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SPECIAL SECTION

Use of LiDAR to examine habitat selection by incubating female wild turkeys in South Carolina

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Abstract

Avian reproductive activities are energetically demanding, leading to periods of heightened risk and reduced energy acquisition. Behavioral decisions by females in response to their physiological requirements are particularly important during nesting, as the availability and distribution of resources around nest sites can affect fitness of incubating females. We evaluated how spatially explicit LiDAR-derived estimates of forest structure and topographical features influenced habitat selection by female eastern wild turkeys (*Meleagris gallopavo silvestris*) during the incubation period. We analyzed spatial data from 83 nesting attempts at the Savannah River Site in South Carolina, USA, during 2021–2022. Female wild turkeys selected for incubation recess locations in pine (*Pinus* spp.) forests with an average basal area of ~14 m^2/ha and density of 335 trees/ha. Selection probability was positively associated with south- and west-facing aspects. Our findings highlight the importance of mature pine forests with understories that enhance foraging opportunities as key factors influencing incubation behaviors in female eastern wild turkeys.

KEYWORDS

behavior, incubation, LiDAR, *Meleagris gallopavo silvestris*, recess movement, resource selection function, wild turkey

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Nest success is an important determinant of population trajectories and a key component underlying avian population dynamics (Martin 1995, Ghalambor and Martin 2002, Martin 2002). Reproductive activities are energetically costly, producing periods of high risk and reduced energy acquisition (Skutch 1962, Fontaine and Martin 2006, Deeming and Reynolds 2015). Specific to nest incubation, females may make behavioral decisions that prioritize their survival over producing young to ensure future reproductive opportunities (Cohen 1966, Simovich and Hathaway 1997, Danforth 1999). Thus, understanding how females make decisions during incubation in relation to individual and nest survival is necessary to inform conservation efforts.

Avian species need to balance their physiological requirements with the cost of reproductive activities (Winder et al. 2016). Ground-nesting individuals are constrained to their nest site, limiting their foraging opportunities, which can have important implications for reproductive success and fitness (Martin 1993a). Behavioral choices made by females in relation to their physiological requirements are particularly important during incubation, as distribution of resources around nest sites may have fitness consequences to incubating females (Jones 2001). During incubation, females make recess movements away from nest sites to forage and engage in self-maintenance activities (Conway and Martin 2000, Coates and Delehanty 2008). Recess movements away from nest sites to locations offering forage and security, then returning to the nest incur costs in the form of time, energy, and mortality risk (Fagerstrom et al. 1982, Clark and Shutler 1999). For example, distant recess movements require time away from the nest, making the nest vulnerable to predation, and may reflect a lack of resources in the vicinity of the nest site (Criscuolo et al. 2000). In response to spatial and temporal variation in resources, females should develop recess behaviors during incubation that maximize their fitness (Martin 1993b, Deeming 2002).

The eastern wild turkey (*Meleagris gallopavo silvestris*; hereafter wild turkey) is a ground nesting uniparental galliform widely distributed across the United States and southern Canada. Wild turkey populations have been declining for several decades throughout broad areas of the species range (Byrne et al. 2015, Chamberlain et al. 2022). Declines are at least partially attributable to reduced reproductive success and productivity (Roberts et al. 1995, Vangilder and Kurzejeski 1995, Pollentier et al. 2014). Specifically, nest success is a driver of population trajectories, necessitating research to understand factors that influence female behaviors during nesting. In particular, landscape characteristics such as elevation, aspect, and slope can influence predation risk and subsequently nest success, as specific terrain may offer increased concealment from predators (Long et al. 2009, Fogarty et al. 2018). Furthermore, as wild turkeys are constrained to the nest site for >25 days, recess movement behaviors are an influential driver of nest survival (Healy 1992, Conley et al. 2015, Bakner et al. 2019, Lohr et al. 2020). Recess movements are likely made based upon factors such as body condition, vegetation conditions, and resource availability within the incubation range (Conway and Martin 2000, Smith et al. 2012, Deeming and Reynolds 2015).

Previous research has described nest-site selection and evaluated effects of vegetation characteristics at the nest site on nest success, but understory vegetation characteristics at the nest site do not always relate with greater nest survival (Crawford et al. 2021, Keever et al. 2023). Moreover, contemporary research suggests that incubation behaviors may have more influence on nest survival than vegetation (Bakner et al. 2019, Lohr et al. 2020). Recess movements can positively influence female survival, whereas reduced movements may be associated with greater predation risk for incubating females (Bakner et al. 2019, Lohr et al. 2020). Likewise, distribution and composition of vegetation communities around the nest site may affect distance and duration of incubation recess movements, indicating either a limitation in resources or potential movement restrictions that may have a greater effect on nest success (Rauter and Reyer 1997, Borgo and Conover 2016, White et al. 2020).

