Travel Distance and Habitat Selection by Female Wild Turkeys on the First Day of Egg Laying

Chad M. Argabright, *School of Renewable Natural Resources, Louisiana State University, Baton Rouge, LA 70803*

Cody Cedotal, *Louisiana Department of Wildlife and Fisheries, 2000 Quail Dr., Baton Rouge, LA 70808*

Michael J. Chamberlain, *Warnell School of Forestry and Natural Resources, 180 E. Green St., Athens, GA 30602*

Bret A. Collier[1], *School of Renewable Natural Resources, Louisiana State University, Baton Rouge, LA 70803*

Abstract: Nest site selection has a critical effect on nest success for eastern wild turkeys (*Meleagris gallopavo silvestris*), yet the underlying drivers of nest site selection are often misrepresented in the literature. Early works typically focused on evaluating behavioral ecology of female wild turkeys before nest initiation, under the assumption that female wild turkeys sought out nest sites well in advance of nest initiation. However, recent work has clearly found no evidence of nest site search behavior before the day of nest initiation, thus increasing the need to focus evaluations of resource selection on the day when nest site selection occurs (i.e., the first day of laying). Our objective was to determine if differential selection for landcover characteristics was occurring on the first day of an egg was laid (e.g., date of nest site selection). We determined movement paths from the roost to the nest on the first day of egg laying (i.e., laying path) using global positioning system data from 164 female wild turkeys in west-central Louisiana during 2014 to 2021. We compared the landcover characteristics used along laying paths to available landcover characteristics. We found that female wild turkeys showed no clear selection of any landcover characteristics along paths they traveled on the day of nest initiation. Our results suggest that nest site selection was not driven by landcover characteristics and that perhaps selection is driven by other, finer-scale environmental factors or alternatively, may have no clear pattern.

Key words: landcover characteristics, Louisiana, nest site selection, *Meleagris gallopavo silvestris*

Journal of the Southeastern Association of Fish and Wildlife Agencies 11:102–109

Understanding resource selection is critical to assessing avian behavior, as resource selection influences survival and fecundity (Holt 1984, Dunning et al. 1992, Martin 1995). During the reproductive period, resource selection is thought to underlie nest success in avian species (Pulliam et al. 1992, Martin 1995, Devers et al. 2007, Johnson 2007), as resource selection is related to nest site selection, which can affect demographics (Clark and Shutler 1999, Jones 2001, Fontaine and Martin 2006, Lima 2009). Along with energy considerations, nest site selection is also thought to be driven by predator avoidance (Dunning et al. 1992, Martin 1998, Conway and Martin 2000) and by abiotic factors (Martin 2001).

Eastern wild turkeys (*Meleagris gallopavo silvestris*, hereinafter, wild turkeys) are a ground-nesting Galliform distributed generally east of the Great Plains in the U.S. and in parts of southeastern Canada (Chamberlain et al. 2022). Wild turkey populations have declined during the last several decades in the southeastern U.S. and long-term declines have been noted in nearly all reproductive indices such as nest success and poults per hen (Byrne et al. 2015, Crawford et al. 2021, Chamberlain et al. 2022, Clawson et al. 2022). Thus, furthering our understanding of how resource selection may influence wild turkey reproduction is needed to inform management for ensuring sustainable wild turkey populations.

Reproduction drives population trajectories for wild turkeys, so previous research has often focused on resource selection during the breeding season. In the southeastern U.S., female wild turkeys will select for landscapes containing mature pine or open mixed hardwood-pine (*Pinus* spp.) forests during the breeding season (Miller et al. 1999, Chamberlain and Leopold 2000, Thogmartin 2001, Miller and Conner 2007). Research has also shown nest site selection for areas near roads (Wood et al. 2018), areas that have been burned within the previous three years (Yeldell et al. 2017), and an avoidance of flooded or low-lying areas (Byrne and Chamberlain 2013). At the nest site, visual obstruction, percent ground cover, and vegetation density are thought to play a role in site selection and nest success (Fuller et al. 2013, Yeldell et al. 2017). However, there is considerable variation throughout the extant literature in the strength of selection and the effect of vegetation characteristics on nest success (Yeldell et al. 2017, Wood et al. 2019, Crawford et al. 2021).

