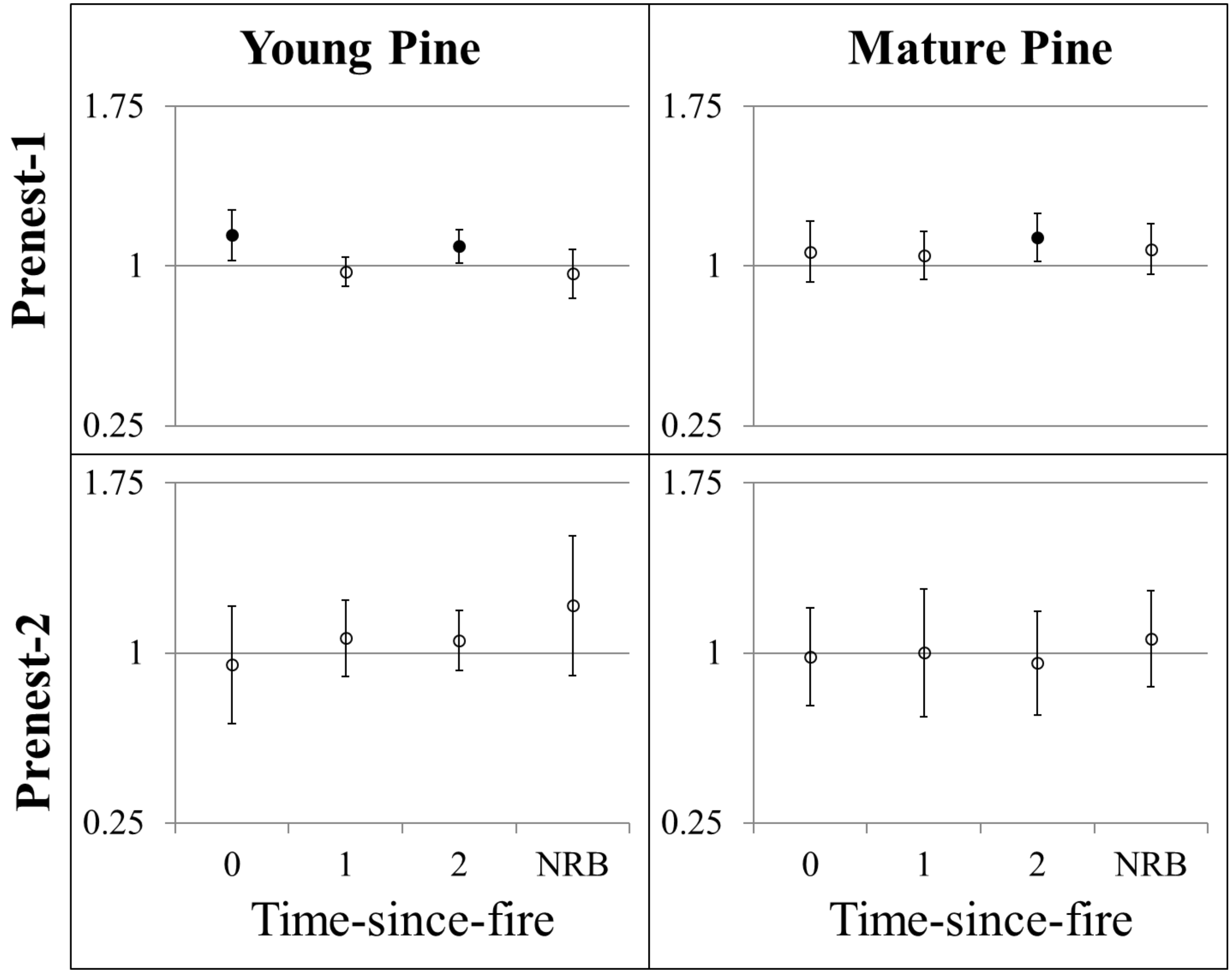

Figure 3.3. Selection ratios of young pine (4-19 years old) and mature pine (≥20 years old) communities during 2 phases of pre-nesting for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) on Silver Lake Wildlife Management

Area, southwest Georgia, USA, during 2015 and 2016. Where selection ratios and confidence intervals > 1 indicate avoidance, < 1 indicate selection, and a selection ratio and confidence interval that includes 1 is considered to be used in proportion to availability.

