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Time-since-fire and stand seral stage affect habitat selection of eastern wild turkeys in a managed longleaf pine ecosystem

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A R T I C L E I N F O

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A B S T R A C T

Longleaf pine (*Pinus palustris*) forests rely on prescribed fire to limit encroachment of hardwoods and maintain early successional understory communities. However, prescribed fire may alter habitat availability while female eastern wild turkeys (*Meleagris gallopavo silvestris*) are reproductively active. In addition, the vigor of vegetation regrowth post-fire is impacted by both midstory and overstory stand-conditions which can be a function of stand age. Therefore, the degree to which prescribed fire affects habitat availability and selection of wild turkeys may be a function of both time-since-fire and the age of the stand fire was applied to. We assessed habitat selection of female wild turkeys during their reproductive cycle in a longleaf pine forest managed with frequent prescribed fire. We captured 63 female wild turkeys during 2015 and 2016 on a longleaf pine-dominated landscape in southwestern Georgia, USA, that was managed with 1–3 year fire-return intervals applied to relatively small burn blocks (mean size of burn = 26.02 ha in 2015; 19.84 ha in 2016) on pine stands of varying age-classes. We attached Global Positioning Systems units to individuals and collected hourly locations from 1 March to 15 August. We then used distance-based analyses to estimate daily selection or avoidance of vegetation communities relative to the known reproductive phenology of individual females. Females selected hardwood stands during pre-nesting and post-nesting phases, but avoided them during the incubation phase. Females used open vegetation communities during all phases of reproduction following pre-nesting. Turkeys selected areas burned ≤ 2 years prior but used different seral stages of pine during different reproductive phases. Specifically, females selected for recently burned mature pine stands during incubation but then selected for recently burned young pine stands, mature pine stands burned 2 years earlier, and open vegetation communities during brooding. Our findings demonstrate that time-since-fire and stand seral age interact to affect how turkeys use pyric landscapes. In general, pine stands providing ample understory vegetation are favored while females are reproductively active. Our data suggests practitioners should try to manage a landscape containing both young and mature pine stands and use prescribed fire to create understory conditions selected by turkeys across all reproductive phases.

1. Introduction

Longleaf pine (*Pinus palustris*) forests historically covered ≥ 36 million ha in the southeastern United States (Landers et al., 1995; Brockway et al., 2005a; Van Lear et al., 2005). Through intensive logging and conversion of sites to agriculture or faster growing species (i.e. loblolly pine [*P. taeda*] and slash pine [*P. elliottii*]), many longleaf pine forests were lost (Landers et al., 1995; Brockway et al., 2005a; 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 fire (Kirkman et al., 2004; Outcalt, 2008). 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., 2005a,b; Van Lear et al., 2005).

Management and restoration of longleaf pine forests relies on

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frequent application of prescribed fire (e.g. 1–3 years) to mimic natural and historic burn frequencies (Brockway et al., 2005a; Oswalt et al., 2012). Frequent fire-return interval reduces fuel loads, limits midstory encroachment of hardwoods, 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 as 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). Differences in vegetation response lead to increased understory diversity and structural heterogeneity (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).

Reestablishment of longleaf pine forests can result in a mosaic of pine seral stages across the landscape. After mechanical removal of the overstory, managers sometimes apply prescribed fire to remove logging slash to prep sites for planting (Brockway et al., 2005a,b). In areas trying to restore longleaf pine forests, managers first plant longleaf pine seedlings wherever conditions are appropriate and plant loblolly pine in sites less conducive to longleaf pine survival and growth. After replanting sites in longleaf pine seedlings, understory vegetation is dominated by herbaceous plants, grasses, and hardwood shrubs, with no midstory or overstory vegetation (Kirkman et al., 2004). 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). Although planting density affects how long after planting young longleaf pines reach the period of stem exclusion (i.e. canopy closure), the resulting understory vegetation at canopy closure is sparse, and similar to conditions in southern pine plantations (Harrington, 2006). After thinning, understory communities respond to reduced canopy cover, coupled with applications of prescribed fire or herbicide, 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; Pecot et al., 2007; Outcalt, 2008).