Herbaceous understory vegetation provides important foraging opportunities for wild turkeys during spring and summer, while also providing concealment from predators (Bowman and Harris 1980, Lehman et al. 2008). Quantifying understory vegetation at spatial scales broader than the area around the nest is difficult. Furthermore, classifications of broad landcover classes may not capture the full range of forest conditions that can indicate the presence of understory vegetation across a study site, complicating the ability to understand how these conditions influence recess movements. Instead, measures of specific forest conditions, such as basal area and tree density can provide a more accurate measurement of forest structural attributes as the spatial arrangement of trees influences

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understory vegetation (Newmaster et al. 2006). Therefore, our objectives were to describe how forest structural conditions and topographical features influenced resource selection by female wild turkeys during the incubation period. We hypothesized incubating females would select recess locations within their incubation range that increased their access to early successional vegetation communities, which would contain important foraging resources. Specifically, we predicted incubating females would select for areas with lower basal area and density of hardwood and pine trees, which promotes a more open understory dominated by herbaceous vegetation. We also predicted that incubating females would select for areas with higher elevation and steeper slopes, as these features would enhance olfactory concealment, reducing predation cues.

STUDY AREA

We conducted research during 2021–2022 on the Savannah River Site (SRS), a 78,000-ha tract owned and operated by the U.S. Department of Energy. The SRS was located on the Upper Coastal Plain and Sandhills physiographic provinces in Aiken and Barnwell counties in South Carolina, USA. Approximately 94% of SRS were forests consisting of loblolly pine (*Pinus taeda*), longleaf pine (*P. palustris*), and bottomland hardwood forests. Half of pine-dominated stands were comprised of trees 30–50 years old, whereas 76% of hardwood stands were >50 years old (White and Gaines 2000). Within pine forests across SRS, basal area ranged from 0–35 m^2/ha and density ranged from 0–2,887 trees/ha. The remaining forested areas included forested swamps, riparian areas, and mixed hardwood stands (Imm and McLeod 2005). There were 7 soil associations represented within SRS and the soil site index ranged from 60–107 (Rogers 1990). Sandy soils occupied uplands and ridges and were less fertile than the loamy clayey soils of the stream terrace and floodplains (White and Gaines 2000). Elevation across SRS ranged from 115 m on the Aiken plateau, 50–80 m on the Brandywine Terrance, 30–50 m on the Sunderland Terrace, and ≤30 m on the Wicomico Terrace. Slope values ranged from 0–23°. Prior to 1951, most of SRS was maintained in agricultural fields or recently harvested timber (White 2005). The U.S. Department of Agriculture Forest Service has increased forest cultivation since 1952, resulting in increased wildlife populations (Imm and McLeod 2005, White 2005). Approximately 30% of SRS was managed for red cockaded woodpeckers (*Picoides borealis*) with prescribed fire applied on a 3–5-year return interval. Common predators of turkeys and turkey nests at SRS included coyote (*Canis latrans*), bobcat (*Lynx rufus*), rat snake (*Pantherophis obsoletus*), gray fox (*Urocyon cinereoargenteus*), Virginia opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*) and great horned owl (*Bubo virginianus*).

METHODS

Capture and handling

We captured female wild turkeys using rocket nets baited with cracked corn during December–March 2021 and January–March 2022. We aged each individual using the presence of barring on the 9th and 10th primaries (Pelham and Dickson 1992) and banded each female with a uniquely-identifiable, aluminum rivet tarsal band (National Band and Tag Company, Newport, KY, USA). In 2021, we fitted all females with a backpack-style GPS/VHF transmitter (Biotrack Limited, Wareham, Dorset, UK; Guthrie et al. 2011). We programmed GPS units to record hourly GPS locations from 0500 to 2000 with one GPS location nightly (2359:58; Cohen et al. 2018). In 2022, we fitted all females with a GPS/ACC/UHF transmitter (E-obs GmbH; Munich, Germany). We programmed GPS units to collect hourly GPS locations from 0400–2000 daily. All units collected data from the day of capture until the battery died or unit was recovered. We immediately released individuals at the capture location following processing.

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Nest monitoring

We monitored live-dead status and general movements of female wild turkeys ≥2 times per week during the reproduction season using a 3-element handheld Yagi antenna and receiver. We remotely downloaded GPS locations once per week via very-high-frequency/ultra-high-frequency (VHF/UHF) handheld command unit receivers. We spatially projected GPS locations in ArcGIS 10.8 (Environmental Systems Research Institute, Redlands, CA, USA) to identify nest locations by determining when locations for a female became concentrated around a single area for several days (Guthrie et al. 2011, Conley et al. 2015, Yeldell et al. 2017, Wood et al. 2019). Nesting females were not disturbed or flushed from nest sites during monitoring but live-dead status was checked daily via VHF/UHF from a distance >20 m. Wild turkey nests require about 27 days of continuous incubation before hatching, but incubation can vary from 25 to 29 days (Williams et al. 1971, Healy and Nenno 1985). When GPS locations or sensors indicated nest termination, we located nest sites using GPS locations to confirm the estimated nest location and determine nest fate.

