

Adult female survival, reproductive success, and breeding habitat relationships of wild turkeys
(*Meleagris gallopavo*) across a precipitation gradient in Kansas

by

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Abstract

The reintroduction of wild turkey (*Meleagris gallopavo*) populations across the United States is a conservation success story. Their recovery during the past 75 years was the result of widespread relocations throughout the eastern and Midwest United States beginning in the 1950s, finally reaching an abundance level to open spring hunting season in Kansas in 1974. However, there is now a suspected near-nationwide population decline for wild turkeys, including Kansas, starting in the mid-2000s in the eastern United States that is progressing westward with severity varying among states. Initial responses to these declines include increasingly smaller bag limits and cancelled hunting seasons, which detrimentally affect state wildlife agencies on economic, cultural, and sociologic levels. To investigate potential factors influencing the demography of wild turkey populations, I captured and marked 297 and 102 female wild turkeys in 2024 and 2025, respectively, using G5-T2A Iridium backpack style transmitters. I remotely monitored the movements of each female weekly during the breeding season to monitor for indications of the bird entering the laying, incubating, or brood-rearing states. When a female successfully incubated a nest, I completed weekly brood flush counts to determine poult survival up to 28 days following hatch. I conducted habitat surveys at used and randomly available nesting and brood-rearing locations to test for resource selection and record potential factors affecting nest, brood, and adult female survival.

Nest-site use across a landscape was best predicted by tree distribution, specifically within a maximum proximity of 286 m and a mean proximity of use at ~34 m, but nests were primarily placed within grassland landcover patches (>70% of nests). At a fine-scale, visual obstruction and woody composition were most influential for modeling nest-site use by wild

turkeys; both increasing the probability of nest-site use. Nest survival estimates were similar between survey years, at a realized nest survival for a 28 day incubation period of 0.17 ± 0.05 in 2024 and 0.15 ± 0.05 in 2025. Private lands had the same estimated nest success ($\hat{S} = 17.45\% \pm 4.0$) as public lands ($\hat{S} = 17.28\% \pm 7.00$). Adult females (≥ 2 years old at time of nesting) had a slightly greater but insignificantly different nest survival estimate ($\hat{S} = 17.78\% \pm 4.0$) than juvenile females ($\hat{S} = 15.49\% \pm 8.14$). Despite not being selected, mean forb composition at 10 m around the nest negatively affected nest daily survival rate ($\beta = -0.0085 \pm 0.003$, LCL = -0.0141, UCL = -0.0029).

Forb composition was ubiquitous among used habitats of both brood-rearing and nesting wild turkeys, possibly indicating areas available for nesting incur disturbance levels detrimental to nest success but beneficial to brood survival. Apparent survival of broods in Kansas was 33% in 2024, and 22% in 2025; Poult survival increased with each week following hatch, starting at 0.53 ± 0.03 (LCL = 0.465, UCL = 0.592) in week one, 0.59 ± 0.04 (LCL = 0.514, UCL = 0.670) in week two, 0.95 ± 0.04 (LCL = 0.755, UCL = 0.992) in week three, and finally 1.00 ± 0.00 in weeks four and five. I estimated laying phase core ranges of females with successful nests to investigate if pre-brood rearing behaviors impacted subsequent poult survival. The laying period core range negatively affected 0–14-day poult survival; At the smallest recorded laying core home range of a brood rearing female, 2.70 ha, poult survival for the first two weeks of life is estimated to be 0.62 ± 0.017 (LCL = 0.589, UCL = 0.655). By the third quantile of core area, 157.13 ha, poult survival decreased by 19% to 0.43 ± 0.048 (LCL = 0.342, UCL = 0.530). Lastly, cumulative, 52-week survival of female wild turkeys was $52.10\% \pm 3.1$ (LCL = 46.4%, UCL = 58.5%) in 2024 and $46.4\% \pm 3.3$ (LCL = 41.2%, UCL = 54.3%) in 2025.

Female wild turkey survival was lowest in the reproductive period, during which 79.4% of all mortalities occurred. Survival of wild turkey females was $49.53\% \pm 0.001$ during the reproductive period and $82.70\% \pm 0.001$ during the non-breeding period. Despite wild turkeys being distributed across an expansive precipitation and resource gradient from east to west, female wild turkey survival did not differ among study regions or hunting management units. For example, the 30 year mean annual precipitation of the western study region was $9.61 \text{ cm} \pm 15.74 \text{ SD}$, while the 30 year mean annual precipitation of the eastern study region was $14.31 \text{ cm} \pm 23.16 \text{ SD}$. Furthermore, of the variables measured, nest habitat (nest visual obstruction up to 50 cm at the nest bowl, woody composition at the nest bowl, forb composition at a 10 m radius around the nest, and visual obstruction up to 50 cm at a 10 m radius around the nest) had no effect on female wild turkey survival during the reproductive period.

Apparent wild turkey nest success values in 2024-2025 (4-30%) among study sites fall slightly below that of pre-2004 (8-54%) apparent nest success for the Great Plains region and appears to regularly entail large variation among study sites, both historically and present-day. Poult survival was similar to that of previous studies (40-52%), although limited references are available pre-2004. Finally, annual survival of female wild turkeys in Kansas falls below a 68% model-averaged female survival estimate preceding the nationwide population decline starting in 2004 published by Lashley et al. (2025). Based on these results, reproductive vital rates support signs of a more limited population trajectory in comparison to the near 50-year population increase following reintroduction. Because both nesting and brood-rearing success suffer from female-specific mortality rather than general failure, adult female wild turkey survival is the most probable origin of the resulting decline.

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Approved by:

Major Professor
Dr. David Haukos

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Chapter 1 – Hierarchical resource selection of nesting wild turkeys across a precipitation gradient in Kansas

Introduction

Management of game populations is dependent on the capability to modify the environments they reside within, as their survival is typically linked to availability of specific resources. The resources most consistently able to be modified by one seeking to manage game populations are those that can be influenced by the common tools of the ax, cow, plow, or match and include plant composition and structure. Due to their relative stationarity, plant composition and structure are also often the most stable variables we may rely on for predicting the presence or absence of a species. Thus, we as managers benefit from attempting to define species' habitat by determining probability of use through selection patterns. Habitat selection patterns are layered within multiple spatial scales and behavioral choices, each shaped by the availability of resources specific to each locale. This creates difficulties in generalizing research results for a single species from neighboring landscapes, ecosystems, or states to unstudied systems. The wild turkey (*Meleagris gallopavo*) is one such species that has a large geographic distribution in North America from Mexico to Canada, but management information stems from research conducted in a limited number of regions. The southeastern region of United States has produced an array of resource selection research investigations relative to wild turkeys but factors influencing resource selection remains understudied in grassland ecosystems such as the Great Plains. The information we do have in agriculturally dominant areas similar to Kansas, USA, such as southwestern and central Wisconsin indicates that nesting wild turkeys utilize grassland-

forest edges, and use of forest-dominant patches may decrease chances of recruitment even though wild turkeys are synonymous with woodland cover (Pollentier et al. 2014a, 2014b, 2017).

Kansas is one such grassland-dominant state where nest-site selection is poorly understood and likely limits wild turkey distribution, adult female survival, and recruitment. In addition to being a grassland-dominant state, Kansas presents a unique opportunity for comparative assessments of habitat selection and availability across a significant longitudinal precipitation gradient. While general needs of female wild turkeys for roost trees in wooded areas, dense visual cover for nesting, and forb-rich patches for brood rearing are understood, there is an information gap on how selection may change among varying compositions and availability of these resources. Management strategies can become complicated when patch or habitat compositions vary in time and space with a precipitation gradient like the one observed in Kansas.

Resources with extensive availability may not emerge as “selected” due to their composition or abundance masking any statistical significance of relative probability of use. A large-scale example of this situation may be differential evidence for patch selection during the nesting season in the Midwest United States where woodlands are limited, but not the densely forested Southeast (Pollentier et al. 2017, Nelson et al. 2022). In woodland-dominant systems, wild turkey nesting habitat consists of sites with greater visual and shrubby cover at the nest location than what is randomly available; frequently nests are placed in open canopy areas or within a minimum of 200 m of a forest edge or woody patch (Lehman et al. 2003, Kilburg 2014, Streich et al. 2015, Pollentier et al. 2017, Yeldell et al. 2017, Wood et al. 2019, Crawford et al. 2021). It is this concept of elucidating contextual resource selection by wild turkeys that is required to better inform management for nesting habitat.

Similar to forested regions, female wild turkeys in grassland-dominant regions select for woody ground cover surrounding nests, with greater visual obstruction around the nest bowl than what is randomly available (Lehman et al. 2003, Hall et al. 2010). Female wild turkeys in the Great Plains readily nest in open areas such as pastures or croplands rather than primarily within woodlands (Lehman et al. 2003, Hall et al. 2007). In the Great Plains, female wild turkeys experience additional management practices potentially affecting nest-site selection and success compared to the eastern temperate forests with greater cattle production at various stocking rates and grazing intensity, larger expanses of row-crop agriculture, increased hay production, different prescribed fire regimes, and woody plant control (Hall et al. 2007, Nielsen et al. 2021). Nest-site characteristics in grassland systems adjacent to Kansas such as South Dakota and northwest Texas, USA, include increased visual obstruction at 1.5 m or less above ground, shrub cover, and aversion to edges (Lehman et al. 2003, 2010; Hall et al. 2007).

The most consistently reported variable selected by nesting female wild turkeys in the Great Plains is visual obstruction, with nest locations having around 2 times greater visual obstruction up to 45 cm compared to what is available at random (Hall et al. 2007). Wild turkeys nesting in the Rolling Plains of the Texas panhandle and southwestern Kansas had mean lowest readable visual obstruction readings (VOR) from various sites ranging from 36.3 to 44.7 cm (Hall et al. 2007). In South Dakota, nest sites were placed within greater shrub cover and farther from forest edges when compared with brood ground-roost locations, with common plant species at the used locations being little bluestem (*Schizachyrium scoparium*), poison ivy (*Toxicodendron rydbergii*), snowberry (*Symphoricarpos occidentalis*), smooth sumac (*Rhus glabra*), and American plum (*Prunus americana*; Lehman et al. 2003, 2010). The mean distance to patch edge for nests was 54.2 m, and mean lowest readable VOR was 29.4 cm also using a

Robel pole (Lehman et al. 2010). No studies have reported forb presence as being important for nest-site selection, even though it is well known that females immediately convert to using forb-dominant areas once broods have hatched (Hall et al. 2003, Lehman et al. 2003). Despite this knowledge from neighboring regions, further context of resource selection across Kansas is necessary to investigate how and if management of a woodland-based bird can coincide with the goal of conserving grasslands currently battling woody encroachment (Londe et al. 2022).

The hierarchy of resource selection is temporally and spatially explicit, needing to be contextualized by life history stages and scales of use. The most applicable scales of use pertaining to habitat selection for managing wild populations are the within-home range patch selection and selection of resource points within home ranges, such as breeding or foraging locations (i.e., 3rd order selection; Johnson 1980). Most species require simultaneous assessment of multiple scales, such as patch use and resource selection points combined, to determine the complete relationship between the animal and resources available across its landscape (McIntyre and Wiens 1999, McGarigal et al. 2016, Zeller et al. 2017, Li et al. 2023). My primary goal was to use resource selection functions to delineate relative use and availability of vegetation resources for nest-site selection by wild turkeys in Kansas at two scales across three defined study regions across a significant precipitation gradient. At the point scale, these resources included habitat measurements of visual obstruction and percent functional plant group composition (grass, forbs, woody vegetation, bare ground, and residual litter) at the nest bowl and 10-m radius around the nest bowl to investigate two possible scales at which selection may be occurring within a patch (Byrne and Chamberlain 2013). At the patch scale, nest placement was assessed among certain patch cover types (grassland, woodland, shrubland, and cropland)

and distance to patch edges to test comparative landscape-level habitat selection. I hypothesized that relative use would increase in grassland patches and with distance from woodland edge in more western nesting locations compared to eastern due to the thin riparian areas unique to western landscapes creating predator highways that may deter nesting females. I also hypothesized that concurrent with previous research, increasing visual cover would be the most important component selected by nesting female wild turkeys across all regions of the state. More specifically, I predicted that visual obstruction at the 25-50cm range will have greater model performance for determining nest-site probability of use, as it is the ideal volume in space of which would conceal a female wild turkey sitting or standing at the nest and concurrent with previous literature. Based on previous patterns of female wild turkeys placing nests under or within shrubs, I hypothesized woody composition would best predict nest bowl selection with a positive relationship. Lastly, I predicted that selection strength towards woody cover would decrease in situations where high levels of visual obstruction were provided.

Study Area

My study area encompassed the eastern two-thirds of Kansas, split into three study regions. These regions were delineated by the following longitudinal boundaries: East (-96.96 to -95.50), Central (-98.49 to -96.96), and West (-100.15 to -98.49; Figure 1.1). From east to west, the three regions represent a negative precipitation gradient along with a gradual shift from tallgrass, to mixed-grass, and finally short-grass prairies. Grasses common to the entire study area included little bluestem, side-oats grama (*Bouteloua curtipendula*), and switchgrass (*Panicum virgatum*). Common forbs include ragweed (*Ambrosia psilostachya*), yellow sweet clover (*Melilotus officinalis*), Illinois bundleflower (*Desmanthus illinoensis*), and annual sunflower (*Helianthus*

annuus). Species most often comprising Kansas riparian areas were bur oak (*Quercus macrocarpa*), hackberry (*Celtis occidentalis*), black walnut (*Juglans nigra*), American elm (*Ulmus americana*), rough-leaf dogwood (*Cornus drummondii*), coral berry (*Symphoricarpos orbiculatus*), and Virginia wild rye (*Elymus virginicus*; Haddock 2024). Common predators of female wild turkeys, their nests, and broods in Kansas were bobcat (*Lynx rufus*), coyote (*Canis latrans*), great horned owl (*Bubo virginianus*), raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), and striped skunk (*Mephitis mephitis*; Thogmartin and Schaeffer 2000, Yeldell et al 2017, Crawford et al. 2021, Nielsen et al 2021).

To describe the composition of my study system, I placed a 95% minimum convex polygon around movement locations recorded from each unique capture flock (13 total) from 2024-2025 (Figure 1.2). I then averaged the landcover values derived from the Kansas Ecological Monitoring dataset among the 13 capture sites within each study region to report the landscape compositions and used the U.S. Department of Agriculture Cropland CROS dataset to report all agriculture-based compositions in 2024 (Boryan et al. 2011, Diamond et al. 2021). All study regions were grassland dominant, with the majority (>65%) of open grasslands being used for livestock grazing throughout the state (Boryan et al. 2011). The West study region contained the largest percentages on average of cropland and mixed-grass prairie (31%, 55% of total area, respectively). The Central study region was composed of the second-highest mean cropland cover, with about 23% of the total area dedicated to cropland and 58% remaining as a combination of tallgrass and mixed-grass prairies. Both the West and Central study regions had <5% forested cover, primarily represented by riparian areas scattered throughout each region. The primary cover types in the East study region were tallgrass prairie (65%) and various forms of woodlands (15%). Cropland cover was the lowest in the East study region with 11% coverage.

Primary crops in the West study region were winter wheat (*Triticum aestivum*, 11% mean total cover) and grain sorghum (*Sorghum bicolor*, 10% mean total cover). Winter wheat (9% mean total cover) was the primary crop in the Central study region followed by grain sorghum (*Sorghum, bicolor*, 4%), soybeans (*Glycine max*, 4%), corn (*Zea mays*, 3%), and alfalfa (*Medicago sativa*, 1%). Soybeans (7% mean total cover) was the primary crop in the East study region. Urban intensity was low in all 3 study regions, with 1% in the East study region compared to 0.35% in the Central study region and 0.55% in the West study region.

Weather metrics during 2024–2025 nesting seasons (Apr-Jun) were derived from county-level weather averages (PRISM group 2025). Mean precipitation across the study area was 9.8 cm (SD = 5.3) in 2024 and 11.8 (SD = 5.8) in 2025. Mean temperature across the study area from April to June was 19.3° C in 2024 and 18.1° C in 2025. By region, 2024 precipitation across the East, Central, and West study regions, was respectively 11.9 cm (SD = 4.3), 7.4 cm (SD = 5.6), and 6.9 cm (SD = 4.3). Precipitation slightly increased in 2025 by region at 13.7 cm (SD = 6.1), 11.2 cm (SD = 6.4), 7.6 cm (SD = 1.5), respectively, in East, Central, and West study regions. Mean temperature for East, Central, and West study regions was 19.4° C, 19.5° C, 18.8° C in 2024, respectively. In 2025, mean temperature by region was slightly cooler at 18.2° C, 18.0° C, and 17.6° C for east, central. and west regions.

Methods

Field Capture and Monitoring

I captured female wild turkeys using baited drop, walk-in, and rocket nets on private and public lands during winter (Jan-Mar) 2024 and 2025. All captured wild turkeys received

aluminum, pop-rivet leg bands with unique numeric identifiers and contact information for reporting recoveries. I measured the mass (kg), tarsus length (cm), wing chord (cm), and exposed culmen length (cm) length for all birds, in addition to spur length (cm) and beard length (cm) for females who had them. All females were aged based on plumage; juveniles were classified as any female with white banding to the tip of the primaries as well as pointed tips of the first primary (Healy and Nenno 1980). Adults were identified by a lack of white banding all the way to the end of the primaries, and a rounded end of the first primary feather.

I fitted each female wild turkey with a 156-g Global Positioning System (GPS), G5-T2A Iridium backpack style transmitter with a very-high-frequency (VHF) component (Advanced Telemetry Systems, Isanti, MN, USA). Transmitters were secured as a backpack using 3/16-inch marine-grade shock cord with knots tied at each attachment point and secured with super-glue. Once deployed, transmitters recorded GPS locations six times per day at 0300, 0700, 1100, 1500, 1900, and 2300 during the breeding season (Mar 1 – Aug 1), 2024 and 2025. Locations were uploaded from the GPS transmitter to the Iridium system every three to five days.

I reviewed movement patterns of each female weekly during the breeding season to monitor for indications of the bird entering the laying, incubating, or brood-rearing reproductive states. I identified the laying state as daily repeated (>3) visits to the same location (<100 -m radius). Incubation state initiations were identified and determined by the female spending at least one night roosting on the ground in a nonforested location. In forested areas, I considered the incubation state to be initiated once the female dramatically decreased her daily step-lengths and was roosting in the same general location of the laying area for at least 24 hours (Carpenter et al. 2022). I estimated an average incubation period of 28 days to estimate the hatch date of all

nests and determined a nest to be failed if a female permanently left the nest or died before incubation day 26 (Healy 1992, Conley et al. 2016).

Landscape-level nest habitat assessment

For investigation of the influence of landscape-scale features on selection of nest sites by female wild turkeys, I used Environmental Systems Research Institute's ArcGIS Pro Geospatial Information System 3.3.0 to classify landcover compositions, define areas of availability, generate random sampling locations, and measure distances to variables of interest. Land cover compositions were based on Kansas Ecological Systems "Mapping Kansas Ecosystems" (KEMS) 2023 data layer. This layer was a 10 x10-m cell raster product created by the Kansas Biological Survey via remotely sensed data and field-based sampling sites to define land cover types across the state (Peterson and Moody 2024). This layer defined 49 vegetation groups in Kansas, including cover types such as eastern floodplain forest, mixed-grass prairie, western lowland grasses, and mixed oak-hickory woodland. To simplify this layer, I combined all vegetation groups with similar functional characteristics into the following groups: woodland, grassland, shrubland, cropland, barren, developed, wetland, and water. These were the cover types retained for the landscape-scale nest-site selection analysis.

I defined availability at the landscape scale by generating random points within a buffered polygon placed around the nesting season locations of marked female turkeys grouped by each capture flock. The process involved the following: 1) placing a minimum convex polygon (MCP) around nesting season locations that were within 4,000 m of another, 2) adding a 2,000 m buffer around that MCP, and 3) generating random locations within each polygon (2,000 m buffer around the MCP), standardized by the number of nests within each polygon (Figure 1.3).

Female wild turkeys begin prospecting for nest habitat two to five days before nest initiation (Conley et al. 2016). I defined nesting season locations for establishing MCPs using only movements from five days before the first known laying attempt to five days before the last known laying attempt in each region. This resulted in the nesting season locations being defined as March 21 to July 10, March 20 to June 29, and March 28 to June 23 for the East, Central, and West study regions, respectively. I established the first MCP by creating minimum convex polygons using the Aggregate Points tool in ArcGIS Pro 3.3.0 with an aggregate distance limit of 4,000 m due to the maximum mean daily distance traveled by female wild turkeys in the pre-laying phase being near this value (Moscicki et al. 2022; Figure 1.3). I then buffered the polygon by 2,000 m to account for the possibility of female wild turkeys venturing outside of the MCP between GPS fixes resulting in the final boundary used to generate random locations (Figure 1.3). I generated 30 random locations for every known used nest location. For example, in the West Region, which contained 175 monitored nests over both years, I generated 5,250 random locations to define availability. Random points and nest locations were then associated with their respective landcover compositions defined in the KEMS polygon layer by using the Spatial Join tool.

I used the Near geoprocessing tool to measure the Euclidian distance from each sampled location (random and nest) to edges of patch types and features of interest. These included distance to trees, water features, cropland, and human development such as roads or houses. Water features included stream orders 1-2 and stream orders 3-9, classified by the Kansas Biological Survey and downloaded from the Kansas Geoportal (hub.kansasgis.org). For estimating the distance to tree, I used a polygon shapefile created from a 5-m resolution raster

file purchased from EarthDefine (earthdefine.com) to classify tree locations. This layer was created using the 2021 National Agriculture Imagery Program imagery.

I report mean and standard deviation (SD) for all measured landscape metrics grouped by study regions. Lastly, when surveying nests in the field I also recorded the dominant land cover type (e.g., forest, shrubland, grassland, or crop) within a 100-m radius of the nest location and later use these for describing nest patch-type selection.

Landscape-level analysis

I used resource selection probability functions to assess nest-site selection among landscape features including patch types and distance to woodland edges. Landscape features investigated as alternative hypotheses in main effects models included nest distance to cropland, urban, trees, stream orders 1-2, and stream orders 3-9. To investigate if selection strength is contextual among regions, I fit interactive effects models using region as an interactive effect of probability of selection of each landscape variable. In total, including the null model, the model set included 15 models. Used locations consisted of all known nest sites from 2024–2025. Random locations included the 30 generated locations per one known nest site. I ranked all models using Akaike's information criterion (AIC) and considered models within 2 Δ AIC units to be competitive (Burnham and Anderson 2002). However, I removed high-ranking models with uninformative variables ($P > 0.05$) from consideration.

Fine-scale nest habitat assessment

I conducted vegetation surveys at nests following either successful completion or failure of the nest. I measured habitat values at 2 scales of the nest location, the first scale being directly at the nest bowl and the second scale being a 10-m radius around the nest bowl, henceforth the

nest site (Figure 1.4). At the nest bowl, I placed a 1x1-m vegetation quadrat around the nest bowl (GPS location of the nest if no eggs were found) and recorded the percent composition of 5 ground cover functional groups: grass, forbs, residual litter, bare ground, and woody-stemmed vegetation. I then placed a coverboard along one of the four edges of the 1 x1-m quadrat, walked 10 m away from the nest and recorded the percent visual obstruction at four height categories at 1-m aboveground (Nudds 1977). The coverboard was 0.5-m wide by 1.0-m tall with 0.25-m sections of alternating color contrasts to denote four total visual obstruction reading (VOR) height categories (0-0.25 m, 0.25-0.50 m, 0.50-0.75 m, and 0.75-1.0 m above ground). I recorded VOR four times at the nest bowl, each time with the coverboard being placed on one of the four cardinal directions of the quadrat at 10 m from the coverboard. I report the mean values within each height category at the nest bowl and use the mean values of each height category to represent visual obstruction at the nest bowl in subsequent resource selection analyses. Lastly, I also recorded substrate directly adjacent to nest bowl (e.g., tree, shrub, bunchgrass, fencepost) and categorical presence-absence of overhead cover types (grass, shrubs, tree) at the nest bowl.

I conducted a similar habitat assessment at the nest site (10-m radius around the nest bowl). For this scale, the observer measured habitat (vegetation quadrat, coverboard readings) at four locations 10 m away from the nest bowl in each cardinal direction. This resulted in a total of four, 1x1-m quadrat compositions being recorded for each of the five functional groups (grass, forbs, residual litter, bare ground, and woody-stemmed vegetation), which I then averaged together across each functional group (Figure 1.4). I report the mean value from the four quadrat readings and use this mean value to represent functional ground cover composition at the nest site (10-m radius around the nest bowl). I recorded coverboard readings only on one side of the quadrat (compared to all four at the nest bowl), which was the side furthest from the nest with

the colored side of the coverboard facing away from the nest bowl. I recorded VOR in each height category 10 m from the coverboard, 20 m from the nest bowl. I averaged the VOR across each height category and used mean values of each height category to represent visual obstruction at the nest site in subsequent resource selection analyses.

Once I surveyed the nest location, I generated two random, available locations per nest site within 400 m of the nest using a random number generator with the first number generated equaling the distance to be traveled and the second the azimuth for traveling direction. All randomized locations were constrained to occur within the same patch type as the nest (i.e., grassland, woodland, shrubland, or cropland). I conducted the same vegetation survey previously described for the nest site at all randomized locations. I report all field-collected measurements as means with standard deviations by study region.

Fine-scale analysis

I used the two random survey locations collected per nest to conduct a resource selection probability function analysis for determining nest habitat selection. The nest-habitat selection analysis included the following variables from the point measurements at the nest location: functional group cover compositions at the nest bowl (percent grass, forbs, woody vegetation, bare ground, residual litter); mean VOR for each height category m at the nest bowl and 10-m radius around the nest; and mean functional group cover compositions 10 m from the nest.

To assess habitat selection for the nest at the scale of the nest bowl and the nest “site” (10 m radius around the nest), I used four initial model suites separately testing selection of VOR and plant compositions at the two scales. I followed these with one final model suite testing the hierarchical importance of each of the variables represented by combining each competitive

model within each model suite. In all four initial model suites, I fitted main effects models in addition to interactive effects of study region and patch type (main ecotype observed within 100 m of the nest) for modeling probability of use. The first model suite, visual obstruction at the nest bowl, tested selection of percent visual obstruction at the four measured height categories. The second model suite, selection of functional plant group compositions at the nest bowl, evaluated which plant functional group was most influential for modeling nest-point selection. The final two model suites contained the same variables, VOR and plant composition, but tested for relative model performance of those variables at the nest-site (10-m radius) scale. I ranked all models using AIC and considered models within 2 Δ AIC units to be competitive (Burnham and Anderson 2002). However, high-ranking models with uninformative variables ($p > 0.05$) were removed from consideration.

Lastly, I used a multivariate analysis of variance (MANOVA) to test regional differences of variables that remained in the final model selected from the resource selection model suites. Using the MANOVA, I tested the hypothesis that the precipitation gradient leads to significant differences in used resource availability among regions, but that the average values of use remain the same among the used resources. To do so, I used the `manova()` function in program R to complete the MANOVA test between two variables among nine groups (East, Central, West; Used and Random; R Core Team 2024). Following the completion of the test, I considered significance at confidence levels of $\alpha = 0.05$ or $p < 0.05$. If significance among groups was ascertained, I then completed a post-hoc, pairwise t -test using a Bonferroni corrected alpha-value and unpooled standard deviation in attempt to control for Type 1 error and account for unequal variances among test groups (Bland and Altman 1995).

Results

Capture and monitoring

I deployed GPS transmitters on 297 and 102 female wild turkeys in 2024 and 2025, respectively, for a total of 399 tracked birds over the 2-year study. From this capture sample, I remotely monitored the status of 330 wild turkey nests in 2024 and 303 nests in 2025; of those, I completed field-based habitat surveys for 219 and 234 nests, respectively. I surveyed habitat for 127 nests in the West study region, 161 nests in the Central study region, and 165 nests in the East study region. Forty-seven (10.4%) surveyed nests were in cropland, 106 (23.4%) in forest, 223 (49.2%) in grassland, and 77 (17.0%) in shrubland based on field observations of the patch cover type within 100 m of the nests. Substrates most used to place nests within or adjacent to were shrubs (39.1%), such as coral berry (*Symphoricarpos orbiculatus*), plum (*Prunus angustifolia* or *P. americana*), dogwood (*Cornus drummondii*), or small (<1.5 m tall) eastern red cedars (*Juniperus virginiana*) as well as bunchgrasses (34.0%) such as little bluestem, big bluestem, and switchgrass (*Panicum virgatum*). The next most common substrate nests were placed next to were live trees (15.5%), downed or dead trees (4.4%), and within winter wheat fields (2.9%). The remaining portions of nests were placed within colonial forb patches (1.5%) such as poison hemlock (*Conium maculatum*), crown vetch (*Securigera varia*), and cultivated alfalfa fields as well as by fence posts (1.8%) and one haybale (<1%). Those nests were spread across 203 individuals with a mean nesting attempt of 1.25 attempts per female in 2024, and 182 individuals with a mean nesting attempt of 1.33 attempts per female in 2025. Of the females that were captured and initiated at least one nest in 2024, 99 (48.8%) survived and initiated at least

one nest during the 2025 breeding season. Apparent nest success across all study sites was 16.7% in 2024 and 17.8% in 2025. There was a high variation of apparent nest success among study sites, exemplified with lowest of 0% at 3 eastern Kansas study sites to a high of 33% at the Kanopolis Lake study site in 2025.

Landscape level resource selection

The proximity to trees interacting with study region as a factor was the top-ranked model for nest location in Kansas (Table 1.3). Within 0-100 m distance from trees, probability of use was up to three times stronger in the West study region in comparison to the Central and East study regions but only reached a maximum probability of use of 0.125 (Figure 1.5). Across all three study regions in the state, probability of use was negatively associated with increasing distance from the nearest tree ($\beta = -0.014$, $SE = 0.0009$). The average distance of nest site use was virtually the same among regions despite much greater area away from trees in the West Region (Figure 1.6). The maximum distance a nest was placed from trees was 286 m, and 155 nests (25%) were placed 0 m away from a tree.

When modeling the relative selection of patch types, the forest patch was the only significant predictor of nest-site selection ($\beta = 1.58$, $SE = 0.59$; Figure 1.7). This being said, probability of use was never >0.08 . The forest cover type comprised a very small amount (7%) of landscapes used by monitored females. Selection for the forest patch was strong ($\beta = 1.57$, $SE = 0.59$) but likely due to the very low availability of wooded areas across Kansas and strong association of nests with nearby tree cover. The majority (70%) of wild turkey nests were placed in grassland

patches, with the West Region having the greatest occurrence (81%), Central Region having the second highest (72%), and the East Region having the lowest (62%) proportion of grassland nests. The forest patch was the second highest cover type for relative use with 18.5% of nests in forest cover, followed by 7% of nests in cropland, 1.9% in shrubland, 0.6% in barren areas, and 0.6% in wetland. All cropland nests were placed in either winter wheat or alfalfa (*Medicago sativa*) fields. Barren areas included cover types such as old limestone quarries. Nests placed in “wetland” areas included three nests placed alongside or within ephemeral ponds and playas or roadside ditches that rarely hold water. Relative use of forest patch types for nesting followed the precipitation gradient, with 31% of East Region nests in forest, 15% of Central Region nests in forest, and only 5% of West Region nests in forest.

Fine-scale resource selection

At the nest bowl, visual obstruction and woody composition were most influential for modeling habitat use at the nest bowl of wild turkeys among measured variables. Both had a positive relationship with the probability of use (Figures 1.9, 1.10). On average, wild turkeys nested in areas with 76.48-88.18% of visual obstruction at the 25-50 cm and woody-stemmed plant composition of 16.97-27.05% within 1-m of the nest bowl (Table 1.2; Figures 1.11, 1.12). Visual obstruction, specifically within the 25-50 cm height category, was most influential on nest-site selection by female wild turkeys when compared to other height categories up to 1 m. Relative selection strength was dependent on the context of the patch type where a female placed a nest (Table 1.4). Probability of use based on increasing visual obstruction was 2.1 times greater in shrubland ($\beta = 0.0408$, $SE = 0.0107$), than when in grassland ($\beta = 0.0191$, $SE = 0.007$) and 2.5 times greater than when in forest ($\beta = 0.0164$, $SE = 0.009$). Cropland patches had the lowest

relative selection strength with increasing visual obstruction (Figure 1.9). The model containing an interactive effect between visual obstruction and study region was competitive with the patch-type model, but lacked a significant interactive effect (Table 1.4). The second model set testing ground cover within 1 m of the nest bowl resulted in the main effect model of woody composition being most parsimonious (Table 1.5). In this instance, selection strength of woody composition did not vary among study regions or patch types even though the patch type interactive effects model had the lowest AIC_c value; the interactive effect was spurious.

At a 10-m radius around the nest bowl, probability of use was again most influenced by visual obstruction within the 25-50 cm height similar to the nest bowl, but instead with the interaction of study region (Table 1.6). Selection of visual obstruction within this height category was positive for all study regions, and greatest in the West Region ($\beta = 0.00009$, SE = 0.0005). However, small size of the beta coefficient along with the large relative standard error demes it unlikely that this component is driving nest-site use. Of the five ground composition variables at the 10-m radius, litter was the most influential without interactive effects of region or patch and probability of use increased with litter composition ($\beta = 0.020$, SE = 0.004; Table 1.7).

From the fifth and final model set comparing the selected models from the original four model sets, the most parsimonious model was the interactive effect between 25-50 cm VOR and woody composition at the nest bowl, outcompeting all models containing interactions with patch type or study region (Table 1.8). This model translates to the hypothesis that selection strength of visual obstruction at the nest was dependent on the level of woody plant composition at the given location, or vice versa. Based on this model, selection strength of visual obstruction within the 25-50 cm height around the nest decreases in areas of high woody composition (Figure 1.13). The probability of use in favor of visual obstruction becomes close to nonexistent once woody

composition reaches around 40% of the nest bowl. Of the nests I measured, 31% had a woody composition of 40% or greater at the nest bowl and, of that portion, 80% were in the Central or East study regions. In areas where woody composition was absent, females have a greater probability of nesting in locations with relatively greater visual obstruction (Figure 1.13). Nests in the West Region exhibited the lowest mean woody composition at the nest bowl at nearly 40% less than the rest of the study area but had visual obstruction at 25-50 cm height virtually equal to that of Central and East study regions (Table 1.2). This relationship is further explained by the kurtosis of woody composition at the nest bowl within our study area being mildly platykurtic ($k = -0.580$) while the kurtosis of visual obstruction at 25-50 cm at the nest bowl was very leptokurtic ($k = 2.14$). Interpretation of the kurtosis would indicate there is greater volatility in 25-50 cm tall visual obstruction used as nesting habitat around the nest bowl across Kansas even though greater levels of visual obstruction increases probability of use in all regions. For woody composition, however, the platykurtic distribution indicates reliable predictability of used values. Mean 25-50 cm VOR at the nest was 81.5% (SD = 21.7) while at the random locations, mean 25-50 cm VOR was 59.6% (SD = 31.6). Nest sites were composed of 23.7% (SD = 28.9) woody composition on average in Kansas, while random locations were composed of 8.3% (SD = 17.6) mean woody composition.

Lastly, visual obstruction within 25-50 cm tall and percent woody composition at the nest bowl were significantly greater at nest locations compared to random locations; Visual obstruction at 25-50 cm tall had significant differences among regions and used versus available locations based on the MANOVA results ($F_{10, 2740} = 33.01$ $p < 0.0001$). Post-hoc, Bonferroni adjusted pairwise comparisons resulted in significant differences of fine-scale measurements (woody composition, VOR 25-50 cm) between what was used versus what was available among

all three study regions (Table 1.9). Additionally, the pairwise comparisons resulted in the VOR at 25-50 cm at used nest sites of the West and Central regions being statistically similar, while the used sites of the East Region were differed from those in the West and Central regions (Table 1.9). Woody composition at used sites, however, was similar among all three regions.

Discussion

In grassland states such as Kansas, my results indicate that nest-site establishment is constrained by tree distribution, specifically within a maximum proximity of 300 m and a mean proximity of use at ~34 m. Tree availability is thus the initial step in the hierarchical-decision making process a female wild turkey makes in arboreal-challenged regions, as she restricts herself to conducting all subsequent decisions within such proximity. This is in spite of the fact that it is not uncommon for female wild turkeys to undertake dispersal up to 3,800 m per day during the pre-laying phase and 3,400 m per day during the laying phase (Moscicki et al. 2022). These multi-thousand-meter dispersal averages indicate that adult females can comfortably leave previous tree-roost locations much further than 300-m and still be capable of returning at the end of the day following a laying event. Behavior of brood-rearing females, however, may explain the dependency of tree proximity for nest-site placement. The primary brood resources of food and cover must be available within traversable distances for survival, possibly causing the self-restriction of nesting females to stay within 300 m of trees. Wild turkey females with broods tend to have small, recursive movements, dispersing an average of 200 m away from the nest immediately following hatch and subsequently 800 m away from the nest on average by day three (Chamberlain et al. 2020, Bakner et al. 2021). These first few days of being alive are the

period with greatest brood mortality and thus the most sensitive to the environments available to them following hatching (Spears et al. 2007). The change in daily dispersal and home range area then plateaus and foraging habitat use is primarily within open land cover types while ground roosting locations contain greater tree densities (Spears et al. 2007, Chamberlain et al. 2020). Without the foresight to place nests within dispersal proximity to resources required by broods, including both open areas for foraging and treed areas for environmental protection and eventual arboreal roosting, the effort of nesting would be moot (Bakner et al. 2021, 2024a). Throughout the Great Plains, wild turkey management will be dependent on maintaining healthy riparian areas that contain the majority of the region's trees and a near quarter-mile buffer zone of grassland where most (>50%) females are expected to disperse for nesting.

Grassland-patch use by nesting wild turkeys was prevalent across Kansas with 70% of females nesting in grassland cover types based on remote sensing data, or at minimum 50% use based on field-collected data. Nest sites in grassland are not uncommon, as female wild turkeys across the Great Plains have repeatedly been recorded nesting in open areas such as pastures or croplands rather than primarily within woodlands (Lehman et al. 2003, Hall et al. 2010). This is also consistent with recurrent findings even in forest-dominant landscapes where wild turkeys place nests in more open areas within ~150 m to 200 m of forest or ecotype edge; doing so may decrease risk of predation because of the increase of herbaceous cover and avoidance of nest predators using forested areas (Kilburg 2014, Streich et al. 2015, Pollentier et al. 2017, Crawford et al. 2021). My results of proximity to common edge types, aside from trees, having no effect on the probability of nest-site placement is unsurprising, as it's been noted that many other large-scale metrics such as landscape composition and fragmentation have little to no support for

influencing wild turkey nest-site selection or success (Yeldell et al. 2017, Wood et al. 2019, Crawford et al. 2021).

Variables that have been recorded affecting survival of wild turkey nests include fine-scale habitat variables such as bare ground as a negative factor and shrub cover increasing survival (Moscicki et al. 2025). In grassland-dominant areas specifically, wild turkeys had increased nest survival in patches enrolled in the U.S. Department of Agriculture Conservation Reserve Program (CRP), likely due to the increased visual obstruction provided there in comparison to grazed, non-CRP patches (Buford 1993). This leads us to the secondary level in the hierarchical decision process, where we observe females disproportionately using denser VOR at 25-50 cm and woody cover in comparison to what was available. Use of these variables was consistent across a gradient of available resources, and selection strength increased in regions and patch types where resources were more limited. Conclusions from areas of predominantly forest, savannah, and shrubland cover types suggest that fine-scale selection within a patch is of little concern to a female assuming the patches provide what they require (Conley et al. 2016, Scholfield et al. 2024). Further statements add that habitat selection may not be occurring at all for nesting females and quantifying nesting habitat should be reduced in research efforts (Scholfield et al. 2024). In our grassland system, significant differences between what was used as a nest site and what was randomly available across all three study regions refutes the concept of nesting habitat being non-limiting within patches in Kansas in its current ecological state. The statistical differences among used and random sites supports the notion that most female wild turkeys partake in environmental discernment preceding the initiation of nests, at least in regions where resources are unevenly distributed. This allows reflection on how

interpretation and application of resource selection theory is dependent on the context of the system being studied.

Regional differences across the Kansas precipitation gradient provided an initial survey design structure to test for changes resource selection strength across a heterogeneous landscape, but was ultimately best described by the interactive relationship of the selected variables of woody composition and 25-50 cm tall visual obstruction. The interactive effects model of woody composition with visual obstruction likely outcompetes the study region and patch-based models because it distills the selection relationship to its simplest parts – the resources themselves. The study region and patch type groups used as interactive effects of fine-scale nest site use are the generalized and subjective study groups I selected to represent a resource gradient created by the precipitation gradient, but both groups contain variation and nuance within them concerning the variables measured. This nuance is likely captured better by using fine-scale measured values, allowing for a more parsimonious model to quantify the pattern occurring. In the first model set, the strength of selection of VOR was dependent on the patch type context, decreasing in patches with uniformity such as cropland. On the other hand, selection strength towards visual obstruction was largest in shrubland patch types, possibly because tall (i.e. >50 cm tall) woody encroachment decreases the herbaceous understory (Wieczorkowski and Lehmann 2022, Liu et al. 2023). This same relationship is reiterated in the final model selected, “vor2*woody”, because patch type is synonymous to generalizing a woody composition gradient.

This final model supports the concept of habitat “slack” for nesting wild turkey management, which means that nesting habitat for wild turkeys can be composed of an optimal range of vegetation composition and structure at the nest site rather than requiring values so specific as the means provided in a single study group (e.g., 76.5% VOR at 25-50 cm and 27.1%

woody composition in the Central Region; Guthery 1999). As a generalist species able to exist across multiple states, wild turkeys can persist across a range of habitat compositions, whereby management can be altered for the region of interest. Based on my results, probability of nest-site placement by wild turkeys is capable of being increased by providing adequate visual obstruction alone, with or without an aspect of shrubby plant composition so long as management is within 300 m of treed riparian areas. Consistent selection of woody composition may be simply due to a repeated habit of wild turkeys identifying a clear visual structure that stands out on the landscape, such as the observations of wild turkeys using fenceposts, trees, and haybales as nesting markers. Twenty-five percent of females placed nests in locations with 0% woody composition, 50% of females placed nests in locations with 10% or less of woody composition, and 75% of females monitored placed nests with 50% or less of woody composition. In contrast, high values of VOR at 25-50 cm above ground were used by a more consistent proportion of females, with the first quartile using visual obstruction of 72.75% or less and the second (50%) quartile using visual obstruction of at least 90%.

This specification of fine-scale wild turkey nesting habitat being capable of facilitation via visual obstruction alone is important for management of wild turkeys in grassland-dominant states as grassland communities remain plagued by woody encroachment. In Kansas, woody encroachment is typically composed of shrubby species such as Russian olive (*Elaeagnus angustifolia*), salt cedar (*Tamarix ramosissima*), dogwood (*Cornus* spp.), and eastern red cedar. These species can occur either as thick groves along a riparian ecotone or shrub “islands” across a prairie, both of which pose a threat to the woody encroachment many grassland managers try to thwart. In 2019 alone, an estimated \$323 million in damages to agricultural production in the Great Plains was due to woody encroachment (Fogarty et al. 2023). Because of this, it is

important to highlight that even though shrub species play a small role in nest habitat use by wild turkeys, it is crucial to instead provide nesting habitat by increasing visual obstruction near treed areas through other means in grassland systems. Specifically, establishing native grasses and native woody-stemmed plants such as wild plum (*Prunus americana*) species that reach the height requirement sought out by nesting females (25-50 cm) may be the most successful avenue for producing wild turkey nest habitat in Kansas. Even more specific, allowing those native grasses to reach the height requirements for adequate visual obstruction (i.e., >25 cm) may be crucial around the riparian areas females are restricted to which can be facilitated through rotational grazing, erosion management via riparian fencing, and prescribed burning (Lyons et al. 2000, Fulgoni et al. 2020, Kauffman et al. 2022, Lituma et al. 2022). This may prove difficult, as 22% of nests where habitat surveys were conducted noted being in areas that had either direct or indirect observation of livestock at the time of the survey; 40% of Kansas is used for grazing (Kansas State University Extension 2026); Winter grazing can significantly affecting the VOR available for ground nesting birds in the following nesting season (West and Messmer 2006). Previous studies have also concluded wild turkeys will not nest in overutilized pastures when moderate to deferred grazing pastures are available even though non-nesting adult use appears to be equal among short duration and continuous grazing paddocks (Merrill 1975). This attraction of wintering flocks to areas of high grazing intensity has uninvestigated chain reactions to subsequent nest-site dispersal (Schulz and Guthery 1987). While the stocking rate was unknown for pastures in my study, stocking rate of grasslands can significantly impact the probability of nest survival and remains a possible issue for nest failure in grasslands (Sabatier et al. 2015). Because of these predicaments, future research may benefit from investigating the effects of grazing on wild turkey nest habitat in Great Plains states.