Because prescribed fire immediately alters vegetation communities and is applied during winter, spring, and summer, which coincides with the reproductive period of eastern wild turkeys (*Meleagris gallopavo silvestris*; hereafter: turkeys), it has potential to alter habitat selection of reproductively active females (Little et al., 2016a; Yeldell et al., 2017b). Prescribed fire shifts the spatial arrangement of resources, affecting how individuals partition their time and space use (Streich et al., 2015; Little et al., 2016b; Yeldell et al., 2017a). For example, turkeys may be attracted to recent burns because of forage availability (Glover and Bailey, 1949; Exum et al., 1987) as insects are found in similar abundance immediately before and after fire (Chitwood et al., 2017) but may be more accessible due to reduced litter cover (Addington et al., 2015). The response of vegetation post-fire is affected by pine stand conditions as well; vigor in understory growth post-fire is diminished in stands with denser midstory and overstory conditions (Wiggers et al., 2013; Addington et al., 2015). Regenerating clear-cuts replanted with longleaf pine provide early successional communities with resources similar to open areas (Dalke et al., 1942; Kennamer et al., 1980). As longleaf pine stands age, high-density plantings inhibit development of the understory though shading, competition, and heavy litter (Dagley et al., 2002; Battaglia et al., 2003; Harrington et al., 2003), reducing forage availability. When stands are selectively thinned, the resulting low-density overstories create suitable conditions for understory growth of herbaceous plants (Kirkman and Mitchell, 2006) that turkeys feed on (Exum et al., 1987). Hardwood stands in pine-dominated landscapes can play an important role by providing roosting cover and forage during seasons when herbaceous plants are sparse (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 change selection of vegetation communities during different reproductive phases (Yeldell et al., 2017b). 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., 2017b). In southwestern 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 vegetation community selection throughout their reproductive season, but the extent of this interaction is unknown.

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 structure and hard mast. Females require substantial nutrient uptake due to the high physiological demand during egg laying and brood-rearing, therefore we hypothesized females would select mature pine 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), and avoid young pine stands regardless of time-since-fire, 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.

2. Materials and methods

2.1. Study area

We conducted research on the Silver Lake Wildlife Management Area (hereafter, SLWMA) and surrounding private lands in southwestern Georgia. The SLWMA was managed by the Georgia Department of Natural Resources-Wildlife Resources Division (GADNR) for hunting and other outdoor recreation activities. The SLWMA encompassed approximately 3900-ha, of which 3392 ha (88%) was dominated by pine (*Pinus* spp.) forests. Of these, 83% (2814.77 ha) were mature pine forests (≥ 20 years old), and 14% (478.21 ha) were young pine plantations (4–19 years old). Although we classify stands hereafter young or mature stands, we recognize that longleaf pine only 20 years post-planting is still relatively young (see Addington et al., 2015); nonetheless, our classifications represent important changes in stand conditions on our site. Stands that we classify as young pine stands were characterized by increased stocking levels and diameter at breast height (DBH) classes ≤ 20.3 cm. Mature pine stands were characterized by lower stocking levels, DBH classes > 20.3 cm, and more open, park-like conditions. Other plant communities included clear-cuts planted in pine, hardwood forests, agricultural fields, and wildlife openings scattered throughout. The SLWMA is managed by GADNR as a northern bobwhite (*Colinus* *virginianus*) focal area. This meant managers trapped and removed mesomammals during late February and early March of 2015 and 2016, which was prior to the onset of any incubation behavior of turkeys in this study.

Dominant overstory species included longleaf pine and to a lesser extent loblolly pine, 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. Other private lands in the area consisted of rural dwellings, cattle pastures, poultry farms and hardwood-dominated forested wetlands.

Prescribed fire was applied to SLWMA throughout the year, but most fires occurred during the dormant season (December 1–March 31) in 2015 (63.3%), and during the growing season (April 1–July 31) 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 SLWMA.

2.2. Animal 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 once per hour from 0500-h to 2000-h and a single roost location at 2359-h (i.e., 17 locations/day) 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 ≤100 m (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 another pre-nesting attempt, started brooding, or if reproductive activity ceased, entered into the post-nesting period. Because turkey nests require continuous incubation approximately 25–29 days before hatching (Williams 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. Any turkey not showing signs of reproductive activity was considered to be in the post-nesting phase, which was from the time of completion of nest or brood rearing activities for each female until 15 August.