GPS-data processing

We performed data processing and analysis in Program R (V.4.1.0; R Core Team 2023). We processed and cleaned raw GPS data by removing fix locations that had a dilution of precision values > 7. To determine dates of nest initiation (i.e., initiation of laying), incubation initiation, and termination of incubation, we projected our spatial-temporal data in ArcGIS 10.8 to visualize when points became concentrated at a specific location. We identified the onset of incubation as the first time an individual remained on the nest overnight (Bakner et al. 2019, Lohr et al. 2020). We censored the first and last day of incubation to reduce spatial prediction bias caused by individuals that commenced incubation halfway through the day (Conley et al. 2015, Bakner et al. 2019). Once the date of incubation initiation was determined, we evaluated locations for the previous 20 days and determined when a female initially visited the nest site (Schofield 2019, Bakner et al. 2024). The date of the first visit was recorded as the date of nest initiation and used as the beginning of the laying period (Conley et al. 2016, Collier et al. 2019). When creating our used and available points, we removed all locations within 27.5 m of our nest site, as this encompassed our GPS error (Bakner et al. 2019).

Environmental covariates

Light detection and ranging (LiDAR) has been used to quantify structural properties of forest ecosystems and can capture more detailed and ecologically meaningful forest structural attributes that can be mapped at fine-scale and broad extents (He et al. 2015, Garabedian et al. 2017). Metrics computed from the LiDAR sensor data such as basal area (cross-sectional area of all stems), stand height, biomass, and stem density are often used as explanatory variables in predictive models to estimate forest attributes (Means et al. 2000, Wulder et al. 2012). Previous studies have used these attributes to evaluate species-habitat relationships, providing insights into how forest structure influences habitat use (Garabedian et al. 2014, 2017). Therefore, we obtained 30-m high-resolution LiDAR derived estimates of density (stems/ha) of all pines, and basal area (m^2/ha) of all pines and hardwoods to evaluate the potential influence of these forest attributes on locations of recess movements. Aggregation of fine-grained landscape data can prevent a mismatch between the grain size of landscape data and species GPS locations (Garabedian et al. 2014). As the GPS error of our units resulted in a 27.5-m buffer, we aggregated our LiDAR from 30 m to 60 m to ensure accuracy and precision of our data. We used high-density (average of 10 returns/m^2) airborne LiDAR data acquired using 2 Leica ALS50-II laser scanners mounted in separate fixed-wing aircraft across SRS in March 2018 prior to spring green-up (Woolpert 2009). We recognize that our field research was initiated

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3 years after LiDAR data were collected; however, previous studies have used the same approach, providing us with confidence that our LiDAR data accurately represented forest metrics at the time of our data collection (Garabedian et al. 2014, 2017). We processed and summarized LiDAR sensor data using the FUSION program for subsequent analysis (McGaughey 2009). The canopy threshold height was 1.5 m when computing total canopy cover. Quality assurance analysis details and point-reduction methods were provided by Reutebuch and McGaughey (2012).

To evaluate potential influences of topographical features (slope, aspect, elevation) on locations of recess movements, we used digital elevation models (DEM) from the United States Geological Survey National Elevation Dataset (http://lta.cr.us.gs.gov/NED). We aggregated slope, aspect, and elevation from 30–60 m to match the scale of our LiDAR data. Then, we converted aspect from a continuous variable to a categorical variable by binning degrees <45 and ≥315 as north, ≥45 and <135 as east, ≥135 and <225 as south, and ≥225 and <315 as west.

Resource selection

To test our hypothesis that incubating females would select recess locations within their incubation range that increased access to early successional vegetative communities, we first estimated 99% laying and incubation ranges for each unique nest. Specifically, we fitted dynamic Brownian bridge movement models (dBBMMs) to the GPS locations of each nesting female during these periods in Program R using package move (Kranstauber et al. 2012, V.4.1.0; R Core Team 2023). We used an error estimate of 20 m, a moving window size of 7 locations, and a margin setting of 3 locations (Byrne et al. 2014, Cohen et al. 2018). We used resource selection functions to examine relationships among topographical features (aspect, elevation, slope) and forest structure metrics to turkey use during laying and incubation (Manly et al. 2002). Forest structure metrics included basal area (m^2/ha) of all overstory, dominant and codominant hardwood tree species, basal area of pine (m^2/ha) of all overstory, dominant and codominant pine tree species, and density (tree/ac) of total plot of live pine tree species. We considered 2 scales of selection: second-order selection (landscape-level) and third-order selection (within laying-period range; Johnson 1980). We examined 2nd-order selection by comparing used points (recess movements) within female incubation ranges to a stratified sampling of available points, generated by selecting one random location per every 60-m pixel, within SRS (Benson 2013). Additionally, we examined 3rd-order selection by comparing used points (recess movements) within female laying ranges to a stratified sampling of available points, with one random location per every 60-m pixel, as female wild turkeys prospect for incubation recess locations during the laying period (Bakner et al. 2024).