Nest sites are rarely visited by hens before laying begins (Conley

1. E-mail: BCollier@agcenter.lsu.edu

et al. 2016, Collier et al. 2019), thus selection of nest sites prior to the breeding season as posited by Badyaev et al. (1996) is likely not occurring. Conversely, emerging evidence suggests that selection of nest sites could only occur on the day the first egg is laid. As such, Schofield (2019) evaluated microhabitat conditions visited by females on the day the first egg was laid, finding that vegetation characteristics associated with nest sites were readily available along paths used by females to access the nest site (Martin 1993) and that nest site vegetation had little effect on nest success.

To better understand potential mechanisms for nest site selection by wild turkeys, our objective was to evaluate selection of landcover characteristics by female wild turkeys along the path that females used on the day they initiated their first nest. We hypothesized that females would exhibit selection for particular landcover characteristics along paths as they approached the nest sites. We predicted that females would select areas with a greater proportion of roads and recently burned areas, greater proportions of upland pine and pine-hardwood, and a lesser proportion of wetland areas.

Study Area

We conducted our research on the Kisatchie National Forest (KNF), Peason Ridge Wildlife Management Area (PRWMA), and Fort Polk WMA (FPWMA) in west-central Louisiana (Figure 1). Our study area experienced a subtropical climate, with mean daily temperatures of 10 C in January and 28 C in July and mean annual rainfall of approximately 151 cm (NOAA 2023). The KNF was managed by the U.S. Forest Service (USFS) and was separated into five ranger districts (RD), from which our work was conducted on the Kisatchie RD (41,453 ha), Winn RD (67,408 ha), Catahoula RD (49,169 ha), and the Vernon Unit of the Calcasieu RD (33,994 ha) located in Natchitoches, Winn, Grant, and Vernon Parishes, respectively. The northern portion of the FPWMA and all of PRWMA were managed by the U.S. Army, and the southern portion was managed by the USFS as part of the Vernon RD. Each of our study areas had similar forest characteristics and land management and were considered one unit for this study. Our study area was composed of pine-dominated forests, hardwood riparian zones, and forested wetlands with forest openings, food plots, pipelines, and forest roads throughout. Overstory trees included loblolly pine (*Pinus taeda*), longleaf pine (*P. palustris*), shortleaf pine (*P. echinata*), slash pine (*P. elliottii*), sweetgum (*Liquidambar styraciflua*), oaks (*Quercus* spp.), hickories (*Carya* spp.), and red maple (*Acer rubrum*). Understory species included yaupon (*Ilex vomitoria*), American beautyberry (*Callicarpa americana*), blackberry (*Rubus* spp.), greenbrier (*Smilax* spp.), wild grape (*Vitis* spp.), broomsedge (*Andropogon virginicus*), woodoats (*Chasmanthium* spp.), and panic grasses (*Panicum* spp. and *Dichanthelium* spp.). Privately owned properties surrounding the public land was predominately even-aged loblolly pine stands primarily managed for wood fiber production, small homesites, pastures, hardwood-dominated wetlands, and agricultural fields. For additional details of the study area see Yeldell et al. (2017).