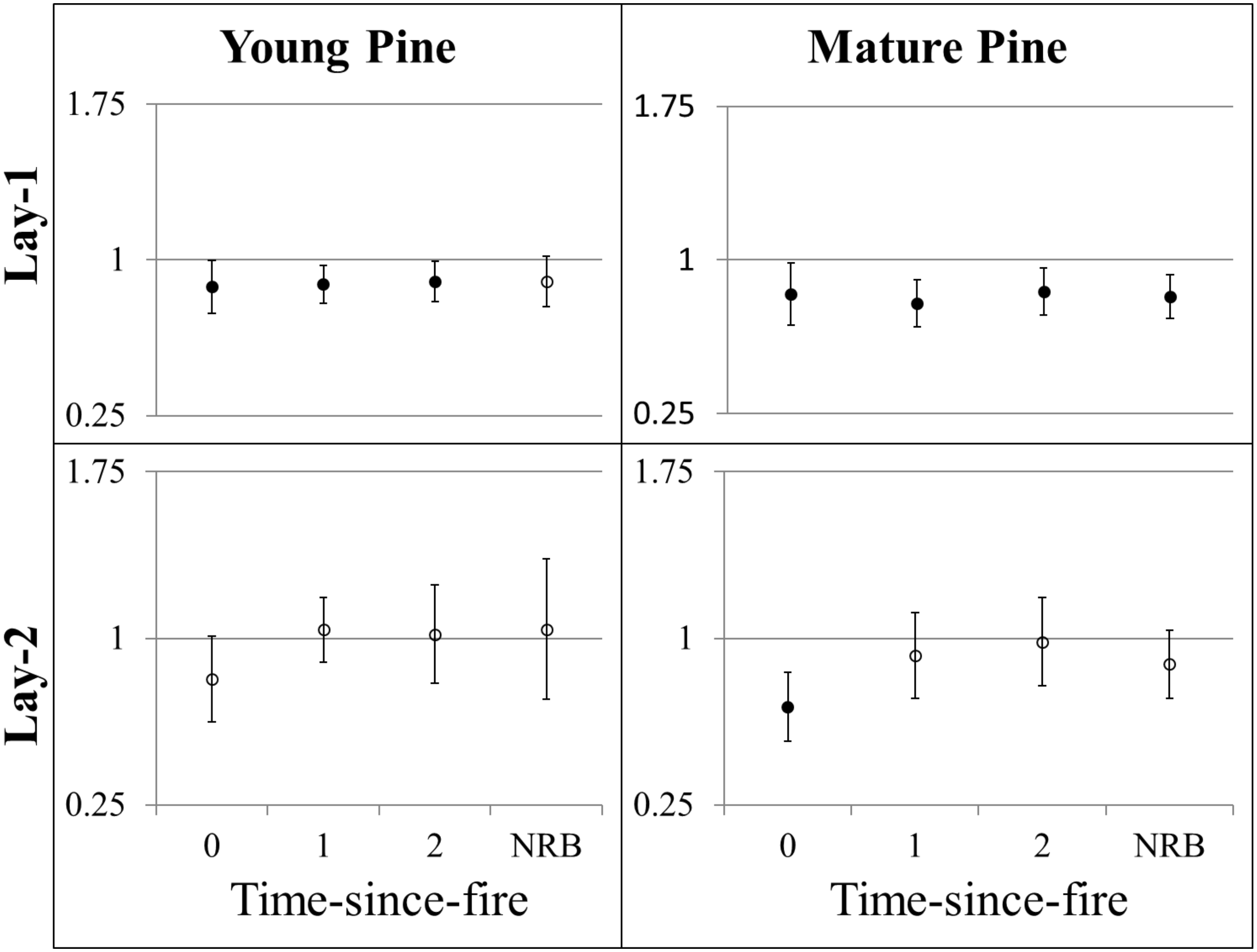

Figure 3.4. Selection ratios of young pine (4-19 years old) and mature pine (≥20 years old) communities during 2 phases of laying for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) on Silver Lake Wildlife Management Area,