Research may also benefit from increasing understanding around use and availability of roost sites during the breeding season in grassland states, as wild turkeys rely on arboreal roosting until the laying period is complete, and incubation has begun. Published research on roost-tree selection during the reproductive stage is limited, but recent findings suggest that female wild turkeys have high fidelity to specific roost trees during the breeding period (Bakner et al. 2024b). With only 5% of the state being forested and even less area containing trees meeting the large trunk diameters and crown heights required by wild turkeys to roost (M. Ware, unpubl. data), nest-site selection by wild turkeys in Kansas likely goes beyond what is measured at the nest bowl as in this chapter. Nest-site selection by wild turkeys is likely anchored by woodland extent and access to roosting “hubs”, leading to restrictive habitat availability (Moser et al. 2013, Bakner et al. 2024b). This anchoring results in limited habitat space and quality for even general dispersion across the landscape, confining the remaining hierarchical selection decisions a female needs to make for nesting into a small, discrete area.

Looking forward, habitat management for nesting wild turkeys in Kansas can rely confidently on increasing visual obstruction up to 50-cm high, specifically immediately around the riparian areas that provide the treed habitat to which they are anchored. Because the 10-m radius measurements of the nest site had virtually no effect on the use of locations for nesting in comparison to the point-level (nest bowl) measurements, heterogenous grassland patches with varying cover may be adequate to facilitate use at minimum. However, survival consequences of nesting in a homogenous patch that consistently provides >70% VOR up to 50 cm may be different from those in heterogenous patches. Croplands, for example, such as winter wheat, provide a similar VOR as grasslands but virtually have more congruency to what is randomly available in the patch creating homogeneity. That homogeneity decreased precision of an

obvious selection pattern; however, croplands had near double the apparent nest success (29%) compared to grasslands (18%) in my sample. Because the consequences of selection (i.e., nest survival) are the direct factor influencing population persistence, wild turkey research in Kansas should naturally begin to investigate the effects of selection decisions on nest mortality. After concluding that two hierarchical decisions are being made by females, first a 300-m restriction to trees and subsequent selection of dense visual obstruction, future assessment can focus instead on quantifying how other life-history processes such as conspecifics and roost tree availability are affecting the nesting habitat available.

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Tables and Figures

Table 1.1. Mean and standard deviation ($\bar{x} \pm \text{SD}$) of landscape-scale measurements of 633 wild turkey nest locations and 18538 random locations across three regions (East, Central, West) in Kansas, USA, 2025-2025. All variables, except for patch area, are proximity measurements measured in meters. For example, the “crop” variable mean reports the mean distance from nest-site locations to the nearest cropland edge in meters. Patch area is reported in hectares and represents the total patch area a nest (or random location) was located.

Region	Nest Locations					
	Crop $\bar{x} \pm \text{SD}$	Urban $\bar{x} \pm \text{SD}$	Stream order 3-9 $\bar{x} \pm \text{SD}$	Stream order 1-2 $\bar{x} \pm \text{SD}$	Tree $\bar{x} \pm \text{SD}$	Patch Area $\bar{x} \pm \text{SD}$
East	864.52 $\pm$ 1067.31	341.81 $\pm$ 310.12	1156.26 $\pm$ 1079.17	216.63 $\pm$ 197.41	24.77 $\pm$ 39.44	26.87 $\pm$ 47.33
Central	356.09 $\pm$ 475.97	388.12 $\pm$ 360.38	1376.27 $\pm$ 1201.95	188.75 $\pm$ 179.04	40.33 $\pm$ 49.5	25.55 $\pm$ 32.56
West	591.28 $\pm$ 701.8	443.66 $\pm$ 402.14	1589.88 $\pm$ 1656.03	170.1 $\pm$ 172.44	38.37 $\pm$ 47.79	6.66 $\pm$ 13.03
pooled	618.7 $\pm$ 836.48	385.48 $\pm$ 356.16	1349.82 $\pm$ 1311.34	194.43 $\pm$ 185.37	33.74 $\pm$ 45.84	20.84 $\pm$ 36.7
Region	Random Locations					
	Crop $\bar{x} \pm \text{SD}$	Urban $\bar{x} \pm \text{SD}$	Stream order 3-9 $\bar{x} \pm \text{SD}$	Stream order 1-2 $\bar{x} \pm \text{SD}$	Tree $\bar{x} \pm \text{SD}$	Patch Area $\bar{x} \pm \text{SD}$
East	977.99 $\pm$ 1249.32	384.64 $\pm$ 372.05	1680.28 $\pm$ 1268.38	244.51 $\pm$ 194.77	89.62 $\pm$ 120.42	77.26 $\pm$ 472.74
Central	462.34 $\pm$ 621.28	539.77 $\pm$ 438.04	1871.95 $\pm$ 1391.52	227.56 $\pm$ 196.78	102.39 $\pm$ 114.26	38.96 $\pm$ 115.21
West	469.92 $\pm$ 648.48	633.07 $\pm$ 447.4	1761.05 $\pm$ 1584.36	256.22 $\pm$ 195.35	224.35 $\pm$ 223.06	42.98 $\pm$ 419.39
pooled	662.18 $\pm$ 952.93	506.41 $\pm$ 429.23	1767.41 $\pm$ 1406.34	242.08 $\pm$ 195.93	131.64 $\pm$ 165.09	54.77 $\pm$ 373.77

Table 1.2. Mean and standard deviation ($\bar{x} \pm \text{SD}$) of habitat measurements recorded at 453 wild turkey nests and 905 random locations within 400 m of a nest. The study took place across 3 study regions (East [$n = 161$], Central [$n = 168$]), and West [$n = 124$]) in Kansas, USA, during 2024-2025. Variables were measured at 1 m around the nest bowl and repeated at 10 m from the nest bowl. Grass, forb, woody, bare ground, and litter are compositional percentages measured inside a 1-m quadrat. Visual obstruction readings (VOR) are percentages measured at 0-25 cm (VOR 1), 25-50 cm (VOR 2), 50- 75 cm (VOR 3), and 75-100 cm (VOR 4) tall.

Variable	Nest Locations			Random Locations		
	East	Central	West	East	Central	West
	$\bar{x} \pm \text{SD}$	$\bar{x} \pm \text{SD}$	$\bar{x} \pm \text{SD}$	$\bar{x} \pm \text{SD}$	$\bar{x} \pm \text{SD}$	$\bar{x} \pm \text{SD}$
Nest grass	33.1 $\pm$ 30.07	39.30 $\pm$ 30.97	34.90 $\pm$ 31.83	45.62 $\pm$ 30.26	57.51 $\pm$ 27.17	48.36 $\pm$ 29.24
Nest forb	19.89 $\pm$ 22.66	12.17 $\pm$ 18.10	19.24 $\pm$ 25.57	21.22 $\pm$ 19.39	14.66 $\pm$ 17.10	17.86 $\pm$ 21.97
Nest woody	25.67 $\pm$ 27.50	27.05 $\pm$ 30.79	16.97 $\pm$ 27.30	10.05 $\pm$ 18.06	8.70 $\pm$ 18.55	5.57 $\pm$ 15.36
Nest bare	2.62 $\pm$ 5.93	3.15 $\pm$ 7.36	4.37 $\pm$ 7.39	5.56 $\pm$ 10.66	4.23 $\pm$ 9.35	9.15 $\pm$ 16.12
Nest litter	18.99 $\pm$ 16.98	18.22 $\pm$ 17.38	24.32 $\pm$ 22.06	17.78 $\pm$ 19.56	14.83 $\pm$ 14.24	18.92 $\pm$ 18.72
VOR 1	95.65 $\pm$ 13.41	93.99 $\pm$ 13.51	93.53 $\pm$ 15.37	91.57 $\pm$ 16.15	87.20 $\pm$ 18.96	83.17 $\pm$ 23.71
VOR 2	88.18 $\pm$ 17.59	76.48 $\pm$ 21.89	79.19 $\pm$ 24.18	68.55 $\pm$ 28.8	55.44 $\pm$ 31.76	53.17 $\pm$ 32.28
VOR 3	67.73 $\pm$ 25.84	49.70 $\pm$ 28.94	55.95 $\pm$ 32.86	44.02 $\pm$ 31.91	31.98 $\pm$ 29.83	31.74 $\pm$ 31.38
VOR 4	50.22 $\pm$ 29.73	29.92 $\pm$ 28.63	36.85 $\pm$ 31.26	30.01 $\pm$ 28.63	19.12 $\pm$ 24.4	22.01 $\pm$ 28.50
10-m grass	41.08 $\pm$ 26.09	50.97 $\pm$ 23.44	40.84 $\pm$ 24.08	44.28 $\pm$ 25.83	54.48 $\pm$ 22.96	44.70 $\pm$ 23.12
10-m forb	23.61 $\pm$ 19.73	15.45 $\pm$ 16.47	21.43 $\pm$ 21.02	22.47 $\pm$ 16.76	13.93 $\pm$ 13.92	16.65 $\pm$ 15.60
10-m woody	13.36 $\pm$ 14.8	10.92 $\pm$ 14.76	7.47 $\pm$ 13.61	8.16 $\pm$ 11.24	7.59 $\pm$ 12.90	5.75 $\pm$ 11.65
10-m bare	5.22 $\pm$ 7.68	4.83 $\pm$ 8.13	7.41 $\pm$ 11.08	6.32 $\pm$ 8.59	6.32 $\pm$ 9.67	11.71 $\pm$ 14.41
10-m litter	16.79 $\pm$ 13.31	17.90 $\pm$ 13.09	23.00 $\pm$ 19.15	18.88 $\pm$ 17.79	17.66 $\pm$ 13.65	21.21 $\pm$ 17.21
10-m VOR 1	93.5 $\pm$ 12.10	90.02 $\pm$ 15.43	89.48 $\pm$ 17.32	90.98 $\pm$ 15.31	86.12 $\pm$ 17.19	80.69 $\pm$ 22.28
10-m VOR 2	81.52 $\pm$ 19.28	63.97 $\pm$ 25.68	68.46 $\pm$ 26.16	68.32 $\pm$ 26.94	53.74 $\pm$ 28.77	50.47 $\pm$ 29.03
10-m VOR 3	60.7 $\pm$ 27.05	39.95 $\pm$ 29.36	44.19 $\pm$ 27.36	44.4 $\pm$ 29.44	31.38 $\pm$ 28.74	31.45 $\pm$ 28.57
10-m VOR 4	44.67 $\pm$ 27.56	25.79 $\pm$ 27.15	30.43 $\pm$ 25.48	31.00 $\pm$ 27.34	19.94 $\pm$ 24.47	22.76 $\pm$ 26.76

Table 1.3. Model ranking of probability of use for 633 nest locations of wild turkeys in Kansas, USA, 2024-2025 where proximity measurements, patch type, and patch area with study region (East, Central, West) were tested as interactive effects. Proximity measurements included the distance to the nearest tree, grassland, cropland, stream orders 1-2, stream orders 3-9, and urban features. Patch types included grassland, cropland, shrubland, forest, and water.

Model^a	<i>K</i>	AIC_c	ΔAIC_c	<i>w_i</i>	Log Likelihood
tree*region	6	5052.45	0.00	1.00	-2520.22
tree	2	5088.73	36.28	0.00	-2542.36
Patch type	7	5394.62	342.17	0.00	-2690.31
patch*region	21	5397.07	344.62	0.00	-2677.51
stream39*region	6	5497.16	444.71	0.00	-2742.58
stream39	2	5506.80	454.35	0.00	-2751.40
urban*region	6	5507.19	454.74	0.00	-2747.59
urban	2	5510.48	458.04	0.00	-2753.24
stream12*region	6	5521.02	468.57	0.00	-2754.51
stream12	2	5525.59	473.14	0.00	-2760.80
Patch size*region	6	5527.45	475.01	0.00	-2757.73
Patch size	2	5530.15	477.70	0.00	-2763.08
crop*region	6	5560.66	508.21	0.00	-2774.33
null	1	5564.79	512.34	0.00	-2781.40
crop	2	5565.46	513.01	0.00	-2780.73

^a Model = main and interactive effects model titles, *K* = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, *w_i* = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 1.4. Model performance for nest habitat selection of 453 wild turkey nests in Kansas, USA, during 2024-2025 at the nest bowl by visual obstruction readings (VOR) at four heights: 0-25 cm (VOR 1), 25-50 cm (VOR 2), 50-75 cm (VOR 3), and 75- 100 cm (VOR 4). Region and patch type were used as interactive effects, where region represents the study region (East, Central, West) in Kansas, and patch type represents 4 patch types that nests were observed within (grassland, shrubland, forest, and cropland).

Model^a	<i>K</i>	AIC_c	ΔAIC_c	<i>w_i</i>	Log Likelihood
n_vor2*patch	8	1551.17	0.00	0.36	-767.53
Quadratic_n_vor2*patch	9	1551.41	0.24	0.32	-766.64
Quadratic_n_vor2*region	7	1552.30	1.12	0.21	-769.11
n_vor2*region	6	1554.07	2.90	0.09	-771.00
n_vor2	2	1557.57	6.40	0.01	-776.78
Quadratic_n_vor2	3	1559.32	8.14	0.01	-776.65
n_vor3*patch	8	1595.56	44.39	0.00	-789.73
n_vor3	2	1597.86	46.68	0.00	-796.92
n_vor3*region	6	1598.12	46.95	0.00	-793.03
n_vor4	2	1653.80	102.63	0.00	-824.90
n_vor4*region	6	1655.49	104.31	0.00	-821.71
n_vor4*patch	8	1660.63	109.46	0.00	-822.26
n_vor1*patch	8	1678.60	127.43	0.00	-831.25
n_vor1	2	1682.70	131.53	0.00	-839.35
n_vor1*region	6	1688.79	137.62	0.00	-838.36
null	1	1731.24	180.07	0.00	-864.62

^a Model = main and interactive effects model titles, *K* = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, *w_i* = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 1.5. Model performance for nest habitat selection of 453 wild turkey nests in Kansas, USA, 2024-2025 at the nest bowl by ground cover composition of 5 functional plant groups (grass, forbs, litter, woody vegetation, and bare ground). Region and patch type were used as interactive effects, where region represents the study region in Kansas (East, Central, West) and patch type represents 4 patch types that nests were observed within (grassland, shrubland, forest, and cropland).

Model^a	K	AIC_c	ΔAIC_c	<i>w_i</i>	Log Likelihood
woody*patch	8	1551.17	0.00	0.36	-767.53
woody	2	1551.41	0.24	0.32	-766.64
woody*region	6	1552.30	1.12	0.21	-769.11
grass*patch	8	1554.07	2.90	0.09	-771.00
grass	2	1557.57	6.40	0.01	-776.78
grass*region	6	1559.32	8.14	0.01	-776.65
bare	2	1595.56	44.39	0.00	-789.73
bare*region	6	1597.86	46.68	0.00	-796.92
bare*patch	8	1598.12	46.95	0.00	-793.03
litter	2	1653.80	102.63	0.00	-824.90
litter*patch	8	1655.49	104.31	0.00	-821.71
litter*region	6	1660.63	109.46	0.00	-822.26
null	1	1678.60	127.43	0.00	-831.25
forb	2	1682.70	131.53	0.00	-839.35
forb*region	6	1688.79	137.62	0.00	-838.36
forb*patch	8	1731.24	180.07	0.00	-864.62

^a Model = main and interactive effects model titles, *K* = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, *w_i* = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 1.6. Model performance for nest habitat selection of 453 wild turkey nests in Kansas, USA, during 2024-2025 at a 10-m radius around each nest bowl by visual obstruction readings (VOR) at 4 heights: 0-25 cm (VOR 1), 25-50 cm (VOR 2), 50-75 cm (VOR 3), and 75- 100 cm (VOR 4). Region and patch type were tested as interactive effects, where region represents the study region (East, Central, West), and patch type represents 4 patch types that nests were found (grassland, shrubland, forest, and cropland).

Model^a	<i>K</i>	AIC_c	ΔAIC_c	<i>w_i</i>	Log Likelihood
Quadratic radius_vor2*region	7	1659.51	0.00	0.53	-822.71
radius_vor2*region	6	1660.59	1.08	0.31	-824.26
radius_vor2	2	1663.05	3.54	0.09	-829.52
Quadratic radius_vor2	3	1663.60	4.09	0.07	-828.79
Quadratic radius_vor2*patch	9	1670.25	10.74	0.00	-826.06
radius_vor2*patch	8	1670.96	11.46	0.00	-827.43
radius_vor3	2	1680.95	21.44	0.00	-838.47
radius_vor3*region	6	1681.42	21.91	0.00	-834.68
radius_vor3*patch	8	1688.97	29.46	0.00	-836.43
radius_vor4	2	1699.92	40.41	0.00	-847.96
radius_vor4*region	6	1702.99	43.48	0.00	-845.46
radius_vor1	2	1708.98	49.47	0.00	-852.48
radius_vor4*patch	8	1709.20	49.69	0.00	-846.55
radius_vor1*region	6	1714.63	55.12	0.00	-851.28
radius_vor1*patch	8	1714.96	55.45	0.00	-849.43
null	1	1731.24	71.73	0.00	-864.62

^a Model = main and interactive effects model titles, *K* = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, *w_i* = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 1.7. Model performance for nest habitat selection of 633 wild turkey nests in Kansas, USA, during 2024-2025 at the nest bowl by ground cover composition of 5 functional plant groups (grass, forbs, litter, woody vegetation, and bare ground). Region and patch type were tested as interactive effects, where region represents the study region (East, Central, West) and patch type represents 4 patch types that nests were found (grassland, shrubland, forest, and cropland).

Model^a	<i>K</i>	AIC_c	ΔAIC_c	<i>w_i</i>	Log Likelihood
litter	2	1711.63	0.00	0.80	-853.81
litter*region	6	1715.89	4.26	0.10	-851.91
litter*patch	8	1716.02	4.39	0.09	-849.96
grass	2	1719.85	8.22	0.01	-857.92
forb*patch	8	1725.73	14.10	0.00	-854.81
grass*region	6	1726.80	15.16	0.00	-857.37
forb	2	1727.17	15.54	0.00	-861.58
grass*patch	8	1727.22	15.59	0.00	-855.56
woody	2	1727.95	16.31	0.00	-861.97
null	1	1731.24	19.60	0.00	-864.62
bare	2	1733.21	21.58	0.00	-864.60
woody*region	6	1733.80	22.16	0.00	-860.87
forb*region	6	1734.86	23.23	0.00	-861.40
woody*patch	8	1736.05	24.42	0.00	-859.97
bare*region	6	1738.58	26.95	0.00	-863.26
bare*patch	8	1739.55	27.92	0.00	-861.72

^a Model = main and interactive effects model titles, *K* = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, *w_i* = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 1.8. Model performance for nest habitat selection of 453 wild turkey nests in Kansas, USA, 2024-2025 at the nest bowl by ground cover composition of 5 functional plant groups (grass, forbs, litter, woody vegetation, and bare ground) and visual obstruction readings (VOR) at 4 heights: 0-25 cm (VOR 1), 25-50 cm (VOR 2), 50-75 cm (VOR 3), and 75- 100 cm (VOR 4). Region and patch type were tested as interactive effects, where region represents the study region in Kansas (East, Central, West) and patch type represents four patch types that nests were found (grassland, shrubland, forest, and cropland). This particular model set was the culmination of most parsimonious models selected from 4 previous model suites, with the addition of the visual obstruction interaction with woody composition (n_vor2*woody) at the nest bowl and the interaction of woody composition at the nest bowl with litter composition at a 10 m radius (woody*x10litter).

Model^a	K	AIC_c	ΔAIC_c	w_i	Log Likelihood
n_vor2*woody	4	1499.27	0.00	1.00	-745.62
quad_n_vor2*patch	8	1551.17	51.90	0.00	-767.53
nest_woody*patch	8	1598.99	99.71	0.00	-791.44
woody*x10litter	4	1603.47	104.19	0.00	-797.72
quad_radius_vor2*region	7	1659.51	160.23	0.00	-822.71
x10litter	2	1711.63	212.36	0.00	-853.81

^a Model = main and interactive effects model titles, K = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, w_i = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 1.9. Results of a post-hoc, pairwise t-test using a Bonferroni corrected alpha-value and un-pooled standard deviation. The nine pairwise comparison groups include three regions in Kansas (East, Central, West) and used nest sites (1) versus available (0) locations within 400 m of 453 wild turkey nests in Kansas, USA, 2024-2025. Woody-stemmed plant composition was measured at the locations using a 1-m 2 quadrat. Visual obstruction readings (VOR) at 25-50 cm were measured using a 50 cm wide coverboard with 25 cm vertical sections. The asterisk (*) denotes significance for pairwise comparisons at $\alpha = 0.05$.

Pairwise comparison			Woody-stemmed plant composition			Visual obstruction at 25-50 cm		
			df ^a	t-statistic	p-adju	df	t-statistic	p-adju
Among-region used comparisons	East (1)	Central (1)	318.031	-0.427	1.00	306.452	5.309	<0.0005*
	West (1)	Central (1)	282.076	-2.940	0.0533	256.961	0.983	1.00
	West (1)	East (1)	272.145	-2.691	0.1136	221.308	-3.530	0.0076*
Used-random comparisons	East (1)	East (0)	236.911	6.614	<0.0005*	473.910	9.370	<0.0005*
	Central (1)	Central (0)	219.577	6.959	<0.0005*	434.338	8.520	<0.0005*
	West (1)	West (0)	167.302	4.371	<0.0005*	323.066	8.804	<0.0005*
Among-region random comparisons	East (0)	Central (0)	649.499	0.945	1.00	641.939	5.519	<0.0005*
	West (0)	Central (0)	570.944	-2.214	0.4089	535.330	-0.846	1.00
	West (0)	East (0)	573.269	-3.234	0.0194*	506.262	-5.966	<0.0005*
Across region and used-random comparisons	East (1)	Central (0)	242.451	7.139	<0.0005*	482.928	14.642	<0.0005*
	West (1)	Central (0)	173.680	3.140	0.0298*	300.724	8.542	<0.0005*
	East (0)	Central (1)	215.303	-6.481	<0.0005*	404.217	-3.387	0.0116
	West (0)	Central (1)	211.543	-8.223	<0.0005*	409.525	-8.745	<0.0005*
	West (1)	East (0)	170.201	2.641	0.1357	270.270	3.989	0.0013*
	East (1)	West (0)	231.568	-8.555	<0.0005*	403.336	-14.283	<0.0005*

^a df = degrees of freedom, t-statistics = test statistics, p-adju = Bonferroni corrected alpha-value

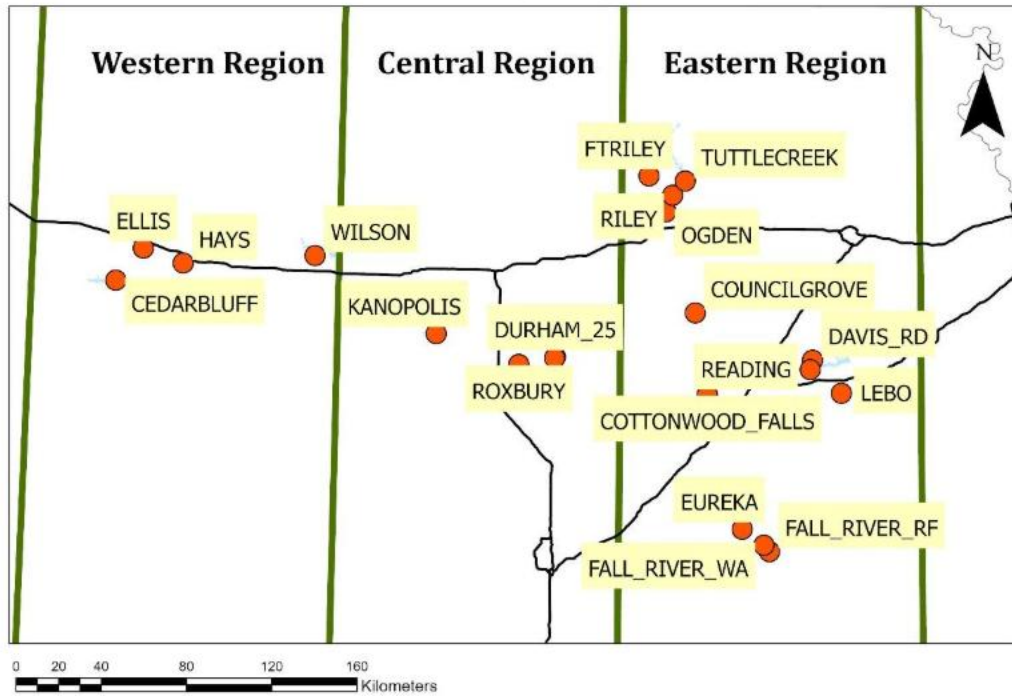


Figure 1.1. Three study regions (East, Central, and West) across 19 different sites where wild turkeys were captured and marked with 140-g G5-T2A Iridium backpack units with global positioning systems (GPS) and Very High Frequency (VHF) radio components in Kansas, USA, during 2024-2025.

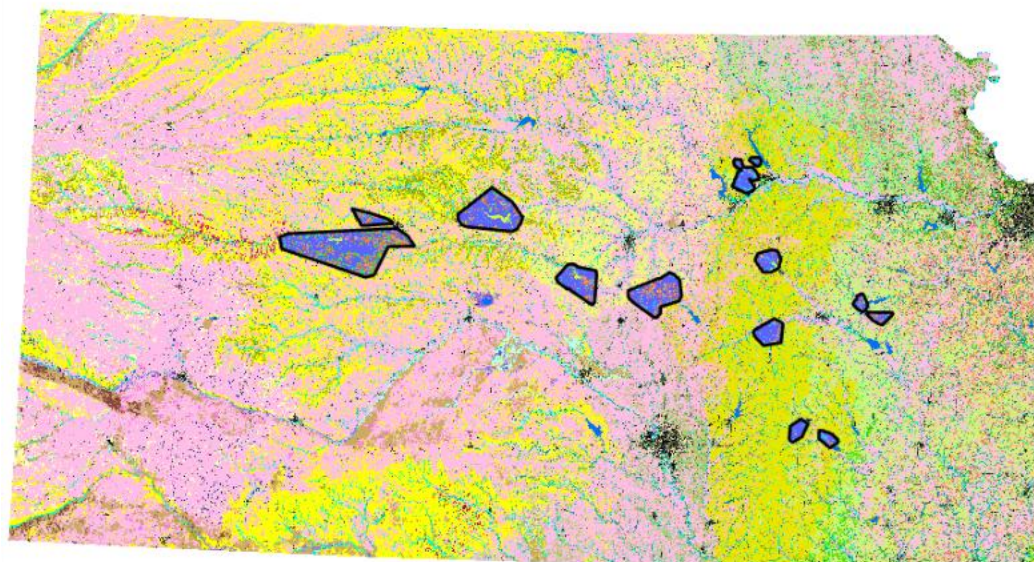


Figure 1.2. Minimum convex polygons placed around wild turkey movement locations across 19 capture site locations in Kansas, USA. Movement locations were collected remotely using GPS backpack transmitters placed on 399 female wild turkeys during the nesting season (April-July) during 2024 -- 2025.

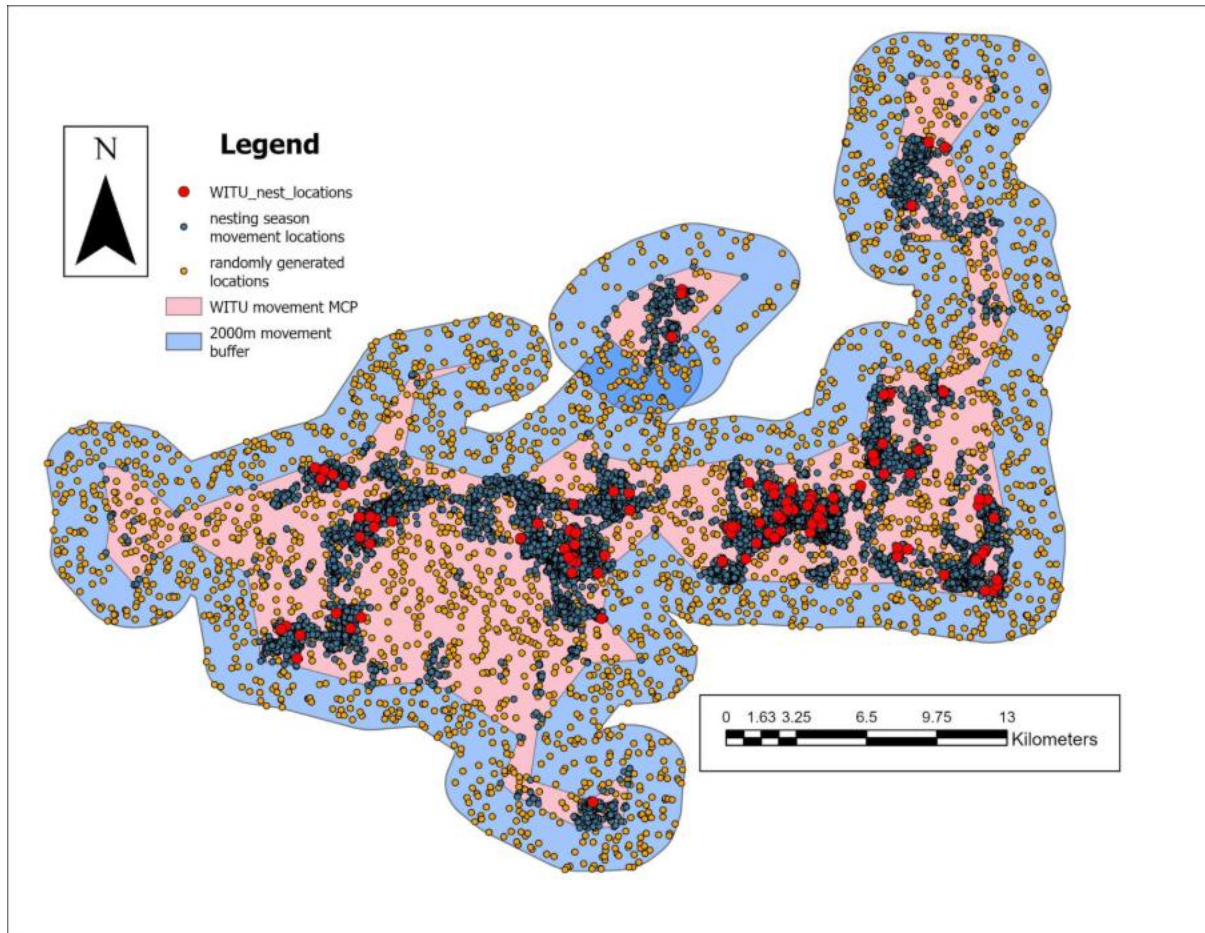


Figure 1.3. An example of movement points, nest locations, and randomly generated locations for 76 nesting female wild turkeys in the Central study region near Durham and Roxbury capture sites, Kansas, USA during 2024 - 2025.

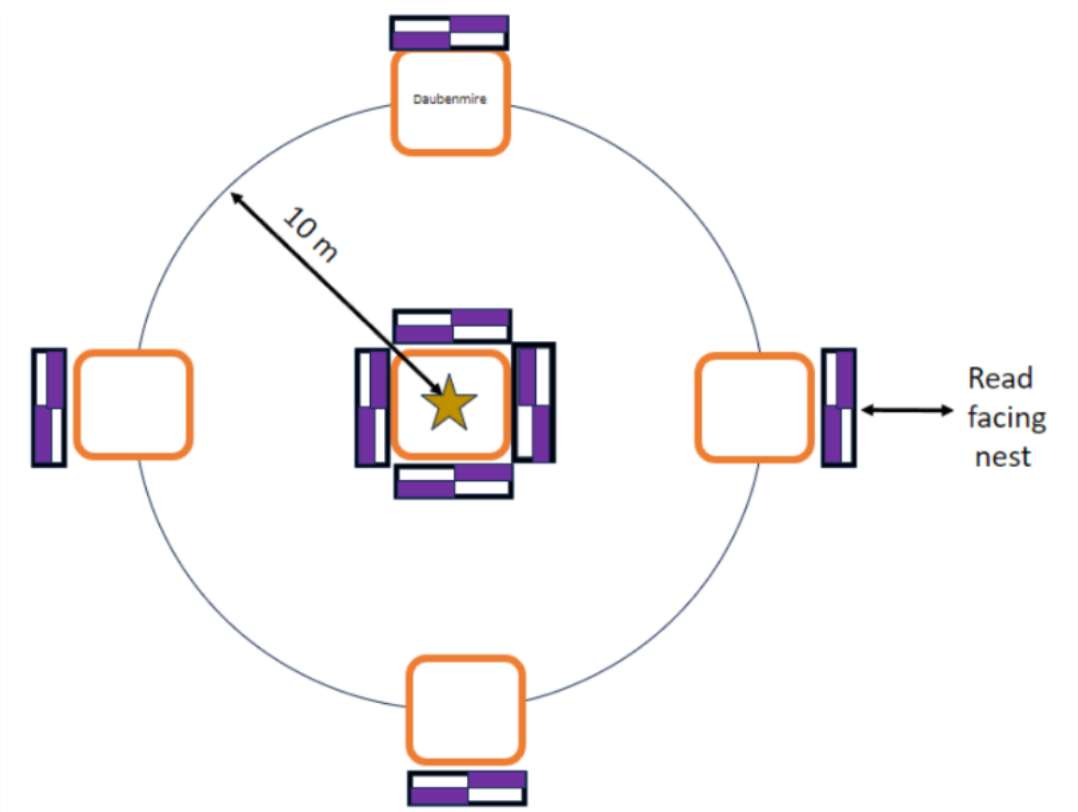


Figure 1.4. Survey design for measuring vegetation characteristics at 453 wild turkey nests across Kansas, USA, during 2024-2025. The star in the center represents the nest or associated random point location, the orange squares represent the 1-m² quadrat used to estimate horizontal cover, and the checkered rectangles show points at 10-m from the center point where each ocular coverboard reading was recorded to estimate vertical cover (always standing 10m away).

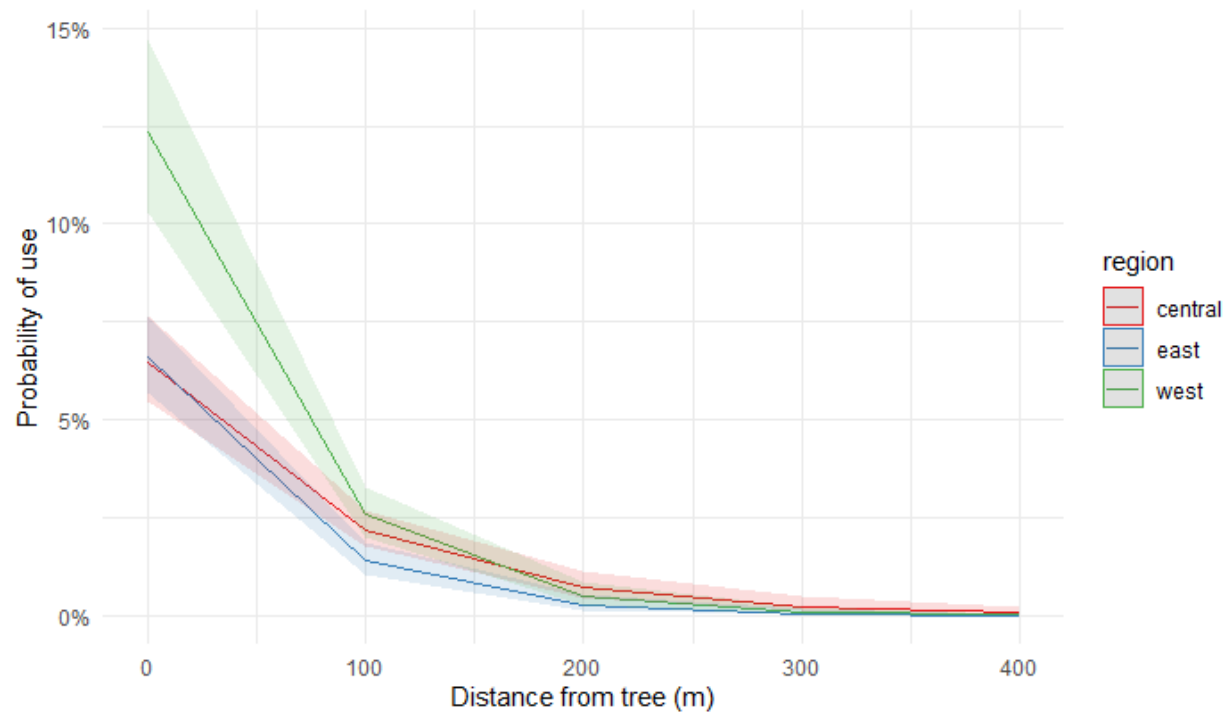


Figure 1.5. Resource selection function ($\text{glm}(y \sim \text{tree_dist} * \text{region}, \text{family} = "binomial")$) results for wild turkey nest sites ($n = 633$) using interactive effects between the distance of a location to the nearest tree and study region (East, Central, West) in Kansas, USA. Data were collected during the nesting season (April-July) of 2024-2025.

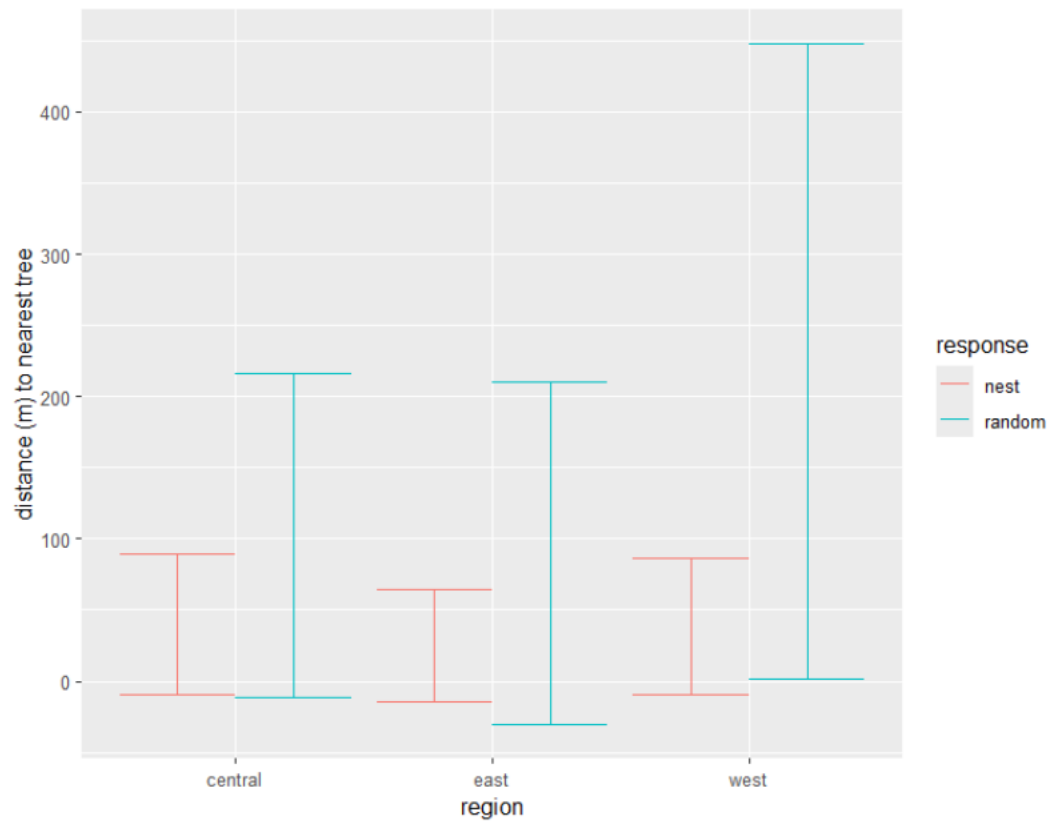


Figure 1.6. Means and standard deviations for tree proximity of 633 wild turkey nest locations and randomly sampled sites. Randomly sampled sites ($n = 30$ points per known nest) were generated within a 2,000-m buffer of a minimum convex polygon placed around all known movement locations collected per each capture site ($n = 13$), from a pooled total of 385 female wild turkeys using GPS backpack transmitters during 2024-2025.

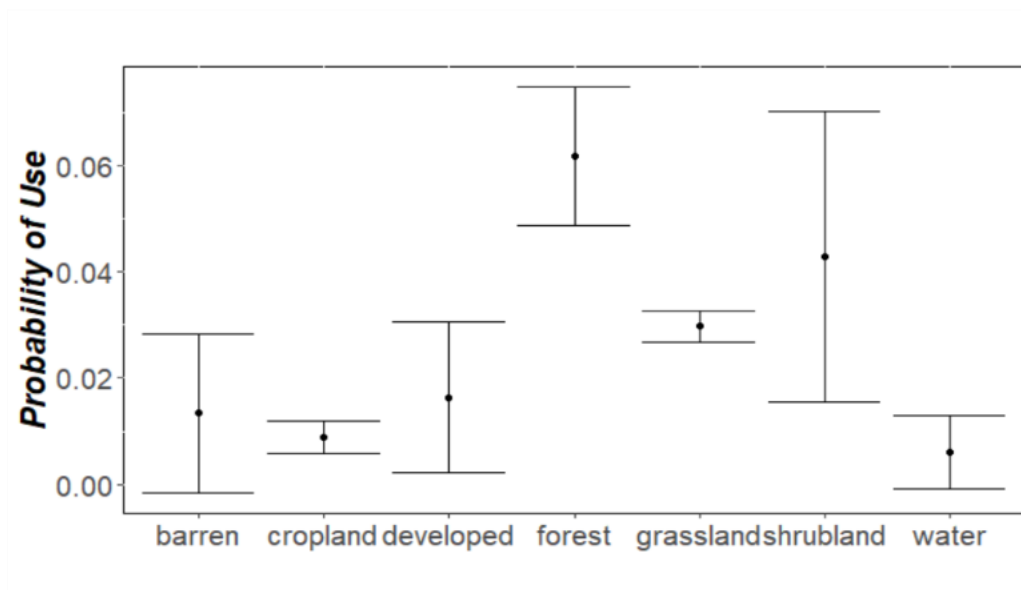


Figure 1.7. Means and standard errors of the relative probability of use for 633 wild turkey nest sites among patch types across Kansas, USA, for 633 nests monitored during 2024- 2025

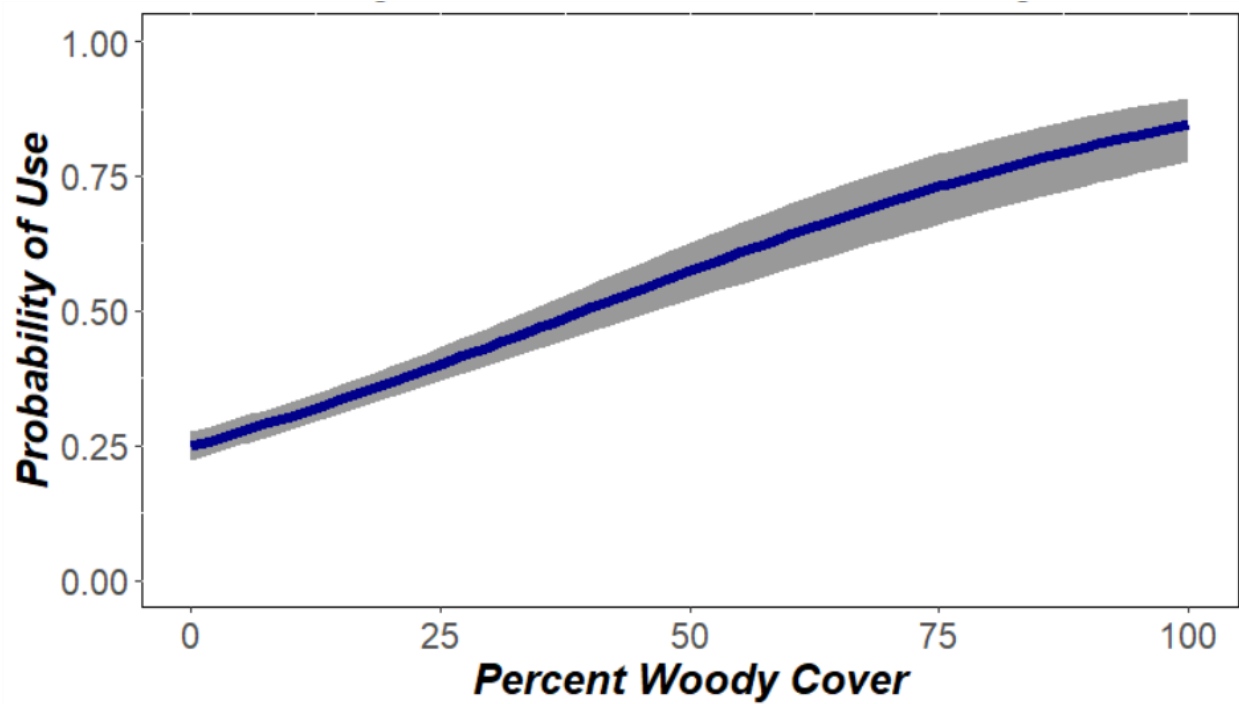


Figure 1.8. Resource selection model ($\text{glm}(y \sim \text{woody}, \text{family} = \text{"binomial"})$) result for 453 wild turkey nest sites using percent woody ground cover within 1-m of the nest bowl. Ground cover composition was measured using a 1-m² quadrat placed around the nest bowl as well as 2 random locations within 400 m of the nest during 2024-2025 in Kansas, USA.