Prior to modelling, we rescaled all variables by subtracting their mean and dividing by standard deviations (Gelman 2008). We tested for collinearity between each of our covariates and excluded covariates using Pearson's correlation with a $r > 0.70$ (Dormann et al. 2013). We fit a single global (i.e., including all covariates) generalized linear mixed model with a binomial response distribution (logistic regression) and logit link to the used-available data (Manly et al. 2002, Johnson et al. 2006). To account for individual-level heterogeneity in selection, we included a random effect for individual wild turkey in our 3rd-order selection model. We did not use a random effect for our 2nd-order model as we wanted to understand population-level resource selection. We used the lme4 package in Program R with a binary (0 = available, 1 = used) response variable to model resource selection (Bates et al. 2014). We did not use model selection techniques to rank candidate models because all covariates were of interest. Basal area of overstory pine was interacted with density of pine, and we used a quadratic function for basal area of pine and basal area of hardwood, as we suspected the relationship might not be linear. To assess how well our resource selection function models explained the data, we used area under the receiver-operating characteristic curves (AUC) calculated with the pROC package in Program R (Zipkin et al. 2012). An AUC value of 0.5 indicated the model provided estimates no better than random predictions, but values > 0.7 indicated a better model fit with more accurate predictions.

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RESULTS

We monitored 83 nesting attempts by female wild turkeys (55 adults, 5 juveniles) during 2021 and 2022. We censored 4 nesting attempts due to lack of GPS data and 18 nesting attempts that were incubated <4 days due to lack of spatial data needed to accurately estimate utilization distributions. Hence, we used 61 nesting attempts (initial attempts = 44, renesting attempts = 17) by 49 females. Mean area of incubation and laying ranges was 14.24 ha (SD = 12.04, min–max = 1.5–58.06 ha) and 338.04 ha (SD = 148.47, min–max = 72.48–794.24 ha), respectively. We used 3,401 recess locations. The average distance traveled during a recess movement was 86.13 m (SD = 95.65, min–max = 27.5–1,274.07 m). We found that 25 nest attempts (41%) were successful (2021 = 8, 2022 = 17).

In our 2nd-order model, parameter estimates for all covariates differed from zero except for north aspect and density of pine (Table 1). Selection probability was positively associated with south- and west-facing aspects. The expected value of selection for west-facing aspects was 0.51 times greater compared to selection of east-facing aspects. As slope and elevation increased, the probability of selection by incubating females increased (Figure 1). We found that incubating females selected for a mean slope of 2.38° (SD = 1.33, min–max = 0.11–7.36°) and elevation of 81.68 m (SD = 14.66, min–max = 25.95–113.65 m). The probability of selection by female wild turkeys increased until a basal area of overstory hardwoods reached 11.36 m^2/ha, after which the probability of selection decreased. Likewise, the probability of selection increased until the basal area of overstory pines reached 20.07 m^2/ha, then probability of selection decreased. We found a significant interaction between basal area of overstory pine and density of pine (Table 1). Specifically, we found that at a lower density of pine, an increase in basal area of overstory pine had a positive effect on the predicted probability of selection, whereas at a greater density of overstory pine, the effect of basal area on predicted probability of selection was minimal (Figure 2). The AUC estimate was 0.73, indicating suitable accuracy for our 2nd-order model.

TABLE 1 Parameter estimates predicting resource selection from 2^{nd}-order selection of female eastern wild turkeys on the Savannah River Site, South Carolina, USA, during 2021–2022. Parameters consist of aspect, elevation, slope, basal area of overstory hardwood trees (m^2/ha), basal area of overstory pine trees (m^2/ha), and density of all live pine trees (tree/ac).

Parameters	β estimate	SE	*z*	*P*-value
Intercept	−4.62	0.05	−94.93	<0.01
Aspect North	0.03	0.07	0.47	0.64
Aspect South	0.43	0.05	8.84	<0.01
Aspect West	0.51	0.05	10.29	<0.01
Elevation	0.54	0.02	21.70	<0.01
Slope	0.30	0.02	17.75	<0.01
Basal area hardwood	−0.18	0.04	−4.25	<0.01
Basal area hardwood^2	−0.09	0.04	−2.55	0.01
Basal area pine	0.51	0.03	16.19	<0.01
Basal area pine^2	−0.17	0.02	−6.97	<0.01
Density pine	0.06	0.03	1.85	0.06
Basal area pine:Density pine	−0.15	0.03	−5.22	<0.01