southwest Georgia, USA, during 2015 and 2016. Where selection ratios and confidence intervals > 1 indicate avoidance, < 1 indicate selection, and a selection ratio and confidence interval that includes 1 is considered to be used in proportion to availability.

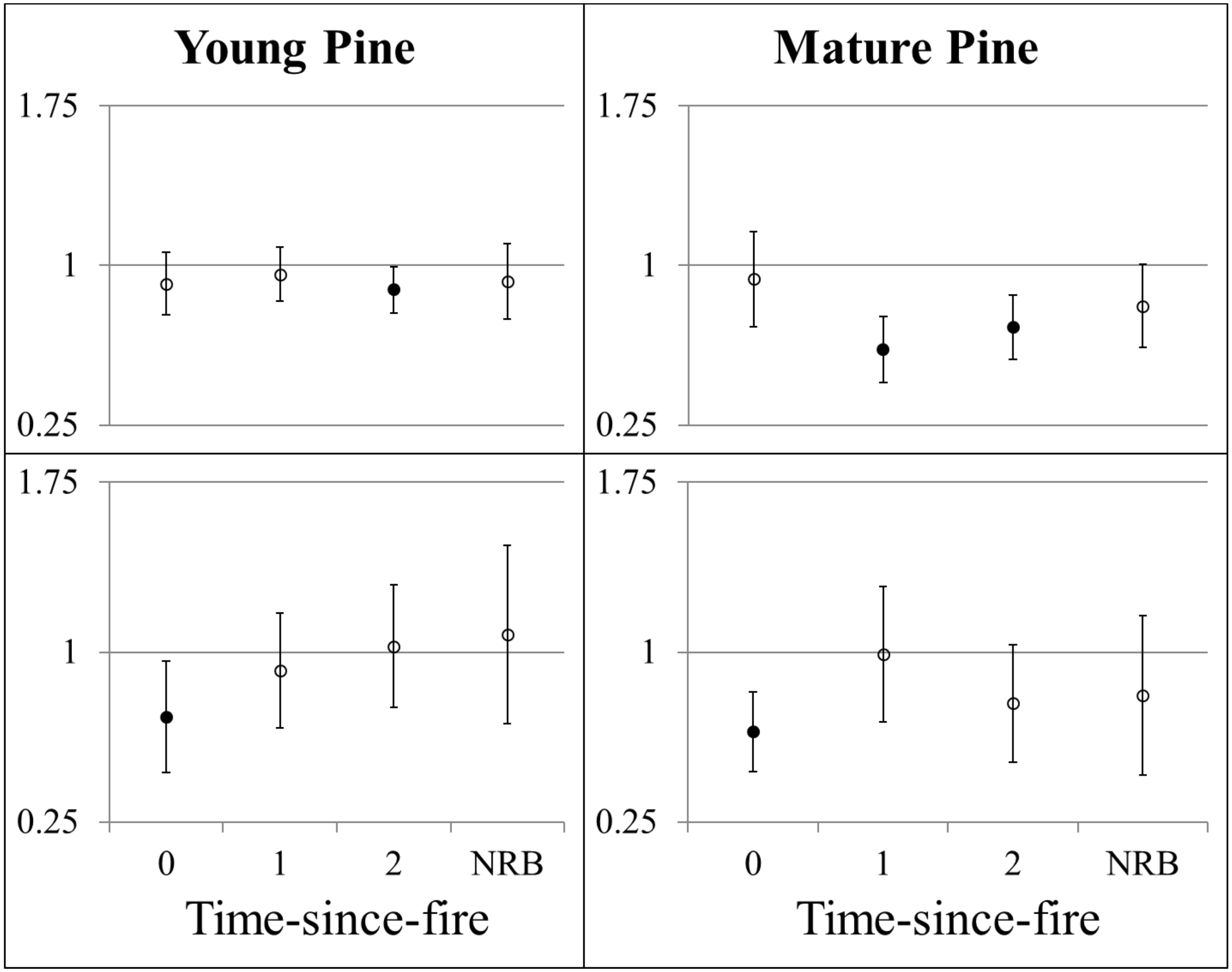

Figure 3.5. Selection ratios of young pine (4-19 years old) and mature pine (≥20 years old) communities during 2 phases of incubation for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) on Silver Lake Wildlife Management Area,

southwest Georgia, USA, during 2015 and 2016. Where selection ratios and confidence intervals > 1 indicate avoidance, < 1 indicate selection, and a selection ratio and confidence interval that includes 1 is considered to be used in proportion to availability.

CHAPTER 4

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

I found that female wild turkeys (turkeys) selected for areas with increased ground cover throughout nesting and brood-rearing periods, but selection for these areas did not influence reproductive success. In addition, I found that females selected for areas with increased patch diversity during nesting and when ground roosting with broods. As patch diversity increased, nest survival increased, but brood survival decreased. However, extraneous covariates (i.e. predation risk) that were unaccounted for in my analysis of brood survival may have influenced my results. Therefore, I offer that future research address the primary mechanisms that reduce nest and brood survival, by assessing the scale at which predators affect nest and brood survival.

I found that throughout the reproductive period females selected pine stands regardless of burn history, but selection varied within reproductive phases. I suggest this is likely due to application of frequent prescribed fire (1-3 years) which resulted in understory vegetation communities preferred by turkeys. In addition, I documented that areas where prescribed fire was excluded (i.e. hardwoods) provided resources used by turkeys outside the reproductive period. Management on SLWMA focused on creating a mosaic of burn histories at relatively small scales (~25ha) to increase patch diversity, which in turn may have increased proximity to foraging opportunities and concealment cover.