Table 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, southwestern Georgia, USA, 2015 and 2016. Reproductively active females were grouped into the following categories based on reproductive phenology: prior to initiating first nest attempt (Pre-nesting), following nest failure or brood loss and prior to a subsequent nest attempt (Pre-nesting), laying a clutch associated with any nest attempt (Laying), incubating a nest (Incubation), brood-rearing (Brooding), and following all nest attempts or after surviving poults reach 28 days old (Post-nesting).

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
Incubation	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

Because habitat selection may be dependent on reproductive activity (Yeldell et al., 2017b), 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. 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 (Hurst, 1992).

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.

2.3. 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 which we describe below. We classified pixels as pine if they consisted of ≥50% longleaf, loblolly, slash, or shortleaf pine in the overstory.

Because understory vegetation is influenced by pine seral stages and plays an important role in turkey habitat selection, we classified pine stands into 2 seral stages based on age of pine within the stand: young

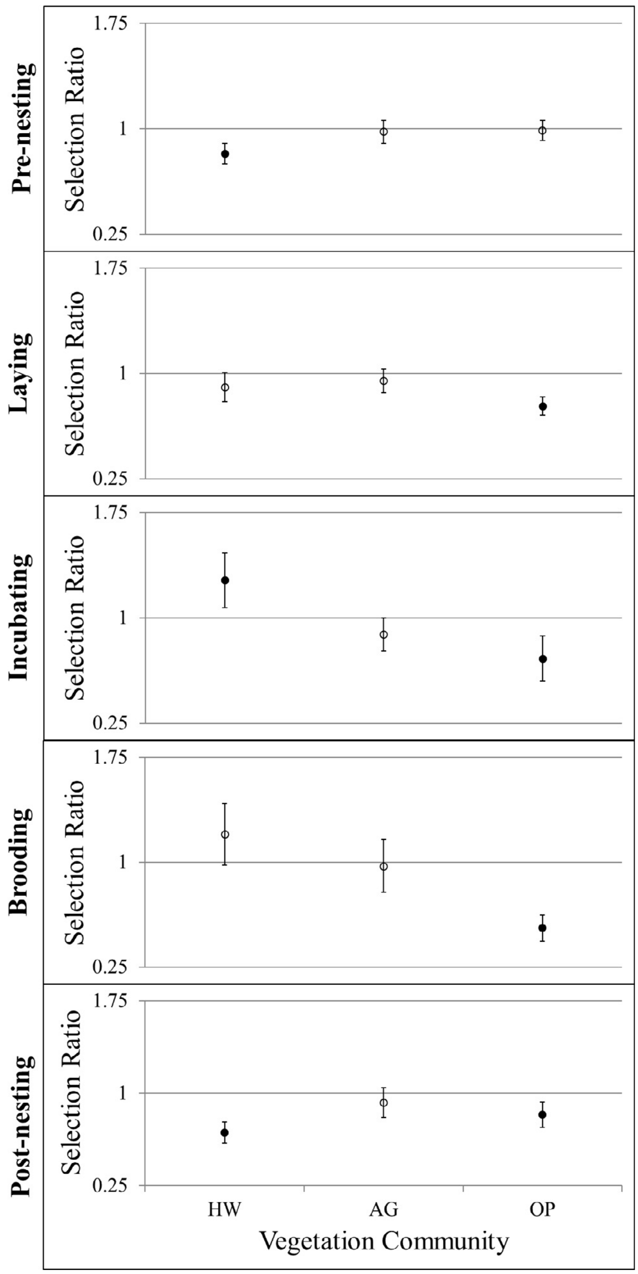

Fig. 1. Selection ratios for hardwood, agriculture fields, and open (i.e. fallow fields, clearcuts planted in pine 0–3 years old) vegetation communities during the reproductive period for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) on Silver Lake Wildlife Management Area, southwestern Georgia, USA, during 2015 and 2016. Estimates > 1 indicate avoidance and estimates < 1 indicate selection, with deviation from 1 indicative of effect size. Error bars show 95% confidence intervals. Black-filled estimate markers indicate statistically significant selection or avoidance as indicated by 95% confidence intervals.