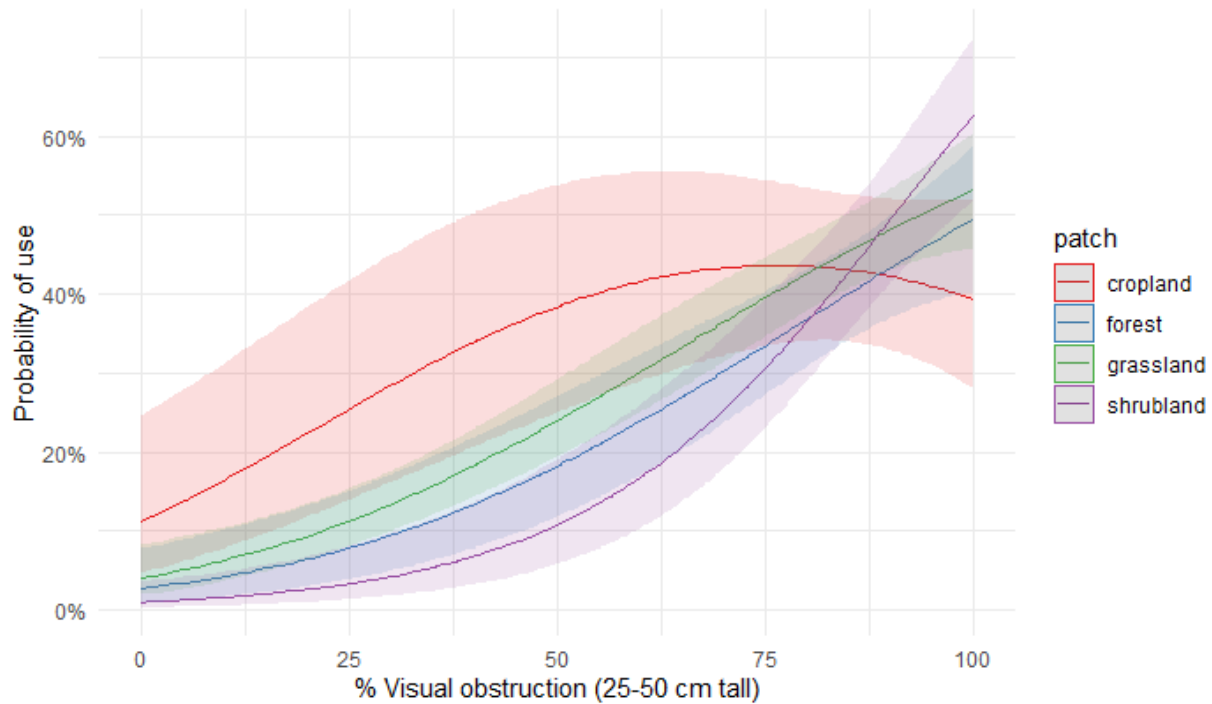


Figure 1.9. Resource selection model ($\text{glm}(y \sim n_vor2 * \text{patch}, \text{family} = "binomial")$) results for 453 wild turkey nests in Kansas, USA, during 2024- 2025. The model was testing the interactive effects between percent visual obstruction (% VOR) at the 25-50- cm height around the nest bowl and primary patch type within 100- m of the nest. Visual obstruction levels were measured using a 1- m tall by 0.50- m wide coverboard with 25- cm vertical height increment blocks. Patch type was determined by estimating the primary cover type within 100- m of the nest during field vegetation surveys. The paired random points for each nest were collected within 400- m within the same patch type following the nest vegetation survey.

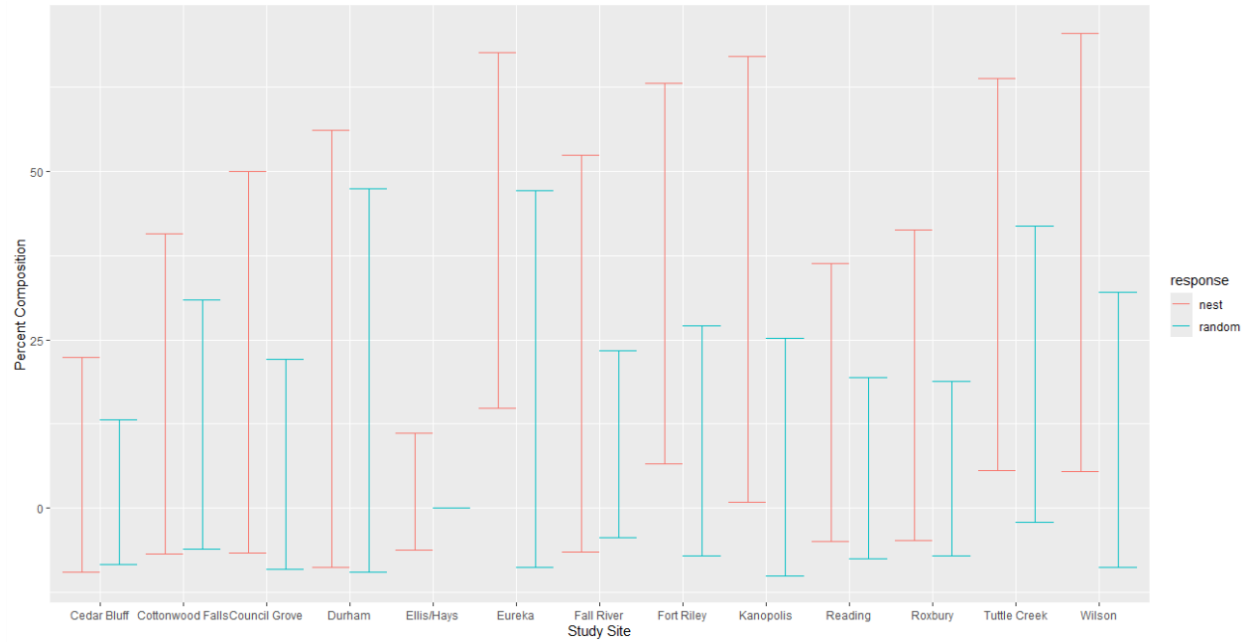


Figure 1.10. Means and standard deviations of the estimated percent woody composition with a 1-m² quadrat placed around 453 wild turkey nests and randomly sampled locations across 13 study sites in Kansas, USA, during 2024 - 2025. Randomly sampled sites ($n = 2$ locations per known nest) were located within 400 m of each nest.

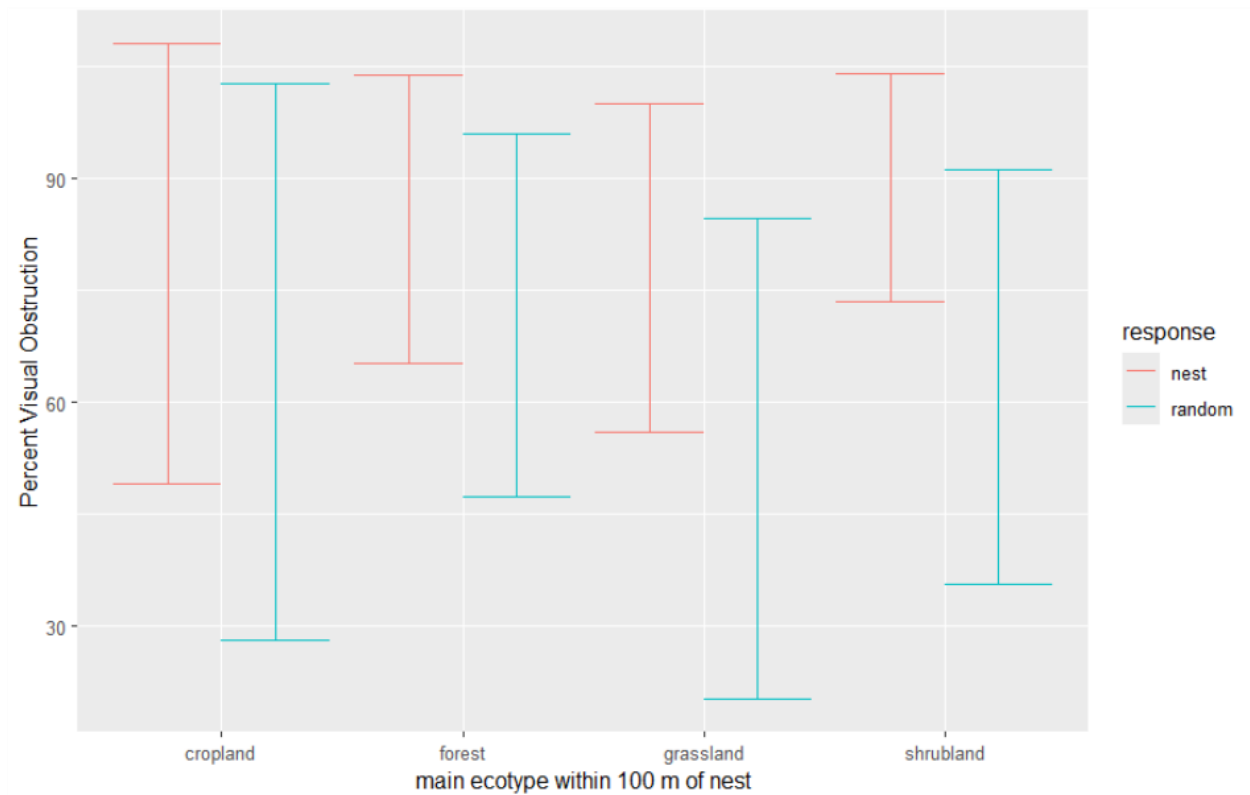


Figure 1.11. Means and standard deviations of the estimated percent visual obstruction at 25-50 cm tall around 453 wild turkey nests and randomly sampled locations across four ecotypes in Kansas, USA, during 2024 - 2025. Randomly sampled sites ($n = 2$ locations per known nest) were located within 400 m of each nest and within the same patch. Percent visual obstruction was measured using a 1- m tall by 0.50 m wide coverboard with 25 cm vertical height increment blocks. Patch type was determined by estimating the primary cover type within 100 m of the nest during field vegetation surveys.

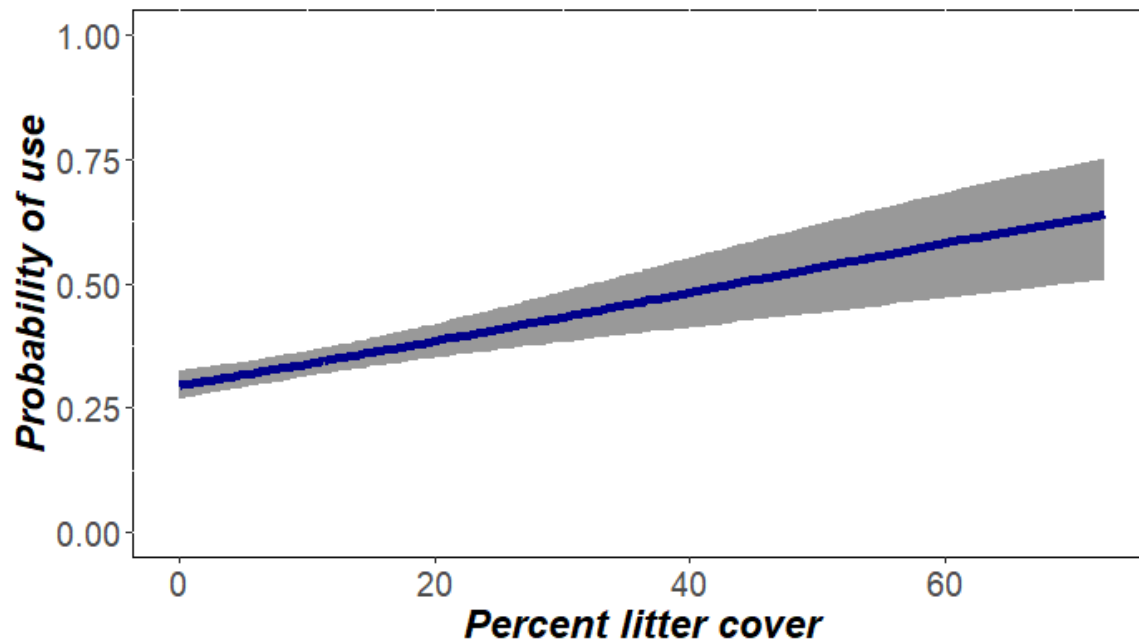


Figure 1.12. Resource selection model ($\text{glm}(y \sim x10\text{litter}, \text{family} = \text{"binomial"})$) result for 453 wild turkey nest sites using percent litter ground cover averaged across composition readings from 4 quadrats placed 10-m away from the nest bowl, one in each cardinal direction.

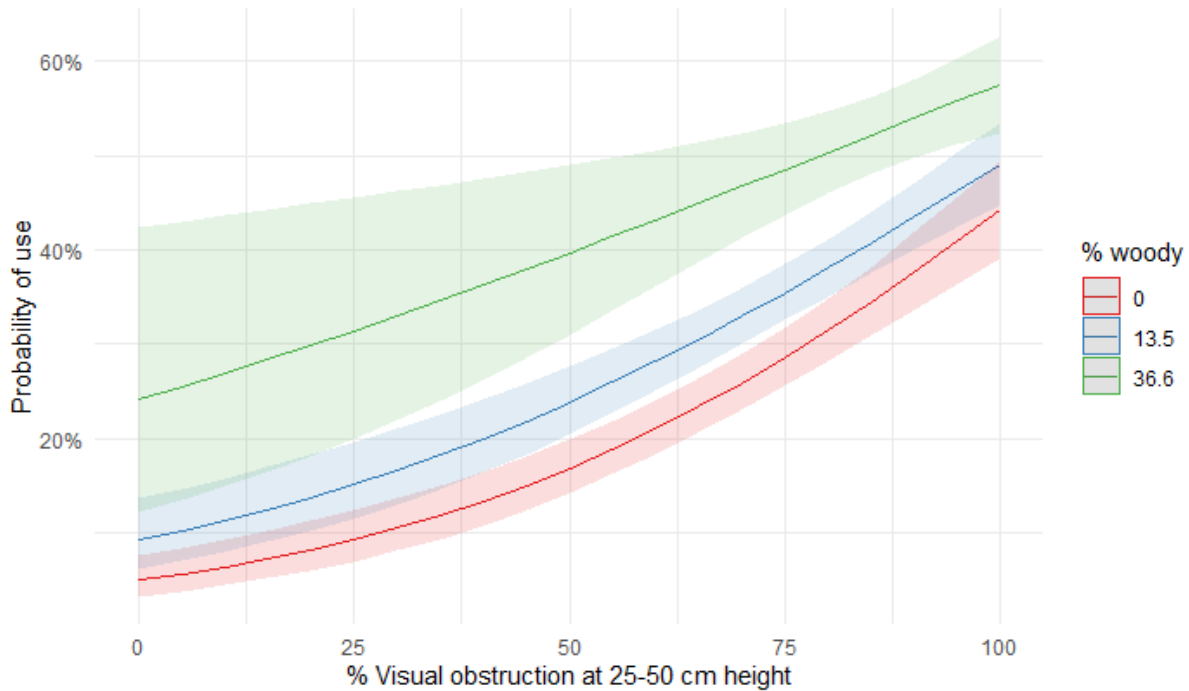


Figure 1.13. Resource selection model ($\text{glm}(y \sim \text{n_vor2} * \text{woody}, \text{family} = "binomial")$) results for wild turkey nest sites using interactive effects between percent woody composition and percent visual obstruction (% VOR) at the 25-50 cm height around the nest bowl. Percent woody composition values (% woody) used as the marginal effects values are the lowest possible value (0), mean, and upper standard deviation from the mean of the sampled nest habitat in 2024-2025 across three regions (East, Central, and West) in Kansas, USA.

Chapter 2 – Success, daily survival rate, and phenology of wild turkey nests in Kansas

Introduction

Ground-nesting birds endure precarious nesting conditions, often experiencing lower nest success when compared to arboreal nesting birds (Flaspohler et al. 2001). To survive a period of such high mortality risk to the nest and attending females, individuals must correctly make an array of possible decisions for nest-site selection to maximize the probability of reproductive success. These decisions mostly involve predator avoidance by selecting nest sites in proper settings for their plumage to function as camouflage within a decision matrix including an advantageous landscape configuration, adequate patch area, and distance to patch edges highly trafficked by predators (Angelstam 1986, Manolis et al. 2002, Troscianko et al. 2016).

Additionally, increasing anthropogenic influences require nesting birds to rapidly adapt to contemporary human management practices and shrinking availability of high-quality nesting habitat patches. Without rapid adaptation, species are at risk of relying on previously reliable behavioral patterns that no longer benefit their fitness, falling into ecological traps (Boal and Mannan 1999, Roberston and Hutto 2006). This adaptation includes awareness of evolutionarily novel features such as livestock presence, the deadly threat of haying, and proximity to human-made features to inform decisions by wild birds for maximizing female and nest survival (Fondell and Ball 2004, Gruebler et al. 2008, Hall et al. 2010, Webb et al. 2012).

Even after a female makes the necessary series of decisions leading to nest placement, nest fate remains somewhat random. Determination of direct versus indirect causes of nest failure have been difficult to discern for ground nesting birds due to unobserved sequences of

events leading to failure, such as the possibility of nest predators consuming the nest only after events of female abandonment. Most unsuccessful nests are subject to the coincidence that a predator accidentally encounters a nest by venturing outside of established corridors or occurrence of a stochastic extreme weather event (e.g., flood, hail);. The probabilities of both events are increasing with landscape alterations and climate change, respectively (Mainwaring et al. 2016, Doherty and Driscoll 2018, Ferreira et al. 2018, Nelson et al. 2023). Departures from average precipitation or increased events of high humidity and rainfall are known to cause increases in nest failure for ground-nesting species (Roberts and Porter 1998, Webb et al. 2012). Obtaining local and current information on intrinsic and extrinsic factors influencing the daily survival rate of ground-nesting birds is pertinent to their population management.

Ground-nesting birds comprise much of a group crucial to North American conservation funding via the 1937 Pittman-Robertson Act, game birds. Although their own distinct guild, ground-nesting game birds act as a catalyst for public support relative to conservation that benefits a large range of wildlife species (Brennan and Kuvlesky 2005). Game birds are unique in that waterfowl and grouse have had an estimated population increase of about 25% since the early 1970s while most other bird guilds are a part of the estimated 3 billion bird loss over multiple decades (Rosenburg et al. 2019). This aberrant increase in comparison to other bird guilds can be attributed to the fact that game birds were hunted to near-extinction levels in the 19th century and brought back from the brink of extinction due to the dedication of hunters and other conservationists realizing this mistake, imposing stricter harvest regulations, and implementing large-scale habitat management strategies. Actions contributing to the reversal of declining population required extreme conservation efforts such as translocations, complete hunting bans in the early to mid-20th century to return them to American landscapes today, and

development of large-scale management strategies (e.g., North American Waterfowl Management Plan).

The wild turkey (*Meleagris gallopavo*) is one such example of conservation success due to intensive management actions. Their recovery during the past 75 years was the result of widespread relocations throughout the eastern and Midwest United States beginning in the 1950s, finally reaching an open spring season in Kansas in 1974 (Capel 1973, Hlavachick and Blair 1997). However, there is now a suspected near-nationwide population decline starting in the mid-2000s in the eastern United States that is progressing westward with severity varying among states. Initial responses to these declines include rendering smaller bag limits and cancelled hunting seasons, which detrimentally affects the economic, cultural, and sociologic aspects of a state wildlife department (Heffelfinger et al. 2013, Arnett and Southwick 2015, Cooper et al. 2015, Chapagain et al. 2020). To change this negative population trajectory, state wildlife departments require investigations on how to prioritize management of wild turkey habitats for the primary causes contributing to the population decline.

Similar to many states, annual brood surveys conducted by Kansas, USA, indicate the population decline has been occurring since at least 2008 following occurrence of peak wild turkey population in the early 21st century. The result of this decline has caused the recent cancellation of the fall hunting season in 2023 and reduction in bag limits following reports of an estimated 40% decline in the Kansas wild turkey population (Gavilan Group 2020). The cause(s) of this decline, as in many states, is unknown and rooted in observations of alarmingly low poult to female ratios such as 0.3 (Butler et al. 2007, Byrne et al. 2015, Shields 2023). This estimate is much below the required estimated minimum ratio of three to one to support a stable wild turkey population and indicates that Kansas may be experiencing inadequate nest or poult survival

(Rolley et al. 1998). While the previous issue of overharvest was a clear culprit of the 18th to 19th century game bird decline, researchers are testing a multitude of hypotheses to investigate the many potential explanations of population declines (Byrne et al. 2015, Nielsen et al. 2018, Boone et al. 2023, Keever et al. 2023, Quehl et al. 2024). One such question for managing ground-nesting birds is fundamental to any population: is wild turkey quality nesting habitat a limiting factor, and thus decreasing their chances of nest success?

Inference around wild turkey quality nest habitat and reproductive success has mostly been derived from the forested southeastern United States, which is beneficial to a holistic understanding of wild turkey ecology but not fully applicable to grassland-dominant areas. Results from these studies indicate that during the incubation state, ground-nesting birds disproportionately use nest sites with relative greater visual obstruction, and females who initiate nests earlier in the breeding season may have increased nest success compared to others (Keever et al. 2023). As a precocial species who leave the nest within hours following hatching, a female must have also placed her nest within traveling distance of a forb-dense patch for the survival of her brood to complete a fully successful reproductive cycle (Wood et al. 2019). Despite these generalities, there remains a lack of understanding for how these factors of nest-site restriction in grassland dominant landscapes affect the resulting female productivity. Landscape attributes such as patch type, patch area, and feature (i.e. roads, edges) proximities appear to influence nest-site selection but have little support for affecting nest survival (Thogmartin 1999). Similarly, selection of increasing visual obstruction by nesting wild turkeys is strongly supported, yet few studies provide evidence that it affects nest success in any way (Little et al. 2016, Yeldell et al. 2017, Moscicki et al. 2025). Because of the geographic and consequential

nuances that occur in wild turkey nest habitat use and nest success, it is crucial to investigate possible limiting factors of nest survival in Kansas.

A female wild turkey must choose a nesting location to endure ~28 days of elevated mortality risk from weather, predators, and a variety of environmental disturbances from livestock and humans (e.g., trampling, haying) to complete a successful incubation. Current hypothesized limiting factors of wild turkey nest success range from negative effects of early harvest season dates to time of nest initiation outweighing benefits of habitat quality (Keever et al. 2023, Quehl et al. 2024). In Kansas, availability of expansive grasslands intermixed with low availability of woodlands is one of the more unique aspects affecting how wild turkeys must select nesting habitat compared to the majority of current research conducted in the heavily forested eastern United States. In the Great Plains system, female wild turkeys are restricted to using nesting habitat within a reasonable (<300 m) distance to arboreal roost sites they require for decreasing predation during any period they are not incubating (Swearigin et al. 2010; Chapter I). The sharp negative east-to-west precipitation in Kansas creates a negative gradient of relative roost tree availability, thus indirectly limiting nest-site availability.

My study goal was to investigate factors affecting nest success that can be addressed via habitat management techniques to increase wild turkey nest success in Kansas. My research question addressed the fundamental considerations necessary to develop conservation strategies for wild turkeys in Kansas – what intrinsic and extrinsic variables influence nest success and does nest-site selection ultimately influence success? Based on these findings, I further assessed at what scale, such as the regional, state-management unit, or landscape patch-level, does this pattern present itself? My objectives were to: 1) estimate nest survival based on geographic extent (wild turkey hunting management unit, study region), 2) determine the effect of female

age on nest success, 3) evaluate the predictive power of nest vegetation components on nest survival, and 4) assess the predictive power of landscape context surrounding the nest, on nest survival. I hypothesized that because female wild turkeys use greater visual obstruction within 25-50 cm heights and woody-stemmed plant composition around the nest bowl, both variables will result in greater nest daily survival (Chapter I). Lastly, I predict that nest survival will be negatively related to distance to edges such as roads and woodlands due to the greater densities of nest predators often found near edges, especially in agricultural landscapes (Chalfoun et al. 2002, Manolis et al. 2002).

Study area

My study area encompassed the eastern two-thirds of Kansas, split into 3 study regions. These regions were delineated by the following longitudinal boundaries: East (-96.96 to -95.50), Central (-98.49 to -96.96), and West (-100.15 to -98.49; Figure 1.1). From east to west, the 3 regions represent a negative precipitation gradient along with a gradual shift from tallgrass to mixed-grass, and finally short-grass prairies. Grasses common to the entire study area included little bluestem (*Schizachyrium scoparium*), side-oats grama (*Bouteloua curtipendula*), and switchgrass (*Panicum virgatum*). Common forbs include ragweed (*Ambrosia psilostachya*), yellow sweet clover (*Melilotus officinalis*), Illinois bundleflower (*Desmanthus illinoensis*), and annual sunflower (*Helianthus annuus*). Species most often comprising Kansas riparian areas were bur oak (*Quercus macrocarpa*), hackberry (*Celtis occidentalis*), black walnut (*Juglans nigra*), American elm (*Ulmus americana*), rough-leaf dogwood (*Cornus drummondii*), coral berry (*Symphoricarpos orbiculatus*), and Virginia wild rye (*Elymus virginicus*; Haddock 2024).

Common predators of female wild turkeys, their nests, and broods in Kansas were bobcat (*Lynx rufus*), coyote (*Canis latrans*), great horned owl (*Bubo virginianus*), raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), and striped skunk (*Mephitis mephitis*; Thogmartin and Schaeffer 2000, Yeldell et al 2017, Crawford et al. 2021, Nielsen et al 2021).

To describe the composition of my study system, I placed a 95% minimum convex polygon around movement locations recorded from each unique capture flock (13 total) from 2024-2025 (Figure 1.2). I then averaged the landcover values derived from the Kansas Ecological Monitoring dataset among the 13 capture sites within each study region to report the landscape compositions and used the U.S. Department of Agriculture Cropland CROS dataset to report all agriculture-based compositions in 2024 (Boryan et al. 2011, Diamond et al. 2021). All study regions were grassland dominant, with the majority (>65%) of open grasslands being used for livestock grazing throughout the state (Boryan et al. 2011). The West study region contained the largest percentages on average of cropland and mixed-grass prairie (31%, 55% of total area, respectively). The Central study region was composed of the second-highest mean cropland cover, with about 23% of the total area dedicated to cropland and 58% remaining as a combination of tallgrass and mixed-grass prairies. Both the West and Central study regions had <5% forested cover, primarily represented by riparian areas scattered throughout each region. The primary cover types in the East study region were tallgrass prairie (65%) and various forms of woodlands (15%). Cropland cover was the lowest in the East study region with 11% coverage. Primary crops in the West study region were winter wheat (*Triticum aestivum*, 11% mean total cover) and grain sorghum (*Sorghum bicolor*, 10% mean total cover). Winter wheat (9% mean total cover) was the primary crop in the Central study region followed by grain sorghum (*Sorghum, bicolor*, 4%), soybeans (*Glycine max*, 4%), corn (*Zea mays*, 3%), and alfalfa

(*Medicago sativa*, 1%). Soybeans (7% mean total cover) was the primary crop in the East study region. Urban intensity was low in all 3 study regions, with 1% in the East study region compared to 0.35% in the Central study region and 0.55% in the West study region.

Weather metrics during 2024–2025 nesting seasons (Apr-Jun) were derived from county-level weather averages (PRISM 2025). Mean precipitation across the study area was 9.8 cm (SD = 5.3) in 2024 and 11.8 (SD = 5.8) in 2025. Mean temperature across the study area from April to June was 19.3° C in 2024 and 18.1° C in 2025. By region, 2024 precipitation across the East, Central, and West study regions, was respectively 11.9 cm (SD = 4.3), 7.4 cm (SD = 5.6), and 6.9 cm (SD = 4.3). Precipitation slightly increased in 2025 by region at 13.7 cm (SD = 6.1), 11.2 cm (SD = 6.4), and 7.6 cm (SD = 1.5) in East, Central, and West study regions, respectively. Mean temperature for East, Central, and West study regions was 19.4° C, 19.5° C, 18.8° C in 2024, respectively. In 2025, mean temperature by region was slightly cooler at 18.2° C, 18.0° C, and 17.6° C for east, central. and west regions.

Methods

Field Capture and Monitoring

I captured female wild turkeys using baited drop, walk-in, and rocket nets on private and public lands during winter (Jan-Mar) 2024 and 2025. All captured female wild turkeys received aluminum, pop-rivet leg bands with unique numeric identifiers and contact information for reporting recoveries. I measured the mass (kg), tarsus length (cm), wing chord (cm), and exposed culmen length (cm) length for all birds, in addition to spur length (cm) and beard length (cm) for females who had them. All females were aged based on plumage characteristics; juveniles were

classified as any female with white banding to the tip of the primaries as well as pointed tips of the first primary (Pyle 2008). Adults were identified by a lack of white banding all the way to the end of the primaries, and a rounded end of the first primary feather.

I fitted each female that exceeded a mass of 4.0 kg with a 156-g Global Positioning System (GPS), G5-T2A Iridium backpack style transmitter with a very-high-frequency (VHF) component (Advanced Telemetry Systems, Isanti, MN). Transmitters were secured as a backpack using marine-grade shock cord with knots tied at each attachment point and secured with super-glue. Once deployed, transmitters recorded GPS locations six times per day at 0300, 0700, 1100, 1500, 1900, and 2300 during the breeding season (Mar 1 – Aug 1), 2024 and 2025. Locations were uploaded from the GPS transmitter to the Iridium system every three to five days.

I reviewed movement patterns of each transmitted female weekly during the breeding season to monitor for indications of the bird entering the laying, incubating, or brood-rearing reproductive states. I identified the laying state as daily repeated (>3) visits to a similar location (<100 -m radius). Incubation state initiations were identified and determined by the female spending at least one night roosting on the ground in a nonforested location. For females nesting in forested areas, I considered the incubation state to be initiated once the female dramatically decreased her daily step-lengths and was roosting in the same general location of the laying area for at least 24 hours (Carpenter et al. 2022). I estimated an average incubation period of 28 days to determine the estimated hatch date of all nests and determined a nest to be failed when a female permanently left the nest or died before incubation day 26 (Healy 1992, Conley et al. 2016).

Apparent nest success and phenology

I report results of wild turkey nest success by year, capture site, and region. This includes apparent nest success, mean nest attempts per female, and number of females that died during a nesting attempt. I report apparent nest success as the total number of successful nests (>1 hatched egg and/or poult observed) divided by the total number of all nests monitored, including multiple attempts. I report individual apparent nest success by dividing the number of successful nests by the number of female wild turkeys that initiated at least one nest throughout each breeding season. For phenological data, I report all dates as the Julian Date grouped by study region, year, and Kansas Department of Wildlife and Parks (KDWP) wild turkey management unit and year (KDWP 2025). I provide the earliest and latest Julian Dates of incubation initiation, including Julian Date quantiles for when 25%, 50%, and 75% of all nests had initiated incubation for each group listed.

Landscape-level nest assessment

I used the Environmental Systems Research Institute's ArcGIS Pro Geospatial Information System 3.3.0 to classify landcover compositions and measure distances to variables of interest. Land cover compositions were based on Kansas Ecological Systems "Mapping Kansas Ecosystems" (KEMS) 2023 data layer. This layer was a 10 x10-m cell raster product created by the Kansas Biological Survey via remotely sensed data and field-based sampling sites to define landcover types across the state (Peterson and Moody 2024). This layer defined 49 vegetation groups in Kansas, including cover types such as eastern floodplain forest, mixed-grass prairie, western lowland grasses, and mixed oak-hickory woodland. To simplify this layer for the patch-based nest survival analysis, I combined vegetation groups with similar functional characteristics

into the following groups: woodland, grassland, shrubland, and cropland. I defined the “patch group” of each nest location as one of these four patch group polygons.

I defined edges at the landscape scale by generating a 20-m half-width buffer around the polylines created from the KEMs polygon layer of different patch types, creating a total buffer width of 40 m around all patch edges. Using this 40-m wide buffer, I counted the total number of nests that occurred within that buffer and classified them as nests within an “edge” patch type. Because previous studies have instead used a 60-m half-width buffer, I also conducted the same edge-definition process with a 120-m wide buffer (Thogmartin 1999). I used the Near geoprocessing tool to measure the Euclidian distance from each nest location to the perimeter of the nearest patch type and features of interest. These included distance to trees, water features, cropland, the previously defined 20-m and 60-m edge buffers, and human development such as roads or houses. For estimating the distance to tree, I had three versions of what defines a “tree” to account for the varying uses a wild turkey has for such a widely varying object on the landscape. Firstly, these versions include “EarthDefine tree”, in which I used a polygon shapefile created from a 5-m resolution raster file purchased from EarthDefine to classify tree locations; EarthDefine tree accounts for all possible trees, including those that may provide shelter for loafing or foraging as this layer captures trees such as small eastern red cedars across a grassland. This layer was created using the 2021 National Agriculture Imagery Program imagery. The second version of tree I used for modeling nest success was known roost-site locations (M. Ware, unpublished data), which includes locations of all known arboreal roosting areas across the study areas as female wild turkeys require arboreal roosting immediately before and after the incubation period. Lastly, the third definition of trees was the “woodland” cover type of the

KEM polygon layer, representing the distance to treed riparian areas in general. I report mean and standard deviation (SD) for all measured landscape metrics grouped by study regions.

Nest vegetation surveys

I conducted vegetation surveys at wild turkey nests following either successful completion or failure of the nest. I measured habitat values at two scales of the nest location, the first scale being directly at the nest bowl and the second scale being a 10-m radius around the nest bowl, henceforth the nest site (Figure 1.4). At the nest bowl, I placed a 1x1-m vegetation frame around the nest bowl (GPS location of the nest if no eggs were found) and recorded the percent composition of five ground cover functional groups: grass, forbs, residual litter, bare ground, and woody-stemmed vegetation. I then placed a coverboard along one of the four edges of the 1x1-m modified Daubenmire frame, walked 10 m from the nest and recorded the percent visual obstruction at four height categories at the height of 1 m (Nudds 1977). The coverboard was 0.5 - m wide by 1.0-m tall with 0.25-m tall sections of alternating color contrasts to denote four total VOR height categories (0-0.25 m, 0.25-0.50 m, 0.50-0.75 m, and 0.75- 1.0 m above ground). I report the mean values within each height category (0-0.25 m, 0.25-0.50 m, 0.50-0.75 m, and 0.75- 1.0 m above ground) at the nest bowl.

I conducted a similar habitat assessment at the nest site (10-m radius around the nest bowl). For this scale, I measured habitat (vegetation frame, coverboard readings) at four locations, 10 m from the nest bowl, one in each cardinal direction. This resulted in a total of four, 1x1-m vegetation frame compositions being recorded for each of the five functional groups (grass, forbs, residual litter, bare ground, and woody-stemmed vegetation), which I then averaged across each functional group (Figure 1.4). I report the mean value from the four

vegetation frame readings and use this mean value to represent functional ground cover composition at the nest site (10-m radius around the nest bowl). I recorded the coverboard readings only on one side of the vegetation frame by walking 10 m from the coverboard again, now 20 m from the nest bowl, and recorded the percent visual obstruction at the same four height categories (0-0.25 m, 0.25-0.50 m, 0.50-0.75 m, and 0.75- 1.0 m above ground). I then averaged the percent visual obstruction across each height category and used the mean values of each height category to represent visual obstruction at the nest site in subsequent nest survival rate analyses. I report all field-collected measurements as means with standard deviations by study region.

Nest daily survival rate (DSR) analysis

I conducted all realized daily nest survival analyses using the Nest Survival model in Program MARK, assuming a 28-day incubation period for wild turkey nests (Rotella 2009). Although previous studies removed any nest attempts past the initial attempt, I retained all attempts in this analysis due to second and third attempt nests comprising a notable amount (24% and 9%, respectively) of successful nests over our two-year study in Kansas (Boone et al. 2023). I considered the constant DSR model without any covariates as the null model for all DSR model comparisons. To derive nest success from models using a constant daily survival (i.e., probability of a nest hatching at least one egg), nest exposure length was calculated using a 28-day encounter period based on a mean estimated 28-day incubation period (Healy 1992, Conley et al. 2015).

The initial model group tested was a two-model set, using only the 2025 nest sample to test for a three-level difference in nest success among female ages. These ages included juveniles

(after-hatch-year; females captured in 2025 as juveniles), known second-year females (juveniles captured in 2024), and greater than second-year females (adults captured in 2024). This set contained the only age-based model that tests three age levels compared to a null model. The second model set compared wild turkey nest survival among age (juvenile versus adult), survey year, study region, KEMS layer patch type, and KDWP management unit to test against the null model. All models in the initial two model sets were single-variable models, with no additive or interactive variables.

For the landscape-context DSR analysis, I modeled DSR as a function of each landscape proximity measurement: distance in meters of nests to the nearest KEMS woodland, roost tree, EarthDefine tree, road, edge buffer, small stream (stream orders 1-2), large stream (stream orders 3-9), and cropland. Additionally, for the landscape-level model set, I modeled DSR as a function of the patch group in which the nest occurred based on the KEMS layer similar to that of the second model set.

For the nest vegetation model set, I modeled DSR as a function of the vegetation variables recorded at the nest site during habitat surveys in single-variable models. This included modeling DSR by ground composition of functional groups (grass, forbs, bare ground, litter, and woody stemmed vegetation) at the nest bowl, 25-50 cm tall visual obstruction percentage at the nest bowl, and mean ground composition of functional groups 10 m around the nest bowl. Visual obstruction within 25-50 cm tall was specifically selected to model nest survival due to selection for the variable by female wild turkeys (Chapter I).

Lastly, I combined selected and compared competitive models from each model set to determine which hierarchical level of management and measurement influenced nest success in

Kansas. I ranked all models based on Akaike Information Criterion corrected for small sample sizes (AIC_c) score and considered all models within a ΔAIC_c of <2.0 as competing models (Burnham and Anderson 2002). I report the model name, number of parameters (K), AIC_c value, ΔAIC_c value, model weight (ω_i), and Log Likelihood of each model. I estimated the nest survival of wild turkey nests, or the probability of a nest hatching at least one egg, within each group assuming a constant daily survival rate ($\hat{S}(.)$). I report the resulting nest success associated with lower (LCI) and upper (UCI) confidence intervals, as well as an estimated standard error (SE) calculated using the Delta method (Powell 2007).

Results

Capture and monitoring

I deployed GPS transmitters on 297 and 102 female wild turkeys in 2024 and 2025, respectively, with one recapture in 2025 for a total of 399 tracked birds over the two-year study (Table 2.1). Of those females, 232 females were captured on private lands and 167 females were captured on public lands. From the initial capture effort in 2024, 265 females survived to enter the nesting season (past Mar 15, Julian Date 75) of which 24.9% ($n = 66$) and 75.1% ($n = 199$) were juveniles and adults, respectively. In 2025, 225 females survived to enter the nesting season of which 42.2% were three years old or greater adults ($n = 95$) from the 2024 capture, 26.7% adults from the 2025 capture ($n = 60$), 17.3% second-year adults (i.e., juveniles captured in 2024, $n = 39$), 12% juveniles ($n = 27$), and 1.8% ($n = 4$) were of unknown age due to loss of data. These unknown-age females were removed from any age-based analysis and reporting. In total, the pooled dataset across both years and all sites was comprised of 71.9% adults and 27.1%

juveniles. From the captured sample, I remotely monitored the status of 330 wild turkey nests in 2024 and 303 nests in 2025 (Table 2.2).

Apparent nest success, propensity, and phenology

Apparent nest success of wild turkeys monitored in Kansas was 16.7% in 2024 and 17.8% in 2025, for a pooled success across all sites and years of 17.2% (Table 2.2). Of the female capture groups monitored across both years, females captured at Wilson Lake capture site in the West Region had the largest apparent nest success on average at 27.5% while the Reading capture site in the East Region had the lowest at 4% success (Table 2.2). Nearly a quarter (24.7%) of nests were on public land, with 14.8% of that portion on U.S. Army Corps of Engineers property, 28.2% on a U.S. Army Military Reservation, 4.0% within a Kansas State Park, and 53.0% on a KDWP wildlife management area. Apparent nest success of wild turkey nests on public lands was 18.8%, virtually equal to nest success on private lands, 17.8%.

The nests monitored were distributed across 203 individuals with a mean nesting attempt of 1.25 attempts per female in 2024, and 182 individuals with a mean nesting attempt of 1.33 attempts per female in 2025. Of the females that were captured and initiated at least one nest in 2024, 99 (48.8%) survived and initiated at least one nest during the 2025 breeding season. Apparent success separated by nest attempts 1-3 was similar in 2024 (10.6%, 4.5%, 1.2%) compared to 2025 (11.6%, 3.3%, 2.0%).

Nest propensity (i.e., proportion of transmitted birds that attempted at least one nest) was 76.6% in 2024 and 80.5% in 2025; However, a relevant note is that these values included 44 females that died during the nesting season in 2024 and 32 females that died during the nesting

season in 2025. After removing the breeding-season mortalities of zero-attempt females, the adjusted nest propensity values were 91.9% and 93.8% in 2024 and 2025, respectively. By age, juveniles had slightly lower nest propensity (87.3%) compared to adults (94.3%), again with breeding season mortalities removed. Of the females that attempted at least one nest, 51.4% nested only once, 33.5% attempted a second nest following failure of the first, and 14.6% attempted a third nest following failure of the first two. I recorded one female who successfully hatched her initial nest attempt on Julian Date 143 (May 23), had her brood fail, and successfully hatched a second nest in the same breeding season on Julian Date 205 (July 24) in which the brood failed as well. Two females were recorded up to four nesting attempts during the 2025 breeding season.