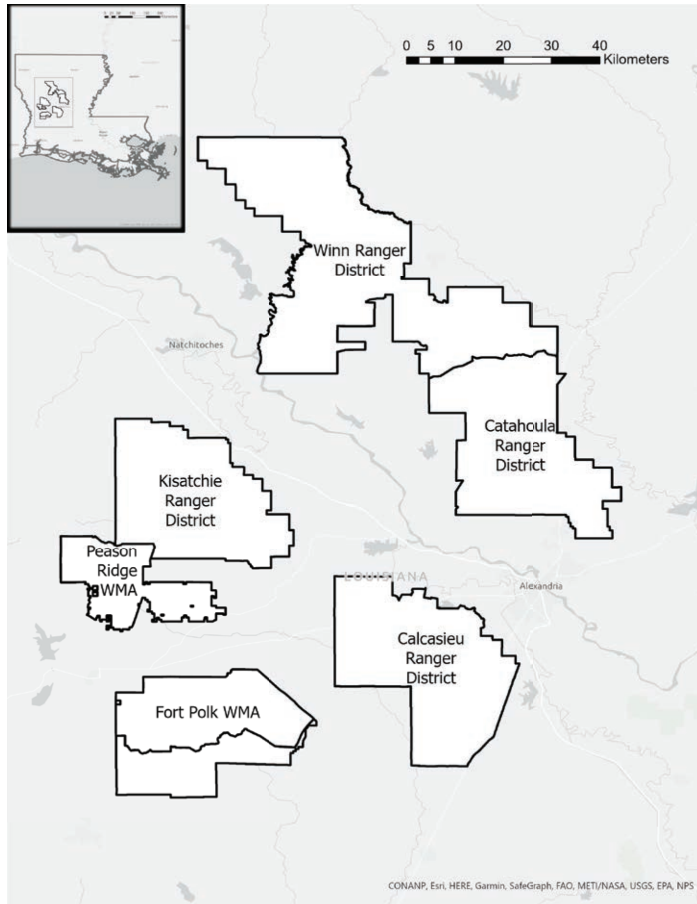

Figure 1. Study areas for evaluating resource selection by female eastern wild turkeys during the first day of egg laying, which included the Fort Polk Wildlife Management Area, four ranger districts of the Kisatchie National Forest (Calcasieu, Catahoula, Kisatchie, and Winn), and Peason Ridge Wildlife Management Area, Louisiana, 2014–2021.

Methods

We captured female wild turkeys using rocket nets from January–March, 2014–2021. We classified females as juveniles or adults based on barring on the 9th and 10th primaries (Pelham and Dickson 1992). We fitted each female with a riveted, uniquely numbered, tarsal aluminum band and a global positioning system (GPS) transmitter equipped with a very high frequency (VHF) emitter (88 g; Lotek Minitrack Backpack, Lotek PinPoint Backpack; Lotek Wireless, Newmarket, Ontario, Canada). We released all individuals at the capture site after processing. All wild turkey capture, handling, and marking procedures were approved by the

Institutional Animal Care and Use Committee at Louisiana State University AgCenter (protocols A2014-013 and A2015-07 and A2018-13).

We programmed GPS transmitters to collect a location hourly from 0500 to 2000 h daily with one roost location at 23:59:58. We used handheld Yagi antennas and a VHF/ultra-high frequency (UHF) PinPoint Commander unit (Lotek Wireless) to download GPS data ≥ 1 time per week throughout the study period. We determined date and time of nest initiation (i.e., beginning of egg laying) and nest incubation following methods from Conley et al. (2015), Bakner et al. (2019), and Lohr et al. (2020), where nest sites were confirmed via VHF telemetry and GPS data evaluation and used the date of the female's earliest GPS fix within a 50-m radius of that nest site as the date of nest initiation.

To create a behavioral trajectory, we drew lines between each GPS point starting at the roost location the night before the first egg was laid and ending at the nest site. Then, to encompass the area the female likely used between each GPS point, we created a 100-m buffer for each female's line using the rgeos package (Bivand et al. 2021) in R (R Core Team 2022), which we defined as the laying path. For each nest attempt, we then exactly replicated each laying path five times and rotated those replicates in random directions originating at the roost location from the night before laying began (Figure 2) to create a set of available but unused paths (hereinafter, random paths) which allowed for evaluation of resource selection relative to the actual laying path given what was available around the roost location (Thogmartin 1999, Fuller et al. 2013, Wood et al. 2019, Schofield 2019).

To create metrics for landcover characteristics, we used 30-m resolution National Land Cover Database (NLCD) imagery from the U.S. Geological Survey (USGS) (Homer et al. 2015). We used 2016 and 2019 NLCD imagery for GPS data on females during 2014–2016 and 2017–2021, respectively. We reclassified the NLCD landcover classes into eight landcover metrics (woody wetlands, herbaceous, shrub/scrub, mixed forest, evergreen forest, deciduous forest, road [developed open, developed low], and infrastructure [developed medium, developed high]) previously indicated to be influential during the reproductive period (Thogmartin 1999, Byrne and Chamberlain 2013, Kilburg et al. 2015, Crawford et al. 2021). For each landcover type, we assigned a value between 0 and 1 based on the proportion of that landcover type within each laying or random path.

We created a normalized difference vegetation index (NDVI) from Sentinel-2 satellite imagery data (10 m-resolution) from 2016 to 2021 (Pettorelli et al. 2005). To create NDVI data for 2014–2015, we used Landsat 7 satellite imagery data (15-m resolution) from USGS (Irons et al. 2012). We selected imagery with <10% cloud cover near the median laying date each year (30 April to 1 May). We separated the imagery into two bands and estimated NDVI in ArcMap 10.8 (ESRI, Redlands, California) as:

$$\text{NDVI} = (\text{Near-Infrared} - \text{Red}) \div (\text{Near-Infrared} + \text{Red})$$

for the entire study area (Ulrey et al. 2022). We estimated the average NDVI for each laying and random path, with the value being between −1 and 1, and used those values for modeling. To estimate forest cover, we used satellite imagery from the U.S. Department of Agriculture's National Agriculture Imagery Program (NAIP), which has a 1-m resolution per pixel. We then used Earth Resources Data Analysis System (ERDAS) Imagine 2020 software (Hexagon AB, Stockholm, Sweden) to recategorize each pixel into two general vegetation categories, forested or open, to calculate the proportion of forested cover (between 0 and 1) for each laying and random path. For each landcover metric, we estimated the proportion of each that fell within the laying path and used those proportions as explanatory covariates in our selection modeling.