pine (YP; 4–19 years post-planting), and mature pine (MP; ≥20 years post-planting). Young pine stands were characterized by increased stocking levels and diameter at breast height (DBH) classes ≤20.3 cm, whereas mature pine stands were characterized by lower stocking levels, DBH classes > 20.3 cm, and more open, park-like conditions. We classified pixels as hardwood stands if they consisted of > 50% hardwoods species. Hardwood stands were often associated with lowland areas bordering lakes and ponds, and upland depressional wetlands, or planted sawtooth oak (*Quercus acutissima*) groves. We classified all planted crops as agriculture. We classified old fields, forest openings and clear-cuts planted in pine (0–3 years post-planting) as open vegetation communities. Although we describe these areas as open in terms of not having any canopy cover, these areas tend to be relatively thick (i.e., high visual obstruction) with herbaceous vegetation. We included clear-cuts in the open classification because managers often used fire to reduce logging slash and prepare stands for replanting in longleaf or loblolly pine (Brockway et al., 2005a), and thus vegetation during the first 3 years after planting is similar to old field communities and managed wildlife openings (Kirkman et al., 2004; Pecot et al., 2007).

Because we were interested in how prescribed fire influenced female turkey selection of pine seral stages, 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 in areas within or similar to our study site converge (Buckner and Landers, 1979; Glitzenstein et al., 2012). On our study site, herbaceous plant density tends to be greatest in the first year post-burn, and steadily decline as time-since-fire increases (Buckner and Landers, 1979); plant diversity peaks at 3 growing seasons post-burn and woody species become more prevalent as density of herbaceous plants declines (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}).

2.4. Habitat selection

We examined habitat selection within turkey home ranges using a use versus availability framework (Benson, 2013). The analysis was restricted to reproductively active females (i.e., turkeys that were known to initiate at least 1 nest). Because fire history is dynamic, and time-since-fire changes every day, 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., 2017b). We defined available vegetation communities as those within an individual's home range. We calculated home ranges as the 95% dBBMM UD that encompassed all locations from 1 March to 15 August and used a window size of 7, margin of 3, and a location error of 20 (Cohen et al., 2018). 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. In other words, we calculated the Brownian motion variance by using all steps in the entire path of the animal and then estimated the daily UDs by integrating the probabilities for each day's GPS locations using the variance estimate derived from the full path. 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 package 'move' (Kranstauber et al., 2017) in R version 3.3.2 (R Core and Team, 2016).

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 (Benson, 2013). Fire history was updated daily to account for prescribed fire application throughout the study period. Updating fire history daily in our analysis allowed the landscape an individual selected from to change for every day in our analysis as we incorporated application of prescribed fire onto the landscape. In other

Table 2
Ranked mean selection ratios of vegetation communities (where 1 is highest mean selection ratio value and 11 is the lowest) for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) during pooled reproductive phases of the breeding season on Silver Lake Wildlife Management Area, southwestern 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.

words, 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 (Benson, 2013). 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 (Benson, 2013). Selection ratios < 1.0 indicated selection and > 1.0 indicated avoidance of vegetation communities (Benson, 2013; Yeldell et al., 2017b). We treated all broods as independent samples regardless if a female was known to have 2 broods within a single nesting season.

3. 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, we found 2 which failed while the female was still laying. Therefore, we monitored 74 incubated nests (51 initial nest attempts, 21 s attempts, and 2 third attempts) from 46 females.

Home range size during pre-nesting was 390.72 ± 36.73 ha and for core areas was 50.21 ± 3.52 ha (Table 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 study period (1 March–15 August) were 529.98 ± 49.51 ha and 57.30 ± 5.26 ha, respectively (Table 1).

We note that our reported selection ratios are the mean response across all turkeys in our sample, and that individual birds can select for widely variable vegetation conditions, as indicated by the associated confidence intervals. During pre-nesting, females (n = 66) selected for hardwood stands (HW: SR = 0.82; 95% CI = 0.75–0.90: Fig. 1, Table 2), and avoided young pine stands burned during the previous 6 months (YP^0: SR = 1.10, 95% CI = 1.01–1.19: Fig. 2, Table 2), and 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: Fig. 2, Table 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), and avoided young pine stands burned < 6 months previous (YP^0: SR = 1.14, 95% CI = 1.03–1.26: Fig. 3, Table 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: Fig. 3, Table 3). However, females (n = 19) in their second pre-nesting period used all vegetation communities in proportion to their availability (Fig. 3, Table 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^{NRB}: 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: Fig. 1, Table 2). Females generally selected for pine stands regardless of seral stage and burn history during their first laying period. 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: Fig. 4, Table 3).