The mean Julian Date of laying initiation for the first nest attempt was almost a week later in the East Region ($\bar{x} = 113.39 \pm 12.87$) when compared to the Central Region ($\bar{x} = 107.78 \pm 11.51$; Table 2.3). Incubation initiations followed suit, at a mean Julian date of 123.03 ± 11.82 in the East Region and 116.56 ± 10.90 in the Central Region. The West Region had a mean laying initiation of Julian Date 111.15 ± 11.41 and a mean incubation initiation of 120.25 ± 11.58 . For all nesting attempts, 50% of incubation initiations were completed by Julian Date 121 in 2024, and 75% of incubation initiations were completed by Julian Date 153 (Table 2.3). In 2025, 50% of incubation initiations of all nesting attempts were completed by Julian Date 126 and 75% were completed by Julian Date 145 (Table 2.3). The earliest known incubation was initiated on Julian Date 97 (April 6), and the latest known incubation began on Julian Date 201 (July 20; Table 2.3). Adult females nested four days earlier ($\bar{x} = 110.18 \pm 12.06$) than juvenile females ($\bar{x} = 114.59 \pm 12.76$) on average, incubation initiations were also about four days earlier on average for adults ($\bar{x} = 119.27 \pm 11.61$) compared to juvenile females ($\bar{x} = 124.14 \pm 11.77$).

Females took 9.22 ± 4.14 days on average from the first estimated day of laying to reach the first day of incubation. Following failure of the first nest attempt, females who renested took a mean of 16.09 ± 8.67 days to exhibit laying behavior again, and 24.07 ± 8.16 days to begin incubating the second nest attempt. Of the females who initiated at least one nest, 26.3% died while incubating. This equates to 9% of nest failures being due to female mortality in 2024, and 12% of nest failures due to female mortality in 2025.

I was able to obtain estimated hatched egg counts for 88 successful nests, and of those nests, the mean value and standard deviation ($\bar{x} \pm SD$) was 6.68 ± 2.59 hatched eggs per nest. Nest attempts had similar means of hatched eggs among attempts (attempt one = 6.93 ± 2.5 hatched eggs; attempt two = 6.60 ± 2.39 hatched eggs; attempt three = 4.71 ± 3.15 hatched eggs). The maximum number of hatched eggs observed was 14, and the minimum was 1 egg.

Nest site use relative to landscape and vegetation at the nest

The majority (71.52%, $n = 432$) of wild turkey nests were in grassland patches based on the remotely sensed data layer from KEMS. Riparian woodlands were the second most common cover type of nests (18.87%, $n = 144$), followed by cropland (7.28%, $n = 44$), and finally shrubland (2.31%, $n = 14$). On average, nests were placed $618.7 \text{ m} \pm 836.48$ from the nearest cropland, $1349.82 \text{ m} \pm 1311.34$ from the nearest large stream order, $194.43 \text{ m} \pm 185.37$ from the nearest small stream order, $33.74 \text{ m} \pm 45.84$ from the nearest EarthDefine tree, $121.10 \text{ m} \pm 189.10$ from the nearest woodland defined by the KEMS layer, and $166.86 \text{ m} \pm 167.69$ from the nearest known roost tree.

I completed field-based vegetation surveys for 219 and 234 nests, respectively, in 2024 and 2025. I surveyed habitat for 127 nests in the western region, 161 nests in the central region,

and 165 nests in the eastern region. Of the field-sampled nests, forty-seven (10.4%) were in cropland, 106 (23.4%) in forest, 223 (49.2%) in grassland, and 77 (17.0%) in shrubland based on discernment of the primary patch type within 100 m of each nest. At the nest, percent woody composition and visual obstruction at 25-50 cm tall were different between used and available locations (Table 1.9). On average, wild turkeys nested in areas with 76.48-88.18% of visual obstruction at the 25-50 cm and woody-stemmed plant composition of 16.97-27.05% within 1-m of the nest bowl (Table 1.2; Figures 1.11, 1.12). Mean percent forb composition at the nest was greater in the West (19.24 ± 25.57) and East (19.89 ± 22.66) regions than Central (12.17 ± 18.10) Region, although widely variable among sites. Mean percent woody composition at the nest was lowest in the West Region (16.97 ± 27.30) compared to the Central (27.05 ± 30.79) and East (25.67 ± 27.50) regions.

Nest daily survival rate

DSR by age group – 2025

Although the single year, three age-group model ($K = 3$, $\Delta AIC_c = 1.16$, $w_t = 0.27$, Log Likelihood = 0.56) did not outcompete the null ($K = 1$, $\Delta AIC_c = 0.00$, $w_t = 0.48$, Log Likelihood = 1.00), my results provide biological evidence for nest success increasing with each year a female lives and nests. Nests of juvenile females had lower daily survival rates (DSR= 0.922, LCL = 0.892, UCL = 0.944, SE = 0.105) in comparison to females that were known to be greater than or equal to three years old (DSR = 0.941, LCL= 0.929, UCL= 0.952, SE = 0.078). Second-year females were not significantly different from either juveniles or third- year birds but did have survival estimates trending slightly above that of juvenile nests (DSR= 0.928, LCL = 0.905, UCL = 0.945, SE= 0.095). These values equate to juvenile females having a realized nest success

in 2025 of almost half that of third year females, at 10.2% and 18.4% nest success, respectively. Second year females had a realized nest success of 12.3% (DSR = 0.9279, LCL = 0.9054, UCL = 0.9454, SE = 0.0101).

Year, age, patch type, study region, ownership type, and KDWP management unit

Patch type was the most parsimonious categorical variable for modeling daily survival rate of wild turkey nests in comparison to KDWP management unit, female age (juvenile versus adult), breeding year, land ownership type (public versus private), and study region (Table 2.4).

However, nest success results of the remaining models are reported due to their management importance. For 2024-2025 combined, daily survival was greatest in Management Unit 2 (DSR = 0.948, LCL = 0.939, UCL = 0.956, SE = 0.075), with a realized nest survival of 0.227 ± 0.075 . Management Unit 4 had the lowest nest survival at 0.106 ± 0.067 (DSR = 0.923, LCL = 0.905, UCL = 0.937, SE = 0.067). Management Units 3 (DSR = 0.933, LCL = 0.924, UCL = 0.941, SE = 0.048) and 6 (DSR = 0.932, LCL = 0.914, UCL = 0.947, SE = 0.091) had virtually the same realized nest survival estimate at 0.144 ± 0.048 and 0.141 ± 0.091 survival, respectively.

Nest survival estimates were similar between survey years, at a realized nest success of 17.0% (DSR = 0.939, LCL = 0.931, UCL = 0.946, SE = 0.049) in 2024 and 14.9% (DSR = 0.934, LCL = 0.926, UCL = 0.942, SE = 0.047) in 2025. Private lands had the same estimated nest survival as public lands, at 0.175 ± 0.040 and 0.173 ± 0.070 , respectively. Adult females (≥ 2 years old at time of nesting) had a slightly greater but statistically similar nest survival estimate at 0.178 ± 0.040 compared to juvenile females' nest survival at 0.155 ± 0.081 .

Nest daily survival rate by landscape context

Refuting my hypothesis, daily survival rate of wild turkey nests in Kansas was not affected by the "edge effect" as commonly noted in predation papers. Distance to edges defined as either a 20-m or 60-m buffer around a patch perimeter did not perform competitively for predicting nest success. At the landscape level, nest daily survival rate was best predicted by the patch type where a nest was located; however, the relationship was weak (Table 2.5). Proximity to cropland appeared first to be a competitive model, but beta value of the parameter ($\beta = 0.0001 \pm 0.000$, LCL = -0.961, UCL = 0.0002) proved to be spurious and thus removed from consideration. Croplands supported the highest value of estimated daily nest survival rate ($S = 0.946 \pm 0.009$, LCL = 0.925, UCL = 0.961), followed by forest ($S = 0.951 \pm 0.005$, LCL = 0.939, UCL = 0.960), grassland ($S = 0.931 \pm 0.004$, LCL = 0.924, UCL = 0.938), and shrubland ($S = 0.920 \pm 0.022$, LCL = 0.865, UCL = 0.954). When these values are derived to nest survival, nest survival nearly doubles between forested patches and grassland patches at 0.242 ± 0.095 and 0.137 ± 0.365 , respectively. Nest survival also doubles when comparing between the 0.211 ± 0.143 nest survival in cropland patches to the 0.0984 ± 0.167 nest survival in shrubland patches.

Nest daily survival rate by vegetation at the nest

Refuting my original hypothesis and despite female wild turkey selection results (Chapter I), visual obstruction within a 25-50 cm height at the nest did not affect daily survival rate of wild turkey nests in Kansas (Table 2.6). Daily survival rate of wild turkey nests was instead most parsimoniously modeled using an additive model of composition of forbs at the 10-m radius around the nest and woody-stemmed vegetation around the nest bowl (Table 2.6). Mean forb composition at 10 m around the nest negatively affected nest daily survival rate ($\beta = -0.0085 \pm 0.003$, LCL = -0.0141, UCL = -0.0029) while composition of woody stemmed vegetation at the

nest bowl increased chances of success ($\beta = 0.0055 \pm 0.002$, LCL = 0.0014, UCL = 0.0095; Figure 2.3).

Discussion

Survival of wild turkey nests significantly differed among hunting management units, with the western management unit four having the smallest realized nest success, the central management unit two having the largest realized nest success, and finally the eastern management units three and six had similar values but between units four and two. The alarmingly low nest success in unit four could be attributed to that management area being on the westernmost edge of the negative precipitation gradient in Kansas, which leads to a lack of wooded riparian cover types used by wild turkeys in Kansas. This gradient likely limits the distribution of roost locations and subsequently nest sites available to wild turkeys in that region. Management units three and six, however, contain more expansive portions of wooded riparian cover types and availability of nesting habitat is likely not as limited due to roost tree availability within those units. Despite their differences, nest survival estimates of all units remained below historic estimates (~30-50%) that preceded the suspected population decline beginning in the early 2000s, indicating nest survival may be a limiting factor for wild turkey populations in Kansas (Table 2.7).

Similarities between nest survival estimates on public and private lands indicates the cause of low nest success in Kansas is not specific to management actions in either group. Declines in wild turkey nest success are ubiquitous among privately owned lands and publicly managed lands.

Despite statistical insignificance between age groups, the small but gradual increase in nest survival from juvenile females, to second year females, to three-year-old (or greater)

females provides reasonable support for a biological effect that is occurring. Previous studies came to similar conclusions, where adult females have a greater survival probability during the incubation period in comparison to juvenile females (Tyl et al. 2023). The conclusion of adult females having greater probabilities of nest success may be particularly pertinent for understanding wild turkey population trajectories, as many reports infer adult female survival is the most crucial vital for improving wild turkey growth rates (Lehman 2022, Londe 2023). Bet-hedging, where a female places her own survival as more important than survival of her nest, may be one explanation for poor juvenile success in a population where surviving to older ages is crucial. In subsequent years, we know that a female wild turkey will be physically larger and most likely more physically capable of egg production and predator protection compared to that of her first year following hatch (Vander Haegen et al. 1988).

Predators are the most referenced cause of nest failure in ground nesting birds due to either direct adult and egg mortality, followed by simple abandonment for bet-hedging towards adult survival (Manolis et al. 2002, Webb et al. 2012). Out of the 385 female turkeys that initiated at least one nest throughout 2024-2025, 17.1% (66 females) were killed while incubating a nest during my study. This being said, agriculture intensification may be introducing new prominent causes of nest failure for wild turkeys in ag-dominant regions (Tyl et al. 2020). Within this study, 100% of the nests that failed due to female abandonment were in a form of agriculture-related cover type; Of these abandoned nests, 40% occurred in grazed areas, 20% were due to smooth brome (*Bromus inermis*) mowing/haying, and 40% were located either entirely within or on the edge of harvested row-crop fields. Ground nesting birds are at risk of trampling or adult disturbance when the only available nesting habitat is available within grazed pastures; that risk likely increases with the density of grazers within that pasture (Johnson et al.

2012). Similarly, adults nesting in fields maintained for hay production or row-crops place themselves at risk of being pushed off the nest or killed by harvesting and mowing equipment (Tyl et al. 2020, 2023).

A juxtaposition to the relatively high number of abandonment cases within agriculture-related patches is the finding that one of the highest patch-based survival rates for nests was in croplands, while grasslands had one of the lowest of the four groups. Row-crop fields such as winter wheat and brome hay fields available across Kansas resemble the ideal nesting habitat for wild turkeys of dense visual obstruction up to 25-50 cm (C. Skidmore, unpublished data). Initially, this observation of use and high nest success may lead one to infer that grassland patches create poor nesting habitat for wild turkeys; However, a more realistic deduction would be that the current state of most grasslands is creating poor nesting habitat for wild turkeys, not grasslands in general. Grasslands that are ungrazed or have low livestock utilization have greater levels of visual obstruction to attract female use, more litter cover, and lower forb composition, benefitting the success of ground nesting birds (Fondell and Ball 2004, Uresk et al. 2009, Ahlering and Merkord 2016). With >70% of wild turkey nests being in grasslands, it is clear that grassland management is likely a key factor to improving nest success in Kansas.

Wild turkey nest success in Kansas is negatively affected by forb composition within at least 10-m of the nest bowl, possibly indicating deleterious effects of intense, routine disturbance and invasive forb species on the ground-nesting bird in grassland ecosystems. One such invasive forb that appeared to be attractive but deleterious to nesting wild turkeys was poison hemlock (*Conium maculatum*). Forbs such as poison hemlock grow dense and fast, providing attractive visual obstruction during the early nesting period and quickly reach heights up to 3 m. Twelve females (3% of field samples, all in central or eastern Kansas) selected nest locations directly

within a patch of this forb, of which only one nest (8%) was successful. Poison hemlock is most notorious for being a toxic plant when ingested due to the volatile, alkaloid chemical coniine that causes muscular paralysis and has the capacity to cause mortality in wild turkeys when ingested (Frank and Reed 1986, 1990). Only 50% of female wild turkeys incubating nests in poison hemlock died following incubation. Because nesting female survival was 50% on average across our study area it is unlikely the nests failed due to toxic plant consumption or exposure. Furthermore, dominant herbaceous cover within 10 m of 34% of failed nests was non-native species (poison hemlock, Johnson grass [*Sorghum halepense*], phragmites [*Phragmites australis*], Russian thistle [*Salsola tragus*], sericea lespedeza [*Lespedeza cuneata*], smooth brome, summer cypress [*Bassia scoparia*], downy brome [*Bromus tectorum*], or Japanese brome [*Bromus japonicus*]), while 41% of successful nests were surrounded dominantly by non-native species, indicating that the problem is likely forb occurrence overall, not just native versus non-native (or poisonous) plants. The more likely reason forb-dominant nest locations fail is due to the larger context of which they're created within – early successional or high disturbance patches.

Early successional patches in the Great Plains ecoregion are most often those formed and retained through frequent and intense disturbances such as annual prescribed burning, haying, and livestock grazing where forbs can thrive through repeated early establishment of barren areas (Fondell and Ball 2004, Brathen et al. 2021). Although sometimes synonymous in a grassland system, grazing, haying, and fire are implemented at largely varying intensities and spatial extents across Kansas, rendering a blanket statement of negative effect of disturbance on wild turkey nest success unsupported and uninformative. The definition of what constitutes early-succession patches is unique to each region. In grassland systems, the resilience of a seral

community can be greatly nuanced depending on the age of establishment and management type (Milchunas and Vandever 2013, Prach and Walker 2019). For further context, a study comparing the effects of grazing on native (never plowed) prairie, early sere (4-year-old) Conservation Reserve Program (CRP) plantings, and mid sere (18-year-old) CRP patches reported larger vegetation basal cover in native, never plowed patches; early sere patches contained significantly larger forb compositions (Milchunas and Vandever 2013). Because of the extreme differences that can occur among grassland patches, management of wild turkeys in the Great Plains ecoregion will depend upon investigating and specifying what constitutes a desirable “grassland” for wild turkey nesting habitat.

Conclusion

Similar to chapter one of this dissertation, conclusions of this chapter reflect the importance of acknowledging the nuance in managing for a generalist game bird species such as the wild turkey across a large spatial scale. Management for the wild turkey based upon the patch-level model alone may wrongly deduce that wild turkey nesting management is based within timber stand improvement alone and not that of the surrounding grasslands. Furthermore, one could focus only on the greater relative selection of woody-stemmed plant composition at the nest bowl, ignoring the fact that the majority of nest survival variation in Kansas may be explained by forb composition within a patch or roost tree availability. Without these additional levels and variables explaining the nuance that occurs for determining nest fate, management practices may be applied too generally for a riparian bird in a grassland-dominant state. This conclusion highlights the importance of avoiding the trap of ecological fallacies when investigating survival and habitat use patterns of wild populations. Reports on wild turkey nest-site use repeatedly call for the management of nesting cover for benefitting wild turkey populations, yet there is little

support that lack of nesting cover is what is causing such low values of nest success (Little et al. 2016, Yeldell et al. 2017, Moscicki et al. 2025). Because nest-site use is dependent on visual obstruction, it is crucial to consider the effects of how availability of selected resources is positioned within or around resources that help or harm nest success. An over-abundance of disturbance in some locations and habitat compression in others is likely creating greater probabilities of random chance encounters with predators and livestock, thus decreasing chances of nest success.

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Tables and Figures

Table 2.1. Capture results by year, study region, wild turkey management unit, and study site for female wild turkeys in Kansas, 2024-2025. Study region is one of three regions (east, central, west) along a longitudinal precipitation gradient across the state. Unit represents four (units two, three, four, and six) wild turkey hunting management units determined by the Kansas Department of Wildlife and Parks. Site represents 21 capture events of female wild turkeys. Wild turkeys were captured using walk-in, rocket-net, and drop-net traps baited with cracked corn and milo from January-March. Females were fitted with a 156-g Global Positioning System (GPS), G5-T2A Iridium transmitter with a very-high-frequency (VHF) component from Advanced Telemetry Systems. Transmitters were secured as a backpack using marine-grade shock cord with knots tied at each attachment point and secured with cyano-acrylic glue. Females were also each fitted with an aluminum pop-rivet leg band containing a numeric individual identifier.

Year	Region	Unit	Site	Adult	Juvenile	Unknown	Total
2024	west	four	Cedar Bluff	37	11	-	48
2024	east	three	Council Grove	26	4	-	30
2024	central	three	Durham	22	18	-	40
2024	west	four	Ellis	4	5	-	9
2024	east	six	Eureka	5	6	-	11
2024	east	three	Fort Riley	8	0	-	8
2024	west	four	Hays	2	2	-	4
2024	central	two	Kanopolis	17	9	-	26
2024	central	two	Marquette	36	1	-	37
2024	east	three	Reading	11	4	-	15
2024	east	three	Riley	13	1	-	14
2024	east	three	Tuttle Creek	10	4	-	14
2024	west	four	Wilson	28	13	-	41
2025	east	six	Cottonwood Falls	11	2	3	16
2025	east	three	Davis Road	9	5	-	14
2025	central	three	Durham 2025	10	7	-	17
2025	east	six	Fall River- RF	5	1	-	6
2025	east	six	Fall River- WA	3	6	-	9
2025	east	six	Lebo	11	2	-	13
2025	east	three	Ogden	9	3	1	13
2025	central	three	Roxbury	10	4	-	14
Total				287	108	4	399

Table 2.2. Apparent success values (# successful nests/ # total nests) of wild turkey nests in Kansas, 2024-2025. Success values are provided as a ratio, followed by the sample size (*n*), for each study site and then grouped by study region (East, Central, West).

Region/Site	2024	2025	Years pooled
East			
Fort Riley	0.174 (<i>n</i> = 23)	0.133 (<i>n</i> = 30)	0.186 (<i>n</i> = 43)
Tuttle Creek	0.111 (<i>n</i> = 18)	0.167 (<i>n</i> = 6)	0.125 (<i>n</i> = 24)
Cottonwood Falls	-	0.222 (<i>n</i> = 18)	0.222 (<i>n</i> = 18)
Council Grove	0.128 (<i>n</i> = 39)	0.292 (<i>n</i> = 24)	0.191 (<i>n</i> = 63)
Davis Road	-	0.300 (<i>n</i> = 10)	0.300 (<i>n</i> = 10)
Lebo	-	0.150 (<i>n</i> = 20)	0.150 (<i>n</i> = 20)
Reading	0.000 (<i>n</i> = 17)	0.167 (<i>n</i> = 6)	0.044 (<i>n</i> = 23)
Fall River WMA	-	0.111 (<i>n</i> = 9)	0.111 (<i>n</i> = 9)
Sundgren	0.118 (<i>n</i> = 17)	0.0 (<i>n</i> = 9)	0.077 (<i>n</i> = 26)
Total	0.114 (<i>n</i> = 114)	0.182 (<i>n</i> = 132)	0.157 (<i>n</i> = 246)
Central			
Durham	0.250 (<i>n</i> = 36)	0.105 (<i>n</i> = 57)	0.161 (<i>n</i> = 93)
Roxbury	-	0.200 (<i>n</i> = 15)	0.200 (<i>n</i> = 15)
Kanopolis	0.200 (<i>n</i> = 25)	0.333 (<i>n</i> = 18)	0.256 (<i>n</i> = 43)
Marquette	0.091 (<i>n</i> = 44)	0.294 (<i>n</i> = 17)	0.148 (<i>n</i> = 61)
Total	0.171 (<i>n</i> = 105)	0.187 (<i>n</i> = 107)	0.179 (<i>n</i> = 212)
West			
Hays	0.500 (<i>n</i> = 4)	0.000 (<i>n</i> = 5)	0.222 (<i>n</i> = 9)
Cedar Bluff	0.143 (<i>n</i> = 56)	0.104 (<i>n</i> = 29)	0.129 (<i>n</i> = 85)
Ellis	0.143 (<i>n</i> = 7)	0.200 (<i>n</i> = 5)	0.167 (<i>n</i> = 12)
Wilson	0.296 (<i>n</i> = 44)	0.240 (<i>n</i> = 25)	0.275 (<i>n</i> = 69)
Total	0.216 (<i>n</i> = 111)	0.156 (<i>n</i> = 64)	0.194 (<i>n</i> = 175)

Table 2.3. Quantiles of total incubation initiations by Julian Date followed by the calendar date of all wild turkey nesting attempts (mean attempts = 1.64 per nesting female, SD = 0.74) in Kansas, 2024-2025. Results are grouped by study region (East, Central, West), pooled across years and study region, and wild turkey hunting management units (two, three, four, six) determined by the Kansas Department of Parks and Wildlife. In 2024, the regular season dates April 17- May 30 and April 16- May 31 in 2025.

INITIATION BY REGION

Year	Region	<i>n</i>	0%	25%	50%	75%	100%
2024	East	99	108 (17 April)	122 (1 May)	134 (13 May)	155 (3 June)	189 (7 July)
	Central	99	97 (6 April)	113 (22 April)	125 (4 May)	152 (31 May)	186 (4 July)
	West	109	106 (15 April)	119 (28 April)	133 (12 May)	153 (1 June)	189 (7 July)
	Pooled	307	97 (6 April)	118 (27 April)	131 (10 May)	153 (1 June)	189 (7 July)
2025	East	128	102 (12 April)	116 (26 April)	126 (6 May)	144 (24 May)	201 (20 July)
	Central	105	101 (11 April)	111 (21 April)	127 (7 May)	147 (27 May)	188 (7 July)
	West	64	104 (14 April)	111 (21 April)	124 (4 May)	148 (28 May)	183 (2 July)
	Pooled	296	101 (11 April)	113 (23 April)	126 (6 May)	145 (25 May)	201 (20 July)

INITIATION BY MANAGEMENT UNIT

Year	Mgmt. unit	<i>n</i>	0%	25%	50%	75%	100%
2024	Two	106	97 (6 April)	114 (23 April)	128 (7 May)	152 (31 May)	189 (7 July)
	Three	120	105 (14 April)	122 (1 May)	131 (10 May)	152 (31 May)	186 (4 July)
	Four	67	106 (15 April)	118 (27 April)	137 (16 May)	152 (31 May)	175 (23 June)
	Six	14	108 (17 April)	113 (22 April)	119 (28 April)	165 (13 June)	189 (7 July)
2025	Two	60	101 (11 April)	110 (20 April)	121 (1 May)	136 (16 May)	184 (3 July)
	Three	142	104 (14 April)	116 (26 April)	126 (6 May)	147 (27 May)	193 (12 July)
	Four	39	104 (14 April)	110 (20 April)	124 (4 May)	154 (3 June)	183 (2 July)
	Six	56	102 (12 April)	117 (27 April)	128 (8 May)	144 (24 May)	201 (20 July)

Table 2.4. Model performance for wild turkey nest daily survival rate predicted using different group types across Kansas, USA, 2024-2025. Patch type represents the patch (cropland $n = 44$, forest $n = 114$, grassland $n = 432$, shrubland $n = 14$) a nest was found based on a remote sensing geographic information systems layer from the Kansas Ecological Monitoring survey. Kansas Department of Wildlife and Parks (KDWP) Unit represents grouping by the wild turkey hunting units (six total, only four represented by our sample) used to determine regulation boundaries for hunting. Female age represents the age of the nesting female, either as an adult (>1 year old) or juvenile (after-hatch-year). Lastly, study region represents three (East, Central, West) regions representing a different longitudinal section of the precipitation gradient in Kansas.

Model ^a	K	AIC _c	Δ AIC _c	w_i	Log Likelihood
s(patch type)	4	3733.92	0.00	0.66	-1862.96
s(KDWP unit)	4	3736.57	2.65	0.18	-1864.29
s(.)	1	3738.01	4.10	0.09	-1868.01
s(year)	2	3739.46	5.54	0.04	-1867.73
s(female age)	2	3739.62	5.70	0.04	-1867.81
s(public vs private)	2	3740.01	6.09	0.03	-1868.01
s(study region)	4	3741.31	7.40	0.02	-1866.66

^a Model = main effects model titles, K = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, Δ AIC_c = difference in AIC_c relative to smallest AIC_c value, ω_i = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 2.5. Model performance for wild turkey nest daily survival rate by landscape context in Kansas, USA, 2024-2025. Patch type represents one of four categories (cropland $n = 44$, forest $n = 114$, grassland $n = 432$, shrubland $n = 14$) where a nest fell within, determined by a remote sensing Geographical Information Systems layer from the Kansas Ecological Monitoring survey. “Woodland” and “cropland” distances were derived from the same remote sensing layer, where woodland represents treed areas, separate from shrublands. Edge was defined as a half-width of either 20 m or 60 m around a patch perimeter of that layer. All distances were measured as the Euclidean distance from the nest to the nearest feature type of interest. Roost tree locations were defined as any tree known to be used as an arboreal roost site of adult female turkeys, 2024-2025. EarthDefine tree represents a finer-scale representation of any trees, not just woodlands or roost trees, which includes those such as small cedar trees in grassland areas.

Model ^a	K	AIC_c	ΔAIC_c	w_i	Log Likelihood
s(patch type)	4	3627.34	0.00	0.45	-1809.67
s(distance to crop)	2	3629.19	1.85	0.18	-1812.60
s(distance to stream orders 1-2)	2	3630.97	3.63	0.07	-1813.49
s(.)	1	3631.24	3.90	0.06	-1814.62
s(distance to woodland)	2	3631.39	4.05	0.06	-1813.70
s(distance to edge, 20m)	2	3632.43	5.09	0.04	-1814.22
s(distance to stream orders 3-9)	2	3632.56	5.22	0.03	-1814.28
s(distance to edge, 60m)	2	3632.64	5.30	0.03	-1814.32
s(distance to roost tree)	2	3632.76	5.42	0.03	-1814.38
s(distance to road)	2	3632.98	5.64	0.03	-1814.49
s(distance to EarthDefine tree)	2	3633.16	5.81	0.02	-1814.58

^a Model = main effects model titles, K = no. of parameters, AIC_c = Akaike’s Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, ω_i = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 2.6. Model performance for wild turkey nest daily survival rate predicted using vegetation measurements ($n = 427$) collected in the field across Kansas, USA, 2024-2025. Vegetation measurements were recorded at the nest bowl or as an average of four points 10 m from the nest in each cardinal direction. Vegetation compositions were measured using a 1-m² vegetation frame. Visual obstruction (VOR) was recorded using a 50-cm wide profile board as an average of the obstruction values measured on four sides of the nest bowl, all within 1-m of the center, at a 25-50 cm height.

Model ^a	K	AIC _c	Δ AIC _c	w_i	Log Likelihood
s(10 m forb + nest woody)	3	2484.94	0.00	0.84	-1239.47
s(10 m forb)	2	2490.05	5.11	0.07	-1243.03
s(10 m woody)	2	2491.05	6.11	0.04	-1243.53
s(nest woody)	2	2491.46	6.52	0.03	-1243.73
s(nest forb)	2	2492.26	7.32	0.02	-1244.13
s(nest litter)	2	2497.38	12.44	0.00	-1246.69
s(.)	1	2497.93	12.99	0.00	-1247.97
s(VOR 25-50 cm)	2	2498.38	13.44	0.00	-1247.19
s(10 m litter)	2	2499.25	14.31	0.00	-1247.63
s(nest grass)	2	2499.67	14.73	0.00	-1247.84
s(10 m grass)	2	2499.93	14.99	0.00	-1247.97
s(nest bare ground)	2	3366.48	881.54	0.00	-1681.24

^a Model = main effects model titles, K = no. of parameters, AIC_c = Akaike's Information

Criterion adjusted for sample size, Δ AIC_c = difference in AIC_c relative to smallest AIC_c value, ω_i = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 2.7. Summary of available metrics from publications reporting wild turkey nest propensity, phenology, and success across the United States.

Citation	Region	Year	Nest Propensity	Success
Roberts and Porter 1998	northeast	1991-1993	na	40%
Hubbared et al. 1999	midwest	1994-1997	na	8-34%
Hennen 1999	midwest	1999	na	32%
Shields and Flake 2006	midwest	1999-2000	93% first, 45% second	45-54%
Barnett 2003	midwest	2000-2001	na	47.6%
Barnett 2003	midwest	2000-2001	na	29.3%-37.9%
Hall et al. 2010	midwest	2000-2004	na	29%
Huffman et al. 2006	midwest	2000-2004	39-65%	33%
Melton 2007	midwest	2005-2007	84%	17.6%
Melton 2007	midwest	2005-2007	67%	11.7%
Pollentier et al. 2014	midwest	2010-2011	90% (adults), 34% (juveniles)	26%
Kilburg et al. 2014	southeast	2011-2012	na	27-39%
Yeldell et al. 2017	southeast	2014-2015	87% first, 66% second, 50% third	15%
Crawford et al. 2021	southeast	2014-2018	100% first, 35% second, 7% third	24%
Chamberlain et al. 2020	southeast	2014-2019	73%	22%
Wood et al. 2019	southeast	2015-2016	96% first, 62% second, 13% third	41%
White 2019	midwest	2016-2018	74% first, 49% second	15-18%
White 2019	midwest	2016-2018	63% first, 25% second	2-5%
Johnson et al. 2022	southeast	2017-2018	78% (adults), 47% (juveniles)	33.9%
Nelson et al. 2023	southeast	2017-2020	na	21%

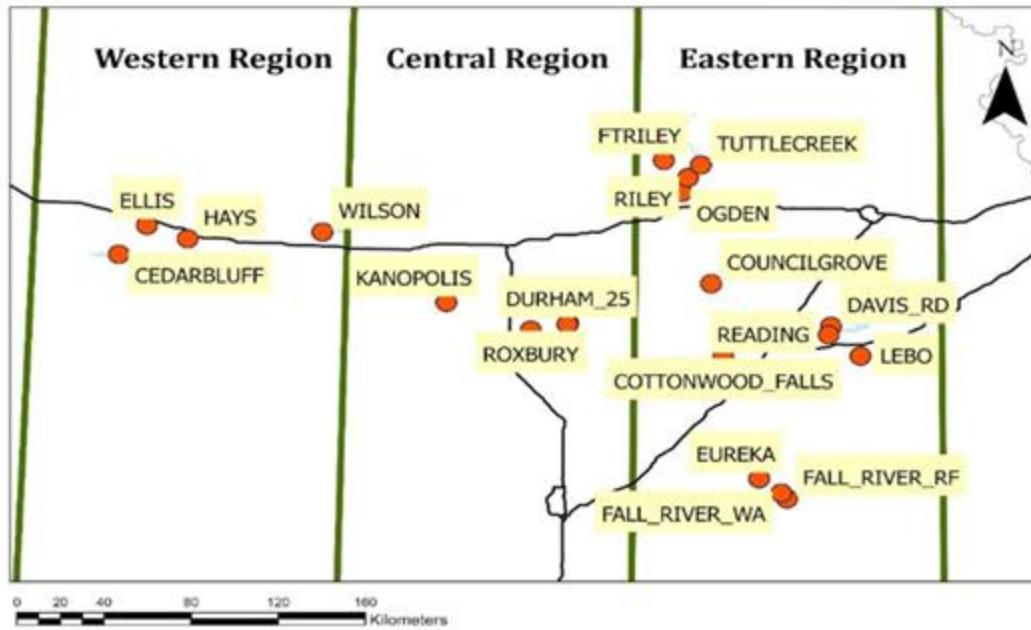


Figure 2.1. The study area split into three study regions (Western, Central, and Eastern) where wild turkeys were captured and marked with 140-gram G5-T2A Iridium backpack units with global positioning systems (GPS) and very high frequency (VHF) radio transmitter components. Captures occurred across 19 different sites in Kansas, 2024-2025.

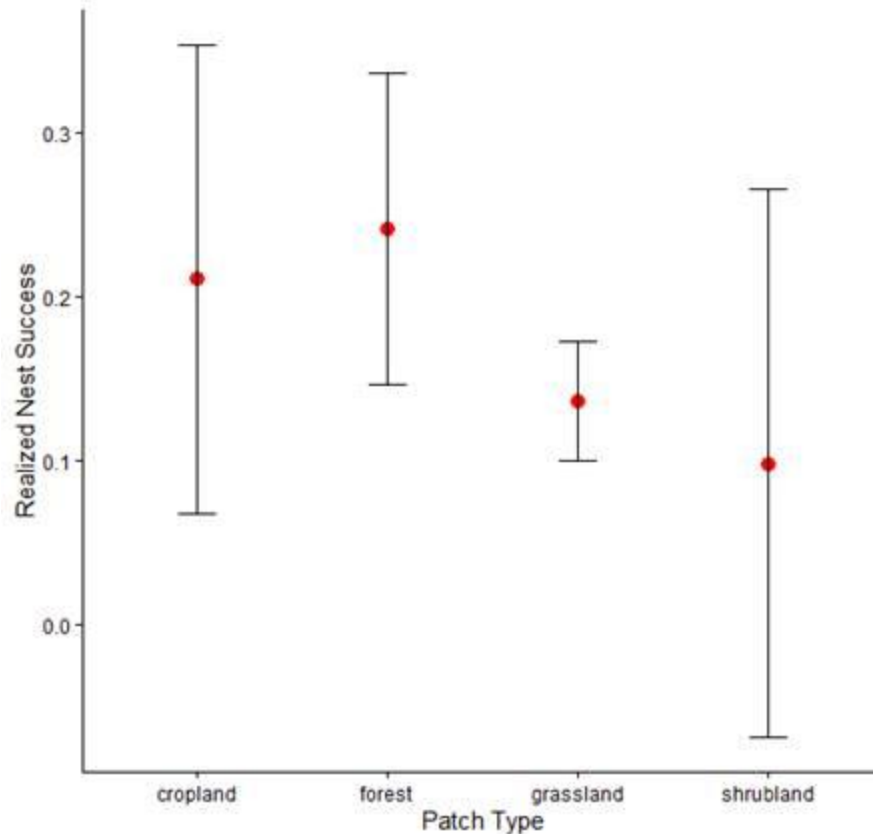


Figure 2.2. Realized nest survival estimates and standard error values (derived using the Delta Method) of wild turkey nests ($n= 633$) across Kansas, USA, 2024-2025, predicted from a model using patch type as a covariate. Patch type was determined by a remotely sensed geographic information systems layer created by the Kansas Ecological Monitoring Survey. Nest locations were determined by monitoring the movements of 399 wild turkeys with 140-gram G5-T2A Iridium backpack units with global positioning systems (GPS) and very high frequency (VHF) radio transmitter components across 19 different sites in Kansas, USA, 2024-2025.

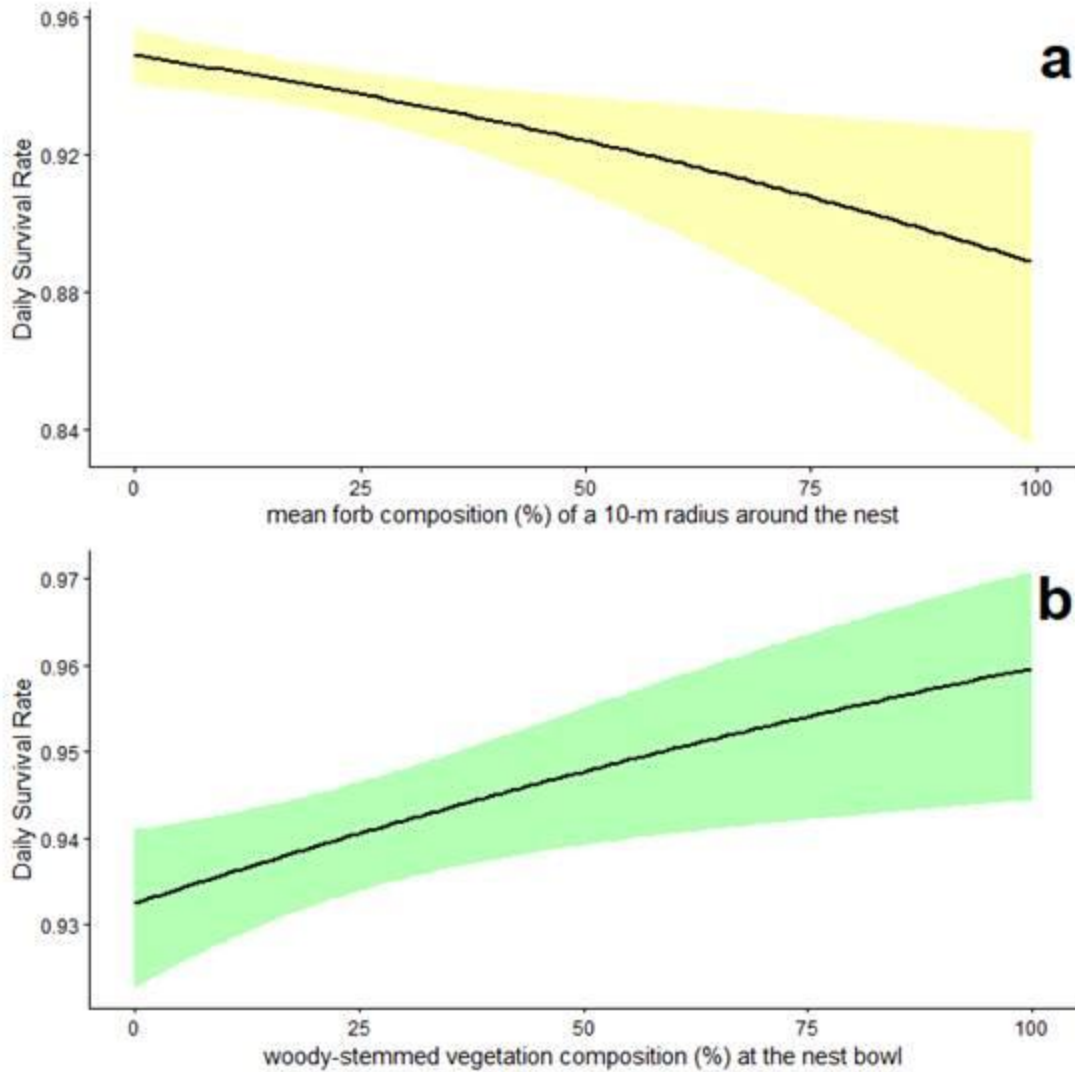


Figure 2.3. Daily survival rate estimates of wild turkey nests ($n = 453$) across Kansas, USA, 2024-2025, predicted from an additive model using two vegetation variables. Mean forb composition (a) was an average of four different horizontal cover estimates using a 1-m² vegetation frame placed 10 m from the nest bowl in each cardinal direction. Woody-stemmed vegetation composition (b) at the nest bowl was measured by placing the 1-m² vegetation frame centered on the nest bowl. Measurements were recorded in the field following the completion or failure of a nest, whose fate was determined by monitoring the movements of 399 wild turkeys with 140-gram G5-T2A Iridium backpack units with global positioning systems (GPS) and very high frequency (VHF) radio transmitter components. Captures occurred across 19 different sites in Kansas, 2024-2025.

Chapter 3 – Brood success, poult survival, and comparative habitat use between the nesting and brood-rearing states of Wild Turkeys in Kansas

Introduction

The reintroduction and establishment of wild turkey (*Meleagris gallopavo*) populations across the United States is a conservation success story that has begun to show declining trends in many occupied areas. While the initial extirpation of the large game bird was easily identified as human caused from overharvest and habitat loss, the catalyst(s) for the current wild turkey population declines that started in the eastern United States during the mid-2000s remain unclear and suffer from the lack of precise abundance and vital rate estimates (Clawson et al. 2015, Chamberlain et al. 2022, Wakeling et al. 2022). The more recent decline in the central United States can be typified by reports such as a 33% decrease in Missouri, 65% in Arkansas, and 40% in Kansas, USA, since the contemporary population peaks during the mid- to late 2000s (Eriksen et al. 2015, Gavilan Group 2020, Chamberlain et al. 2022). The decline of wild turkey populations across such a large region is hypothesized to be caused by a variety of reasons and wide-spread research is on-going to understand factors influencing population declines including increasing predator abundance, landscape change, deviations from normal precipitation, disease, and harvest chronology (Pollentier et al. 2014a, Melville et al. 2015, Little et al. 2016, Lavoie et al. 2017, Wakefield et al. 2020, Wightman et al. 2023).

In response to a statistical population reconstruction model reporting nearly 50% of the Kansas wild turkey population had been lost in addition to notable field observations of flock numbers, harvest, and poult-to-female ratios decreasing, the state began to take conservation action (Gavilan Group 2020). In 2023, the Kansas Department of Wildlife and Parks canceled

the fall wild turkey hunting season to help alleviate stress on the wild turkey population through reducing female mortality. However, harvest pressure from the spring and fall hunting seasons is only one of the possible hypotheses explaining causes for the current wild turkey population decline in Kansas (Lavoie et al. 2017, Wakefield et al. 2020, Nelson et al. 2022, Wightman et al. 2024). Reduced recruitment is a common cause for declining resident game bird species that can frequently be traced back to the familiar conservation hurdle of habitat loss and degradation. Habitat loss is often the root of many other indirect causes in species population decline such as increased risk of predation, lack of food, or issues with thermoregulation due to the environment (Nelson et al. 2021).

A minimum of a >3:1 poult:female ratio is necessary to maintain a wild turkey population (Rolley et al. 1998). However, previous Kansas poult-per-female ratios were estimated to range from 1.4 to 0.3 in certain regions, which indicates that the quality and composition of wild turkey brood habitat or survival may be limiting populations in the state (Rolley et al. 1998, Butler et al. 2007). The Kansas Rural Mail Carrier index of summer poult and female surveys in recent years reflect similar results of a declining population, with an index of 1.17 to 2.33 poult-per-female between 2012 to 2018. This red flag highlights a need to understand factors influencing declines in brood counts and overall wild turkey abundance.

Wild turkey broods require a structurally and functionally diverse area to provide a gradient of resource types needed for survival as they evolve from a hatched nest into flight-capable poults around days 10-14 (Nelson et al. 2022, 2023). During the flightless period, poults are at increased risk of predation and unable to independently thermoregulate; thus, broods are most vulnerable during the initial two weeks of life. During this preflight state, broods need

access to visual cover, most often via shrubby cover, for ground roosting and forb-prominent areas for optimal foraging (Spears et al. 2007). Potential brood habitat is well-documented as a heterogeneous patch containing more forbs than grass or woody vegetation for foraging with cover tall enough to hide poults but short enough for the female to view their surroundings (Day et al. 1991, Spears et al. 2007). Additionally, quality brood habitat requires adequate number of intermittent shrubs or downed trees for ground roosting and has a ground understory distributed moderately enough that small poults may easily move throughout (Day et al. 1991, Spears et al. 2007).