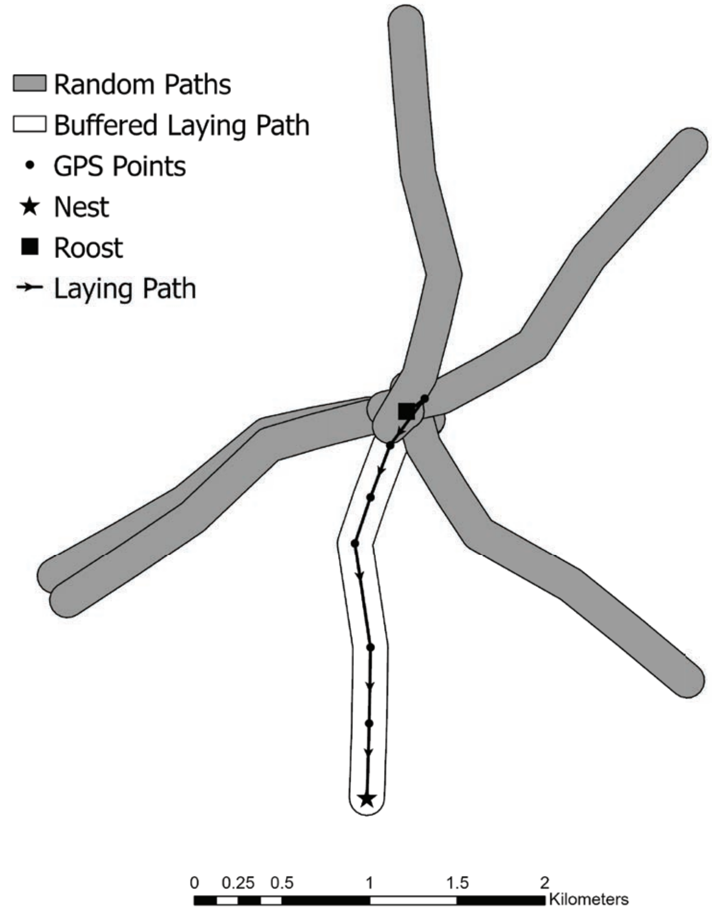

Figure 2. Used laying path (clear) and randomly rotated unused paths (gray) for a female eastern wild turkey monitored in west-central Louisiana during 2014–2021. The roost (square) and the nest (star) identify the start and ending locations of the laying path, respectively.

Additionally, we used spatial data provided by the USFS and U.S. Army to identify if each laying path had been subjected to any prescribed fires or timber harvest (i.e., thinning and clearcuts; 1 = yes, 0 = no; burn or logging, respectively) within the previous three years (Yeldell et al. 2017, Sullivan et al. 2020; Table 1).

We evaluated each landscape metrics' effect (Table 1) on selection by individual female along laying paths using logistic regression in R (R Core Team 2022). We used a Pearson correlation test to determine if potentially correlated covariates should be removed ($|r| \geq 0.6$) (Dormann et al. 2018). We developed a candidate model set based on the proportion of each landcover type, burned, logged, NDVI, and forest cover (along with relevant interactions between covariates; Table 1), with the models we used being based on what was seen as important in previous research (Thogmartin 1999, Byrne and Chamberlain 2013, Kilburg et al. 2015, Yeldell et al. 2017, Sullivan et al. 2020, Crawford et al. 2021). From these, we also created a global logistic regression model including all covariates. We compared laying paths (used) to five identical random paths (available). Five identical random paths are sufficient to estimate ecologically relevant availability for our wild turkey females, as being identically shaped to the original laying path accounts for individual female movement patterns, and five random paths in five random directions most often covered a wide range of possible directions while allowing for some overlap between our estimations of used and available laying paths (Wisz et al. 2008, Benson 2013, Street et al. 2021). For our analyses, we used the Akaike Information Criteria (AIC_c) value to determine model support relative to all models, including the null model (Burnham et al. 2011). Models with an evidence ratio ≤ 2 based on the AIC weight of the lowest AIC model best explained the variation in laying path versus random path (Burnham and Anderson 2002, Dick 2004).