I found that female turkeys selected pine stands regardless of seral stage, providing evidence that uneven aged management at the stand scale may benefit turkeys during the reproductive period. In addition, I found that females on SLWMA selected open vegetation communities throughout all phases of reproduction and following the reproductive period, whereas they selected hardwood communities before and after the reproductive season. Agricultural fields were selected in proportion to their availability during all phases, which likely limits the importance of these in longleaf pine landscapes dominated by early successional vegetation maintained with frequent prescribed fire.

Female turkeys are in their reproductive cycle for a considerable portion of the year (~25%), and application of prescribed fire did not directly influence nest or brood survival. Females selected for understory vegetation characteristics during nesting and brood-rearing that resulted from plant succession following prescribed fire, but these characteristics did not influence nest or brood survival. Understory communities present in open and pine dominated vegetation communities provide abundant foraging opportunities and escape cover turkeys prefer throughout the reproductive season. Likewise, prescribed fire applied in a mosaic fashion creates diverse understory conditions that increase patch diversity favored by female turkeys during nesting and brood-rearing. In addition, hardwood stands provide vegetation communities that turkeys select for during most of the year outside of the reproductive period, highlighting the importance of these stands in an upland pine dominated landscape. Therefore, I suggest if management objectives are to benefit turkeys, managers should continue to use prescribed fire in longleaf pine forests with 1 to 3 year fire return intervals at small scales (~25 ha). In addition, I suggest managers maintain open and hardwood vegetation communities to create a mosaic of vegetation communities providing resources needed by turkeys throughout the year.