Despite recent advances in knowledge of wild turkey brood ecology, much remains to be understood of factors driving the observed poult-to-hen ratios used by managers as a population index. Chamberlain et al. (2020) stated that behavioral decisions such as displacement per day affect daily survival of broods more so than home-range composition. Brood home range compositions are commonly described as forb-dominant and providing visually obstructive cover for brood-rearing females, indicating that composition should play a role in increasing fitness (Day et al. 1991, Spears et al. 2007). However, it is not uncommon for resource selection to not always equate to increased survival during the reproductive period. For example, wild turkey nest-site selection is consistently based on increased visual cover, but such selection rarely translates into increasing nest success (Chapter I; Little et al. 2016, Yeldell et al. 2017, Wood et al. 2018, Moscicki et al. 2025). Broken ecological pathways such as the evolution of resource selection no longer benefitting individual fitness may be one reason wild turkey recruitment remains concerningly low. On the other hand, one cause for the lack of a relationship between habitat use and brood survival may be that brood habitat is not limiting and resources required for stable poult survival are adequately available; thus, having no measurable effect on survival.

However, relationships among habitat use, resource selection, and brood survival remains unknown in many wild turkey populations occupying grassland systems. Knowledge of resource selection by nesting and brood-rearing females in grassland-dominant systems and if those evolved patterns are benefitting brood or poult survival is required for development of any wild turkey management strategy.

Separation of investigation of reproductive stages and identification of resource limitations can be useful for providing management plans for each life event. Factors influencing wild turkey nesting and brood-rearing ecology are inextricably ecologically linked, with both contributing to eventual population recruitment monitored by poult-to-hen ratios. However, available information indicates that available wild turkey nesting and brood-rearing habitat differ in functional composition and management practices (Wood et al. 2018). Further complicating availability of reproductive habitat for nesting and brood-rearing wild turkey in grassland and grassland-savanna systems is presence of mature roosting trees (M. Ware, unpublished data). In agriculturally dominant, tree-scarce landscapes could be distribution of potential roost trees create “spatial anchors” from which nesting and brood-rearing female wild turkeys have limited options to diversify habitat use for each reproductive state that may increase predation risk (Smith et al. 2019). However, without the context of the correlative effect among reproductive states, inference around improving habitat for wild turkey nesting and brood-rearing survival is limited.

As a prey species, female wild turkeys are trapped in the “behavioral response race”, weighing decisions that may benefit them in certain aspects, such as access to adequate brood foraging habitat, but potentially reducing fitness by increasing exposure to other risk factors as a result of that decision; for example, subsequently overlapping nest sites with greater predator

abundances (Smith et al. 2019). Such a behavioral response race is rooted in the hypothesis that because predators rely on prey and if the resources a prey relies on, such as selected habitat features, are located only within where predators are relatively abundant, prey populations are ultimately doomed (Smith et al. 2019; C. Skidmore, unpublished data). However, if through management of the range in which a prey population resides reduces predation risk and increases eventual recruitment, populations may once again rebound to stability (Huffaker 1958, Smith et al. 2019). In grassland systems, landscape characteristics and associated heterogeneity required to provide nesting and brood-rearing habitat for persistence of wild turkey populations is uncertain. Further, the relative influence of landscape factors influencing nest success, brood/poult survival and subsequently recruitment is uncertain. Given the limited availability of potential nesting and brood-rearing habitat due to required occurrence of adequate roost trees in grassland systems, it is important to compare the relative structural and compositional variables of nesting and brood-rearing sites to test if habitat requirements for all reproductive states are being discretely supported, or if certain states lack adequate sufficient quality habitat, negatively influencing recruitment (Chapter I).

Information on wild turkey brood ecology is particularly lacking in grassland-dominant regions – in particular, the Great Plains. My goal was to investigate habitat use and selection by brood-rearing female wild turkeys in Kansas to determine if required habitat features for brood and poult survival differ from those influencing selection of nest sites (Chapter I). My objectives are 1) test for selection of plant functional group compositions and visual obstruction levels to determine which variables are being sought out by brood rearing females, 2) estimate survival of broods and individual poults across Kansas to assess if poult and brood success relative to nest success (Chapter II) are at levels concerning enough to influence recruitment that is reflective in

declining poult-to-hen ratios, and (3) compare functional and structural vegetation components used among nesting, brood foraging, and brood ground roosting habitat to determine what constitutes a cohesive landscape that facilitates both the nesting and brood rearing phases.

Study Area

My study area encompassed the eastern two-thirds of Kansas, split into 3 study regions. These regions were delineated by the following longitudinal boundaries: East (-96.96 to -95.50), Central (-98.49 to -96.96), and West (-100.15 to -98.49; Figure 1.1). From east to west, the 3 regions represent a negative precipitation gradient along with a gradual shift from tallgrass, to mixed-grass, and finally short-grass prairies. Grasses common to the entire study area included little bluestem (*Schizachyrium scoparium*), side-oats grama (*Bouteloua curtipendula*), and switchgrass (*Panicum virgatum*). Common forbs include ragweed (*Ambrosia psilostachya*), yellow sweet clover (*Melilotus officinalis*), Illinois bundleflower (*Desmanthus illinoensis*), and annual sunflower (*Helianthus annuus*). Species most often comprising Kansas riparian areas were bur oak (*Quercus macrocarpa*), hackberry (*Celtis occidentalis*), black walnut (*Juglans nigra*), American elm (*Ulmus americana*), rough-leaf dogwood (*Cornus drummondii*), coral berry (*Symphoricarpos orbiculatus*), and Virginia wild rye (*Elymus virginicus*; Haddock 2024). Common predators of female wild turkeys, their nests, and broods in Kansas were bobcat (*Lynx rufus*), coyote (*Canis latrans*), great horned owl (*Bubo virginianus*), raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), and striped skunk (*Mephitis mephitis*; Thogmartin and Schaeffer 2000, Yeldell et al 2017, Crawford et al. 2021, Nielsen et al 2021).

To describe the composition of my study system, I placed a 95% minimum convex polygon around movement locations recorded from each unique capture flock (13 total) during 2024-2025

(Figure 1.2). I then averaged the landcover values derived from the Kansas Ecological Monitoring dataset among the 13 capture sites within each study region to report the landscape compositions and used the U.S. Department of Agriculture Cropland CROS dataset to report all agriculture-based compositions in 2024 (Boryan et al. 2011, Diamond et al. 2021). All study regions were grassland dominant, with the majority (>65%) of open grasslands being used for livestock grazing throughout the state (Boryan et al. 2011). The West region R contained the largest percentages on average of cropland and mixed-grass prairie (31%, 55% of total area, respectively). The Central Region was composed of the second-highest mean cropland cover, with about 23% of the total area dedicated to cropland and 58% remaining as a combination of tallgrass and mixed-grass prairies. Both the West and Central regions had <5% forested cover, primarily represented by riparian areas scattered throughout each region. The primary cover types in the East Region were tallgrass prairie (65%) and various forms of woodlands (15%). Cropland cover was the lowest in the East Region with 11% coverage. Primary crops in the West Region were winter wheat (*Triticum aestivum*, 11% mean total cover) and grain sorghum (*Sorghum bicolor*, 10% mean total cover). Winter wheat (9% mean total cover) was the primary crop in the Central Region followed by grain sorghum (*Sorghum, bicolor*, 4%), soybeans (*Glycine max*, 4%), corn (*Zea mays*, 3%), and alfalfa (*Medicago sativa*, 1%). Soybeans (7% mean total cover) was the primary crop in the East Region. Urban intensity was low in all 3 study regions, with 1% in the East Region compared to 0.35% in the Central Region and 0.55% in the West Region.

Weather metrics during 2024–2025 nesting seasons (Apr-Jun) were derived from county-level weather averages (PRISM group 2025). Mean precipitation across the study area was 9.8 cm (SD = 5.3) in 2024 and 11.8 (SD = 5.8) in 2025. Mean temperature across the study area

from April to June was 19.3° C in 2024 and 18.1° C in 2025. By region, 2024 precipitation across the East, Central, and West regions, was respectively 11.9 cm (SD = 4.3), 7.4 cm (SD = 5.6), and 6.9 cm (SD = 4.3). Precipitation slightly increased in 2025 by region at 13.7 cm (SD = 6.1), 11.2 cm (SD = 6.4), 7.6 cm (SD = 1.5), respectively, in East, Central, and West regions. Mean temperature for East, Central, and West regions was 19.4° C, 19.5° C, 18.8° C in 2024, respectively. In 2025, mean temperature by region was slightly cooler at 18.2° C, 18.0° C, and 17.6° C for East, Central, and West regions, respectively.

Methods

Field Capture and Monitoring

I captured female wild turkeys using baited drop, walk-in, and rocket nets on private and public lands during winter (Jan-Mar) 2024 and 2025. All captured wild turkeys received aluminum, pop-rivet leg bands with unique numeric identifiers and contact information for reporting recoveries. I measured the mass (kg), tarsus length (cm), wing chord (cm), and exposed culmen length (cm) length for all birds, in addition to spur length (cm) and beard length (cm) for females when present. All females were aged based on plumage; juveniles were classified as any female with white banding to the tip of the primaries as well as pointed tips of the first primary (Healy and Nenno 1980). Adults were identified by a lack of white banding to the end of the primaries, and a rounded end of the first primary feather.

I fitted each female wild turkey with a 156-g Global Positioning System (GPS), G5-T2A Iridium backpack style transmitter with a very-high-frequency (VHF) component (Advanced Telemetry Systems, Isanti, MN, USA). Transmitters were secured as a backpack using marine-grade shock cord with knots tied at each attachment point and secured with cyanoacrylate glue. Once

deployed, transmitters recorded GPS locations 6 times per day at 0300, 0700, 1100, 1500, 1900, and 2300 during the breeding season (Mar 1 – Aug 1), 2024 and 2025. Locations were uploaded from the GPS transmitter to the Iridium satellite system every 3 to 5 days.

I reviewed movement patterns of each female wild turkey weekly during the breeding season to monitor for indications of the bird entering the laying, incubating, or brood-rearing reproductive states. I identified the laying state as daily repeated (>3) visits to the same location (<100 -m radius). Initiation of the incubation was identified and determined by the female spending at least one night roosting on the ground in a nonforested location. In forested areas, I considered the incubation phase to be initiated once the female dramatically decreased her daily step-lengths and was roosting in the same general location of the laying area for at least 24 hours (Carpenter et al. 2022). I estimated an average incubation period of 28 days to determine the estimated hatch date of all nests and determined a nest to be failed if a female permanently left the nest or died before incubation day 26 (Healy 1992, Conley et al. 2016).

I surveyed successful nests within 48 hours of the estimated hatch date or the female wild turkey permanently leaving the nest to count the number of hatched eggs in the nest bowl. Hatched eggs appeared broken in half, with membranes sometimes detached from the outer eggshell.

Depredated eggs were identified by appearing either “punched”, with a hole in the side of the egg and the insides removed, or completely crushed, sometimes leaving only eggshell fragments behind. I monitored poult survival weekly until they reach at least 28 days (about 4 weeks) old or when all poults in the brood experienced mortality (Healy 1992, Conley et al. 2016, Chamberlain et al. 2020). To determine brood survival each week, I first identified most recent downloaded GPS location of brood-rearing females. I would then go to the location the following morning between 0500 to 0900, using VHF telemetry to find and flush the female from her roosting or

foraging location, depending on the time of contact. During the flush event, I would count the number of poults observed either on the ground or flushing from the site to determine 1) if the female still had a live brood and 2) the number of surviving poults. I would record the following variables after each brood survival check was completed, including following a flush where zero poults were observed with the female: survey date, time of flush, female individual identifier, number of poults seen, number of poults heard, if it was a single or mixed age brood, female behavior (roosting, close [<10 m] flush, grouped with one or more other females, female found dead), and brood behavior (ground roosting, tree roosting, foraging, loafing, running away). I also recorded the location (latitude and longitude) where each female was flushed, and visually determined the immediately surrounding primary cover type (grassland, cropland, shrubland, forest, road) and cropland type if applicable.

Nesting, brood foraging, and brood ground roosting vegetation surveys

I surveyed wild turkey nests, brood foraging, brood ground roosting habitat using the same methods. I conducted vegetation surveys at nests following either successful completion or failure of the nest. I measured brood foraging habitat by randomly selecting six mid-morning (0900 or 1100) locations from the downloaded GPS locations of brood-rearing females and surveying those locations within 14 days of the position fix. The six foraging habitat locations were composed of three locations randomly selected from the first two weeks (0-14 days old) following brood hatch and three locations randomly selected from the second two weeks (14-28 days old) following brood hatch. In addition to measuring brood foraging habitat, I measured brood ground roosting habitat for the first two weeks after hatching. I randomly selected three

nighttime (2400) locations for each brood during days 0-14, using the assumption that they were ground roosting with the female during this time.

At these used locations, I measured the vegetation directly at the nesting, brood foraging, or brood ground roosting location point, as well as at four points at a 10-m radius surrounding the center point (Figure 1.4). At the center point, I placed a 1x1-m vegetation quadrat and recorded the percent composition of five ground cover functional groups: grass, forbs, residual litter, bare ground, and woody-stemmed vegetation. I then placed a coverboard along one of the four edges of the 1x1-m quadrat, walked 10 m from the center point and recorded the percent visual obstruction at four height categories at 1-m above ground (Nudds 1977). The coverboard was 0.5-m wide by 1.0-m tall with 0.25-m sections of alternating color contrasts to denote four total visual obstruction reading (VOR) height categories (0-0.25 m, 0.25-0.50 m, 0.50-0.75 m, and 0.75-1.0 m above ground). I recorded VOR four times at the center point at 10 m from the coverboard, each time with the coverboard being placed on one of the four cardinal directions of the quadrat. I report the mean values within each height category at the center point and use the mean values of each height category to represent visual obstruction at the center point in subsequent resource selection analyses.

I conducted a similar habitat assessment at the 10-m radius around the center point. For this scale, the observer measured habitat (vegetation quadrat, coverboard readings) at four locations 10 m away from the center point in each cardinal direction. This resulted in a total of four, 1x1-m quadrat compositions being recorded for each of the five functional groups (grass, forbs, residual litter, bare ground, and woody-stemmed vegetation), which I then averaged across each functional group (Figure 1.4). I report the mean value from the four quadrat readings and use this mean value to represent functional ground cover composition at the used foraging site

(10-m radius around the center point). I recorded coverboard readings only on one side of the quadrat (compared to all four at the nest bowl), which was the side furthest from the center point with the colored side of the coverboard facing away from the center point. I recorded VOR in each height category 10 m from the coverboard, 20 m from the center point. I averaged the VOR across each height category and used mean values of each height category to represent visual obstruction at the foraging site in subsequent analyses.

Once I surveyed the used nesting, brood foraging, or brood ground roosting location, I generated two random, available locations per used site within 400 m using a random number generator with the first number generated equaling the distance to be traveled and the second the azimuth for traveling direction. I conducted the same vegetation survey previously described for the used location at all randomized locations. I report all used and random location measurements as means with standard deviations by study region. I report all brood foraging habitat measurements split into flightless (0-14 days old) and flight-able (14-28 days old) age groups.

Home range estimation

I estimated home ranges for three reproductive states for adult female wild turkeys using a 50% and 95% Kernel Density Estimate (KDE; Worton 1989, Sheather 2004, Weglarczyk 2018).

Home ranges were estimated for the egg-laying state, flightless state of brood rearing (0-14 days after hatch), and flight-capable state of brood rearing (14-28 days after hatch). The egg-laying state included all movement locations from the start of the first day of identified laying up to the first night of incubation. The brood-rearing state included all movement locations beginning the day of hatching to either the end of the stated period (flightless or flight-capable) or the last

known day the brood was alive if the brood failed. I estimated all home ranges using the `hr_kde()` function in the Animal Movement Tools (`amt`) package in Program R, which calculates a specified home range type (i.e., “KDE”) using animal movement data and a smoothing parameter unique to each individual (Signer et al 2019). I report all home ranges in hectares, with the mean and standard deviation ($\bar{x} \pm SD$) for each year, study region, and reproductive state. I compare the variability of home range area within the population among states by calculating the coefficient of variation ($CV = SD / \bar{x}$) for each reproductive state, region, and year, as well as each region with the years pooled.

Brood survival analyses

I derived apparent brood survival by dividing the total number of successful broods by the total number of broods, split by successive weeks through five weeks after hatch. I estimated weekly survival of individual poult starting day of hatch and ending at six weeks after hatch using the known-fate Lukacs survival model for young of marked females in Program MARK (White and Burnham 1999, Lukacs et al. 2009, Chamberlain et al. 2020). For this analysis, I removed all broods with insufficient data (<2 brood flush counts). I acknowledge the use of the Lukacs survival model with wild turkeys may violate a main assumption of the model in that wild turkey females can participate in communal brood-rearing and are well known to comingle broods (Lukacs et al. 2009). Out of the 109 total broods we monitored, I observed at least 23 females who amalgamated with one or more females while simultaneously being observed with a brood. I used two model comparison sets to assess factors influencing poult survival in Kansas. The first model suite included variables fundamental to testing common patterns in poult survival. This suite included the grouping variables of year and study region (East, Central, West), covariates

of hatch Julian Date, and nest attempt. For these models, I allowed survival to either vary through time ($S(t)$) or be held as constant through time ($S(.)$). I held detection probability as constant ($p(.)$) for all models due to wild turkey poult detection being high (~84%) during flush counts and wild turkey poults not being a difficult to detect (Lukacs et al. 2004, Quehl et al. 2025). The null model was considered where survival and detection probability were held constant, with no grouping variables or covariates.

In the second model suite, I tested the following hypotheses: poult survival varies based upon the respective female's laying state core home range (50% KDE), poult survival varies with the core home range of the brood-rearing female in the flightless (0-14 days after hatch) phase of the poults, and poult survival is best predicted based upon survival varying among specifically the flightless (weeks 1-2) and flight-capable (weeks 3-6) periods of life. Because it is well-documented that poult survival does vary through time, I consider the fully time-varying ($S(t)$) model with detection held as constant ($p(.)$) as the standard for model comparison in this suite. I ranked all models using Akaike Information Criterion (AIC) and considered models within 2 Δ AIC units to be competitive (Burnham and Anderson 2002). However, most supported models with uninformative variables ($p > 0.05$) were removed from consideration. I report the number of parameters (K) in each model, the AIC value, Δ AIC, model weight (w_i), and Log Likelihood of all models.

Habitat selection analyses for brood foraging and ground roost

I used resource selection functions to determine foraging habitat use by brood ages 0-28 days old with the used foraging locations and two random locations collected per used location (Johnson et al. 2006). Brood foraging habitat selection analyses included the following variables:

functional group cover compositions at the used point (percent grass, forbs, woody vegetation, bare ground, residual litter); mean VOR for each height category m at the used point and 10-m radius around the used foraging point; and mean functional group cover compositions 10 m from the used foraging point. In addition to brood foraging habitat, I conducted resource selection analyses for brood-ground roosting habitat. Brood ground-roosting habitat included only the ground roosting points measured during the first two weeks of life (0-14 days old) when broods were primarily flightless, along with the two randomly generated locations per used location within 400 m.

To assess habitat selection for brood-foraging habitat at the scale of the use point and the used “site” (10-m radius around the foraging point), I used four model suites separately testing selection for levels of VOR and plant compositions at the two scales. In all four initial model suites, I fitted main effects and interactive effects models of study region and patch type (main ecotype observed within 100 m of used foraging and random points) to model probability of use. The first model suite, visual obstruction at the foraging point, tested selection for percent visual obstruction at the four measured height categories.

The second model suite, selection for functional plant group compositions at the used foraging point, evaluated which plant functional group was most influential for modeling foraging-point selection. The final two model suites contained the same variables, VOR and plant composition, but tested for relative model performance of those variables at the foraging site (10-m radius) scale. I ranked all models using the AIC and considered models within 2 Δ AIC units to be competitive (Burnham and Anderson 2002). However, supported models with uninformative variables ($p > 0.05$) were removed from consideration. I report the number of parameters (K) in each model, the AIC value, Δ AIC, model weight (w_i), and Log Likelihood of each model. I

compiled a final model suite testing the hierarchical importance of each of the variables represented by combining each competitive model within each model suite.

Comparative brood and nest habitat use

I used a multivariate analysis of variance (MANOVA) to test for differences among reproductive habitat types of the brooding-rearing and nesting life states. I predicted that brood ground-roosting and foraging habitat would be similar to that of female wild turkey nesting habitat relative to use of visual obstruction and woody plant composition. I included variables identified as influential by resource selection or survival during this study, resulting in the use of woody-stemmed plant composition and visual obstruction at 25-50-cm for the center of each use point, as well as the mean forb composition and mean litter composition of the 10-m radius surrounding each use point (Chapter I). I used the `manova()` function in Program R to test between two variables among four groups (brood foraging days 0-14, brood foraging days 14-28, flightless brood ground roosting, and nesting habitat; R Core Team 2024). I tested for statistical significance at $\alpha = 0.05$. If significance among groups was ascertained, I then completed an analysis of variance (ANOVA) for each variable of interest. Finally, I completed a post-hoc, pairwise *t*-test using a Bonferroni corrected alpha-value in attempt to control for Type One errors during pair-wise comparisons and account for unequal variances among test groups (Bland and Altman 1995).

Results

Brood monitoring and apparent brood survival

I deployed GPS transmitters on 297 and 103 female wild turkeys in 2024 and 2025, respectively, for a total of 399 tracked birds over the 2-year study. From this capture sample, I remotely monitored the status of 330 wild turkey nests in 2024 and 303 nests in 2025; of those, I completed field-based surveys for 219 and 234 nests, respectively. I monitored 109 broods across Kansas during this study (2024 $n = 55$, 2025 $n = 54$; Table 3.1). The earliest known hatch date of a brood was May 12 and May 11 in 2024 and 2025, respectively, while the latest known hatch date of a brood in 2024 and 2025 was July 28 and August 12, respectively. I was able to obtain estimated hatched egg counts for 88 of the successful nests; of those nests, the mean value and standard deviation ($\bar{x} \pm SD$) was 6.68 ± 2.59 hatched eggs per nest. Nest attempts had similar means of hatched eggs among attempts (attempt 1 = 6.93 ± 2.5 ; attempt 2 = 6.60 ± 2.39 ; attempt 3 = 4.71 ± 3.15). The maximum number of hatched eggs observed was 14; the minimum was 1 egg.

Of the monitored broods, I was able to estimate the apparent fate of 92 broods. The 17 censored broods were primarily on inaccessible property. Apparent survival of broods in Kansas was 33% in 2024 and 22% in 2025 (Table 3.1). Relative trends of apparent brood survival varied among regions across years; In 2024, the East study area had the largest apparent brood survival (55%) followed by the West (35%) and finally Central (13%) study areas. Whereas in 2025, apparent brood survival decreased by 80% in the East study area (11%), increased by 100% in the Central study area (26%), and remained similar in the West study area (38%) compared to 2024. In 2024, apparent brood survival from the day of hatch to week 2 (Days 1-7) was 67%, 53% into week 3, 48% into week 4, and 33% into week 5 (Table 3.1). Apparent brood survival had a slightly steeper decay in 2025, dropping from 61% to 35% from week 2 to week 3, but then leveling out to 28% in week 4 and 22% in week 5 (Table 3.1). Nineteen broods (21% of all

broods) failed due to adult female mortality, 11 in 2024 and 8 in 2025, with all events being suspected due to predation.

Female laying home ranges and brood home ranges by age

Home range area varied among regions, years, and reproductive states (Table 3.2). There was no clear biological pattern of larger or smaller home range areas among any group. The laying state tended to have the lowest amount of variation in home range area among individuals based on lower coefficients of variation (Tables 3.2, 3.3). Brood-rearing home ranges appear to be highly variable, as the majority of standard deviations for both flightless and flight-able age periods were larger than the mean resulting in inflated coefficients of variation (Table 3.3). When regions and years were pooled, the coefficient of variation indicated that as adult females transition from the laying (nesting) phase, to the first two weeks of brood rearing, and the second two weeks of brood rearing, home range areas become increasingly variable among individuals (Table 3.3).

Lukacs chick survival model for poult survival

I retained 89 broods with sufficient data (>2 poult counts or >1 poult count with confirmed adult female mortality) for estimating poult survival in the first model suite. Poult survival was best predicted when allowing survival to vary through time and holding detection probability constant (Table 3.4). Using this model without any covariates, poult survival for the duration of a six-week period following hatching was 0.30 ± 0.02 (lower [LCL] and upper [UCL] 95% confidence limit, LCL = 0.26, UCL = 0.35). Detection probability of poults (p) was estimated to be 0.65 ± 0.03 (LCL = 0.59, UCL = 0.71). Poult survival increased with every week, 0.53 ± 0.03 (LCL =

0.46, UCL = 0.59) in week 1, 0.59 ± 0.04 (LCL = 0.51, UCL = 0.67) in week 2, 0.95 ± 0.04 (LCL = 0.76, UCL = 0.99) in week 3, and finally 1.00 ± 0.00 in both weeks 4 and 5 (Figure 3.2).

I retained 81 broods with sufficient location data (>2 days of laying movement data) to estimate home ranges for the nest laying phase and at least the first phase brood survival (ages 0-14) in the second model comparison set (Table 3.5). Poult survival was best predicted when survival was grouped as flightless (0-14 days after hatch) and flight-able (>14 days after hatch) weeks of life, with an additive covariate of the laying period 50% isopleth (Table 3.5; Figure 3.3).

Brood foraging and ground roosting habitat use

I completed 230 foraging habitat and 148 ground-roost surveys split among 52 and 72 unique broods, respectively, across the study regions (Tables 3.6, 3.7, 3.8). Of the locations surveyed for brood-foraging habitat, the majority of foraging locations were in grasslands (47%). The second most common cover type used for brood foraging was woodland (28%), followed by cropland (15%) and shrubland (10%). Flightless broods had the largest relative use of ground-roost locations in woodlands (39%), followed by grasslands (35%), shrublands (18%), and finally croplands (8%).

Resource selection for foraging-habitat use was best modeled using the interactive model of forb composition and patch type (forb*patch), where there was a positive influence of forb presence on point use ($\beta = 0.024$, SE = 0.008, $P = 0.003$; Table 3.9). Selection strength towards forb composition was greatest in croplands, with a 75% relative probability of use in 100% forb composition, but events of 100% forb composition were uncommon (Figure 3.4). Forests and grasslands had a uniform probability of use across a range of forb composition, meaning that

selection strength did not change with changes in forb composition (Figure 3.4). Visual obstruction at the center point did not influence brood-foraging habitat use. All visual obstruction models at the center point were outcompeted by the null and exhibited spurious coefficients (Table 3.10). Similarly, the 10-m radius around the point of brood-foraging visual obstruction showed no predictive power for estimating probability of brood use, while forb composition interacting with patch type was supported (Tables 3.11, 3.12). However, relationships between use and patch type changed among patches within the 10-m radius model compared to the center-point model results. Probability of use at the 10-m radius was only significantly, and positively, predicted by the forb*forest patch type interaction ($\beta = 0.031 \pm 0.012$, $P = 0.009$; Figure 3.5).

Contrasting brood foraging-habitat use, brood ground-roost use was best modeled by both visual obstruction and functional group compositions (Tables 3.13, 3.14, 3.15, 3.16). At the center of the ground-roost location as well as at the 10-m radius around the roost location, visual obstruction within a 0-25 cm height interacting with patch type (VOR1*patch) best predicted use of the measured variables (Tables 3.13, 3.15). Selection strength increased with percent visual obstruction in croplands, decreased slightly with percent visual obstruction in forests, and remained uniform in grasslands and shrublands (Figure 3.6). Woody plant composition interacting with patch type was most influential for modeling probability of use at the center point, while litter composition had the greatest influence for modeling probability use for selection at the 10-m radius around a ground-roost location (Tables 3.14, 3.16). Although both model suites had the patch type interactive model outperforming the main effects model, further inspection indicated that the interactive term was spurious based on coefficient values and interactive term significance. Probability of use was positively influenced by woody plant

composition at the center point ($\beta = 0.020 \pm 0.006$, $P = 0.0004$; Figure 3.7) and litter composition at the 10-m radius around the center point ($\beta = 0.034 \pm 0.008$, $P < 0.0001$; Figure 3.8).

Comparative nesting and brood rearing habitat

Woody-stemmed plant composition at the center point, visual obstruction within 25-50 cm height at the center point, forb composition at a 10-m radius around a used point, and litter composition at a 10-m radius around a used point differed among nest, brood foraging, and brood ground-roosting site groups (MANOVA, $F_{12, 2478} = 40.51$, $P < 0.0001$). Univariately, litter composition (ANOVA, $F_{3,827} = 1.43$, $P = 0.23$) as well as the forb composition ($F_{3,827} = 0.41$, $P = 0.74$) at a 10-m radius around used points did not differ among habitat types, despite forb composition negatively affecting nest success (Chapter II) but benefiting brood foraging use. Woody plant composition ($F_{3,827} = 23.99$, $P < 0.0001$) and visual obstruction at a 25-50 cm height ($F_{3,827} = 227.34$, $P < 0.0001$) at the center point of used locations, however, differed among habitat groups.

Nest locations had greater proportion of woody-stemmed plants and visual obstruction at 25-50 cm tall compared to brood foraging sites of both ages, flightless (0-14 days old) and flight-able (14-28 days old; Table 3.17). This positive relationship between nest site use, visual obstruction and woody plant composition was similar to selection of brood ground roosting locations. However, nest locations also had greater values of both variables even in comparison to ground roosts (Table 3.17). Brood-foraging habitat during the flightless period differed from brood ground-roosting habitat only in woody-stemmed plant composition at the center point, with greater percentage of woody-stemmed plants at brood ground-roosting locations (Tables

3.17). Woody-stemmed plant composition, visual obstruction within 25-50 cm tall, 10-m radius forb composition, or 10-m radius litter composition did not differ between brood-age groups for foraging habitat (Table 3.17).

Discussion

Wild turkey poult survival across Kansas is lowest and most sensitive to external variables during the flightless period of life, defined generally as the first two weeks following hatch. One such variable that affects flightless poult survival is the behavior of the brood-rearing female during the nest laying state that results in either large or small home range areas that occurs in the period about a month and a half before broods hatch. Core home range estimates during the brood-rearing state exhibited considerable variation among individual females, possibly inferring more sensitivity to the environment during brood rearing but is less consequential compared to the decisions leading up to nesting. Environmental variables that affected brood-habitat use included forb composition for diurnal foraging and woody composition paired with visual obstruction 0-25 cm tall for ground roosting, all of which were positively related with use. Even though female wild turkeys with broods seek out greater relative values of woody composition and visual obstruction, selection for nest sites indicated significantly greater values of both in comparison. Concerning forb composition, however, wild turkey habitat for nesting, brood foraging, and brood ground roosting all have statistically identical values. Forb-rich and easily maneuverable (low-VOR) brood foraging habitat appears to be readily available based the synonymous values among all three regions and the used versus available locations; Brood ground roosting habitat, however, may be a limiting factor and a component to improving brood survival during the most sensitive period of a poult's life, which is the flightless phase.

Brood foraging and ground roosting habitat

Wild turkey brood-foraging habitat is best described as early successional or frequently disturbed areas, with limited canopy cover allowing for understory growth of a forb-rich grassland or meadow (Powell et al. 2022, Nelson et al. 2023). In my grassland study system, brood foraging occurred primarily within grasslands while ground roosting was equally split between woodlands and grasslands. Female wild turkeys are frequently noted as relying on forb-dominated patches adjacent to or within woodlands to raise their brood (Day et al. 1991, Nelson et al. 2023).

Access to both quality foraging and ground roosting habitats in close proximity is crucial for a female and her brood that may not move more than a few hundred meters within 48 hours after hatching (Spears et al. 2007, Chamberlain et al. 2020, Nelson et al. 2023). Reliance of precocial broods on forb-dominant areas is driven by the requirements for poults to forage on protein and nutrient dense insects (Healy 1992, Sullins et al. 2018, Reeves 2018). Previous studies have observed forb patch use to be stronger within the first few days compared to being more generalized in the later weeks following hatch (Chamberlain et al. 2020). Development of intermediate levels of forb richness, rather than dense areas of single forb species such as the poison hemlock colonies described in Chapter 2, appears to be most beneficial to brood use in the Great Plains (C. Marchese, unpublished data). I observed no significant differences in forb composition between flightless and flight-capable brood ages, as well as nest locations, possibly indicating that forb availability or brood-foraging habitat in general is not limited within our study areas.

The influence of woody cover and visual obstruction, however, varied among used locations for breeding states and study regions. Both surrogate measures of protective cover also influenced resource selection for brood-ground roosting and nesting habitat within the grassland

study system. This distinct pattern of selection and differences in habitat use among reproductive states may indicate that the “protective cover” during brood ground roosting sought by female wild turkeys during the breeding season is the more limiting variable for management across the state. Cover, measured through both visual obstruction and functional plant groups such as woody-stemmed plants, is required by broods for intrinsic functions such as thermoregulation and managing external variables such as predator avoidance (Nelson et al. 2022, 2023). The definition of adequate cover is specific to each life stage, and despite being a bird that requires arboreal roosts throughout its life cycle, female wild turkeys tend to avoid completely canopied areas with their brood yet still rely on structures such as downed limbs or thick shrubs for ground roosting during the pre-flight period (Spears et al. 2007, Nelson et al. 2023). Anecdotally, I documented repeated use of downed and dead limbs as ground roosts, which is likely represented by the significant result of “litter” within a 10-m radius of the roost location also predicting site use.

Even though woody cover is important for brood ground-roost cover, it is important to properly define what woody cover represents, especially within a grassland ecosystem. Across study areas, woody cover at ground-roost locations was ~15%, which is similar to Nelson (2022) reporting that brooding females did not use areas with >27% woody cover. Woody cover in a Great Plains grassland system mostly represents low- and mid-height growing shrubs such as coral berry (<1 m above ground, *Symphoricarpos orbiculatus*), which was the dominant woody cover at 29% of all ground roosting sites. Used woody cover in the study area was also represented by young versions of native woody plants that are kept in check through frequent and intense disturbance (i.e., fire), such as rough-leaf dogwood (*Cornus drummondii*) and eastern red cedar (*Juniperus virginiana*). This pattern of disturbance shaping various habitat types

required by female wild turkeys seems to be recurrent across the United States, as in the Southeast where broods primarily roosted in intermediate (3-6 yr return) burn area but foraged in annual burn areas (Wood et al. 2018).

The balance of habitat selection for both wooded areas and early successional vegetation associations highlight the importance of having plentiful edge habitat within a home range for a female with broods so that small poults can easily access necessary resources, which can be produced through actions such as patch-burn grazing (Day et al. 1991, Nelson et al. 2023). In addition to being tools for creating a mosaic of brood foraging and ground-roosting habitat in close proximity, disturbances such as fire allow for repression of woody encroachment that most often presents itself as shrublands across the Great Plains. Shrublands, similar to the nesting period (Chapters I and II), was one of the least used cover types for both brood foraging and brood ground-roosting locations, inferring possible avoidance and negative consequences of the cover type quickly expanding across Kansas (C. Skidmore, unpublished data, Fogarty et al. 2023).

Brood home range

Habitat quality, although sometimes difficult to define, can influence how much movement or space use is required for wildlife to fulfill all resource needs. Habitat quality and proximity of multiple required resources can be especially important during critical windows of reproductive timing such as the first two weeks of survival for flightless wild turkey broods (Johnson 2007, Nelson et al. 2023). There is little information on the home range area, habitat selection, and survivorship resulting from these behavioral decisions by female wild turkeys with broods, especially in the Great Plains. Previous studies indicate that the total area used by a brood

changes significantly as the brood ages or across the region within a state, complicating the definition and management scale of brood habitat (Bowling et al. 2015, Chamberlain et al. 2020, Nelson et al. 2023). Biologically, estimates of home range area for flightless and flight-capable broods showed some increase in area with age for certain regions and years but was ultimately too variable and inconsistent to conclude with much certainty that home ranges increase or decrease with brood age. The lack of a consistent trend appears to be the pattern itself, however, in that the one consistency is that brood space use and home ranges are highly sensitive to the region and immediately surrounding environment. Therefore, brood home range area and ultimately brood habitat management is not on a single spatial scale, but instead specific to each local system and composition of cover types.

Reports of 0–28-day core home range areas increasing from 0.8 ha to 27.9 ha in the forested east are notably smaller compared to those in the Midwest United States (Chamberlain et al. 2020). Brood home-range areas in the Great Plains region nearly quadruple, with estimates of 42.1 ha to 126.7 ha in South Dakota (Day et al. 1991) and an average of 97.6 ± 8.1 ha in Illinois, USA (Delahunt 2010). My estimates of core home ranges of female wild turkeys with broods in Kansas are similar to those from the Great Plains region, in that home ranges are larger than those estimated in southeastern states as well as more variable than those presented in forest-dominant areas. Such regional differences in home range are likely due to resource availability and juxtaposition (e.g., forage, water, predator escape cover, roost sites), with broods in the Midwest being required to travel greater distances to fulfill their daily needs (Viana et al. 2018, Gardiner et al. 2019). Because increasing daily movement effort has a pattern of decreasing brood survival, it is pertinent to continue investigating what contributes most to brood habitat quality and thus survival and recruitment in the Great Plains (Chamberlain et al. 2020).

Factors affecting brood survival

Apparent survival of wild turkey broods to 28-days post hatch varies among years and states but includes estimates such as 33% in Georgia (Nelson et al. 2023), 36% in South Dakota (Shields and Flake 2006), 36.25% in the southeastern United States (Chamberlain et al. 2020), and 52% in Iowa (Hubbard et al. 1999). Apparent success of broods reaching 28 days of age in Kansas (22-33%) falls within the low end for the range of previously reported values, but is not aberrantly low in comparison to historic estimates even as it varied between study years. Mammalian predation is the most suspected cause of brood mortality compared to the possibilities of nonpredatory caused deaths such as disease, starvation, or exposure (e.g., weather) even though determining cause of a brood's disappearance relies heavily on assumptions unless directly observed (Hubbard et al. 1999). A large portion (32.8%) of unsuccessful broods within my study failed due to specifically female mortality; 90% of those females died within the flightless phase of brood rearing. Because of these observations, I conclude that despite brood survival estimates being on the lower range of previously recorded values, brood recruitment in Kansas is likely limited more so by other life events than those directly associated with brood-specific survival.

My estimate of poult survival through time supports the concept that broods are most at risk of predation during the first two weeks of life, which is the flightless period (Hubbard et al. 1999, Spears et al. 2007, Chamberlain et al. 2020, Nelson et al. 2023). Furthermore, poults reached a weekly survival estimate of nearly 100% once they reached the capability to arboreally roost, supporting the conclusion that poult survival is equal to that of the adult female after reaching that state. In addition to being most at risk to predation during the first two weeks after hatching, the flightless period is the most difficult for poult thermoregulation (Roberts and Porter

1998). Deviations of heating degree days and precipitation from local averages negatively affect the probability of poult survival; however, it is suggested these factors act more as a cumulative effect rather than single occurrences (Roberts and Porter 1998, Schwerner et al. 2007). Even though the summer breeding period became increasingly warmer between earliest and latest hatch dates, I observed no evidence of Julian date or nest attempt being predictors of poult survival, possibly indicating thermoregulation is not a primary survival issue within my study system.

Although survival of flightless broods was not most parsimoniously modeled using the core home range of the brood in our study, it would be reasonable to consider its use and application (Ver Hoef and Boveng 2015). Home range area is often indicative of habitat quality, with the marginal value theorem predicting that animals will initiate or continue movement when the energy put towards resource acquisition within a patch is more costly than energy required to move to a more resource-dense patch (Kittle et al. 2015, Menezes 2022, Séchaud et al. 2022). Inference from the brood home range model supports the conclusion that brood core home ranges during the first week of life have a negative relationship with flightless brood survival. However, my results reframe the focus of which behavioral decisions shape poult survival away from brood-specific variables instead towards what precedes the brood-habitat selection decisions made by female wild turkeys during the nest laying state. The laying home range model had greater support as a better predictor of poult survival in addition to the laying state being a preliminary determinant of what landscapes where nests are placed. In a grassland system where spatial anchors of available roost trees drastically limit the dispersal capabilities of every life stage for wild turkeys, especially that of small poults, management objectives that focus on results of nest placement behavior more so than brood-rearing behavior should be

considered. Furthermore, because laying-state home range sizes of female wild turkeys were fairly consistent when compared to brood-rearing home ranges, the lay-state behavior may be a statewide, population-level management variable. Brood rearing behavior, on the other hand, seems to be more local or site-dependent that would require case-by-case management approaches. Going forward, investigating why the laying state core home range, which can be simplified into the movement of a female between a grassland nest site and an arboreal roosting location(s) within a riparian area once per day, will likely be the key to improving brood survival in the Great Plains region.

Conclusions

Managing for wild turkey brood success in Kansas appears to be inextricably linked to behaviors made during the nesting season based on laying-state home range and nest-site selection. Consequences of nest-site selection, which directly influences annual poult recruitment as its precursor, indicates that forb composition at the nest site negatively affects nest survival (Chapter II). Even though brood-foraging habitat is influenced through forb composition, the recurrent and intensive disturbance that maintains forbs appears to be ubiquitous in Kansas based on the similarities of forb occurrence among all habitat types. In terms of the laying-state core home range area negatively affecting subsequent poult success, it is likely that factors of roost tree distribution or density across the state is restricting nest-site placement to areas that are unfavorable for poult survival specifically within the first two weeks of life. Furthermore, low poult-to-hen ratios are only one outcome of the latent variable causing possible population declines from breeding season consequences. Because nest success is the preliminary requirement for future poult counts, investigating brood survival and selection alone likely do not answer the complete question of why such low ratios are being recorded. Going forward,

investigations of variables such as ground-cover availability and predator densities specifically within defined radii of trees meeting arboreal roosting requirements of wild turkeys may benefit poult management across the Great Plains region.

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Tables and Figures

Table 3.1. Apparent success values (# successful broods/ # total broods) of wild turkey broods in Kansas, USA, 2024-2025. Success values are provided as a ratio of the number of broods that survived each respective week of life following hatch divided by the number of monitored broods. Region represents the study region (East, Central, West) of which the brood was located in, representing a longitudinal, negative precipitation gradient from eastern to western Kansas. Originally, 109 broods were monitored in all; however, 17 broods were removed due to insufficient information to determine fate. Brood survival was determined through weekly poult counts via adult females marked with 140-g G5-T2A Iridium backpack units with global positioning systems (GPS) and very-high-frequency (VHF) radio components.

2024					
Region	<i>n</i>	Days 1-7	Days 7-14	Days 14- 21	Days 21- 28
East	15	0.73	0.55	0.55	0.55
Central	11	0.60	0.47	0.40	0.13
West	20	0.70	0.55	0.50	0.35
Total	46	0.67	0.52	0.48	0.33
2025					
Region	<i>n</i>	Days 1-7	Days 7-14	Days 14- 21	Days 21- 28
East	19	0.47	0.26	0.16	0.11
Central	19	0.58	0.42	0.37	0.26
West	8	1.00	0.38	0.38	0.38
Total	46	0.61	0.35	0.28	0.22

Table 3.2. Home ranges ($\pm$ SD; ha) estimated in three reproductive states of brood-rearing, adult female wild turkeys ($n = 81$) in Kansas, USA, 2024-2025, using 50% and 95% isopleths. States include the egg laying phase, the flightless period of brood rearing (0-14 days after hatch; brood age 1), and the flight-capable period of brood rearing (14-28 days after hatch; brood age 2). The egg laying state includes all movement locations from the start of the first day of identified laying up to the first night of incubation, and the brood-rearing state includes all movement locations beginning the day of hatching to either the end of the stated period (flightless or flight-capable) or the last known day the brood was alive if the brood failed.