Results

We captured 304 female wild turkeys from 2014 to 2021 (270 adults, 34 juveniles). Fifty-eight females died or had transmitter failure before nesting season began (51 adults, 7 juveniles) and 39 did not attempt to nest (24 adults and 15 juveniles), for an estimated nesting rate of 89% for adults ($n = 219$) and 44% for juveniles ($n = 27$; 84% overall). We observed 197 first nest attempts, but we censored 33 due to two or more missed GPS locations along the laying path, which left 164 unique laying paths. Nest initiation dates ranged from 14 March to 26 May ($\bar{x} = 13$ April, SE = 1 day). Mean total distance traveled along laying paths was 1690 m (SE = 85; range = 90–7676; Figure 3). The linear distance between roost sites the night before laying began and nest sites on the first day of laying was on average 956 m (SE = 65, range = 24–7085) and the median speed per time step (two consecutive GPS locations) was 198 m hour^{-1} (SE = 9, range = 4–1990).

We found no correlation between covariates ($|r| < 0.6$). We observed no evidence that the covariates we evaluated influenced selection to the point of biological relevance along laying paths (Table 2). Our results did indicate that laying paths were less likely to contain woody wetlands ($\beta = -1.214$; $CI = -2.427 - -0.188$; Figure 4) when compared to random paths.

Table 1. List of covariates and data sources used to define landcover characteristics contained within each laying and random path for female eastern wild turkeys in west-central Louisiana during 2014–2021. See text for more information about data sources. Each covariate's value is either a percentage based on its proportion within each laying or random path (%; continuous; all NAIP- or NLCD-source covariates), a number between -1 and 1 for each path (continuous; NDVI), or a binomial 0 or 1 based on its presence or absence for each path (categorical; Burn and Logging). Definitions for NLCD covariates are simplified from the USGS definitions.

Covariate	Source[a]	Definition
Forested	NAIP	Identification of trees by pixel color using Earth Resources Data Analysis System (ERDAS) Imagine 2020 software.
Open	NAIP	Identification of a lack of trees by pixel color using ERDAS Imagine 2020 software.
Woody wetlands	NLCD	Forest or shrubland vegetation are > 20% of cover with the soil or substrate being periodically saturated or covered with water.
Herbaceous	NLCD	Graminoid or herbaceous vegetation cover > 80% of the pixel.
Shrub/scrub	NLCD	Shrubs < 5 m tall cover > 20% of the pixel. Includes true shrubs and young/stunted trees.
Evergreen forest	NLCD	Trees > 5 m tall cover > 20% of the pixel. > 75% of tree species maintain leaves throughout the year, with the canopy never being without green foliage.
Deciduous forest	NLCD	Trees > 5 m tall cover > 20% of the pixel. > 75% of tree species shed foliage seasonally.
Mixed forest	NLCD	Trees > 5 m tall cover > 20% of the pixel. Neither deciduous nor evergreen species comprised > 75% of total tree cover.
Roads	NLCD	Combination of NLCD classes "Developed, Open Space" and "Low Intensity." Impervious surfaces accounted for 10–49% of total pixel.
Infrastructure	NLCD	Combination of NLCD classes "Developed, Medium Intensity" and "High Intensity." Impervious surfaces accounted for 50–100% of total pixel area.
NDVI	ESA/USGS	Quantification of vegetation by measuring the difference between near-infrared and red-light reflections.
Burn	USFS/Army	Areas burned within the previous 3 yr.
Logging	USFS	Areas thinned or clearcut within the previous 3 yr.

a. NAIP: National Agriculture Imagery Program; NLCD: National Land Cover Database; ESA: European Space Agency; USGS; USFS: U.S. Forest Service; Army: U.S. Army.