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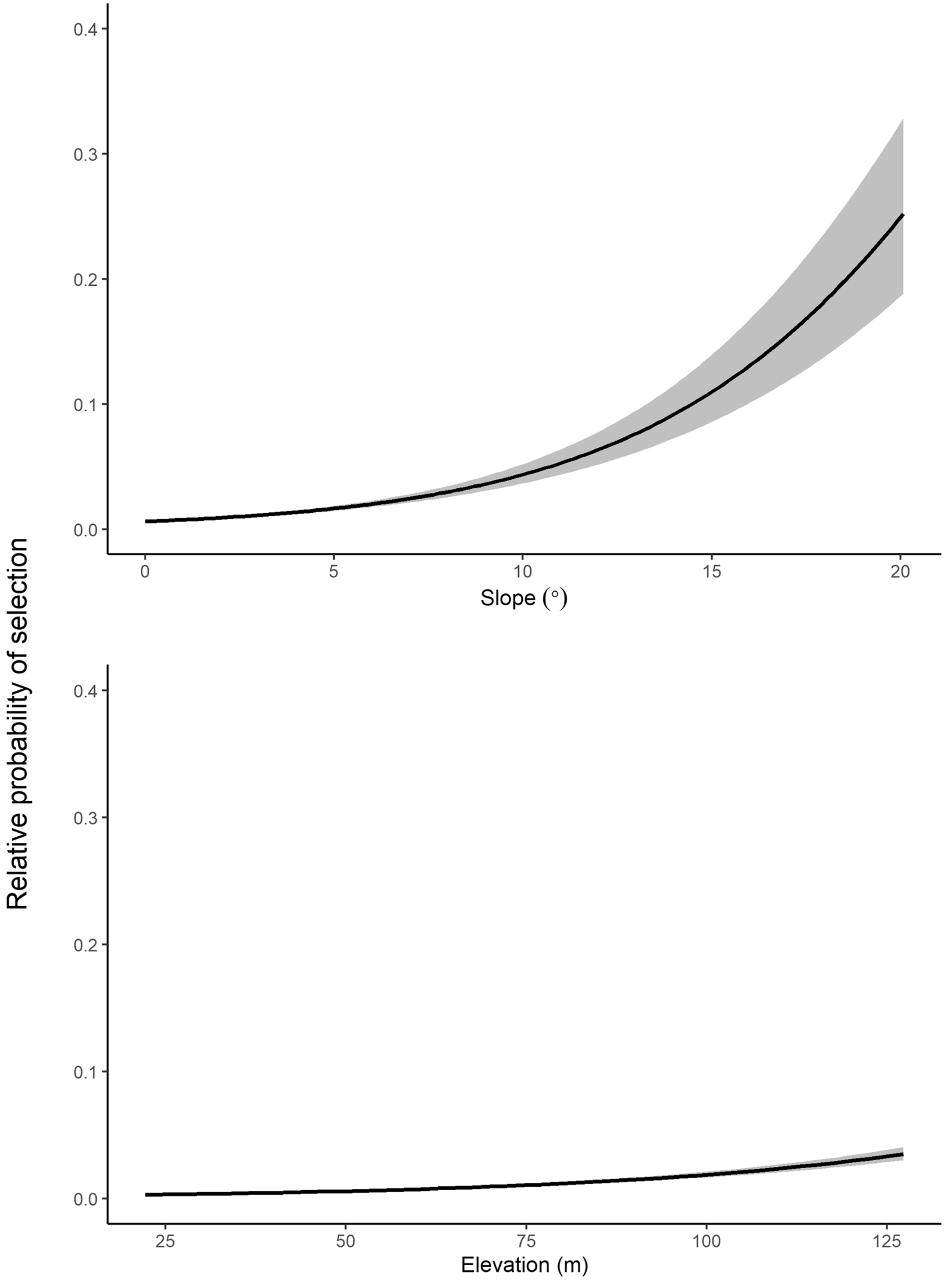

FIGURE 1 Predicted relative probability of habitat selection relative to slope and elevation (solid line) with 95% confidence intervals (gray ribbon) from the 2nd-order global model for incubating female eastern wild turkeys on the Savannah River Site, South Carolina, USA, during 2021–2022.