Reproductive state	Region			Regions pooled
	West	Central	East	
2024				
laying 50%	63.02 ± 44.88	56.56 ± 39.91	63.27 ± 52.6	61.01 ± 44.61
laying 95%	269.73 ± 163.31	226.13 ± 139.08	254.64 ± 197.46	252.04 ± 163.07
brood age 1 50%	74.78 ± 157.54	35.71 ± 39.17	62.74 ± 63.21	58.78 ± 110.22
brood age 1 95%	331.77 ± 716.09	165.92 ± 191.31	292.34 ± 293.93	266.52 ± 502.72
brood age 2 50%	70.93 ± 127.47	116.1 ± 354.21	35.45 ± 56.12	75.42 ± 211.72
brood age 2 95%	329.36 ± 544.85	463.44 ± 1328.04	178.88 ± 252.3	330.91 ± 813.66
2025				
laying 50%	74.57 ± 78.74	70 ± 46.48	37.25 ± 34.41	56.13 ± 51.15
laying 95%	306.65 ± 285.5	284.48 ± 198.25	145.42 ± 132.76	226.12 ± 201.73
brood age 1 50%	47.1 ± 69.22	39.69 ± 36.44	31.89 ± 50.21	37.78 ± 49.33
brood age 1 95%	218.04 ± 306.64	172.21 ± 160.61	138.97 ± 207.82	166.86 ± 212.67
brood age 2 50%	56.42 ± 51.17	29.23 ± 30.03	36.55 ± 45.04	36.09 ± 40
brood age 2 95%	256.88 ± 215.63	135.32 ± 139	172.22 ± 208.02	167.73 ± 181.52
Years pooled				
laying 50%	66.27 ± 55.29	63.47 ± 43.32	46.91 ± 43.25	58.67 ± 47.69
laying 95%	280.11 ± 200.62	256.14 ± 172.13	185.98 ± 165.87	239.59 ± 182.21
brood age 1 50%	66.39 ± 136.3	37.75 ± 37.32	42.78 ± 56.22	48.48 ± 86.17
brood age 1 95%	297.31 ± 617.9	169.15 ± 173.76	193.1 ± 248.63	217.65 ± 389.94
brood age 2 50%	67.58 ± 113.62	66.08 ± 231.04	36.11 ± 48.83	56.42 ± 155.17
brood age 2 95%	312.63 ± 485.68	274.53 ± 868.61	174.89 ± 222.54	252.07 ± 600.83

Table 3.3. Coefficients of variation (CV) of wild turkey home ranges, calculated by dividing the standard deviation by the sample mean. Home ranges were estimated in three reproductive phases of brood-rearing, adult female wild turkeys ($n = 81$) in Kansas, USA, 2024-2025, using 50% and 95% isopleths. Phases include the egg laying phase, the flightless period of brood rearing (0-14 days after hatch; brood age 1), and the flight-capable period of brood rearing (14-28 days after hatch; brood age 2). The egg laying phase includes all movement locations from the start of the first day of identified laying up to the first night of incubation, and the brood rearing phase includes all movement locations beginning the day of hatching to either the end of the stated period (flightless or flight-capable) or the last known day the brood was alive if the brood failed. Home ranges were estimated using the `hr_kde()` function in the Animal Movement Tools (`amt`) package in Program R and were reported in hectares (ha).

Reproductive state	Study region			Regions pooled
	West	Central	East	
2024				
laying 50%	0.71	0.71	0.83	0.73
laying 95%	0.61	0.62	0.78	0.65
brood age 1 50%	2.11	1.10	1.01	1.88
brood age 1 95%	2.16	1.15	1.01	1.89
brood age 2 50%	1.80	3.05	1.58	2.81
brood age 2 95%	1.65	2.87	1.41	2.46
2025				
laying 50%	1.06	0.66	0.92	0.91
laying 95%	0.93	0.70	0.91	0.89
brood age 1 50%	1.47	0.92	1.57	1.31
brood age 1 95%	1.41	0.93	1.50	1.27
brood age 2 50%	0.91	1.03	1.23	1.11
brood age 2 95%	0.84	1.03	1.21	1.08
Years pooled				
laying 50%	0.83	0.68	0.92	0.81
laying 95%	0.72	0.67	0.89	0.76
brood age 1 50%	2.05	0.99	1.31	1.78
brood age 1 95%	2.08	1.03	1.29	1.79
brood age 2 50%	1.68	3.50	1.35	2.75
brood age 2 95%	1.55	3.16	1.27	2.38

Table 3.4. Model performance for poult weekly survival rate for wild turkey broods ($n = 89$) in Kansas, USA, 2024-2025. The models were fit using the Lukacs chick survival with a marked adult model in program MARK. Poult survival was modeled with detection probability as constant ($p(\cdot)$) and survival probability as either constant ($s(\cdot)$) or varying weekly over time ($s(t)$) with region or year as grouping variables and nest attempt or hatch Julian Date (JD) as covariates. Region was the three longitudinal sections of the study area, representing a negative precipitation gradient from the regions of east, central, and west Kansas. Nest attempt represented the attempt number (first, second, third, or fourth) that the brood was hatched from, and hatch Julian date was the date of which the brood hatched. Weekly poult counts were conducted by monitoring female wild turkeys marked with 140-g G5-T2A Iridium backpack units equipped with global positioning systems (GPS) and Very High Frequency (VHF) radio components.

Model	K	AICc	ΔAIC_c	w_i	Log Likelihood
$S(t) p(\cdot)$	6	1252.82	0.00	0.54	1240.33
$S(t, \text{year}) p(\cdot)$	11	1253.12	0.30	0.46	1229.53
$S(t, \text{region}) p(\cdot)$	16	1271.26	18.44	0.00	1235.89
$S(\cdot, \text{region}) p(\cdot)$	4	1334.16	81.66	0.00	1325.93
$S(\cdot, \text{year}) p(\cdot)$	3	1343.38	90.89	0.00	1337.25
$S(\cdot) p(\cdot)$: null	2	1353.85	101.35	0.00	1349.78
$S(\cdot, \text{nest attempt}) p(\cdot)$	2	1360.14	107.64	0.00	1356.07
$S(\cdot, \text{hatch JD}) p(\cdot)$	2	1361.82	109.32	0.00	1357.75

^a Model = main effects model titles, K = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, ω_i = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 3.5. Model performance for poult weekly survival rate for wild turkey broods ($n = 81$) in Kansas, USA, 2024-2025. The models were fit using the Lukacs chick survival with a marked adult model in program MARK. Poult survival was modeled with detection probability as constant ($p(\cdot)$) and survival probability varying weekly over time ($s(t)$) or with survival weeks grouped into either flightless poult weeks (weeks 1-2) and flight-capable poult weeks (weeks 3-6). Covariates included the laying 50% kernel density estimate (KDE) and the “age one” (weeks 1-2 after hatch) 50% KDE of the respective broods’ home range. Weekly poult counts and home range values were estimated by monitoring female wild turkeys marked with 140-g G5-T2A Iridium backpack units equipped with global positioning systems (GPS) and very-high-frequency (VHF) radio components.

Model	K	AIC _c	Δ AIC _c	w_i	Log Likelihood
S (weeks grouped, laying 50% KDE), $p(\cdot)$	3	1129.42	0.00	0.93	1123.27
S (weeks grouped), $p(\cdot)$	2	1134.48	5.06	0.07	1130.41
S (t, age one 50% KDE), $p(\cdot)$	3	1150.00	20.58	0.00	1143.85
S (t, laying 50% KDE), $p(\cdot)$	1	1158.64	29.22	0.00	1156.62
S (weeks grouped, age one 50% KDE), $p(\cdot)$	3	1166.46	37.04	0.00	1162.39
S (t), $p(\cdot)$	5	1169.37	39.95	0.00	1158.99

^a Model = main effects model titles, K = no. of parameters, AIC_c = Akaike’s Information Criterion adjusted for sample size, Δ AIC_c = difference in AIC_c relative to smallest AIC_c value, ω_i = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 3.6. Mean and standard deviation ($\bar{x} \pm \text{SD}$) of habitat measurements recorded at 144 wild turkey brood foraging locations for 0-14 days old and 292 random locations within 400 m of that used foraging location. The study took place across 3 study regions (East [$n = 41$], Central [$n = 52$]), and West [$n = 51$]) in Kansas, USA, during 2024-2025. Variables were measured at 1 m around the foraging location and repeated at 10 m from the foraging location. Grass, forb, woody, bare ground, and litter are compositional percentages measured inside a 1-m quadrat. Visual obstruction readings (VOR) are percentages measured at 0-25 cm (VOR 1), 25-50 cm (VOR 2), 50- 75 cm (VOR 3), and 75-100 cm (VOR 4) above ground.

Variable	Foraging Locations: Days 0-14			Random Locations: Days 0-14		
	East	Central	West	East	Central	West
Center grass	41.54±27.75	45.19±29.72	49.88±26.92	48.92±28.09	49.46±29.18	50.75±27.32
Center forb	28.39±19.48	21.73±23.8	17.1±16.4	23.48±17.71	19.18±19.79	15.58±15.64
Center woody	5.49±10.77	9.71±17.1	3.04±7.62	5.5±12.9	8.25±15.37	4.5±12.72
Center bare	13.85±16.75	9.23±11.77	11.24±14.86	8.73±14.07	7.72±11.07	9.89±15.91
Center litter	12.41±10.85	13.92±11.11	18.75±16.73	13.38±15.78	15.39±15.7	19.26±18.73
VOR 1	52.32±40.84	51.44±43.34	29.88±35.72	54.42±42.62	51.9±43.15	28.9±36.92
VOR 2	35.53±37.16	33.95±35.19	15.00±21.09	39.18±36.27	35.25±36.69	18±26.47
VOR 3	20.94±26.19	16.87±22.56	8.31±13.29	23.39±27.77	19.27±27.44	10.8±18.84
VOR 4	14.54±20.8	9.63±17.48	4.91±8.98	14.99±22.35	11.19±19.75	7.09±13.44
10-m grass	37.44±23.5	44.38±24.86	39.98±21.35	45.26±22.99	46.78±24.08	40.39±21.56
10-m forb	31.34±27.05	18.97±19.62	17.16±11.38	22.48±14.2	16.67±17.32	16.91±15.12
10-m woody	5.79±6.24	8.1±11.78	6.17±8.86	7.13±10.26	7.31±12.47	7.44±11.59
10-m bare	16.03±18.16	10.45±12.35	14.42±14.76	11.44±15.57	10.73±10.91	12.27±14.08
10-m litter	12.76±11.01	18.2±10.71	22.04±16.56	13.74±15.2	18.91±14.27	23.01±15.61
10-m VOR 1	52.67±39.39	51.06±42.41	32.13±38.08	53.07±40.95	51.09±42.54	29.01±36.85
10-m VOR 2	35.43±34.45	37±35.77	21.48±28.14	40.31±36.13	34.55±35.05	18.97±25.83
10-m VOR 3	24.54±28.93	20.29±23.17	13.22±19.2	25.48±28.94	20.67±27.39	12.69±20.37
10-m VOR 4	18.83±24.29	12.03±17.06	8.73±14.95	18.67±23.98	13.01±21.45	9.16±16.65

Table 3.7. Mean and standard deviation ($\bar{x} \pm \text{SD}$) of habitat measurements recorded at 86 wild turkey brood foraging locations for 14-28 days old and 165 random locations within 400 m of that used foraging location. The study took place across 3 study regions (East [$n_{\text{used}} = 22$], Central [$n_{\text{used}} = 41$]), and West [$n_{\text{used}} = 23$]) in Kansas, USA, during 2024-2025. Variables were measured at 1 m around the foraging location and repeated at 10-m from the foraging location. Grass, forb, woody, bare ground, and litter are compositional percentages measured inside a 1-m quadrat. Visual obstruction readings (VOR) are percentages measured at 0-25-cm (VOR 1), 25-50 cm (VOR 2), 50- 75 cm (VOR 3), and 75-100 cm (VOR 4) above ground.

Variable	Foraging Locations: Days 14-28			Random Locations: Days 14-28		
	East	Central	West	East	Central	West
Center grass	40.5±28.83	39.95±28.82	51.74±20.76	40.02±27.87	50.99±25.56	52.72±21.1
Center forb	24.73±23.86	20.41±20.03	17.61±16.44	25.26±21.63	17.19±18.95	19.13±18.95
Center woody	8.64±15.21	13.05±18.26	4.78±12.01	8.71±14.97	6.62±15.38	1.85±5.9
Center bare	15.09±22.03	12.68±17.89	8.48±14.26	14.24±20.27	8.57±13.1	11.74±13.55
Center litter	11.05±8.47	14.39±10.74	17.61±17.31	11.52±9.74	16.75±16.62	15.11±8.91
VOR 1	34.99±39.54	46.43±41.67	27.46±36.57	32.56±37.33	49.32±42.47	26.21±34.53
VOR 2	24.46±33.65	29.95±34.49	15.96±27.86	26.39±34.97	28.97±34.9	14.83±24.58
VOR 3	18.29±30.12	22.79±31.96	10.38±20.53	21.1±33.09	17.09±26.48	7.54±15.65
VOR 4	14.6±26.51	18.43±29.35	6.71±12.95	17.42±30.76	11.41±21.37	3.95±9.17
10-m grass	39.22±20.87	36.79±21.06	47.23±16.98	41.3±25.14	45.5±23.57	46.01±17.83
10-m forb	25.14±18.56	19.63±19.67	13.86±10.91	26.12±19.65	15.46±14.44	15.43±12.92
10-m woody	7.92±9.28	10.71±13.11	7.01±7.46	6.61±9.77	6.9±12.88	5.18±9.5
10-m bare	14.97±14.09	12.88±15.09	10.11±12.54	13.88±17.29	11.56±13.77	12.17±11.8
10-m litter	12.06±6.72	19.87±12.43	21.68±15.11	12.36±8.41	20.18±14.87	21.11±12.29
10-m VOR 1	31.7±35.45	47.08±40.71	28.41±36.11	32.11±36.68	48.12±41.23	26.2±33.72
10-m VOR 2	24.13±30.55	30.53±34.58	16.6±24.05	26.36±34.4	28.25±34.4	15.86±23.62
10-m VOR 3	17.95±26.61	21.43±30.89	9.08±15.25	22.38±33.47	17.06±26.77	7.96±14.32
10-m VOR 4	13.63±21.47	16.96±28.75	6.57±12.07	18.8±32.14	10.24±20.73	4.82±11.95

Table 3.8. Mean and standard deviation ($\bar{x} \pm \text{SD}$) of habitat measurements recorded at 148 wild turkey brood ground roosting locations for 0-14 days old and 292 random locations within 400 m of that used foraging location. The study took place across 3 study regions (East [$n_{\text{used}} = 38$], Central [$n_{\text{used}} = 47$]), and West [$n_{\text{used}} = 63$]) in Kansas, USA, during 2024-2025. Variables were measured at 1-m around the foraging location and repeated at 10-m from the foraging location. Grass, forb, woody, bare ground, and litter are compositional percentages measured inside a 1-m quadrat. Visual obstruction readings (VOR) are percentages measured at 0-25 cm (VOR 1), 25-50 cm (VOR 2), 50- 75 cm (VOR 3), and 75-100 cm (VOR 4) above ground.

Variable	Ground Roost Locations: Days 0-14			Random Locations: Days 0-14		
	East	Central	West	East	Central	West
Center grass	32.84 $\pm$ 27.42	32.66 $\pm$ 27.38	43.87 $\pm$ 28.01	34.79 $\pm$ 26.97	45.75 $\pm$ 32.24	46.47 $\pm$ 28.79
Center forb	33.26 $\pm$ 22.52	17.55 $\pm$ 17.59	19.21 $\pm$ 19.89	33.75 $\pm$ 18.97	18.06 $\pm$ 20.82	18.66 $\pm$ 17.95
Center woody	13.16 $\pm$ 17.06	19.68 $\pm$ 19.01	10.32 $\pm$ 20.31	9.54 $\pm$ 13.88	12.06 $\pm$ 20.05	5.97 $\pm$ 13.52
Center bare	7.89 $\pm$ 13.60	10.53 $\pm$ 16.98	7.70 $\pm$ 11.33	9.04 $\pm$ 15.60	7.99 $\pm$ 12.20	14.23 $\pm$ 21.48
Center litter	12.71 $\pm$ 12.43	20.11 $\pm$ 20.16	18.89 $\pm$ 18.21	13.96 $\pm$ 13.63	16.03 $\pm$ 15.96	15.21 $\pm$ 15.08
VOR 1	54.23 $\pm$ 43.09	56.22 $\pm$ 44.24	29.91 $\pm$ 36.35	52.88 $\pm$ 41.15	53.95 $\pm$ 43.52	29.16 $\pm$ 36.66
VOR 2	46.61 $\pm$ 40.34	47.47 $\pm$ 41.64	21.06 $\pm$ 28.57	38.04 $\pm$ 37.61	38.57 $\pm$ 38.40	17.43 $\pm$ 26.05
VOR 3	35.34 $\pm$ 35.80	30.81 $\pm$ 31.46	11.98 $\pm$ 18.35	25.23 $\pm$ 31.09	25.41 $\pm$ 32.44	9.73 $\pm$ 17.53
VOR 4	27.01 $\pm$ 29.78	17.28 $\pm$ 20.96	8.57 $\pm$ 15.60	18.16 $\pm$ 25.78	15.13 $\pm$ 22.91	6.63 $\pm$ 13.89
10-m grass	34.45 $\pm$ 22.85	32.91 $\pm$ 23.88	39.76 $\pm$ 19.70	37.14 $\pm$ 25.17	41.70 $\pm$ 26.16	44.07 $\pm$ 22.40
10-m forb	30.39 $\pm$ 17.21	17.14 $\pm$ 15.80	17.66 $\pm$ 14.08	28.56 $\pm$ 15.32	17.69 $\pm$ 15.92	16.16 $\pm$ 13.46
10-m woody	10.57 $\pm$ 10.12	17.15 $\pm$ 15.08	11.26 $\pm$ 16.08	8.70 $\pm$ 9.76	8.81 $\pm$ 13.77	6.67 $\pm$ 12.49
10-m bare	10.32 $\pm$ 11.48	11.69 $\pm$ 11.26	8.98 $\pm$ 8.95	11.76 $\pm$ 16.29	11.01 $\pm$ 13.15	14.31 $\pm$ 17.31
10-m litter	14.13 $\pm$ 11.81	21.99 $\pm$ 14.45	22.36 $\pm$ 18.03	13.81 $\pm$ 13.42	21.41 $\pm$ 18.18	19.01 $\pm$ 14.51
10-m VOR 1	53.73 $\pm$ 42.72	54.73 $\pm$ 43.55	30.70 $\pm$ 37.39	49.76 $\pm$ 40.80	52.85 $\pm$ 43.46	29.79 $\pm$ 36.58
10-m VOR 2	44.13 $\pm$ 37.76	42.98 $\pm$ 38.20	22.39 $\pm$ 29.84	37.11 $\pm$ 36.62	38.78 $\pm$ 39.16	18.98 $\pm$ 26.11
10-m VOR 3	29.41 $\pm$ 28.90	31.55 $\pm$ 31.16	13.45 $\pm$ 21.37	24.07 $\pm$ 28.03	27.23 $\pm$ 33.22	10.80 $\pm$ 16.79
10-m VOR 4	19.35 $\pm$ 21.70	21.66 $\pm$ 24.78	10.18 $\pm$ 18.38	16.05 $\pm$ 21.13	16.12 $\pm$ 22.79	7.66 $\pm$ 14.24

Table 3.9. Model performance for wild turkey brood (0-28 days old after hatch) foraging habitat use of 52 broods, 231 foraging locations, and 457 randomly generated locations within 400 m of the used site in Kansas, USA, 2024-2025 at the used point by ground cover composition of 5 functional plant groups (grass, forbs, litter, woody vegetation, and bare ground). Region and patch type were used as interactive effects, where region represents the study region in Kansas (East, Central, West) and patch type represents 4 patch types that brood forage locations were observed within (grassland, shrubland, forest, and cropland).

Model ^a	<i>K</i>	AIC _c	ΔAIC _c	<i>w_i</i>	Log Likelihood
forb*patch	8	875.75	0.00	0.43	-429.77
grass	2	878.06	2.31	0.13	-437.02
grass*patch	8	878.74	3.00	0.1	-431.27
litter*patch	8	878.84	3.09	0.09	-431.31
bare	2	879.48	3.73	0.07	-437.73
forb	2	880.06	4.31	0.05	-438.02
null	1	880.14	4.39	0.05	-439.07
woody	2	880.54	4.80	0.04	-438.26
litter	2	881.56	5.81	0.02	-438.77
woody*patch	8	883.35	7.60	0.01	-433.57
bare*patch	8	883.43	7.69	0.01	-433.61
grass*region	6	885.00	9.25	0.00	-436.44
bare*region	6	885.99	10.25	0.00	-436.94
woody*region	6	887.20	11.45	0.00	-437.54
forb*region	6	887.77	12.03	0.00	-437.83
litter*region	6	888.85	13.11	0.00	-438.37

^a Model = main effects model titles, *K* = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, *w_i* = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 3.10. Model performance for wild turkey brood (0-28 days old after hatch) foraging habitat use of 52 broods, 231 foraging locations, and 457 randomly generated locations within 400 m of the used site in Kansas, USA, 2024-2025 at the used point by visual obstruction readings (VOR) at four heights: 0-25 cm (VOR 1), 25-50 cm (VOR 2), 50-75 cm (VOR 3), and 75- 100 cm (VOR 4). Region and patch type were used as interactive effects, where region represents the study region (East, Central, West) in Kansas, and patch type represents 4 patch types that brood foraging locations were observed within (grassland, shrubland, forest, and cropland).

Model ^a	<i>K</i>	AIC _c	ΔAIC _c	<i>w_i</i>	Log Likelihood
null	1	880.14	0.00	0.21	-439.07
n_vor4*patch	8	880.62	0.48	0.17	-432.20
n_vor3*patch	8	880.79	0.64	0.15	-432.29
n_vor2*patch	8	881.54	1.40	0.11	-432.66
n_vor2	2	881.81	1.67	0.09	-438.9
n_vor3	2	882.09	1.94	0.08	-439.03
n_vor4	2	882.11	1.97	0.08	-439.05
n_vor1	2	882.13	1.99	0.08	-439.06
n_vor1*patch	8	884.93	4.78	0.02	-434.36
n_vor4*region	6	889.22	9.08	0.00	-438.55
n_vor2*region	6	889.48	9.34	0.00	-438.68
n_vor3*region	6	889.51	9.36	0.00	-438.69
n_vor1*region	6	890.01	9.86	0.00	-438.94

^a Model = main effects model titles, *K* = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, *ω_i* = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 3.11. Model performance for wild turkey brood (0-28 days old after hatch) foraging habitat use of 52 broods, 231 foraging locations, and 457 randomly generated locations within 400 m of the used site in Kansas, USA, 2024-2025 at a 10-m radius around each used foraging location by visual obstruction readings (VOR) at 4 heights: 0-25 cm (VOR 1), 25-50 cm (VOR 2), 50-75 cm (VOR 3), and 75- 100 cm (VOR 4). Region and patch type were tested as interactive effects, where region represents the study region (East, Central, West), and patch type represents 4 patch types that foraging locations were observed within (grassland, shrubland, forest, and cropland).

Model ^a	<i>K</i>	AIC _c	ΔAIC _c	<i>w_i</i>	Log Likelihood
null	1	880.14	0.00	0.29	-439.07
radius_vor4	2	882.06	1.91	0.11	-439.02
radius_vor1	2	882.13	1.98	0.11	-439.05
radius_vor2	2	882.13	1.99	0.11	-439.06
radius_vor3	2	882.14	1.99	0.11	-439.06
radius_vor4*patch	8	883.62	3.47	0.05	-433.70
radius_vor3*patch	8	883.86	3.71	0.05	-433.82
radius_vor2*patch	8	884.19	4.05	0.04	-433.99
radius_vor1*patch	8	884.41	4.27	0.03	-434.10
radius_vor2*region	6	888.89	8.75	0.00	-438.38
radius_vor4*region	6	889.20	9.06	0.00	-438.54
radius_vor3*region	6	889.57	9.43	0.00	-438.72
radius_vor1*region	6	889.83	9.68	0.00	-438.85

^a Model = main effects model titles, *K* = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, *w_i* = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 3.12. Model performance for wild turkey brood (0-28 days old after hatch) foraging habitat use of 52 broods, 231 foraging locations, and 457 randomly generated locations within 400 m of the used site in Kansas, USA, 2024-2025 at a 10-m radius around each used foraging location by ground cover composition of 5 functional plant groups (grass, forbs, litter, woody vegetation, and bare ground). Region and patch type were tested as interactive effects, where region represents the study region (East, Central, West), and patch type represents 4 patch types that foraging locations were observed within (grassland, shrubland, forest, and cropland).

Model ^a	K	AIC_c	ΔAIC_c	w_i	Log Likelihood
forb*patch	8	865.13	0.00	0.94	-424.46
litter*patch	8	871.90	6.77	0.03	-427.85
bare*patch	8	873.25	8.12	0.02	-428.52
woody*patch	8	875.65	10.52	0.00	-429.72
forb	2	878.24	13.11	0.00	-437.11
woody	2	878.48	13.35	0.00	-437.23
null	1	880.14	15.01	0.00	-439.07
grass*patch	8	880.62	15.49	0.00	-432.20
grass	2	880.80	15.67	0.00	-438.39
litter	2	881.69	16.55	0.00	-438.83
bare	2	881.85	16.72	0.00	-438.92
forb*region	6	884.64	19.51	0.00	-436.26
woody*region	6	884.79	19.65	0.00	-436.33
litter*region	6	888.28	23.15	0.00	-438.08
grass*region	6	888.29	23.16	0.00	-438.09
bare*region	6	889.86	24.72	0.00	-438.87

^a Model = main effects model titles, K = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, w_i = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 3.13. Model performance for wild turkey brood (0-14 days old after hatch) ground roosting habitat use from 72 broods and 148 ground roost locations, and 292 randomly generated locations within 400 m of the used site in Kansas, USA, 2024-2025 at the used point by visual obstruction readings (VOR) at four heights: 0-25 cm (VOR 1), 25-50 cm (VOR 2), 50-75 cm (VOR 3), and 75- 100 cm (VOR 4). Region and patch type were used as interactive effects, where region represents the study region (East, Central, West) in Kansas, and patch type represents 4 patch types that brood ground roosting locations were observed within (grassland, shrubland, forest, and cropland).

Model ^a	<i>K</i>	AIC _c	ΔAIC _c	<i>w_i</i>	Log Likelihood
n_vor1*patch	8	557.47	0	0.38	-270.57
n_vor2*patch	8	557.96	0.49	0.30	-270.81
n_vor4*patch	8	559.53	2.06	0.14	-271.60
n_vor3*patch	8	560.33	2.86	0.09	-272.00
n_vor3	2	562.73	5.26	0.03	-279.35
n_vor2	2	562.83	5.36	0.03	-279.40
n_vor4	2	563.01	5.53	0.02	-279.49
null	1	563.97	6.5	0.01	-280.98
n_vor1	2	565.91	8.43	0.01	-280.94
n_vor3*region	6	570.02	12.54	0.00	-278.91
n_vor4*region	6	570.29	12.82	0.00	-279.05
n_vor2*region	6	570.31	12.83	0.00	-279.06
n_vor1*region	6	573.92	16.44	0.00	-280.86

^a Model = main effects model titles, *K* = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, *ω_i* = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 3.14. Model performance for wild turkey brood (0-14 days old after hatch) ground roosting habitat use from 72 broods and 148 ground roost locations, and 292 randomly generated locations within 400 m of the used site in Kansas, USA, 2024-2025 at the used point by ground cover composition of 5 functional plant groups (grass, forbs, litter, woody vegetation, and bare ground). Region and patch type were used as interactive effects, where region represents the study region in Kansas (East, Central, West) and patch type represents 4 patch types that brood ground roosts were observed within (grassland, shrubland, forest, and cropland).

Model ^a	K	AIC _c	Δ AIC _c	w_i	Log Likelihood
woody*patch	8	547.35	0	0.55	-265.51
bare*patch	8	548.11	0.76	0.38	-265.89
grass*patch	8	552.83	5.47	0.04	-268.25
woody	2	553.15	5.79	0.03	-274.56
forb*patch	8	558.04	10.69	0.00	-270.85
litter*patch	8	558.34	10.98	0.00	-271.00
grass	2	559.85	12.49	0.00	-277.91
woody*region	6	560.06	12.71	0.00	-273.93
litter	2	563.74	16.39	0.00	-279.86
null	1	563.97	16.62	0.00	-280.98
bare	2	564.79	17.44	0.00	-280.38
forb	2	565.97	18.62	0.00	-280.97
grass*region	6	566.36	19.01	0.00	-277.08
bare*region	6	568.80	21.45	0.00	-278.3
litter*region	6	570.25	22.89	0.00	-279.03
forb*region	6	574.00	26.64	0.00	-280.90

^a Model = main effects model titles, K = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, Δ AIC_c = difference in AIC_c relative to smallest AIC_c value, ω_i = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 3.15. Model performance for wild turkey brood (0-14 days old after hatch) ground roosting habitat use from 72 broods and 148 ground roost locations, and 292 randomly generated locations within 400 m of the used site in Kansas, USA, 2024-2025 at a 10-m radius around each used point by visual obstruction readings (VOR) at four heights: 0-25 cm (VOR 1), 25-50 cm (VOR 2), 50-75 cm (VOR 3), and 75- 100 cm (VOR 4). Region and patch type were used as interactive effects, where region represents the study region (East, Central, West) in Kansas, and patch type represents 4 patch types that brood ground roosting locations were observed within (grassland, shrubland, forest, and cropland).

Model ^a	K	AIC_c	ΔAIC_c	w_i	Log Likelihood
radius_vor1*patch	8	556.63	0.00	0.38	-270.15
radius_vor2*patch	8	557.28	0.65	0.28	-270.47
radius_vor4*patch	8	558.32	1.69	0.16	-270.99
radius_vor3*patch	8	558.78	2.15	0.13	-271.22
radius_vor4	2	563.05	6.42	0.02	-279.51
null	1	563.97	7.34	0.01	-280.98
radius_vor3	2	564.27	7.64	0.01	-280.12
radius_vor2	2	564.59	7.96	0.01	-280.28
radius_vor1	2	565.79	9.15	0.00	-280.88
radius_vor4*region	6	570.71	14.08	0.00	-279.26
radius_vor3*region	6	571.83	15.2	0.00	-279.82
radius_vor2*region	6	572.29	15.66	0.00	-280.05
radius_vor1*region	6	573.72	17.09	0.00	-280.76

^a Model = main effects model titles, K = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, ω_i = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 3.16. Model performance for wild turkey brood (0-14 days old after hatch) ground roosting habitat use from 72 broods and 148 ground roost locations, and 292 randomly generated locations within 400 m of the used site in Kansas, USA, 2024-2025 at a 10-m radius around each ground roosting location by ground cover composition of 5 functional plant groups (grass, forbs, litter, woody vegetation, and bare ground). Region and patch type were tested as interactive effects, where region represents the study region (East, Central, West) and patch type represents 4 patch types that brood ground roosting locations were observed within (grassland, shrubland, forest, and cropland).

Model ^a	<i>K</i>	AIC _c	ΔAIC _c	<i>w_i</i>	Log Likelihood
litter*patch	8	543.43	0	0.79	-263.55
litter	2	546.36	2.93	0.18	-271.17
forb*patch	8	551.62	8.19	0.01	-267.64
grass*patch	8	553.02	9.59	0.01	-268.34
litter*region	6	553.21	9.79	0.01	-270.51
bare*patch	8	557.05	13.62	0.00	-270.36
forb	2	559	15.57	0.00	-277.49
woody*patch	8	562.32	18.89	0.00	-272.99
grass	2	562.94	19.51	0.00	-279.46
null	1	563.97	20.54	0.00	-280.98
bare	2	564	20.57	0.00	-279.99
woody	2	565.93	22.5	0.00	-280.95
forb*region	6	566.08	22.65	0.00	-276.94
grass*region	6	567.5	24.07	0.00	-277.65
bare*region	6	570.18	26.75	0.00	-278.99
woody*region	6	573.68	30.25	0.00	-280.74

^a Model = main effects model titles, *K* = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, *ω_i* = AIC_c weight, Log Likelihood = Natural logarithm of the likelihood function.

Table 3.17. Results of a post-hoc, pairwise t-test using a Bonferroni corrected p-value and un-pooled standard deviation. The six pairwise comparison groups include habitat types of four reproductive stages of female wild turkeys in Kansas, USA, 2024-2025. The habitat types include nesting locations ($n = 453$), brood foraging locations for 0-14 days (brood forage 1; $n = 144$) post hatch and 14-28 (brood forage 2; $n = 86$) days post hatch, and brood ground roosting locations for ages 0-14 (ground roost; $n = 148$) of wild turkeys. Woody-stemmed plant composition was measured at the used locations using a 1-m² quadrat. Visual obstruction readings (VOR) at 25-50 cm were measured using a 50 cm wide coverboard with 25 cm vertical sections. Bolded P values denote significance for pairwise comparisons at $\alpha = 0.05$.

Variable		Pairwise Comparison					
		brood forage 1 brood forage 2	brood forage 1 nest	brood forage 1 ground roost	brood forage 2 nest	brood forage 2 ground roost	nest ground roost
Percent Woody plant cover	df ^a	148.20	534.93	251.32	204.14	207.96	360.36
	t	1.74	10.16	4.62	6.32	2.30	-3.97
	P	0.51	<0.001	<0.001	<0.001	0.14	0.001
Visual obstruction 25-50 cm	df	178.81	184.62	285.23	99.63	200.62	178.77
	t	-0.65	18.47	1.74	15.41	2.14	-14.05
	P	1.00	<0.001	0.50	<0.001	0.20	<0.001
Percent 10-m radius forb cover	df	199.85	228.56	275.58	126.35	169.78	284.50
	t	-0.92	-0.90	-0.89	0.28	0.16	-0.13
	P	1.00	1.00	1.00	1.00	1.00	1.00
Percent 10-m radius litter cover	df	190.21	267.80	284.60	137.67	212.36	240.42
	t	0.20	0.68	1.90	0.37	1.56	1.59
	P	1.00	1.00	0.35	1.00	0.72	0.69

^a df = degrees of freedom, P = p-value significance based upon Bonferroni corrected alpha-value

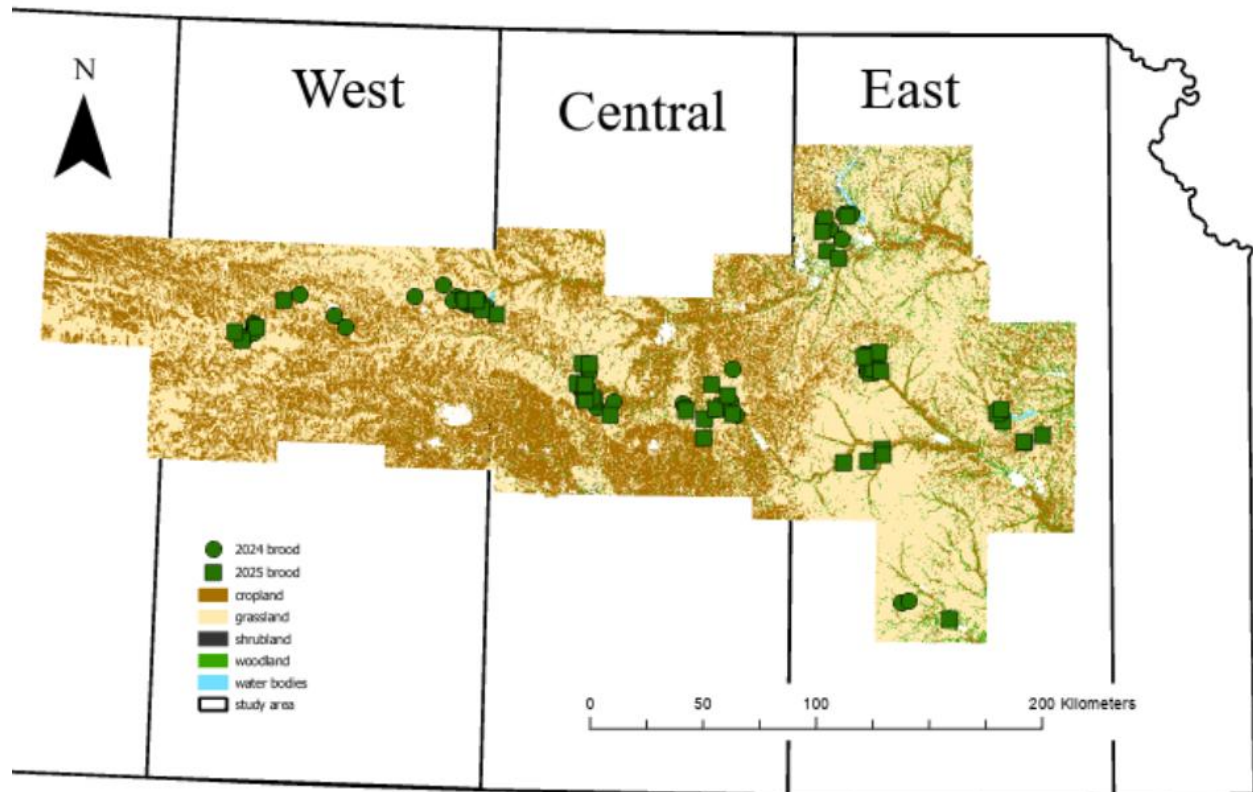


Figure 3.1. Wild turkey brood locations ($n = 109$) across three study regions (East, Central, West) in Kansas, USA, 2024–2025. Female wild turkeys were monitored via 140-g G5-T2A Iridium backpack units with global positioning systems (GPS) and very-high-frequency (VHF) radio components.

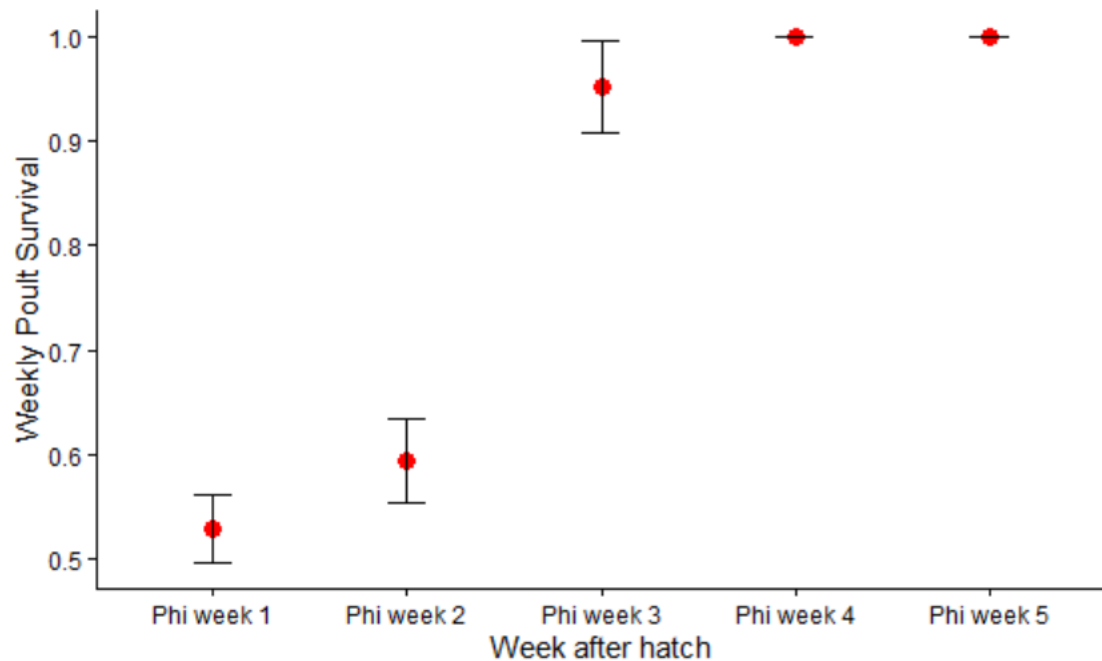


Figure 3.2. Weekly poult survival estimated by week after hatch for wild turkey broods ($n = 89$) in Kansas, USA, 2024-2025, using the Lukacs chick-survival model in Program MARK. Red dots represent the mean derived estimate of poult survival, while the black bars represent the standard error around the estimate. Weekly poult counts were conducted by monitoring female wild turkeys marked with 140-g G5-T2A Iridium backpack units equipped with global positioning systems (GPS) and very-high-frequency (VHF) radio components.

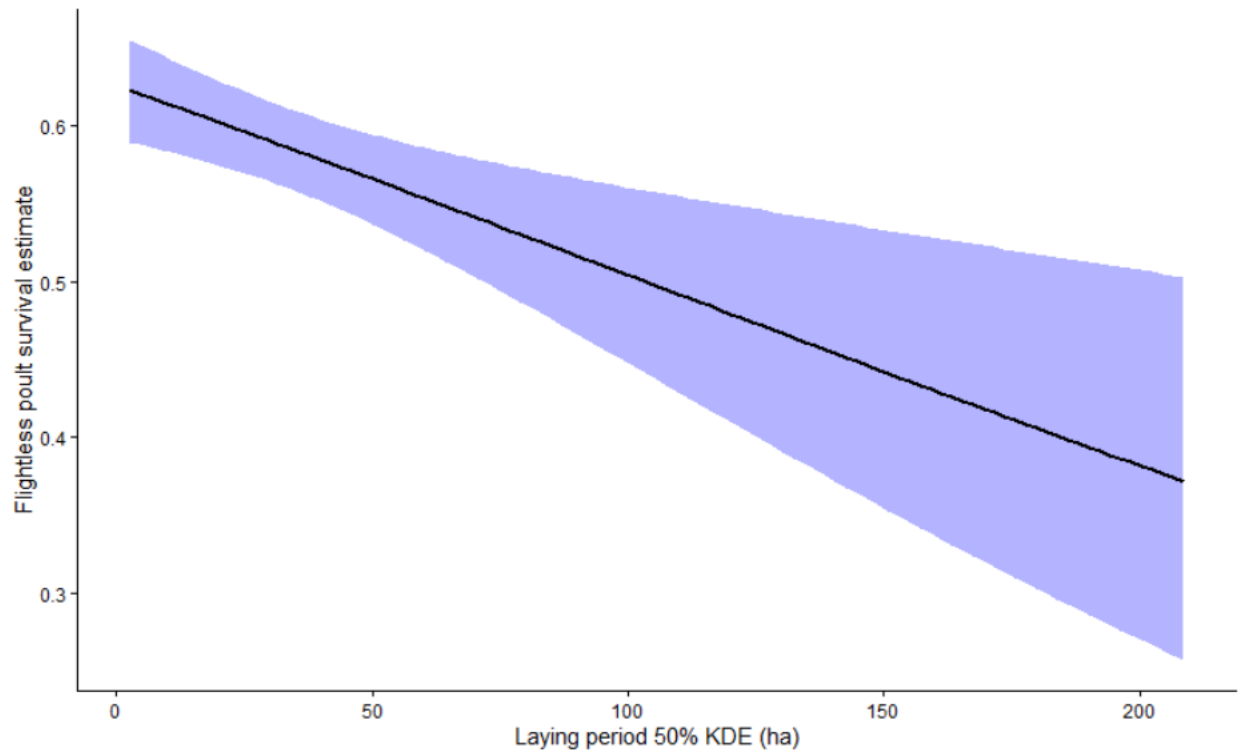


Figure 3.3. Survival estimates for flightless wild turkey poults (ages 0-14 days old, $n = 81$ broods) with the laying period home range of the brood-rearing female as a predictor variable in Kansas, USA, 2024-2025. Survival was estimated using the Lukacs chick survival model in Program MARK. Laying home ranges were estimated using a 50% kernel density estimator (KDE), measured in hectares. Weekly poult counts were conducted by monitoring female wild turkeys marked with 140-g G5-T2A Iridium backpack units equipped with global positioning systems (GPS) and very-high-frequency (VHF) radio components.