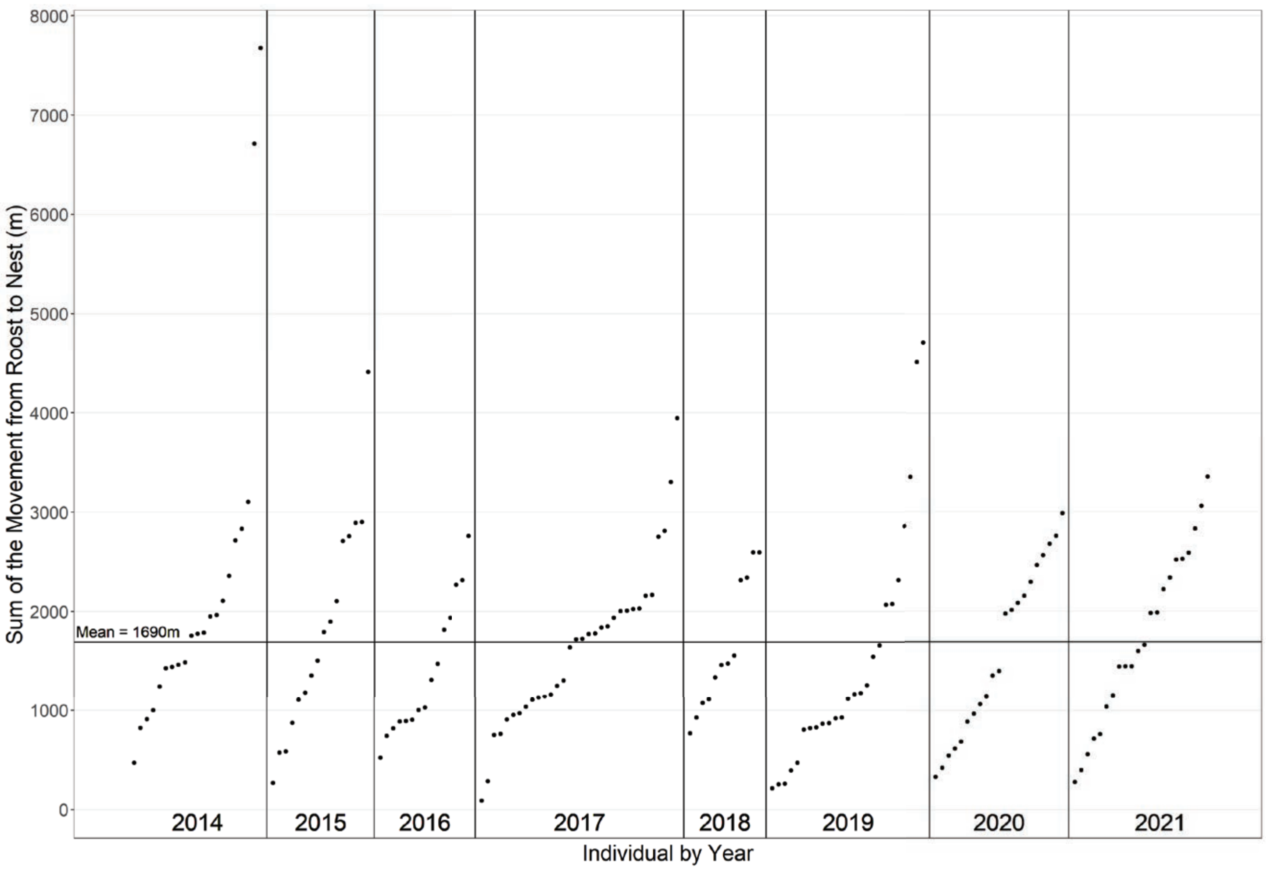

Figure 3. Total distance moved from the roost to the nest on the first day of laying for female eastern wild turkeys in west-central Louisiana during 2014–2021.

Table 2. Logistic regression model selection with matched-pairs case-control sampling, where the used laying path were cases and five random paths were controls, to show selection of landcover types along paths used prior to laying the first egg in the first nest of female eastern wild turkeys in west-central Louisiana during 2014–2021. Model selection was based on Akaike's Information Criterion for each potential model (AIC_c), number of parameters (*K*), ΔAIC_c, the Akaike weight of evidence (w_i), and the evidence ratio based on the lowest AIC_c model (ER). See Table 1 for covariate definitions and data sources.

Model	*K*	AIC_c	ΔAIC_c	w_i	ER
Woody wetlands	2	879.77	0.00	0.43	1.0
Evergreen forest × Woody wetlands	4	882.59	2.82	0.11	3.9
Herbaceous	2	882.69	2.92	0.10	4.3
Null	1	883.30	3.53	0.07	6.1
Infrastructure	2	883.37	3.60	0.07	6.1
Forested	2	884.07	4.30	0.05	8.6
Roads	2	884.10	4.33	0.05	8.6
Deciduous forest	2	884.14	4.37	0.05	8.6
Evergreen forest	2	884.26	4.49	0.05	8.6
Mixed forest	2	884.91	5.14	0.03	14.3
Mean NDVI	2	884.95	5.18	0.03	14.3
Logging	2	885.13	5.35	0.03	14.3
Shrub/scrub	2	885.16	5.39	0.03	14.3
Open	2	885.18	5.41	0.03	14.3
Burn	2	885.23	5.46	0.03	14.3
Evergreen forest × Deciduous forest	4	886.70	6.93	0.01	43.0
Forested × Open	4	886.96	7.19	0.01	43.0
Mixed forest × Deciduous forest	4	887.40	7.63	0.01	43.0
Global	13	896.45	16.68	0.00	>100