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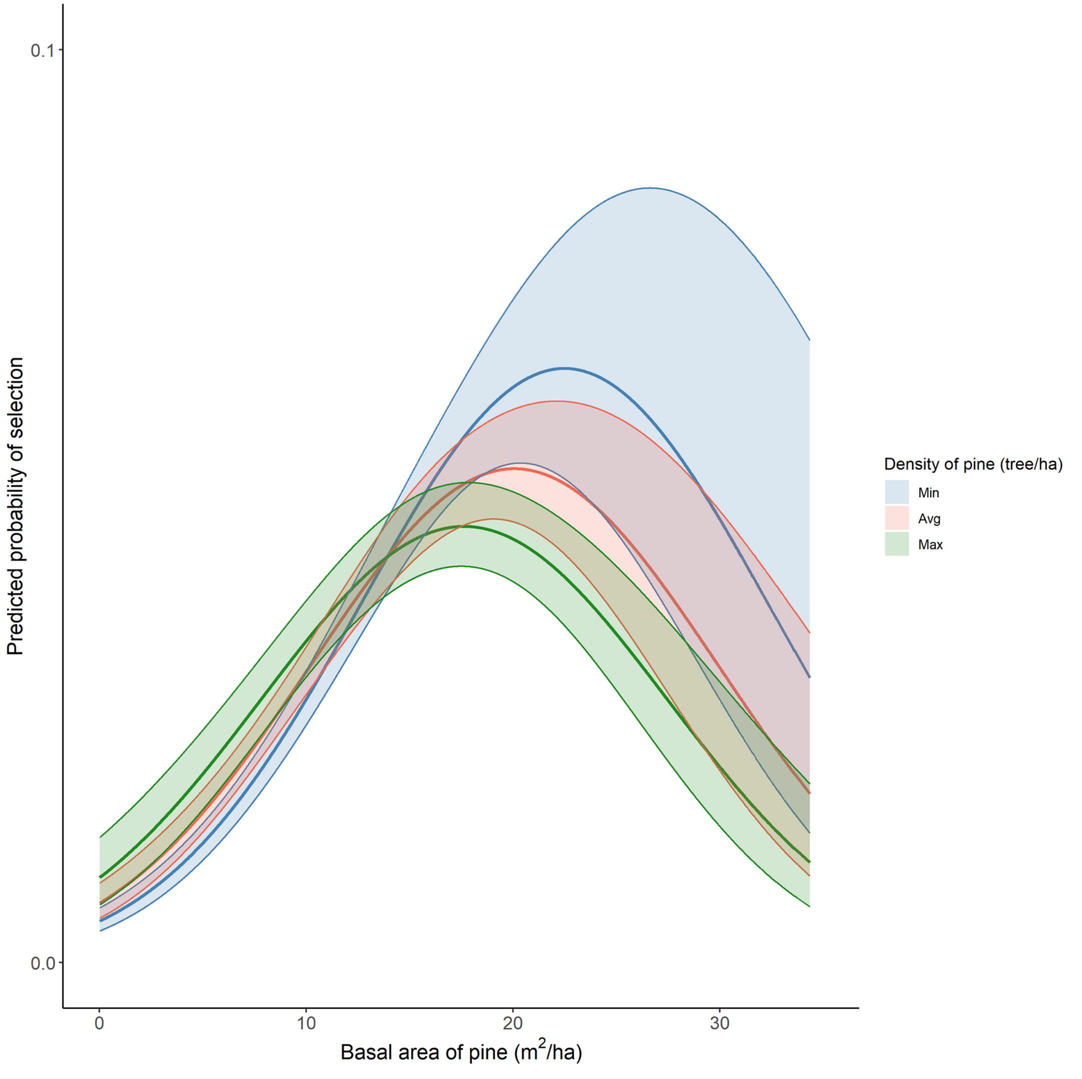

FIGURE 2 Interaction plot of the effect of basal area of overstory pine and pine density on the predicted probability of selection with 95% confidence intervals (shaded ribbon) from 2nd-order model by female eastern wild turkeys on the Savannah River Site, South Carolina, USA, during 2021–2022. The minimum, average, and maximum densities of pine were 19.15, 278.85, and 538.58 tree/ha, respectively.

In our 3rd-order model, parameter estimates for all covariates statistically differed from zero (Table 2). Selection probability was positively associated with south- and west-facing aspects and negatively associated with north-facing aspect. We found that as slope increased by 1 unit (°), the probability of selection increased by 20%, and as elevation increased by 1 unit (m), the probability of selection decreased by 26% (Table 2). The probability of selection by female wild turkeys increased until the basal area of overstory pine reached 18.74 m^2/ha, after which the probability of selection decreased. Conversely, the probability of selection by female wild turkeys decreased until the basal area of overstory hardwoods reached 13.75 m^2/ha, after which the probability of selection increased. The interaction between basal area of overstory pine and density of pine was significant, with an increase in overstory basal area of pine at a lower density of pine having a positive effect on the predicted probability of selection (Figure 3). The AUC estimate was 0.76, indicating suitable accuracy of our 3rd-order model.

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TABLE 2 Parameter estimates predicting resource selection from 3rd-order selection of female eastern wild turkeys on the Savannah River Site, South Carolina, USA, during 2021–2022. Parameters consist of aspect, elevation, slope, basal area of overstory hardwood trees (m^2/ha), basal area of overstory pine trees (m^2/ha), and density of all live pine trees (tree/ha).

Parameters	β estimate	SE	*z*	*P*-value
Intercept	−4.82	0.24	−20.34	<0.01
Aspect North	−0.23	0.07	−3.15	<0.01
Aspect South	0.42	0.05	8.24	<0.01
Aspect West	0.28	0.05	5.24	<0.01
Elevation	−0.30	0.04	−6.83	<0.01
Slope	0.19	0.02	10.12	<0.01
Basal area hardwood	−0.43	0.04	−10.20	<0.01
Basal area hardwood^2	0.09	0.02	4.46	<0.01
Basal area pine	0.48	0.03	15.27	<0.01
Basal area pine^2	−0.23	0.03	−8.18	<0.01
Density of pine	−0.24	0.04	−3.59	<0.01
Basal area pine:Density pine	−0.19	0.04	−5.37	<0.01

DISCUSSION

Incubation is energetically expensive, requiring female wild turkeys to periodically leave the nest to acquire resources. Resource acquisition influences female fitness, and during incubation the landscape surrounding the nest dictates resource availability to incubating females (Dudko et al. 2018). However, quantifying the area beyond 30 m of the nest site is difficult and often impractical. We used LiDAR to quantify forest metrics at a spatial scale commensurate with wild turkey reproductive ecology (laying and incubation ranges) and found that as basal area of pines increased, females selected to be closer to areas with a lower density of pine trees. Additionally, we found that females traveled an average of 86 m away from nests during recesses and locations selected for recesses were in areas with an increased slope and in the south and west direction.