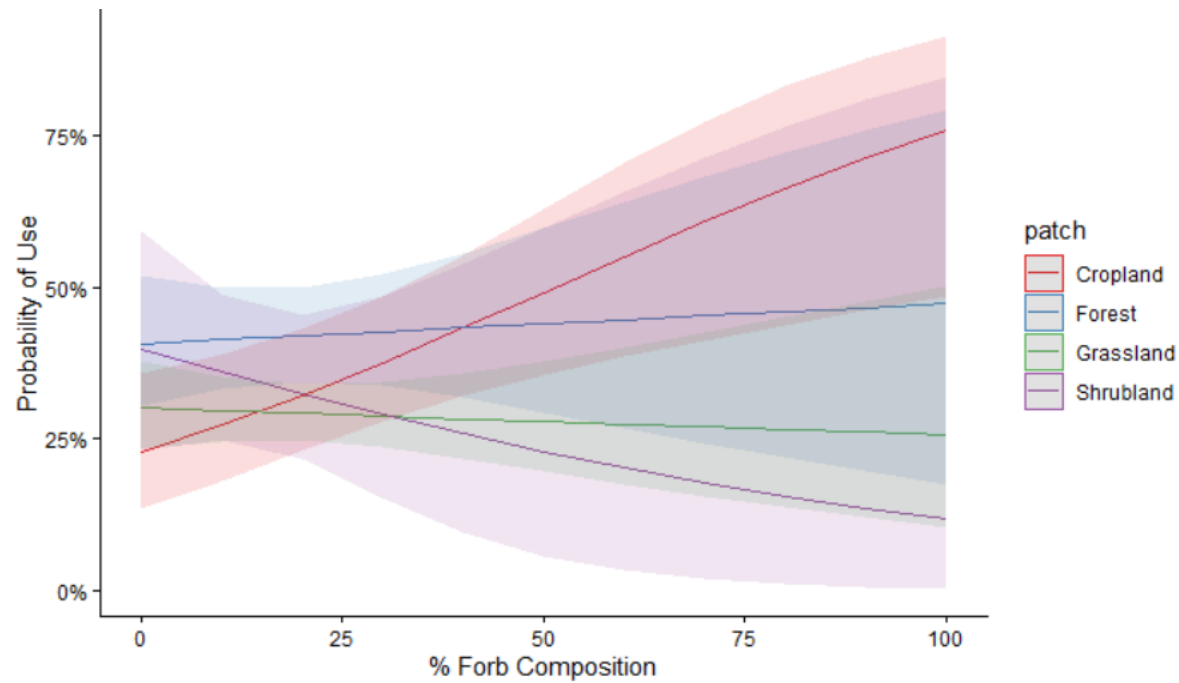


Figure 3.4. Relative selection strength for mean forb composition at the center point of wild turkey brood forage locations ($n_{\text{used}} = 230$, $n_{\text{random}} = 457$) among four patch types (cropland $n_{\text{used}} = 34$, forest $n_{\text{used}} = 65$, grassland $n_{\text{used}} = 108$, shrubland $n_{\text{used}} = 23$). Forb composition was measured using a 1-m² vegetation frame placed over the brood use and random locations. Brood-use location was determined by remote download of GPS locations from an adult female turkey, known to be brood rearing from weekly brood survival checks. Females were monitored via 140-g G5-T2A Iridium backpack units with global positioning systems (GPS) and very-high-frequency (VHF) radio components in Kansas, USA, during 2024–2025.

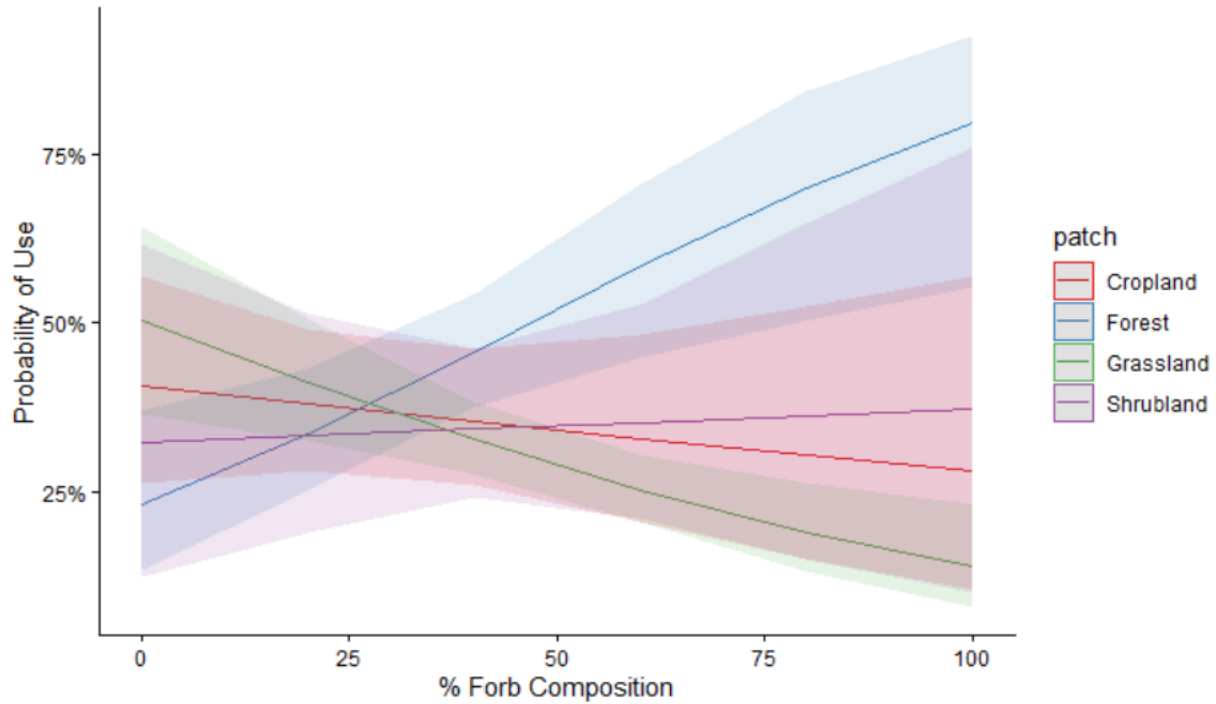


Figure 3.5. Relative selection strength for mean forb composition within 10 m of wild turkey brood forage locations ($n_{\text{used}} = 230$, $n_{\text{random}} = 457$) among four patch types (cropland $n_{\text{used}} = 34$, forest $n_{\text{used}} = 65$, grassland $n_{\text{used}} = 108$, shrubland $n_{\text{used}} = 23$) for broods ages 0-28 days old. Forb composition was averaged among four, 1x1-m vegetation frames recorded in each cardinal direction from the known brood use location. Brood use location was determined by remote download of GPS locations from an adult female turkey, known to be brood rearing from weekly brood survival checks. Females were able to be monitored via 140-g G5-T2A Iridium backpacks units with global positioning systems (GPS) and very-high-frequency (VHF) radio components in Kansas, USA, during 2024-2025.

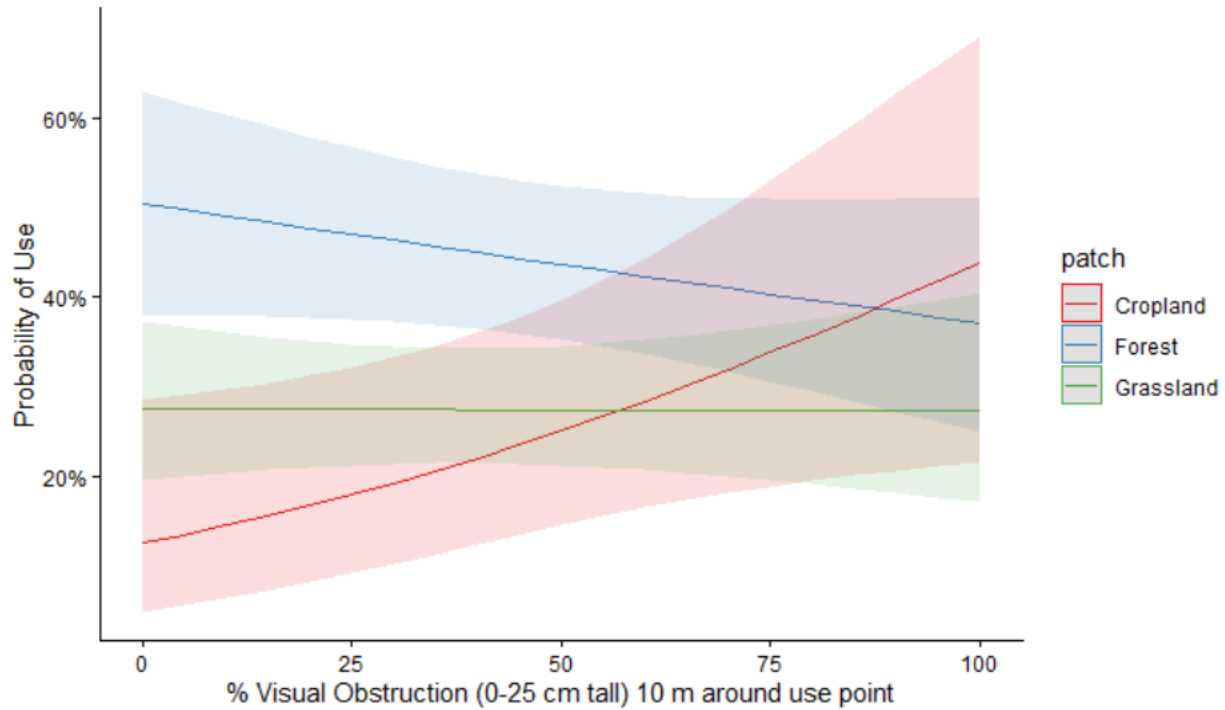


Figure 3.6. Relative selection strength for visual obstruction within 0-25 cm height at ground roost locations ($n_{\text{used}} = 148$, $n_{\text{random}} = 292$) of wild turkey broods among patch types for wild turkey broods 0-14 days old. Patch types include cropland ($n_{\text{used}} = 12$), forest ($n_{\text{used}} = 57$), grassland ($n_{\text{used}} = 51$), and shrubland ($n_{\text{used}} = 27$). However, shrubland was removed for ease of visualizing the other three interactions. The shrubland response showed a uniform selection strength across visual obstruction, with wide confidence intervals overlapping all three other patch types. Females were monitored via 140-g G5-T2A Iridium backpack units with global positioning systems (GPS) and very-high-frequency (VHF) radio components in Kansas, USA, during 2024–2025.

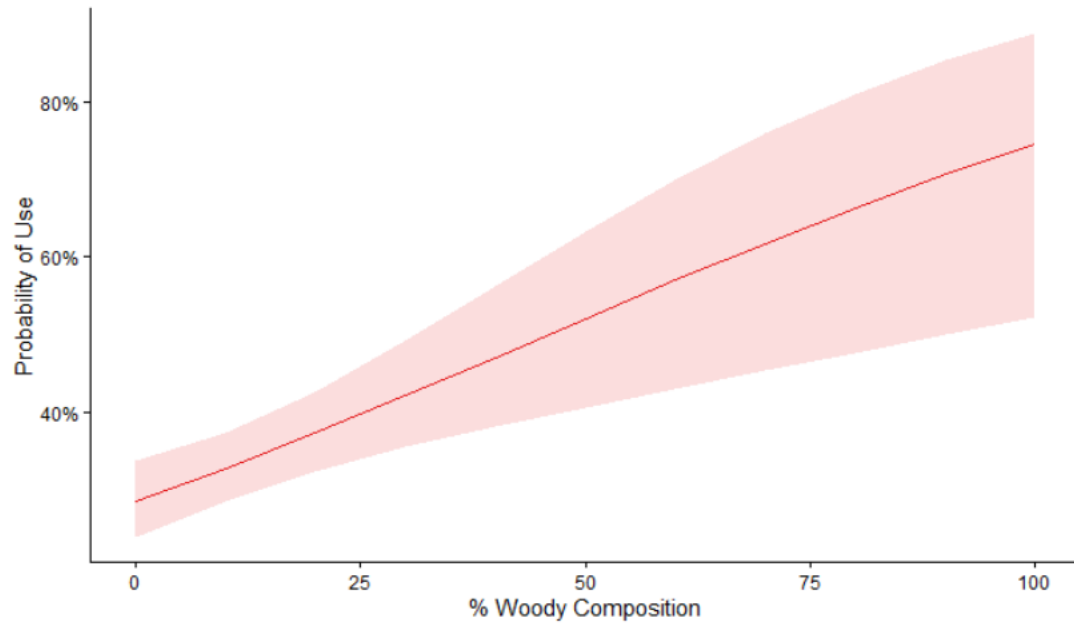


Figure 3.7. Probability of use of wild turkey brood ground roosting locations based on woody-stemmed plant composition at the center of ground roost locations ($n_{\text{used}} = 148$, $n_{\text{random}} = 292$). Woody plant composition measured using a 1x1-m vegetation frame recorded at a known brood roost use location. Brood use location was determined by remote download of GPS locations from an adult female turkey, known to be brood rearing from weekly brood survival checks. Females were able to be monitored via 140-g G5-T2A Iridium backpacks units with global positioning systems (GPS) and very-high-frequency (VHF) radio components in Kansas, USA, during 2024-2025.

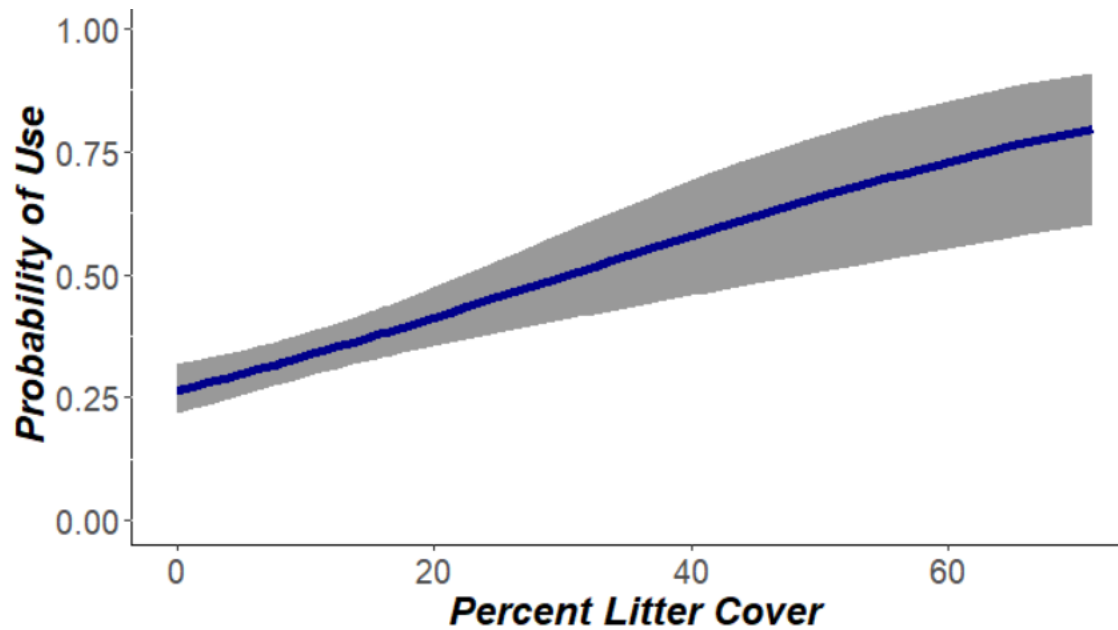


Figure 3.8. Probability of use for litter composition at a 10 m radius around brood ground roost locations ($n_{\text{used}} = 148$, $n_{\text{random}} = 292$) for wild turkey broods 0-14 days old. Litter composition was averaged among four, 1x1-m vegetation frames recorded in each cardinal direction from the known brood ground roost location. Brood use location was determined by remote download of GPS locations from an adult female turkey, known to be brood rearing from weekly brood survival checks. Females were able to be monitored via 140-g G5-T2A Iridium backpacks units with global positioning systems (GPS) and very-high-frequency (VHF) radio components in Kansas, USA, during 2024-2025.

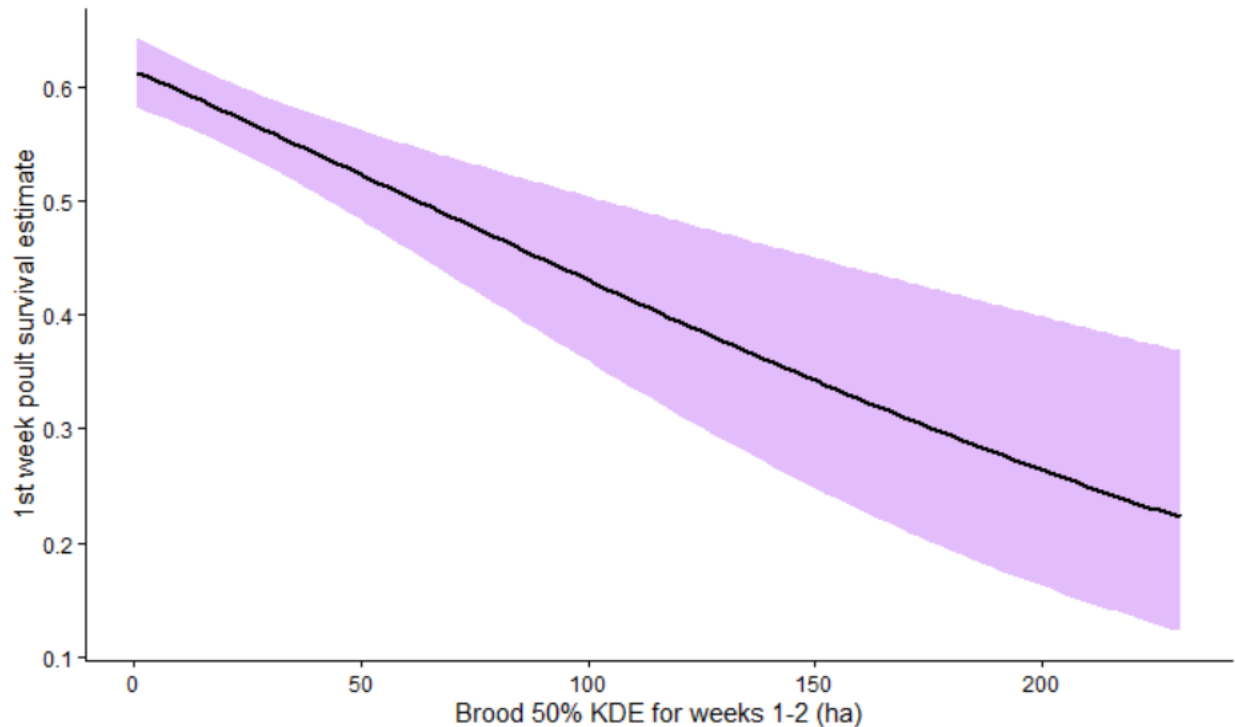


Figure 3.9. Survival estimates for wild turkey poults during the first week after hatch with the brood flightless period (ages 0-14, n= 81 broods) home range of the brood-rearing female as a predictor variable in Kansas, USA, 2024-2025. Survival was estimated using the Lukacs chick survival model in Program MARK. Brood-rearing female home ranges were estimated using a 50% kernel density estimator (KDE), measured in hectares. Weekly poult counts were conducted by monitoring female wild turkeys marked with 140-g G5-T2A Iridium backpack units equipped with global positioning systems (GPS) and very-high-frequency (VHF) radio components.

Chapter 4 – Survival of female wild turkeys across a precipitation gradient in Kansas

Introduction

Wildlife populations are composed of individuals existing along a continuum of resources related to their fitness, such as food availability or predator exposure risk levels. The distribution of individuals within a population is depicted by a gradient of space use from relatively high-quality habitat, which best supports annual fecundity and recruitment, to those occupying areas less conducive to their overall fitness. Although habitat quality for many species is approaching conditions considered skewed toward the latter situation, especially for rare or specialized species, more common, generalist species such as resident game birds still provide investigators an opportunity to evaluate population-level fitness across gradients of habitat quality. Wild turkeys (*Meleagris gallopavo*) fall into such a category, as populations remain sufficiently abundant to support harvest as a population management tool, but many populations are experiencing a near-nationwide decline and currently receiving heightened conservation attention.

Wild turkeys have been studied in detail in states across southern and eastern United States such as Pennsylvania, Tennessee, Georgia, Louisiana, and Texas, all of which have noted population declines during the past two decades following contemporary population peaks during the late 1990s – early 2000s (Collier et al. 2007, Wood et al. 2019, Chamberlain et al. 2022, Johnson et al. 2022). Results from these research efforts have provided invaluable insights into the ecology and conservation of wild turkeys, including effects of predators (including

humans) on wild turkey movement and space use, decreased survival of females during the nesting season, and a negative effect of rainfall on female survival and nest success (Moore et al. 2010, Lavoie et al. 2017, Yarnall 2019, Wightman et al. 2023). However, these studies are primarily composed of singular geographic populations in forested ecosystems.

There is a need for synchronously monitoring potential metapopulations of wild turkeys across grassland landscapes in the Great Plains ecoregion lacking independent contemporary estimates of adult survival and fundamental information on how environmental variables may affect population vital rates. Concern for rapidly declining wild turkey populations specific to the Great Plains region stems from studies such as Lehman et al. (2022) in South Dakota, USA, where estimated population growth rate ($\lambda = 0.74$) was insufficient for maintaining a wild turkey population. A previous study in Kansas, USA, reported a poult-per-hen ratio as low as 0.3, well below the suggested minimum of 3:1 to support a stable wild turkey population (Rolley et al. 1998, Butler et al. 2007). Indices such as the annual poult-per-hen surveys can be helpful for detecting wild turkey population declines in Kansas but still leave managers with little to no information on factors to manage for reversing the decline. Currently, there is a lack of information on factors potentially affecting vital rates of wild turkey populations in the Great Plains region. However, emerging population models indicate female survival as the most important vital rate determining population growth rates in comparison to nest or brood-rearing success (Rolley et al. 1998, Tyl 2019, Lehman et al. 2022, Lashley et al. 2025).

Female wild turkey survival is primarily driven by being a prey animal, hunted by humans through controlled, typically spring season regulations and year-round by other predators such as great horned owls (*Bubo virginianus*), coyotes (*Canis latrans*), and bobcats (*Lynx rufus*).

Prey species such as wild turkeys may mitigate mortality risk by residing in areas that make predation more difficult, such as areas with either lower predator occurrence or increased cover complexity for visual and olfactory concealment (Huffaker 1958, Smith et al. 2019). Behavioral changes may also benefit female survival such as altering movement patterns following the encounter of a perceived predator or choosing to take longer recesses from the nest during incubation (Lohr et al. 2020, Carpenter et al. 2023, Wightman et al. 2023). Survival of female wild turkeys is especially precarious during the breeding season, during which predation rates increase significantly during incubation and brooding flightless young (Kurzejeski et al. 1987, Pollentier et al. 2014b, Tyl et al. 2023). Although predation is the primary cause of death in wild turkeys (Kurzejeski et al. 1987), research also suggests that predators common within the geographic range of wild turkeys do not have diets that commonly contain evidence of wild turkey consumption and presence of some predators such as coyotes may even increase the chance of nest success (Kamler et al. 2016, Melville et al. 2015, Nielsen et al. 2017). This may indicate that the issue of decline in wild turkey populations is not the fundamental presence of predators, but instead the varying densities of predators responding to a changing landscape and encountering female wild turkeys during incubation and brood-rearing reproductive states (Lovell et al. 1997, Nielsen et al. 2017).

Based on this knowledge, there is a need to evaluate annual and seasonal survival of female wild turkeys across a resource gradient, represented as a negative east to west precipitation gradient, in grassland landscapes in the Great Plains region. My primary goal was to estimate and compare annual and life-stage specific survival of female wild turkeys among 3 regions with varying landcover composition and precipitation levels in Kansas. Using these

values, my first objective was to compare the contemporary female wild turkey survival rates from Kansas, during an assumed population decline, to historic female survival rates of other Great Plains states. My second objective was to address the question “Is female survival during the reproductive period due to the individualistic (rather than female amalgamation) nesting activity females partake in, or because of the phenological period itself due to its association with increased temperatures, precipitation events, and dispersal from wintering grounds?” In the first case, I would expect survival to vary by time (e.g., week), increasing between the initial nesting period during which the majority of females are incubating to the late summer period when fewer females are partaking in individualist reproductive activities due to nest or brood failure. In the latter case of survival being associated with the spring to summer period, I predicted that a model for survival based on the breeding versus nonbreeding period best depicts patterns in female wild turkey survival.

Because mortality of nesting birds is often most at risk during the reproductive period, my second goal was to investigate potential causal relationships between nesting habitat and behavior of female wild turkeys and survival rates. I hypothesized that because survival is an important vital rate, female wild turkeys would partake in a form of bet-hedging by choosing nesting habitat that not only influences nest survival (Chapter II), but also female survival as well. To test this, my objective was to assess the predictive power of variables shown to influence nest success in Kansas, including woody cover and forb composition, in addition to visual obstruction that has no apparent effect on survival but are selected by nesting wild turkeys (Chapter II). If female survival is best predicted by visual obstruction, we may have support that

wild turkeys do partake in bet-hedging in Kansas by selecting nest locations that do not increase nest success but do increase female survival.

Study area

My study area encompassed the eastern two-thirds of Kansas, split into 3 study regions. These regions were delineated by the following longitudinal boundaries: East (-96.96 to -95.50), Central (-98.49 to -96.96), and West (-100.15 to -98.49; Figure 1.1). From east to west, the 3 regions represent a negative precipitation gradient along with a gradual shift from tallgrass to mixed-grass, and finally short-grass prairies. Grasses common to the entire study area included little bluestem (*Schizachyrium scoparium*), side-oats grama (*Bouteloua curtipendula*), and switchgrass (*Panicum virgatum*). Common forbs include ragweed (*Ambrosia psilostachya*), yellow sweet clover (*Melilotus officinalis*), Illinois bundleflower (*Desmanthus illinoensis*), and annual sunflower (*Helianthus annuus*). Species most often comprising Kansas riparian areas were bur oak (*Quercus macrocarpa*), hackberry (*Celtis occidentalis*), black walnut (*Juglans nigra*), American elm (*Ulmus americana*), rough-leaf dogwood (*Cornus drummondii*), coral berry (*Symphoricarpos orbiculatus*), and Virginia wild rye (*Elymus virginicus*; Haddock 2024). Common predators of female wild turkeys, their nests, and broods in Kansas were bobcat (*Lynx rufus*), coyote (*Canis latrans*), great horned owl (*Bubo virginianus*), raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), and striped skunk (*Mephitis mephitis*; Thogmartin and Schaeffer 2000, Yeldell et al 2017, Crawford et al. 2021, Nielsen et al 2021).

I placed a 95% minimum convex polygon around movement locations recorded from each unique capture flock (13 total) to describe landcover composition during 2024–2025 (Figure 1.2). I averaged landcover values derived from the Kansas Ecological Monitoring dataset among

the 13 capture sites within each study region to report landscape compositions and used the U.S. Department of Agriculture Cropland CROS dataset to report all agriculture-based compositions in 2024 (Boryan et al. 2011, Diamond et al. 2021). All study regions were grassland dominant, with the majority (>65%) of grasslands used for livestock grazing throughout the state (Boryan et al. 2011). The West Region contained the largest percentages on average of cropland and mixed-grass prairie (31% and 55% of total area, respectively). The Central Region was composed of the second-highest mean cropland cover, with about 23% of the total area dedicated to cropland and 58% remaining as a combination of tallgrass and mixed-grass prairies. Both the West and Central regions had <5% forested cover, primarily represented by riparian areas scattered throughout each region. The primary cover types in the East Region were tallgrass prairie (65%) and various forms of woodlands (15%). Cropland cover was the lowest in the East Region with 11% coverage. Primary crops in the West Region were winter wheat (*Triticum aestivum*, 11% mean total cover) and grain sorghum (*Sorghum bicolor*, 10% mean total cover). Winter wheat (9% mean total cover) was the primary crop in the Central Region followed by grain sorghum (*Sorghum, bicolor*, 4%), soybeans (*Glycine max*, 4%), corn (*Zea mays*, 3%), and alfalfa (*Medicago sativa*, 1%). Soybeans (7% mean total cover) was the primary crop in the East Region. Urban intensity was low in all 3 regions, with 1% in the East Region compared to 0.35% in the Central Region and 0.55% in the West Region.

Weather metrics during 2024–2025 nesting seasons (Apr-Jun) were derived from county-level weather averages (PRISM 2025). Mean precipitation across the study area was 9.8 cm (SD = 5.3) in 2024 and 11.8 (SD = 5.8) in 2025. Mean temperature across the study area from April to June was 19.3° C in 2024 and 18.1° C in 2025. By region, 2024 precipitation across the East,

Central, and West regions, was respectively 11.9 cm (SD = 4.3), 7.4 cm (SD = 5.6), and 6.9 cm (SD = 4.3). Precipitation slightly increased in 2025 by region at 13.7 cm (SD = 6.1), 11.2 cm (SD = 6.4), and 7.6 cm (SD = 1.5) in East, Central, and West regions, respectively. Mean temperature for East, Central, and West regions was 19.4° C, 19.5° C, 18.8° C in 2024, respectively. In 2025, mean temperature by region was slightly cooler at 18.2° C, 18.0° C, and 17.6° C for East, Central. and West regions, respectively.

Methods

Field capture and monitoring

I captured female wild turkeys using baited drop, walk-in, and rocket nets on private and public lands during winter (Jan–Mar) 2024 and 2025. All captured wild turkeys received aluminum, pop-rivet leg bands with unique numeric identifiers and contact information for reporting recoveries. I measured body mass (kg), tarsus length (cm), wing chord (cm), and exposed culmen length (cm) length for all birds, in addition to spur length (cm) and beard length (cm) for females when present. All females were aged based on plumage. Juveniles were classified as any female with white banding to the tip of the primaries as well as pointed tips of the first primary (Healy and Nenno 1980). Adults were identified by a lack of white banding to the end of the primaries, and a rounded end of the first primary feather.

I fit each female wild turkey >4.0 kg with a 156-g Global Positioning System (GPS), G5-T2A Iridium backpack style transmitter with a very-high-frequency (VHF) component (Advanced Telemetry Systems, Isanti, MN, USA). Transmitters were secured as a backpack using marine-grade shock cord with knots tied at each attachment point and secured with super-

glue. Once deployed, transmitters recorded GPS locations six times per day at 0300, 0700, 1100, 1500, 1900, and 2300 during the breeding season (Mar 1–Aug 1), 2024 and 2025. Locations were uploaded from the GPS transmitter to the Iridium system every 3 to 5 days.

I reviewed weekly movement patterns of each female during the breeding season to monitor for indications of the bird entering the laying, incubating, or brood-rearing reproductive states. I identified the laying state as daily repeated (>3) visits to the same location (<100 -m radius). Incubation state initiation was identified and determined by the female spending at least one night roosting on the ground in a nonforested location. In forested areas, I considered the incubation phase to be initiated once the female dramatically decreased her daily step-length and was roosting in the same general location of the laying area for at least 24 hours (Carpenter et al. 2022). I used an average incubation period of 28 days to estimate hatch date of all nests and determined a nest to fail when a female permanently left the nest or died before incubation day 26 (Healy 1992, Conley et al. 2016). I surveyed successful nests within 48 hours of the estimated hatch date or the female permanently leaving the nest.

I identified female mortalities by monitoring daily movement locations and transmitter activity levels at least once per week during the breeding season (Mar–Aug) and at least once per month during the non-breeding season (Sep–Feb). If the female was not known to be incubating a nest, I identified mortalities by observing female movements and monitoring the transmitter activity sensor within a 24–48-hour period of a suspected mortality. Females with a transmitter activity sensor level at 0 for 24–48 hours may have been killed on the nest, as incubating females tended to recess from the nest a few times per day. The activity sensor records the percentage of time spent in any form of motion between GPS coordinate recordings. Once I identified a

mortality location, I would navigate to the last known GPS location of the female's transmitter to search for any sign of a corpse as well as the transmitter. If the corpse was found, notes on the state of the corpse such as broken bones, plucked feathers, split feather rachises, or corpse caching, would be recorded. Similarly, we recorded the state of the transmitter including bite marks or chewed backpack cords. Because GPS downloads only occurred a maximum of every 3-5 days during the breeding season and every 2-weeks in the nonbreeding season, most mortalities were not surveyed in a timely (i.e., <24 hr period) enough fashion to determine an accurate cause of mortality. Due to this, I only report causation of mortality for females whose death was a clear factor, such as a wheat swather, illness, or motorized vehicle. However, the week associated with each mortality was easily ascertained by movement and activity data. Lastly, I report mortalities based on the life event during which they occurred, including incubating, brood-rearing, and roosting behaviors.

I summarized female wild turkey mortalities by cover type and proximity to landscape features of interest or those commonly associated with predator ecology. Land cover compositions were based on Kansas Ecological Systems "Mapping Kansas Ecosystems" (KEMS) 2023 data layer. This layer was a 10 x10-m cell raster product created by the Kansas Biological Survey via remotely sensed data and field-based sampling sites to define land cover types across the state (Peterson and Moody 2024). This layer defined 49 vegetation groups in Kansas, including cover types such as eastern floodplain forest, mixed-grass prairie, western lowland grasses, and mixed oak-hickory woodland. I combined vegetation groups with similar functional characteristics into the following groups: woodland, grassland, shrubland, and

cropland. I defined the “patch group” of each mortality location as one of these 4 patch group polygons.

Because edge habitats are commonly associated with predator ecology, I measured the proximity of each mortality to the nearest “edge” patch type. I defined edges at the landscape scale by generating a 20-m half-width buffer around the polylines created from the KEMS polygon layer of different patch types, creating a total buffer width of 40 m around all patch edges.

Additionally, I measured the distance from each mortality to the nearest public lands boundary, with mortalities that fell within a boundary of a public land tract received a distance value of zero. I also measured the distance of all mortalities to the nearest known arboreal roosting location. Arboreal roosting locations included locations of all known arboreal roosting areas across the study areas (M. Ware, unpublished data). To complete each of these proximity measurements, I used the Near geoprocessing tool to measure the Euclidian distance from each mortality location to the perimeter or point of the nearest features of interest.

Nest-related variables

Similar to mortality location classifications, I measured nest proximity to landscape features of interest or those commonly associated with predator ecology (“edge” patch types, cropland) using the Near geoprocessing tool to measure the Euclidian distance from each nest location to the perimeter or point of the nearest features of interest. These proximity values included distance to trees of any size, cropland, the previously defined 20-m edge buffers, and known arboreal roosting locations (M. Ware, unpublished data). For estimating distance to tree, I used a polygon shapefile purchased from EarthDefine to classify tree locations created from a 5-m resolution raster file based on the 2021 National Agriculture Imagery Program in Kansas. This

tree layer accounts for all possible trees as small as eastern red cedars across a grassland to provide a distribution of trees that may provide shelter for loafing or foraging female wild turkeys.

Home-range estimation

I estimated home ranges for adult female wild turkeys during the laying state of all first nesting attempts using a 50% and 95% Kernel Density Estimate values (KDE; Worton 1989, Sheather 2004, Weglarczyk 2018). The egg-laying state included all movement locations from the start of the first day of identified laying to the first night of incubation. I estimated all home ranges using the `hr_kde()` function in the Animal Movement Tools (`amt`) package in Program R, which calculates a specified home range type (i.e., “KDE”) using animal movement data (Signer et al 2019). I report all home ranges in hectares, with the mean and standard deviations ($\bar{x} \pm SD$) for each year and study region (Chapter III).

Apparent female survival and mortality

I report results of female wild turkey apparent survival by year, capture site, and region.

Apparent female survival for 2024 was the total number of females that survived a 52-week period from February 26, 2024 to February 17, 2025. Apparent female survival in 2025 was the number of females that survived a 52-week period from February 24, 2025 to February 16, 2026.

I also report apparent female wild turkey survival by age and year. Female wild turkeys were classified as adults at capture during either 2024 or 2025. Females were classified as juveniles at captures during either 2024 or 2025. Second-year female wild turkeys are classified as juvenile

females captured in 2024 and survived into 2025 to become confirmed, 2-year-old female wild turkeys.

Kaplan Meier cumulative survival analyses

I used a Kaplan-Meier survival analysis with staggered entry to estimate annual female wild turkey survival during 2024–2025 and 2025–2026, where each bird with a unique band identifier was considered an individual during each year (Kane et al. 2007, Humberg et al. 2009, Goel et al. 2010). Week one in the annual analysis was determined by two weeks following the first initial capture effort to account for possible mortalities due to capture. I estimated annual survival for female wild turkeys grouped by year, age, study region, and Kansas Department of Wildlife and Parks (KDWP) wild turkey hunting management unit. Year included the 2024 and 2025 survival period and age included females grouped as either adults or juveniles. Study region grouped the survival curves by the three study regions (East, Central, and West) located along a negative precipitation gradient. Wild turkey hunting management unit categorized the cumulative annual survival by the four KDWP hunting management units (2, 3, 4, 6) where females were captured. I report the week of greatest change in estimated survival annually and for the breeding season. I determined the change in breeding season survival as the difference between the estimated cumulative survival in survival week 26 minus the estimated cumulated survival in week 3, which represents the peak of nesting and brood rearing for wild turkeys in my data. Finally, I report the 52-week cumulative survival with associated standard error, and lower and upper 95% confidence levels each group.

Known-fate cumulative survival analyses

I used the Known-Fate model in the RMark package in Program R to assess potential effects of individual covariates on female survival (White and Burnham 1999). I used three model suites to compare predictive power of different covariates on female survival. Model suite one tested the relative influence of different time covariates on annual survival. The first time covariate was survival varying weekly, denoted as $[\hat{S}(\sim\text{time})]$. The second time covariate was annual cycle phase, where I specified that weekly survival only varied between the 29-week nonbreeding period and the 23-week breeding period ($[\hat{S}(\sim\text{phase})]$). The final covariate was survival year, 2024 or 2025, which I test as both an additive term ($[\hat{S}(\sim\text{time} + \text{year})]$, $[\hat{S}(\sim\text{phase} + \text{year})]$) and interactive term ($[\hat{S}(\sim\text{time} * \text{year})]$; $[\hat{S}(\sim\text{phase} * \text{year})]$) with the previous two covariates.

The subsequent 2 model suites tested the predictive power of multiple covariates during only the 23-week reproductive period, first at the landscape scale and second at a finer scale of nest-site use. The landscape-scale reproductive period survival model suite tested three covariates that were proximity measurements from a female's first nesting attempt to a landscape feature of interest: distance to the nearest roost tree (Roost m), nearest tree of any type or size (Tree m), nearest cropland (Crop m), and nearest "edge" patch defined as a 20-m half width around all patch perimeters (Edge 20m). Two additional covariates were kernel density estimates (KDE) from the laying phase of a female's first attempt nest, including the 50% KDE core range (Lay 50 KDE) and 95% KDE home range (Lay 95 KDE). The fine-scale, reproductive period survival model suite tested six different covariates measured at first attempt nest locations that were significant for either resource selection or survival of wild turkey nests (Chapters I, II). These measurements include woody plant composition (nest woody) within a 1-m² vegetation

frame placed around the nest, visual obstruction up to 50-cm tall around the nest bowl split into two height groups (vor1 = 0-25-cm tall, vor2 = 25-50-cm tall), forb composition within a 1-m² vegetation frame measured four times at 10 m in each cardinal direction from the nest bowl (forb 10m), and visual obstruction at the same two height groups (vor1_10m, vor2_10m) but measured at a 10-m radius away from the nest bowl in each cardinal direction.

I ranked models in each suite based on Akaike Information Criterion (AIC) corrected for small sample sizes (AIC_c) score and considered all models within a ΔAIC_c of <2.0 as competing models (Burnham and Anderson 2002). I report the number of parameters (K), AIC_c value, ΔAIC_c , model weight (w_i), and deviance of each model. I estimated the realized survival of female wild turkeys across a 52-week period assuming a constant weekly survival rate ($[\hat{S}(\sim 1)]$), which I use as the null model for all three model suites. I report the 23-week breeding and 29-week nonbreeding period survival of female wild turkeys using the $\hat{S}(\sim \text{phase})$ model, where weekly survival was allowed to vary between the two periods but was constant within each unique period. I report the resulting female wild turkey survival estimates with lower (LCI) and upper (UCI) 95% confidence intervals, as well as an estimated standard error (SE) calculated using the Delta method (Powell 2007).

Results

I deployed GPS transmitters to 297 and 102 female wild turkeys in 2024 and 2025, respectively, with one recapture in 2025 for a total of 399 tracked birds over the 2-year study (Table 2.1). Of the 399 females monitored during 2024–2025, 63.16% (252 females) died before the end of the

2-year monitoring period (Figure 4.1). The majority of females that died (200 females) did so during the breeding season, which equated to 79.4% of all deaths or 50.13% of the total sample.

Capture, monitoring, and apparent survival

I began the 2024 annual survival period on February 26 and the 2025 annual survival period on February 24, based on the 2-week censor period following the initial capture for each field season. I removed 35 females captured in 2024 and 7 females captured in 2025 from all survival reports and analyses due to the females dying within two weeks of their release date to censor for capture-related mortality. In 2025, one female's (adult, Central Region, 2024 Marquette capture site) transmitter battery entered low battery on 6/9/2025 and subsequently stopped transmitting data and was removed from all survival analyses in 2025. Also in 2025, four females (three from the East region, Cottonwood Falls capture site; one from East region, Ogden capture site) had unrecorded ages from the capture and were not included in age-based survival analyses.

Annual apparent female survival of wild turkeys in Kansas during 2024–2025 was greatest in the East region at 62.2%, followed by the West region at 57.3% and Central region at 55.1% (Table 4.1). Although the largest apparent female survival across both years was in the East region, this region also had the most notable differences in survival between 2024 (71.2%) and 2025 (54.8%; -16.4 percent point change) compared to the Central (-8.3% change) and West (-4.9% change) regions. Of our study sites that had a substantial sample size, the Council Grove study site in the East region had the largest value of female wild turkey apparent survival at 88.9% in 2024 and subsequently 50.0% in 2025 (Table 4.1). In comparison, the Tuttle Creek study site had the lowest female apparent survival when averaged across the 2 years at 43.8%

(54.5% in 2024 and 20% in 2025). When comparing among female ages, juvenile female wild turkeys had larger annual apparent survival (66.2%) compared to adult females (61.9%) in 2024 (Table 4.2). When we were able to account for second-year females in 2025, apparent survival increased from 49.4% for general adults, to 53.8% for second year females, and finally to 70.4% for juvenile females.

I classified the beginning of the reproductive-season period of survival based on the earliest known nest initiation from both years, where the earliest nest initiation (laying) date in 2024 was March 24 (survival week 4) and the earliest laying date in 2025 was March 31 (survival week 6). The earliest and latest incubation initiation dates in 2024 were April 6 (survival week 6) and July 7 (survival week 19), respectively (Table 2.3). The earliest and latest incubation initiation date in 2025 was April 11 (survival week 11) and July 20 (survival week 21), respectively. For further context, the earliest known brood hatch in 2024 was May 12 and latest known brood-rearing date was August 7 (survival week 24). In 2025, the first brood-rearing event began on May 11, with the latest known brood monitored ending on August 12 (survival week 25). Based on these recorded dates, I originally classified the nesting season survival weeks as the survival weeks that fall within these survival weeks, which are weeks 4-24 in 2024 and weeks 6-25 in 2025. However, to adjust for any observational error such as missed early nesting events as well as to establish congruent seasons between the 2 years, I established the reproductive-specific survival season as survival weeks 3-26.

Mortality locations of wild turkey females based on cover type observationally varied among regions but were predominantly in grassland cover types (55.2%) compared to woodland (32.9%), cropland (9.1%), or shrubland (2.8%; Table 4.3; Figure 4.1). In the more forest-

dominant East Region, mortalities primarily occurred within woodland cover types for 5 of the 9 study sites (Table 4.3). In comparison, mortalities of the Central and West regions were located most often within grasslands for all study sites (Table 4.3). There was no clear pattern in mortality proximity values to variables of interest, where all regions exhibited surprisingly similar values of mortality distance to roost trees and edge patch types (Table 4.4).