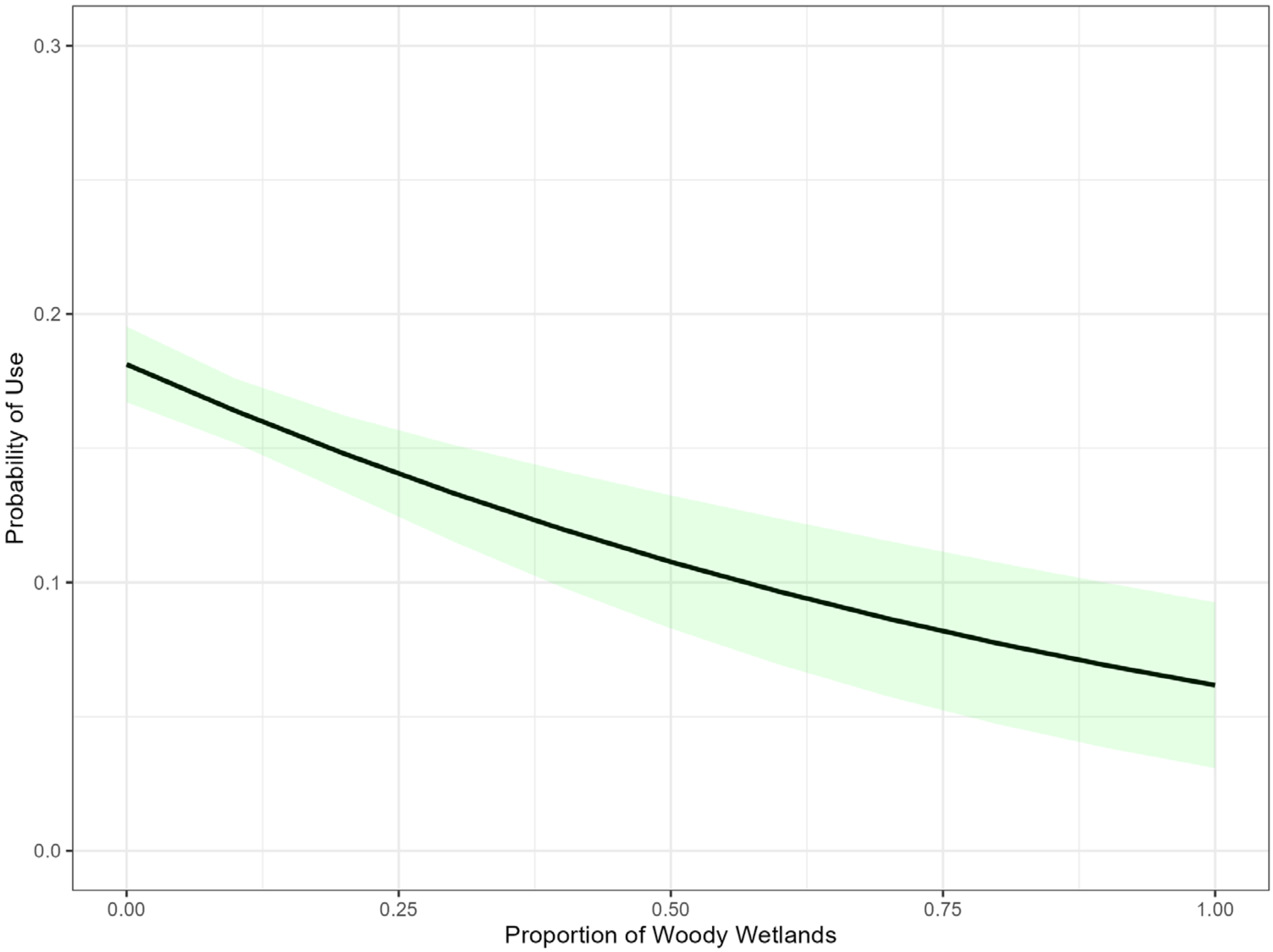

Figure 4. Predicted probability of use for woody wetlands as female eastern wild turkeys moved from the roost to the nest on the first day of laying in west-central Louisiana during 2014–2021.