An optimal nest location should provide access to areas for incubation recesses that offer productive foraging opportunities and enhanced protection from predators (Watters et al. 2002, Amar et al. 2004). We found that female wild turkeys selected for areas with an average pine basal area of 13.99 m^2/ha and, within incubation ranges, avoided pine stands with basal areas greater than 18.74 m^2/ha. Pine stands with basal area ranging from 9.2 to 16.1 m^2/ha provided optimal herbaceous cover within mature open pine systems (Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative 2017). Pine forests with a more open canopy allow increased exposure of sunlight to the forest floor, which promotes herbaceous vegetation and provides important foraging patches for wild turkeys (McGuire et al. 2001, Wood et al. 2019). Additionally, our observed interaction between basal area and pine density provides further support that females are selecting for mature pine stands with low tree density and an open herbaceous understory. However, selection of mature pine forests in our study area may also reflect the widespread availability of these stands across the landscape (Garabedian et al. 2014). Within pine forests across SRS, the average basal area was 50.1 m^2/ha and average density was 111.9 tree/ha, suggesting that our results may be partially driven by the fact that these pine stands were ubiquitous in distribution. Therefore, rather than demonstrating strong selection for specific forest attributes, our findings could simply indicate that females may have selected pine forests with basal area and tree densities relative to availability within their ranges.