Causes of mortality included 2 cases of suspected illness. One case appeared to be avian pox determined by the wart-like growths on the head of the female at the time of the mortality recovery (Wilson capture site). The other was an unknown cause, but the corpse was found desiccated and completely intact (Marquette capture site). One female in the Cottonwood Falls capture flock, was hit and killed by a train in November 2025. Out of the 385 female turkeys that initiated at least one nest throughout 2024–2025, 17.1% (66 females) died while incubating a nest. Twenty females (18.4% of all brood rearing females, or 32.8% of all failed broods) died while rearing broods. The majority (90%) of females that died while rearing broods did so during the initial 0-14 days following hatch, which is the flightless period of precocial wild turkey broods.

Kaplan-Meier cumulative survival

I observed no significant differences among survival groups (year, female age, study region, KDWP management unit) for female wild turkeys across Kansas for cumulative annual survival (Table 4.5; Figures 4.2, 4.3). Cumulative, 52-week survival of female wild turkeys was 52.10% $\pm$ 3.1 (LCL= 46.4%, UCL = 58.5%) in 2024 and 46.4% $\pm$ 3.3 (LCL = 41.2%, UCL= 54.3%) in 2025 (Table 4.5). Weeks of greatest decline in cumulative survival were consistent among groups, identifying survival weeks 8-11 (April 14 to May 5) as those with the largest change

over time (Table 4.5; Figures 4.2, 4.3). However, when dividing survival groups by female age, survival weeks 8-11 did exhibit steep declines but were surpassed by weeks 13-14 in adults and 16-17 in juveniles (Table 4.5). Changes female wild turkey survival from the start of the breeding season to the end of the breeding season appeared to be consistent among approaches and groups, ranging from a lowest estimated change of -30.8% in juveniles based on the age-dependent Kaplan-Meier model to the largest estimated change of -46.4% change in 2025 in the year-dependent Kaplan-Meier model (Table 4.5)

Known-fate survival estimates

In the first model suite testing the predictive power of time (survival varying by week), year, and phase (survival varying by breeding versus nonbreeding period), the fully time varying model was most supported (Table 4.6; Figure 4.4). Weekly survival of female wild turkeys in Kansas was lowest during the reproductive period between exposure weeks 5-20 but was otherwise stable throughout the year (Figure 4.4). Study year had no significant effect on predicting survival over time or among phases (Table 4.6). Although not competitive with the $\hat{S}(\sim\text{time})$ model, the $\hat{S}(\sim\text{phase})$ model allowing survival to vary between, but remain constant within, the 23-week reproductive period and a 29-week nonbreeding period still outperformed the null model. Based on this model, survival of female wild turkey was 57.28% during the reproductive period and 78.70% during the nonbreeding period. The constant weekly survival rate (WSR) was 0.9761 ± 0.002 (LCL = 0.9725, UCL = 0.9791) for the 23-week reproductive period. The constant WSR for the 29-week nonbreeding period was 0.9918 ± 0.010 (LCL = 0.9896, UCL = 0.9935).

Both model suites using the 23-week reproductive period and nesting-related covariates resulted in no supported hypotheses outcompeting the null model (Tables 4.7, 4.8). The landscape-level model set testing the predictive power of roost tree proximity, general tree or cover proximity, cropland proximity, and edge proximity to first attempt nest locations in addition to the laying phase core and home ranges resulted in spurious covariate values for all predictors. Similarly, the fine-scale model set testing the predictive power of first-attempt nest habitat on female survival resulted in all models being “competitive” with the null and all predictive covariate values overlapping zero, ultimately concluding spuriousness as well. In conclusion, I found that of the measured variables having a measurable effect on breeding season female wild turkey survival in Kansas.

Discussion

Of the variables I measured, no measurable effect of geographic area, nest site landscape features, or nesting habitat on the survival of female wild turkeys was identified in Kansas. Female survival was best estimated using a fully time-varying (weekly) known-fate model, supporting previous conclusions that female wild turkey mortality is most dependent on the action of partaking in reproductive activities such as incubation or brood rearing (Byrne and Chamberlain 2018, Yarnall et al. 2020, Bakner et al. 2026). Female weekly survival begins to noticeably decline around week 8 (~April 8), which is same time period when females are entering into nesting incubation states (Table 2.3). Subsequently, the period with the lowest weekly female survival is weeks 10-15 (Apr 29–Jun 3), which directly overlaps with the 25th to 75th quantiles of incubation initiation dates for these data (~Apr 22–Jun 13). Female weekly

survival returns to pre-incubation levels around week 19 (~Jul 1), the same timeframe for which the majority of the tagged female wild turkeys completed incubation initiations (~Jul 2–20).

Apparent annual female survival decreased with each year of life among juvenile, second-year females, and after-second-year females. This is concerning with the growing level of support for adult female survival being the most important factor for increasing population trajectories (Lehman 2022, Londe 2023). Classifying female survival into two age classes, adults and juveniles, may not be capturing the subtle but sequentially important differences that occurs in female survival and probabilities of nest success among age groups. Londe et al. (2023) concluded that adult females, not juvenile females, contributed the most to population growth. Lehman et al. (2022) observed the exact same pattern of adult-specific survival influencing population declines more so than juvenile females. This aligns with the results from Chapter II where apparent nest success increased with each year of life in our 2025 sample across the 3 female age groups, nearly doubling from second-year to after-second-year females. Juveniles may partake in poorer nesting behavior overall, with lower female survival probability specifically during the incubation period compared to adults, but the cause of this remains to be understood (Tyl et al. 2023). In the case of the “super-hen” hypothesis, the concept of a collection of a few superior-producing females driving population demography, may be arising from females that are simply able to survive one year to the next in an uncertain environment, rather than embodying rare genetics or dispositions (Gerber et al. 2018). Byrne et al. (2022) reported that successful nesting females in the first year of observation were almost six times more likely to be successful the following year compared to unsuccessful females. Badyaev and Faust (1996) observed that older females exhibited greater nest-site fidelity than younger

females, even though it appeared that individual sites had no effect on nest success. If this increase in recurrently high nest success in individuals is due to the age-based experience, selected nest habitat, or the overall fitness and bodily health of the female remains to be unknown.

Mortalities during brood rearing, specifically the 90% of brood-rearing mortalities that occurred during the flightless period of brood life, may further emphasize the causal risk female wild turkeys place themselves in when entering phases of individualism during the reproductive period. Incubation and flightless brood-rearing states are the most individualized acts a female wild turkey undergoes, likely even more so during the laying period where there is evidence of common home range overlaps (Goodman et al. 2026). Similarly, the arboreal roosting brood-rearing state is where instances of brood amalgamation are most commonly observed, compared to the initial 0-14 days of life when females grouping up with one or more conspecifics is rarely reported. Based on this, the next frontier for determining how to increase female wild turkey survival during the reproductive period likely requires investigating landscapes that affect rates of conspecific interactions. Findings in Chapter III indicate that laying core range area significantly and negatively influences brood survival during the flightless phase of life – is this due to more solitary females finding it more difficult to survive in landscapes where they are further separated from conspecifics?

Contrasting conclusions that have emerged from the southeastern United States, I found no evidence for the laying-state home range area having a measurable effect on female wild turkey survival. However, the study proposing the relationship concluded the relationship was weak and likely not biologically meaningful (Goodman et al 2026). Instead, Goodman et al.

(2026) observed that increasing conspecific range overlap during laying state was benefitting nest success, rather than having any notable effect on female survival. Lohr et al. (2020), in what appears to be an earlier subset of the Goodman et al. (2026) data, detected stronger support for female survival being positively affected by increased daily dispersal during the incubation state at the risk of increasing nest failure at the same time. Bakner et al. (2019) found the opposite effect, deducing that increased dispersal actually benefitted nest success at least until the final days of nesting, further complicating the nuances of how movement behavior affects nest and female survival. From these findings, it is likely that although the laying state range area does not have notable influence on female wild turkey survival, other behavioral choices (e.g., dispersal events) remain worth investigating across all vital rates for implications.

Selection of nest habitat is one such behavior that has received minimal attention in relation to how it may or may not affect female wild turkey survival. In published wild turkey literature, female nesting behavior (i.e., dispersal metrics) and weather patterns have appeared more often than the variables of the physical location of the nest relative to effects on female survival (Lowrey et al. 2000, Lohr et al. 2020, Goodman et al. 2026). This is surprising, because it would seem reasonable to infer that because nest success is related to habitat surrounding the nest, such as woody composition, the female required to remain there for 28 days would be affected in some way as well. However, my results provided no support for such a statement and the lack of any influence by nesting habitat on female wild turkey survival is likely the reason it is not represented in published literature; statistically insignificant results rarely reach publication (Kimmel et al 2023, Yang et al 2023, Bik 2024).

Resource use and availability appears to have little to no effect on female wild turkey survival in Kansas, not only during the reproductive period, but across an entire 52-week exposure period. Even though my sample population was distributed across an extremely diverse precipitation and subsequently resource gradient, different geographic areas exhibited no significant differences among female survival estimates. Female survival was similar across longitudinal study areas and among all wild turkey hunting management units in Kansas, possibly inferring that the causation of wild turkey mortality is not resource based, but being pressured by a larger systemic mechanism that I did not measure. One common external factor that can affect female survival across large extents is aberrant weather, where events such as increased temperature or precipitation can increase mortality risk (Yarnall et al. 2020). A Wisconsin study was able to determine that certain cover types have larger instances of mortality compared to others, with grasslands having greater female survival compared to forests (Pollentier et al. 2014b). The lack of variation in female wild turkey survival across the geographic extent of my study is unique to that vital rate - nest survival and brood success both had notable differences among geographic regions (Chapters II, III).

There is a growing collection of literature reporting survival estimates and suspected causes, such as predator type, of wild turkey female mortality. However, the primary cause of the female survival decline remains uncertain. Annual female wild turkey survival in Kansas is similar to that observed in Wisconsin, USA ($51.5\% \pm 3.5$; Pollentier et al. 2014b). However, the Wisconsin population exhibited lower juvenile female survival (35%) in comparison to adult survival (63%), which was the opposite pattern which I observed (Pollentier et al. 2014b). My observations of greater juvenile survival were more congruent to conclusions of Iowa, USA,

from 1993–1996, where apparent juvenile survival (71%) was slightly above apparent adult survival (68%; Hubbard et al. 1999). A study in South Dakota reported similar patterns, with juvenile survival estimated to be 75% and 73% and adult survival at 67% and 64% in 1999 and 2000, respectively (Shields and Flake 2006). Coinciding with the pattern of wild turkey decline, more recent female survival estimates from South Dakota now report a general female survival of 49% to 52% (Tyl et al. 2023). Historically, estimates of annual female survival in Kansas were 45% in 1993 (south central), 39% in 2001 (east central), and 42-48% in 2005 (south central; Miller 1993, Scalf 2000, Hennen and Lutz 2001, Brunjes 2005).

In terms of vital rates, female survival is becoming the most supported cause of wild turkey population decline (Lehman et al. 2022, Londe et al. 2023, Lashley et al. 2025). Two separate studies, one a field-based population assessment in South Dakota, the other a meta-analysis combining multiple populations across the United States to estimate female survival before and after the nationwide decline, came to similar conclusions. Increasing, or stable, wild turkey populations require an annual female survival of 68% or greater (Lehman et al. 2022, Lashley et al. 2025). In my study, all estimates of annual female survival fell 10-24 percentage points below this requirement, indicating that efforts to increase female survival including cancellation of the fall hunting season in Kansas to help protect female survival are well-warranted.

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Tables and Figures

Table 4.1. Apparent annual survival (# alive females/ # total number of females) of female wild turkeys in Kansas, USA, capture in winter 2024 and 2025. Success values are provided for each study site and grouped by study region (East, Central, and West; Figure 4.1).

Region/Site	2024	2025	Years pooled
East			
Fort Riley	0.737 (<i>n</i> = 19)	0.609 (<i>n</i> = 23)	0.667 (<i>n</i> = 42)
Tuttle Creek	0.545 (<i>n</i> = 11)	0.200 (<i>n</i> = 5)	0.438 (<i>n</i> = 16)
Cottonwood Falls	-	0.563 (<i>n</i> = 16)	0.563 (<i>n</i> = 16)
Council Grove	0.889 (<i>n</i> = 27)	0.500 (<i>n</i> = 18)	0.733 (<i>n</i> = 45)
Davis Road	-	0.700 (<i>n</i> = 10)	0.700 (<i>n</i> = 10)
Lebo	-	0.500 (<i>n</i> = 12)	0.500 (<i>n</i> = 12)
Reading	0.538 (<i>n</i> = 13)	0.400 (<i>n</i> = 5)	0.500 (<i>n</i> = 18)
Fall River WMA	-	0.636 (<i>n</i> = 11)	0.636 (<i>n</i> = 11)
Eureka	0.636 (<i>n</i> = 11)	0.500 (<i>n</i> = 4)	0.600 (<i>n</i> = 15)
Total	0.716 (<i>n</i> = 81)	0.548 (<i>n</i> = 104)	0.622 (<i>n</i> = 185)
Central			
Durham	0.581 (<i>n</i> = 31)	0.500 (<i>n</i> = 34)	0.538 (<i>n</i> = 65)
Roxbury	-	0.667 (<i>n</i> = 12)	0.667 (<i>n</i> = 12)
Kanopolis	0.696 (<i>n</i> = 23)	0.500 (<i>n</i> = 16)	0.615 (<i>n</i> = 39)
Marquette	0.528 (<i>n</i> = 36)	0.400 (<i>n</i> = 15)	0.490 (<i>n</i> = 51)
Total	0.589 (<i>n</i> = 90)	0.506 (<i>n</i> = 77)	0.551 (<i>n</i> = 167)
West			
Hays	0.75 (<i>n</i> = 4)	1.00 (<i>n</i> = 3)	0.875 (<i>n</i> = 7)
Cedar Bluff	0.575 (<i>n</i> = 40)	0.368 (<i>n</i> = 19)	0.508 (<i>n</i> = 59)
Ellis	0.429 (<i>n</i> = 7)	1.00 (<i>n</i> = 3)	0.600 (<i>n</i> = 10)

Wilson	0.605 ($n = 38$)	0.556 ($n = 18$)	0.589 ($n = 56$)
Total	0.591 ($n = 89$)	0.535 ($n = 43$)	0.573 ($n = 132$)

Table 4.2. Apparent annual survival values (# alive females/ # total number of females) by age of female wild turkeys in Kansas, USA, captured during winter 2024 and 2025. Age groups include the primary groups of juveniles and adults, as well as “second year” adults, which represent juveniles that were captured in 2024 and survived into 2025.

Age	2024	2025	Years pooled
adult	0.619 ($n = 194$)	0.494 ($n = 154$)	0.563 ($n = 348$)
second year	-	0.538 ($n = 39$)	-
juvenile	0.662 ($n = 65$)	0.704 ($n = 27$)	0.674 ($n = 92$)
Grand Total	0.629 ($n = 259$)	0.527 ($n = 220$)	0.583 ($n = 479$)

Table 4.3. Proportion of female wild turkey mortality locations in each of the 4 primary cover types throughout Kansas, USA, 2024–2025. Mortality values are provided as a ratio for each cover type for each site and then grouped by study region (East, Central, West; Figure 4.1). Female wild turkeys were captured in the winters of 2024 and 2025 and remotely monitored via 140-g G5-T2A Iridium backpack units with global positioning systems (GPS) and Very High Frequency (VHF) radio components. Cover types were determined using a remote sensing layer created from the Kansas Ecological Monitoring database.

Region/Site	Cover type			
	Cropland	Grassland	Shrubland	Woodland
East				
Fort Riley	0.182 (<i>n</i> = 4)	0.409 (<i>n</i> = 9)	0 (<i>n</i> = 0)	0.409 (<i>n</i> = 9)
Tuttle Creek	0.100 (<i>n</i> = 1)	0.300 (<i>n</i> = 3)	0.100 (<i>n</i> = 1)	0.500 (<i>n</i> = 5)
Cottonwood Falls	0.500 (<i>n</i> = 5)	0.300 (<i>n</i> = 3)	0 (<i>n</i> = 0)	0.200 (<i>n</i> = 2)
Council Grove	0.050 (<i>n</i> = 1)	0.450 (<i>n</i> = 9)	0 (<i>n</i> = 0)	0.500 (<i>n</i> = 10)
Davis Road	0 (<i>n</i> = 0)	0.500 (<i>n</i> = 2)	0 (<i>n</i> = 0)	0.500 (<i>n</i> = 2)
Lebo	0 (<i>n</i> = 0)	0.833 (<i>n</i> = 5)	0 (<i>n</i> = 0)	0.167 (<i>n</i> = 1)
Reading	0 (<i>n</i> = 0)	0.364 (<i>n</i> = 4)	0.091 (<i>n</i> = 1)	0.545 (<i>n</i> = 6)
Fall River WMA	0 (<i>n</i> = 0)	0.714 (<i>n</i> = 5)	0 (<i>n</i> = 0)	0.286 (<i>n</i> = 2)
Eureka	0 (<i>n</i> = 0)	0.333 (<i>n</i> = 3)	0 (<i>n</i> = 0)	0.667 (<i>n</i> = 6)
Total	0.111 (<i>n</i> = 11)	0.434 (<i>n</i> = 43)	0.020 (<i>n</i> = 2)	0.434 (<i>n</i> = 43)
Central				
Durham	0.061 (<i>n</i> = 2)	0.515 (<i>n</i> = 17)	0 (<i>n</i> = 0)	0.424 (<i>n</i> = 14)
Kanopolis	0 (<i>n</i> = 0)	0.529 (<i>n</i> = 9)	0.118 (<i>n</i> = 2)	0.353 (<i>n</i> = 6)
Roxbury	0.143 (<i>n</i> = 1)	0.429 (<i>n</i> = 3)	0 (<i>n</i> = 0)	0.429 (<i>n</i> = 3)
Marquette	0.111 (<i>n</i> = 3)	0.556 (<i>n</i> = 15)	0 (<i>n</i> = 0)	0.333 (<i>n</i> = 9)
Total	0.071 (<i>n</i> = 6)	0.524 (<i>n</i> = 44)	0.024 (<i>n</i> = 2)	0.381 (<i>n</i> = 32)
West				

Hays	0 ($n = 0$)	1.00 ($n = 1$)	0 ($n = 0$)	0 ($n = 0$)
Cedar Bluff	0.139 ($n = 5$)	0.806 ($n = 29$)	0.028 ($n = 1$)	0.028 ($n = 1$)
Ellis	0.250 ($n = 1$)	0.750 ($n = 3$)	0 ($n = 0$)	0 ($n = 0$)
Wilson	0 ($n = 0$)	0.679 ($n = 19$)	0.071 ($n = 2$)	0.250 ($n = 7$)
Total	0.087 ($n = 6$)	0.754 ($n = 52$)	0.043 ($n = 3$)	0.116 ($n = 8$)
Grand Total	0.091 ($n = 23$)	0.552 ($n = 139$)	0.028 ($n = 7$)	0.329 ($n = 83$)

Table 4.4. Proximity distances (m) to common features of interest relative to 252 female wild turkey mortality locations throughout Kansas, USA, 2024–2025. Female wild turkeys were captured in the winters of 2024 and 2025 and remotely monitored via 140-g G5-T2A Iridium backpack units with global positioning systems (GPS) and Very High Frequency (VHF) radio components. Proximity values were measured remotely in a Geographic Information System, where mortality locations that fell within the item of interest’s boundary were given a value of 0 m. Public lands represent all government-owned lands across our study area, such as United States Army Corps of Engineers, United States Department of Defense, and Kansas Wildlife Management Areas. Roost trees were known nightly roost locations of non-nesting or brood-rearing female wild turkeys, and “edge” represents a 40 m wide (20 m half-width) buffer placed around all cover types throughout the study area.

	Public lands (m)	Roost tree (m)	Edge (m)
Region/ Site	$\bar{x} \pm \text{SD}$	$\bar{x} \pm \text{SD}$	$\bar{x} \pm \text{SD}$
East (<i>n</i> = 99)			
Fort Riley	175.39 ± 371.5	93.37 ± 104.64	43.02 ± 59.44
Tuttle Creek	980.52 ± 908.13	171.82 ± 201.9	10.91 ± 14.81
Cottonwood Falls	5960.98 ± 3849.01	245.4 ± 231.26	66.87 ± 120.27
Council Grove	1084.64 ± 1843.15	98.07 ± 174.8	33.43 ± 62.06
Davis Road	1794.98 ± 2707.65	137.38 ± 129.32	10.91 ± 18.56
Eureka	5714.45 ± 1386.17	116.65 ± 155.39	27.46 ± 31.77
Fall River WMA	564.16 ± 951.21	203.76 ± 163.63	61.63 ± 111.39
Lebo	6920.76 ± 2079.42	133.62 ± 149.75	22.55 ± 17.19
Reading	911.26 ± 1109.9	162.71 ± 297.29	16.88 ± 23.98
Total	2111.86 ± 2924.35	139.44 ± 183.56	34.71 ± 63.89
Central (<i>n</i> = 84)			
Durham	7332.53 ± 4012.8	139.06 ± 147.24	24.14 ± 42.6
Kanopolis	1080.4 ± 1722.27	289.55 ± 350.72	72.75 ± 131.81
Marquette	3791.16 ± 2314.99	199.67 ± 214.48	61.32 ± 74.15
Roxbury	5538.08 ± 4081.56	120.67 ± 102.55	10.29 ± 13.91

Total	4779.38 ± 3927.27	187.47 ± 225.24	44.77 ± 79.4
West (<i>n</i> = 69)			
Cedar Bluff	3298.49 ± 6658.87	216.76 ± 353.14	62.87 ± 82.19
Ellis	20592.31 ± 4535.81	143.22 ± 198.39	13.35 ± 14.19
Hays	0 ± -	46.65 ± -	49.41 ± -
Wilson	2277.74 ± 4230.13	340.85 ± 745.91	22.85 ± 38.16
Total	3839.01 ± 6979.99	260.39 ± 540.37	43.56 ± 67.03

Table 4.5. Cumulative survival estimates of female wild turkeys across 3 study regions (East, Central, and West; Figure 4.1) and 2 years (2024, 2025) in Kansas, USA. Cumulative survival was estimated using a Kaplan-Meier analysis, with female wild turkeys grouped by 4 categories: study year, female age (adult, juvenile), study region, and Kansas Department of Wildlife and Parks (KDWP) wild turkey hunting management unit (4, 6, 3, 2). Weeks of greatest change in survival (ΔS) represent the survival week in which the maximum change in female survival was observed. In 2024, week 1 begins on February 26, 2024 and week 52 ends on February 17, 2025; In 2025, week 1 begins on February 24, 2025 and ends on February 16, 2026. The majority of the “Weeks of greatest ΔS ” were between weeks 8-10 for both years. Breeding season ΔS represents the change in survival between survival weeks 3 to 26 of both years, which contains the peak nesting and brood rearing phases of female wild turkeys. The 52-week survival, standard error (SE), lower confidence level (LCL) and upper confidence level (UCL) represent the cumulative survival of female wild turkeys across the entire, annual Kaplan-Meier period.

Group	Weeks of greatest ΔS	Breeding season ΔS	52-week survival	SE	LCL	UCL
Year						
2024	9-10 ($\Delta S = -0.046$)	-0.365	0.521	0.031	0.464	0.585
2025	8-9 ($\Delta S = -0.067$)	-0.464	0.473	0.033	0.412	0.543
Female Age						
Adult	13-14 ($\Delta S = -0.046$)	-0.437	0.480	0.025	0.433	0.533
Juvenile	16-17 ($\Delta S = -0.053$)	-0.308	0.575	0.052	0.482	0.685
Region						
East	8-9 ($\Delta S = -0.054$)	-0.373	0.492	0.037	0.425	0.569
Central	8-9, 10-11 ($\Delta S = -0.047$)	-0.437	0.501	0.039	0.431	0.582
West	9-10 ($\Delta S = -0.061$)	-0.424	0.508	0.044	0.429	0.600
KDWP management unit						
4	9-10 ($\Delta S = -0.053$)	-0.44	0.493	0.058	0.392	0.621
6	10-11 ($\Delta S = -0.092$)	-0.407	0.444	0.068	0.330	0.599
3	8-9 ($\Delta S = -0.057$)	-0.375	0.508	0.035	0.445	0.58
2	8-9 ($\Delta S = -0.062$)	-0.435	0.510	0.041	0.435	0.597

Table 4.6. Model performance for survival of female wild turkey captured during winter 2024 and 2025 ($n = 490$ females) during a 52-week annual survival period across Kansas, USA, 2024–2026. Survival was predicted using a known fate model with 3 different covariates: Time (week), year ($n = 263$ in 2024, $n = 227$ in 2025), and phase. The year covariate was the year of the 52-week survival, which was either 2024–2025 or 2025–2026, starting in February 2024 and 2025. The final covariate, phase, was the survival period broken into a 29-week (Sep–Feb) nonbreeding phase and a 23-week (Mar–Aug) breeding phase.

Model^a	K	AIC_c	ΔAIC_c	w_i	Deviance
S (~time)	52	2642.675	0.000	0.73	<0.0001
S (~time + year)	53	2644.679	2.005	0.27	2538.34
S (~phase * year)	4	2665.003	22.329	0.00	2657.00
S (~phase)	2	2673.084	30.410	0.00	130.74
S (~phase + year)	3	2675.079	32.404	0.00	2669.08
S (~time * year)	104	2680.117	37.442	0.00	2470.80
S (~1)	1	2738.964	96.290	0.00	198.62

^a Model = main effects model titles, K = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, w_i = AIC_c weight, Deviance = Relative measure of model goodness of fit.

Table 4.7. Model performance for female wild turkey survival ($n = 345$ females) during a 23-week reproductive period (Mar–Aug) across Kansas, USA, 2024–2025. Survival was estimated using a known-fate model with 6 different covariates. Three covariates were proximity measurements from a female’s first nesting attempt to the following landscape features: distance to the nearest known roost tree (Roost m), distance to the nearest tree of any type or size (Tree m), distance to the nearest cropland (Crop m), and the distance to the nearest “edge” patch defined as a 20-m half width around all patch perimeters (Edge 20 m). Two covariates were kernel density estimates (KDE) from the laying phase of a female’s first attempt nest, including 50% KDE core range (Lay 50 KDE) and 95% KDE home range (Lay 95 KDE). Female wild turkeys were captured in winters of 2024 and 2025.

Model^a	K	AIC_c	ΔAIC_c	w_i	Deviance
S (~ Roost m)	2	1135.661	0	0.194	1131.659
S (~ 1)	1	1135.825	0.164	0.179	107.054
S (~ Lay 50 KDE)	2	1135.870	0.209	0.175	1131.868
S (~ Tree m)	2	1135.977	0.317	0.165	1131.976
S (~ Lay 95 KDE)	2	1136.197	0.536	0.148	1132.195
S (~ Crop m)	2	1137.592	1.932	0.074	1133.591
S (~ Edge 20m)	2	1137.819	2.158	0.066	1133.817

^a Model = main effects model titles, K = no. of parameters, AIC_c = Akaike’s Information Criterion adjusted for sample size, ΔAIC_c = difference in AIC_c relative to smallest AIC_c value, w_i = AIC_c weight, Deviance = Relative measure of model goodness of fit.

Table 4.8. Model performance for female wild turkey survival ($n = 282$ females) during a 23-week reproductive period (Mar–Aug) across Kansas, USA, 2024–2025. Survival was estimated using a known-fate model with 6 different covariates measured at first attempt nest locations that were significant for either resource selection or survival of wild turkey nests (Chapters I and II). Covariates include woody plant composition (nest woody) within a 1-m² vegetation frame placed around the nest, visual obstruction up to 50-cm tall around the nest bowl split into 2 height groups (vor1 = 0-25 cm tall, vor2 = 25-50 cm tall), forb composition within a 1-m² vegetation frame measured 4 times at 10 m in each cardinal direction from the nest bowl (forb 10m), and visual obstruction at the same 2 height groups (vor1_10m, vor2_10m) but measured at a 10-m radius away from the nest bowl in each cardinal direction.

Model^a	K	AIC_c	ΔAIC_c	w_i	Deviance
S(~1)	1	950.826	0.000	0.246	105.069
S(~nest woody)	2	951.137	0.312	0.211	947.135
S(~vor2_10m)	2	952.040	1.214	0.134	948.038
S(~vor2)	2	952.291	1.466	0.118	948.289
S(~vor1)	2	952.5869	1.763	0.102	948.587
S(~forb_10m)	2	952.701	1.876	0.096	948.699
S(~vor1_10m)	2	952.788	1.962	0.092	948.786

^a Model = main effects model titles, K = no. of parameters, AIC_c = Akaike's Information Criterion adjusted for sample size, Δ AIC_c = difference in AIC_c relative to smallest AIC_c value, w_i = AIC_c weight, Deviance = Relative measure of model goodness of fit.

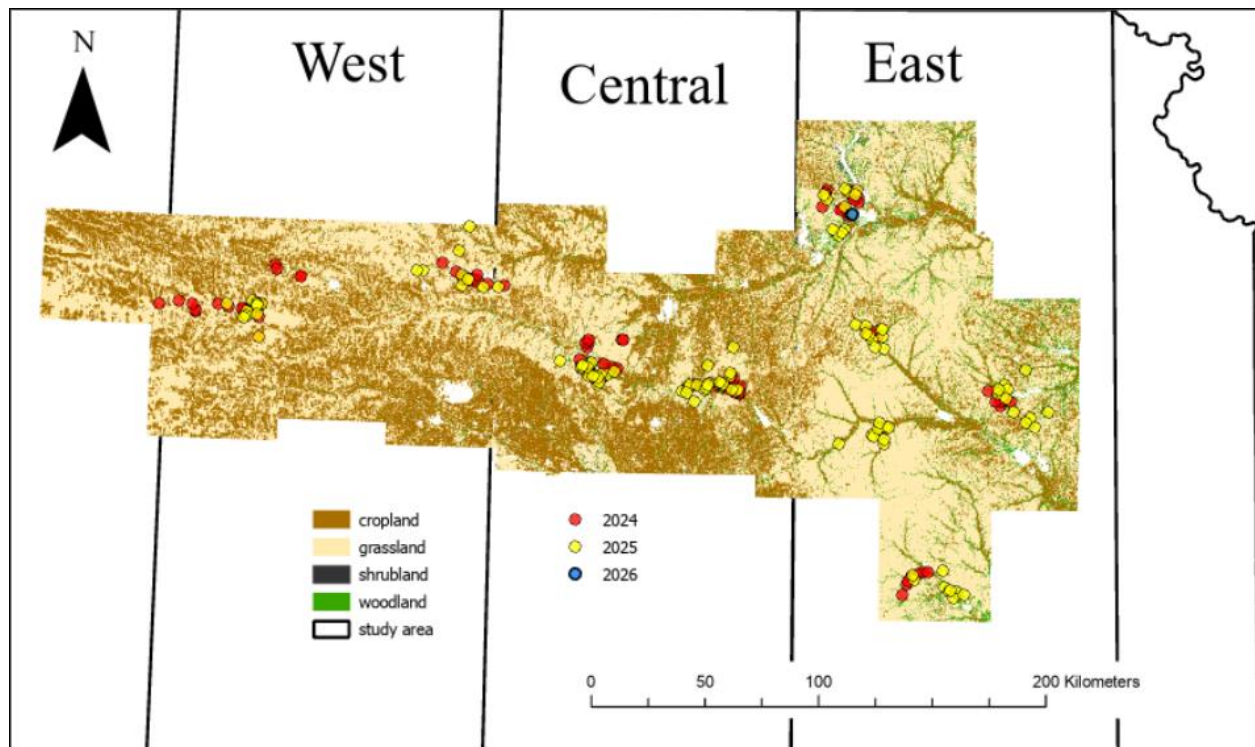


Figure 4.1. Mortality locations of female wild turkeys across three study regions (West, Central, and East) in Kansas, USA, during 2024–2026. Female wild turkeys were captured in winters of 2024 and 2025 and remotely monitored via 140-g G5-T2A Iridium backpack units with global positioning systems (GPS) and Very High Frequency (VHF) radio components.

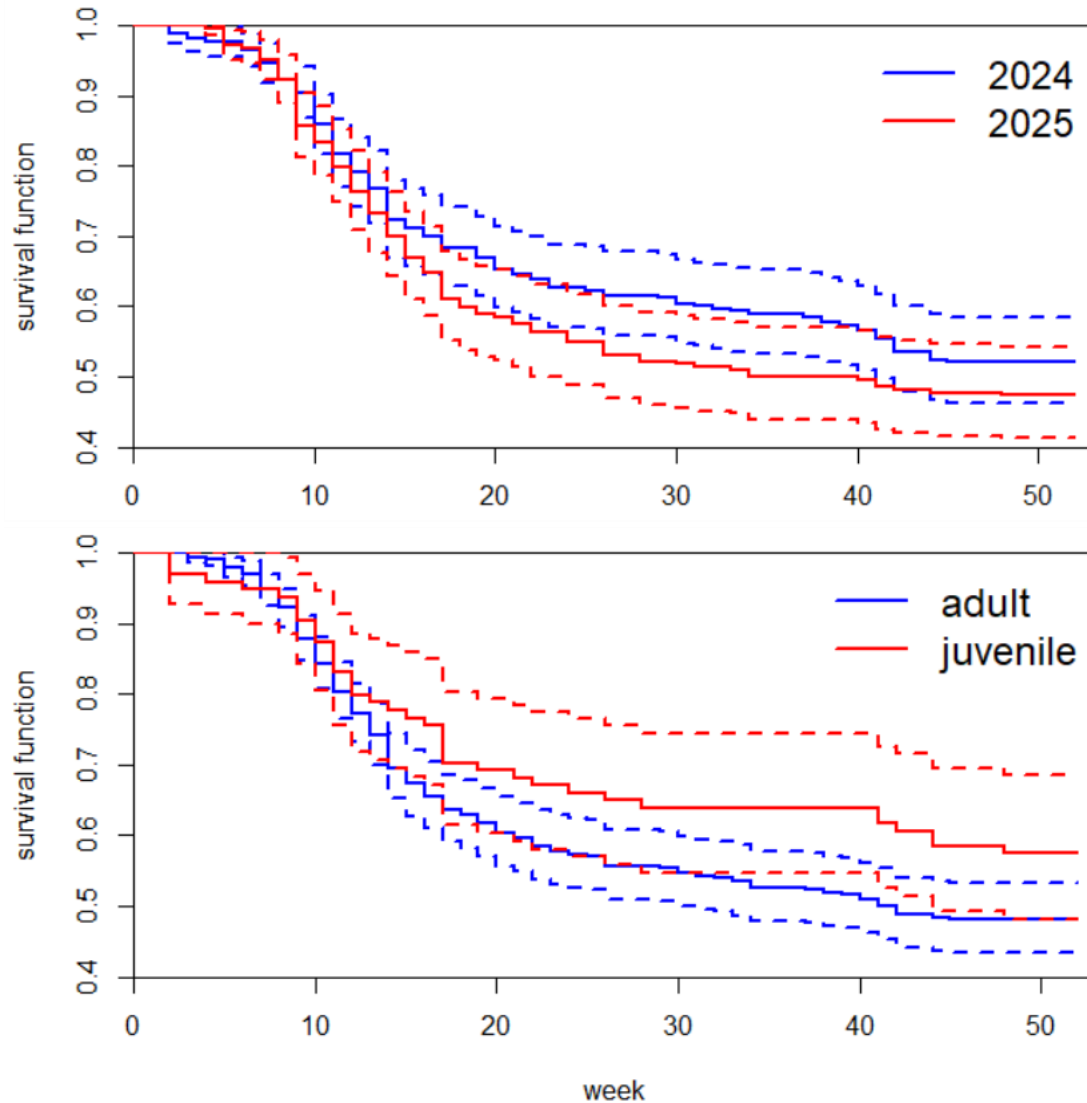


Figure 4.2. Kaplan-Meier curve for cumulative estimated annual survival (solid lines) and corresponding 95% confidence intervals (dashed lines) of female wild turkeys grouped by year (2024–2025; top) and age (adult, juvenile; bottom), in Kansas, USA, 2024–2026. In 2024, week 1 began on February 26, 2024 and week 52 ended on February 17, 2025; In 2025, week 1 began on February 24, 2025 and ended on February 16, 2026. Female wild turkeys were captured in winters of 2024 and 2025 and remotely monitored via 140-g G5-T2A Iridium backpack units with global positioning systems (GPS) and Very High Frequency (VHF) radio components.

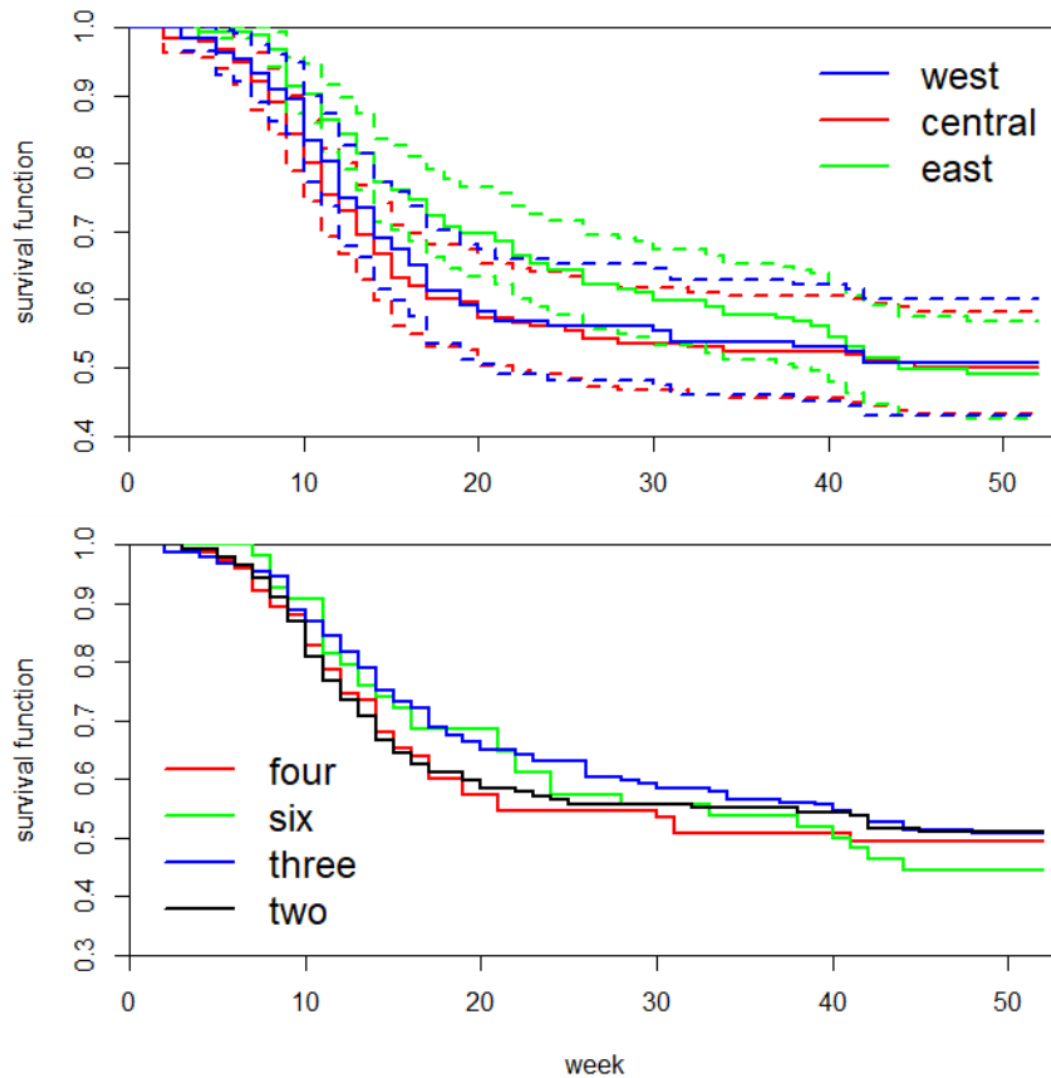


Figure 4.3. Kaplan-Meier curve for cumulative estimated annual survival (solid lines) and corresponding 95% confidence intervals (dashed lines) of female wild turkeys grouped by study region (East, Central, and West; top) and Kansas Department of Wildlife and Parks wild turkey hunting management unit (4, 6, 3, 2; bottom), in Kansas, USA, 2024–2026. In 2024, week 1 began on February 26, 2024, and week 52 ends on February 17, 2025; In 2025, week 1 began on February 24, 2025, and ends on February 16, 2026. Female wild turkeys were captured in the winters of 2024 and 2025 and remotely monitored via 140-g G5-T2A Iridium backpack units with global positioning systems (GPS) and Very High Frequency (VHF) radio components.

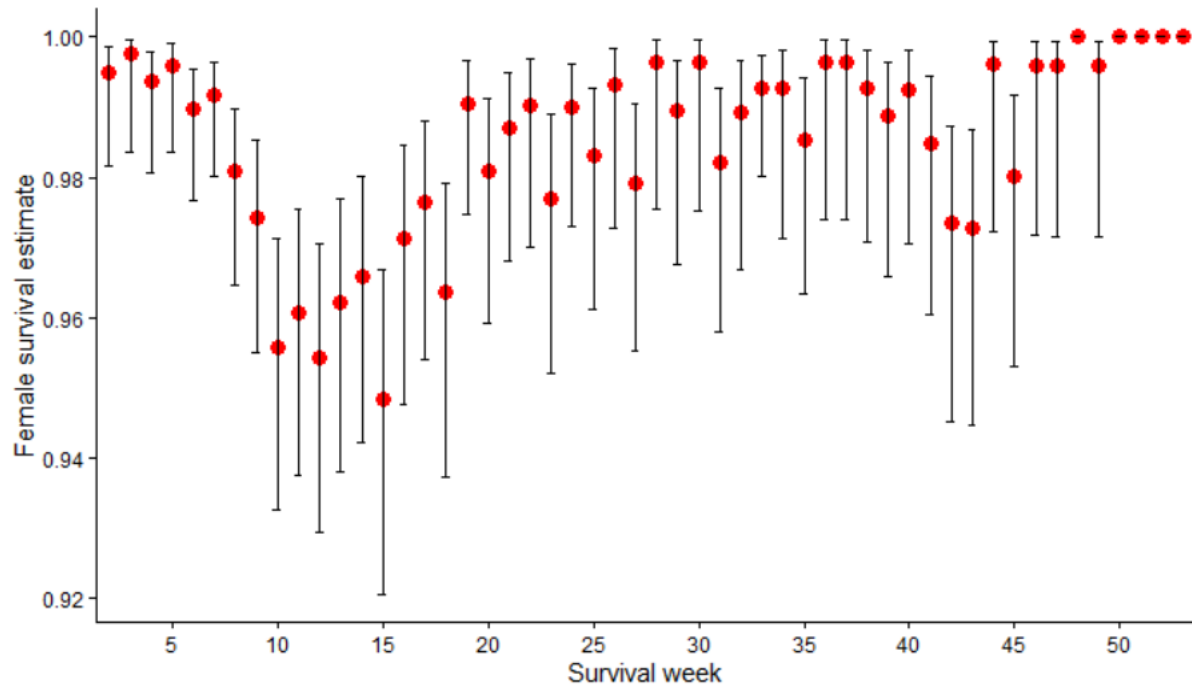


Figure 4.4. Weekly survival estimates ($\hat{S}_t$) of female wild turkeys over an annual period in Kansas, USA, 2024–2026. In 2024, week 1 began on February 26, 2024, and week 52 ends on February 17, 2025; In 2025, week 1 began on February 24, 2025, and ends on February 16, 2026. Female wild turkeys were captured in the winters of 2024 and 2025 and remotely monitored via 140-g G5-T2A Iridium backpack units with global positioning systems (GPS) and Very High Frequency (VHF) radio components.