Discussion

Wild turkey resource selection during the reproductive period is thought to have consequences for both female survival and reproductive success (Chamberlain and Leopold 1998, Thogmartin 1999, Kilburg et al. 2015, Lohr et al. 2020). Using GPS-based movement data for female wild turkeys on the day of nest initiation, we determined that landscape metrics commonly used to evaluate resource selection within ranges or around nest sites (Sullivan et al. 2020, Crawford et al. 2021, Keever et al. 2023) did not play a biologically significant role in habitat selection on the day of nest initiation. The only statistically significant effect was the avoidance of wetlands, which represent areas typically not used by wild turkeys for nesting (Crawford et al. 2021). Additionally, female wild turkeys showed no selection for burned areas or presence of roads along laying paths, which differs from previous studies on resource selection by wild turkeys during the reproductive period (Thogmartin 1999, Miller and Conner 2007, Martin et al. 2012, Yeldell et al. 2017, Cohen et al. 2019). Our results indicate that landcover metrics provide little insight into selection criteria used by wild turkeys on the day of nest initiation in pine-dominated landscapes, like those seen across most of the southeastern U.S.

Female wild turkeys likely have enough behavioral plasticity to use all landcover types we considered in our analyses during the nesting period, which could possibly explain lack of selection for or against most landcover types. Recent work by Schofield (2019) indicated that female wild turkeys increased daily movements during egg laying, but that increase occurred concomitant with a decrease in space use, which is indicative of a lack of site familiarity (Conley et al. 2016). Schofield (2019) hypothesized that during the egg laying period, female movements were more akin to prospecting areas within a reduced range where nesting activity would ultimately occur. Thus, female movements were used presumably to identify and assess resource availability and distribution, as opposed to already having garnered that information prior to the onset of breeding as suggested by Badyaev et al. (1996). As such, resource selection along the laying path during nest site selection is generally indistinguishable from selection during movements by females throughout the reproductive period.

The relationships between behavioral decisions made by female wild turkeys and subsequent demographic consequences are poorly understood (Conley et al. 2015, Conley et al. 2016). Contemporary research across the southeastern U.S. noted that landcover type and nest site vegetation were not primary drivers of wild turkey nest success (Crawford et al. 2021, Keever et al. 2023). Similarly, our results suggest that landcover used on the day of nest initiation did not influence nest site selection other than females avoiding wetland areas. Although resource selection by reproductively active female wild turkeys has been discussed exhaustively in wild turkey literature, researchers have collectively been unable to identify clear patterns in resource selection and their consequences on population productivity (Crawford et al. 2021, Keever et al. 2023).

We suggest that future work evaluating drivers of wild turkey resource selection during nesting takes a more holistic approach that includes behavior ecology, conspecific activities, and predator-prey interactions, rather than purely focusing on the effects of vegetation characteristics. Our understanding of the behavioral ecology of wild turkeys during the reproductive period has increased via access to GPS technology (Collier and Chamberlain 2011) which offers a clearer picture of behaviors across a broad range of study sites relative to previous direct observations of individual wild turkey flocks (Watts and Stokes 1971, Healy 1992). By shifting focus to evaluating how individual wild turkey behaviors and their social effects change throughout the reproductive season, researchers may be able to provide more rigorous assessments of factors driving reproductive success (Bakner et al. 2019, Lohr et al. 2020, Ulrey 2021, Ulrey et al. 2022). When paired with understanding the links between predators and wild turkeys and the ties that vegetation characteristics could have with all these social, behavioral, and ecosystem effects, research can more accurately inform land managers whose only tool to increase wild turkey populations is to target specific vegetation characteristics with habitat improvements. Habitat improvements will always play a role in supporting wild turkey populations, but they cannot be used as a panacea to improve wild turkey nest success.

Acknowledgments

Funding and support were provided by the Louisiana Department of Wildlife and Fisheries, the Louisiana State University (LSU) Agricultural Center, and School of Renewable Natural Resources at LSU, the U.S. Forest Service, and the Warnell School of Forestry and Natural Resources at the University of Georgia. We are grateful to the suite of biologists, graduate students, and technicians who provided significant time and assistance with both trapping and data collection. This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, McIntire Stennis project under No. 7001494.

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