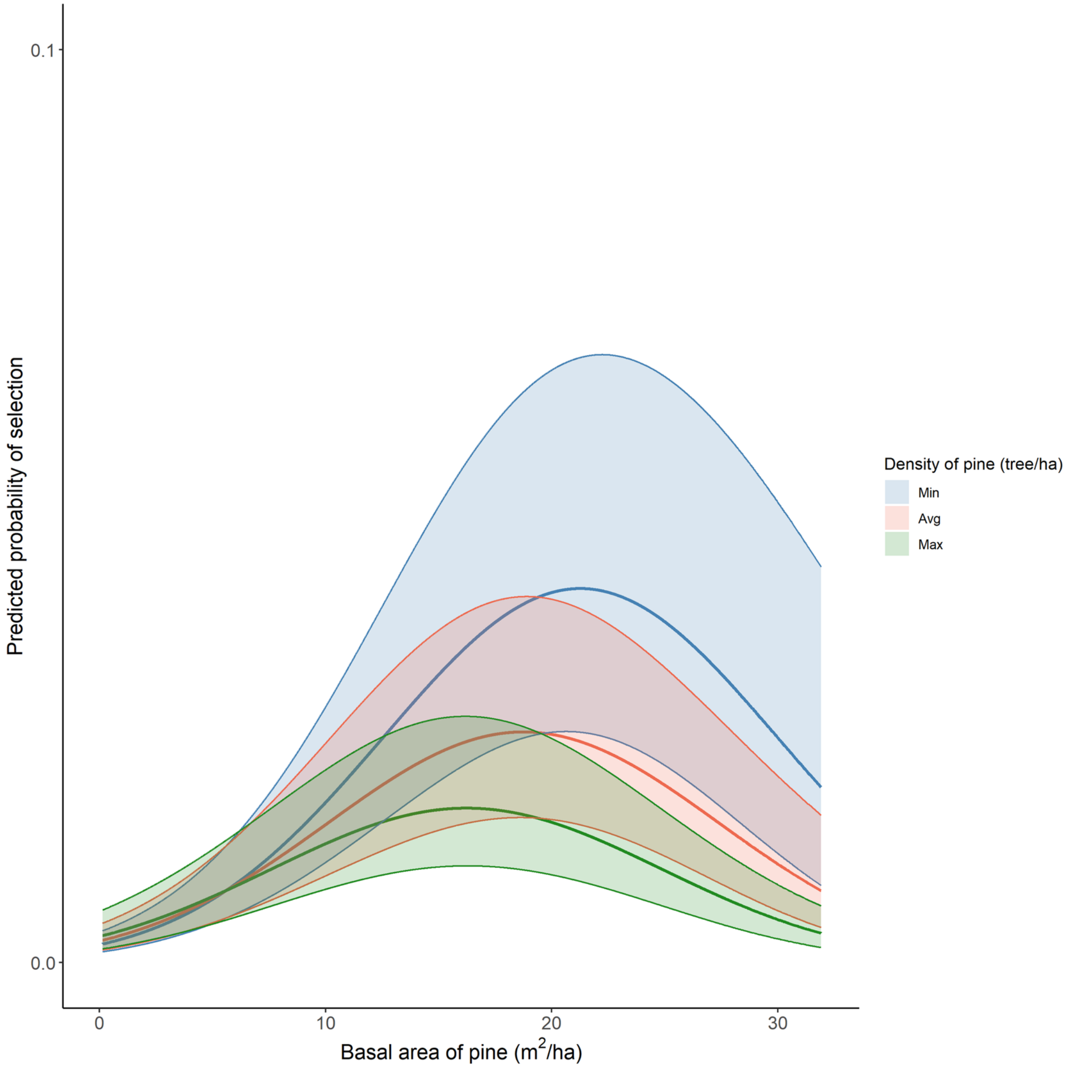

FIGURE 3 Interaction plot of the effect of basal area of all overstory dominant and codominant pine trees and density of live pine trees on the predicted probability of selection with 95% confidence intervals (shaded ribbon) from the 3rd-order model by female eastern wild turkeys on the Savannah River Site, South Carolina, USA, during 2021–2022. The minimum, average, and maximum densities of pine were 31.89, 366.26, and 777.19 tree/ha respectively.

Vegetation communities in the southeastern United States are strongly associated with elevation and soil moisture (Drews et al. 2002). Higher elevations within our study site were associated with well-drained soils suited to supporting the growth of mature pine forests (Rogers 1990, White and Gaines 2000). We found that at the 2nd-order scale of selection, female wild turkeys were more likely to select areas at higher elevations, which is consistent with our findings that female wild turkeys select mature pine forests, which are more likely to occur at higher elevations. However, within incubation ranges, we found strength of selection decreased as elevation increased. We interpret this shift from selection to avoidance to indicate that incubation ranges are generally located in areas of higher elevation compared to the broader landscape, but that within the incubation ranges, females are constrained by the availability of elevation.

Orientation of nest sites can alleviate or intensify thermal extremes through exposure to solar radiation and wind effects (Burton 2006, Long et al. 2009). We noted an overall positive relationship between locations chosen for recess

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movements and south- and west-facing slopes, but a negative relationship with north- and east-facing slopes. Previous studies suggested that protection of nest sites from strong winds was the main factor in nest-site selection of great bustards (*Otis tarda*; Magaña et al. 2009) and lesser rhea (*Rhea pennata*; Barri et al. 2009). Across the southeastern United States, prevailing winds are generally westerlies, with winds moving in a west to east direction (Martin and Konrad 2006). However, during spring to early summer, winds often come from the southeast, influenced by coastal fronts, and from the southwest, driven by storm systems originating in the Gulf of Mexico (Raichle and Carson 2009). Furthermore, wind speed and direction are known to affect foraging behavior of olfactory predators and potentially influence habitat selection by their prey (Ruzicka and Conover 2011). When selecting loafing locations, sharp-tailed grouse (*Tympanuchus phasianellus*) selected grasslands with rising airflows and relatively large variability in airflow direction and speed that concealed them from olfactory predators (Conover and Borgo 2009). Greater sage-grouse (*Centrocercus urophasianus*) did not locate nests in areas where conditions would cause odor to disperse rapidly (Conover et al. 2010). Our findings suggested that most female wild turkeys selected south- and west-facing slopes for their recess movements, which may serve as an anti-predation strategy. By positioning themselves upwind, it's plausible that female wild turkeys could conceal their scent from olfactory predators.

To evaluate potential influences of vegetation characteristics at nest sites on various metrics of reproductive success (e.g., nest success), researchers often measure understory vegetation within some pre-defined distance of the nest. However, these measurements overlook important factors such as wind direction, precipitation, and thermal conditions, which can influence incubation behaviors and nest success (Carroll et al. 2015, Tanner et al. 2017, Gehrt et al. 2023). Additionally, contemporary research suggests that nest-site selection by female wild turkeys occurs at spatial scales larger than the immediate area of the nest, as female recess movements extend well beyond areas where vegetation at nest sites is typically quantified (Bakner et al. 2019, 2024; Lohr et al. 2020). Furthermore, contemporary research typically used land cover data layers, which characterize the land cover but do not provide insights into forest structure, beyond identifying the type of land cover present. Therefore, we offer that by analyzing spatially explicit LiDAR-derived estimates of forest structure and topography and relating those estimates to female recess movements, we have provided a more ecologically-relevant spatial scale at which to evaluate vegetation structure surrounding nests. Our findings underscore the importance of pine stands with an average basal area of 14 m^2/ha to nesting female wild turkeys, consistent with previous studies in landscapes similar to SRS (Wood et al. 2018). We recommend that management efforts focus on ensuring the availability of pine stands averaging 14 m^2/ha basal area across managed pine landscapes. Future research should continue to use LiDAR to explore how habitat structure influences wild turkey movements and habitat selection and incorporate prescribed fire effects and climatic conditions.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ETHICS STATEMENT

Our study adhered to relevant regulations and guidelines regarding the ethics of animal welfare. Capture, handling, and marking procedures were approved by the Institutional Animal Care and Use Committee at the University of Georgia (Protocol A2020 06-018-Y1-A0).

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DATA AVAILABILITY STATEMENT

Data are available on reasonable request from the authors.

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