During incubation, females (n = 62) avoided hardwood stands (HW: SR = 1.27, 95% CI = 1.07–1.46: Fig. 1, Table 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 (Fig. 2, Table 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 (Fig. 5, Table 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: Fig. 5, Table 3).

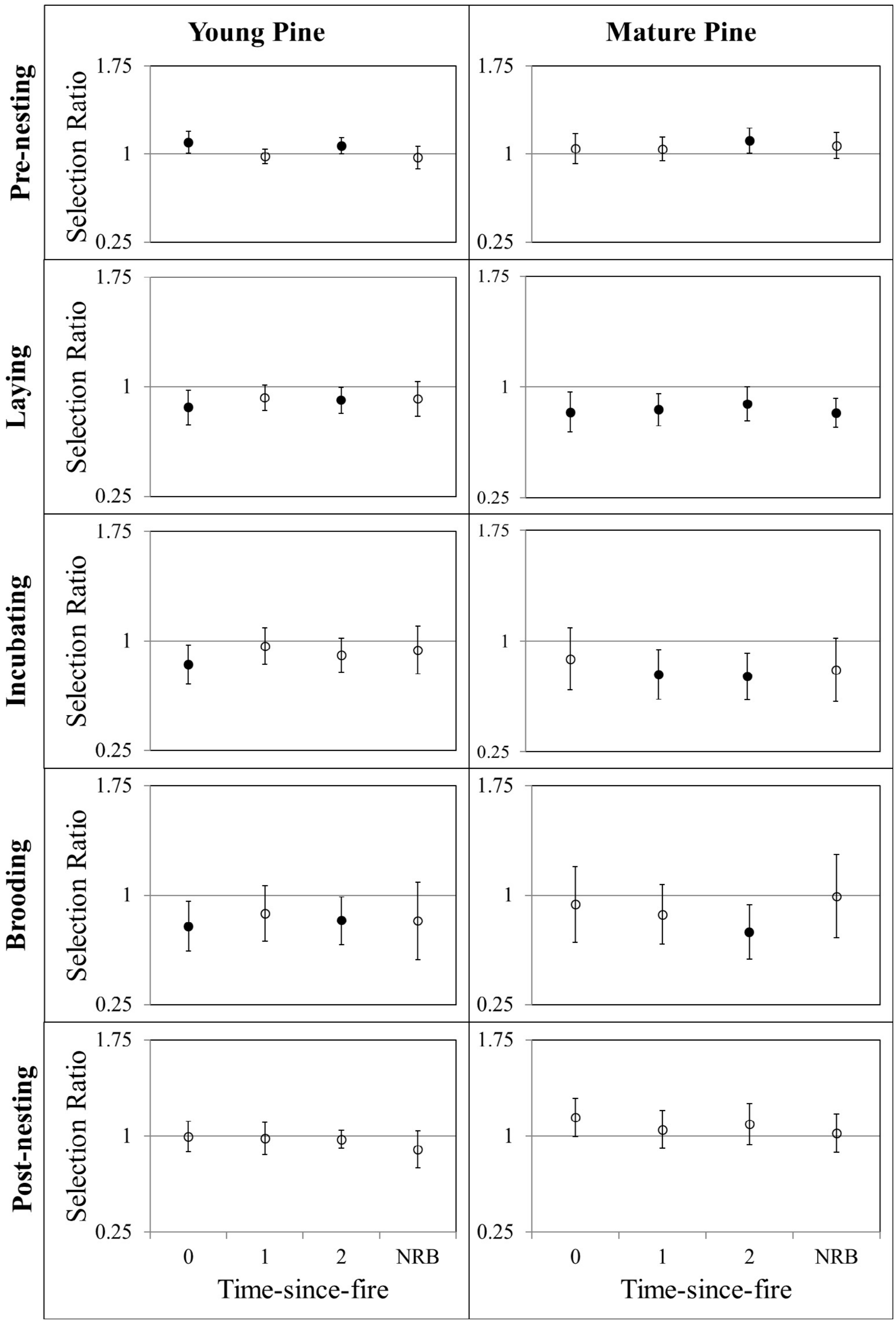

Fig. 2. Selection ratios for young pine (4–19 years old) and mature pine (≥20 years old) communities throughout the reproductive period for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) on Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2015 and 2016. Estimates > 1 indicate avoidance and estimates < 1 indicate selection, with deviation from 1 indicative of effect size. Error bars show 95% confidence intervals. Black-filled estimate markers indicate statistically significant selection or avoidance as indicated by 95% confidence intervals.

During brood rearing, females (n = 21) used open vegetation communities (OP: SR = 0.53, 95% CI: 0.43–0.62: Fig. 1, Table 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: Fig. 2, Table 2). All other vegetation communities were selected in proportion to their availability (Table 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: Fig. 1, Table 2), and selected all other stands in proportion to their availability (Fig. 2, Table 2). Agricultural areas were used in proportion to their availability during all phases (Fig. 1, Table 2).

4. Discussion

Stand seral stage and time-since-fire interact to produce vegetation communities selected or avoided by wild turkeys. Turkeys selected vegetation communities differently throughout the reproductive season, and pine seral stage influenced how turkeys selected recently burned areas. Vegetation communities providing ample understory vegetation were generally favored during the reproductive period. Turkeys tended to selected areas burned ≤2 years prior but selected

Table 3
Ranked mean selection ratios of vegetation communities (where 1 is highest mean selection ratio value and 11 is the lowest) for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) during multiple reproductive phases of the breeding season on Silver Lake Wildlife Management Area, southwestern 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.

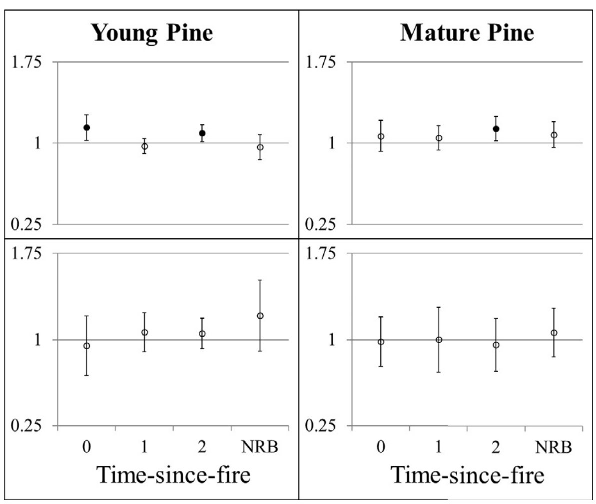

Fig. 3. Selection ratios of young pine (4–19 years old) and mature pine (≥20 years old) communities during 2 phases of pre-nesting for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) on Silver Lake Wildlife Management Area, southwestern Georgia, USA, during 2015 and 2016. Estimates > 1 indicate avoidance and estimates < 1 indicate selection, with deviation from 1 indicative of effect size. Error bars show 95% confidence intervals. Black-filled estimate markers indicate statistically significant selection or avoidance as indicated by 95% confidence intervals.

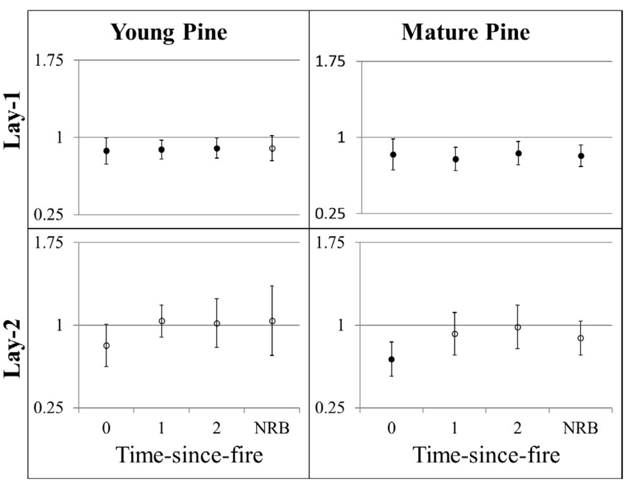

Fig. 4. Selection ratios of young pine (4–19 years old) and mature pine (≥20 years old) communities during 2 phases of laying for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) on Silver Lake Wildlife Management Area, southwestern Georgia, USA, during 2015 and 2016. Estimates > 1 indicate avoidance and estimates < 1 indicate selection, with deviation from 1 indicative of effect size. Error bars show 95% confidence intervals. Black-filled estimate markers indicate statistically significant selection or avoidance as indicated by 95% confidence intervals.

different seral stages of pine during different reproductive phases. Specifically, females tended to select recently burned mature pine stands during nesting but then selected for recently burned young pine stands, open vegetation communities, and mature pine stands burned 2 years earlier during brooding.

For example, females did not select agricultural fields at any point during our study. We expected these agricultural fields to be selected for, especially immediately after planting during April and May, which encompassed most of the laying and nesting periods, because sprouting plants and green vegetation available following planting are readily consumed by turkeys (Dalke et al., 1942; Hurst, 1992). However, the herbaceous understory communities provided by frequently-burned longleaf pine forests may provide adequate forage and additional cover for turkeys, lessening the importance of agricultural fields. In contrast to agricultural fields, open vegetation communities were selected by turkeys during all reproductive phases except during pre-nesting. Turkeys primarily consume green vegetation and ground dwelling insects (Glover and Bailey, 1949; Schemnitz, 1956; Healy, 1985; Exum et al., 1987). Vegetation cover increases with increasing time since disturbance (Lemon, 1949; Buckner and Landers, 1979), and females on our study site selected nest sites with increased ground cover and visual obstruction (Streich et al., 2015; Little et al., 2016b). Likewise, females on our study site selected areas with increased ground cover during brood rearing (Wood, 2017). Therefore, it is not surprising that females selected open vegetation communities during most phases associated with reproduction.

Females selected hardwood stands during pre-nesting and post-nesting. This pattern is consistent with other research in the southeastern United States, which demonstrates 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., 2016a). 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

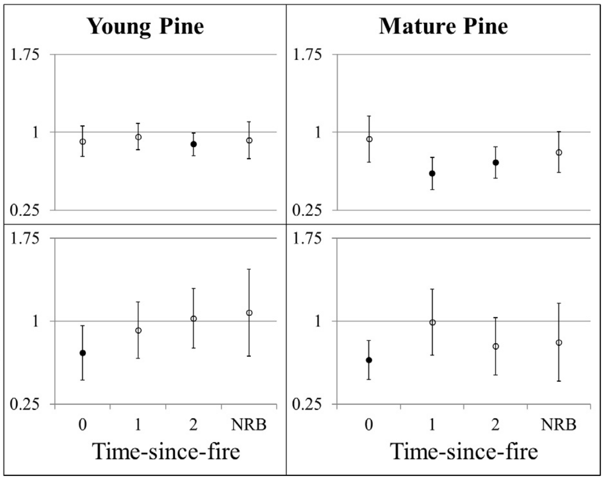

Fig. 5. Selection ratios of young pine (4–19 years old) and mature pine (≥20 years old) communities during 2 phases of incubation for reproductively active female eastern wild turkeys (*Meleagris gallopavo silvestris*) on Silver Lake Wildlife Management Area, southwestern Georgia, USA, during 2015 and 2016. Estimates > 1 indicate avoidance and estimates < 1 indicate selection, with deviation from 1 indicative of effect size. Error bars show 95% confidence intervals. Black-filled estimate markers indicate statistically significant selection or avoidance as indicated by 95% confidence intervals.

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 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 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., 2017c). 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. After two growing seasons these stands would normally have standing cover composed of bunch grasses, shrubs, and seedlings. It seems likely that females are associating with these stands due to reduced canopy cover, which similar to open vegetation communities, results in increased understory vegetation preferred by turkeys (Little et al., 2016a).

Throughout the reproductive period, females selected 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 (~25 ha) 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 (Yeldell et al., 2017c).

5. Conclusions and management implications

Turkeys selected 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. In terms of seral stages during laying, incubation, and brooding phases selection was highest for open vegetation communities, a class that made up a small proportion of the landscape. The next most selected vegetation communities (based on mean selection ratio values) were mature pine stands followed by young pine stands. Therefore, we recommend that mature longleaf be retained using single-tree selection to maintain open, park-like conditions of these stands. Creation of early seral areas can be facilitated and emphasized in areas currently in planted pine or those with a history of agriculture. 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., 2017c). We suggest that this management scheme results in herbaceous understory communities preferred by turkeys during the reproductive period. Quality turkey habitat includes open vegetation communities across the landscape, and females on our study site selected these vegetation conditions throughout their reproductive period. Likewise, hardwood stands in longleaf pine systems provide important resources for turkeys outside of the reproductive season. 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. Our data cannot speak to the scale and composition of open and hardwood vegetation communities needed across the landscape. Future research should seek to delineate the landscape-scale diversity of vegetation communities necessary to affect turkey habitat quality.

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