Nesting and Brooding Ecology of Eastern Wild Turkey in South-Central Tennessee

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Abstract

In recent years there has been growing concern for eastern wild turkey (*Meleagris gallapova)* populations in the southeastern U.S. because of noticeable declines in productivity and harvest. Tennessee has also seen a decrease in turkey harvest in some counties and a decrease in poult-hen ratios during the summer surveys. This study was designed to identify potential cause(s) of the decline in seasonal productivity. We gathered data on reproduction and resource-selection of nesting and brooding hens to better understand what could be causing the decline in seasonal productivity. We used hierarchical conditional logistic regression with matched pairs to compare use versus availability at the landscape and site-specific levels for both nest and brood locations. To model nest and poult survival we used a hierarchical model selection process using the nest survival model and known-fate model in the RMark interface. We monitored 206 hens during the nesting season and determined average nesting rate (75.7%), clutch size of successful nests (9.3), and nest success per hen per season (33.9%) for 2017-2018. Nesting hens selected vegetative cover types, such as shrublands and old fields, that provided increased visual obstruction and cover over the nest. Percent cover above the nest was positively associated with daily nest survival. Broods selected areas that had greater fragmentation of herbaceous cover types and areas that were closer to deciduous forests and shrublands. Forb abundance was positively selected for poult habitat at the site-specific level. Poult survival (2017 = 1.5%; 2018 = 9.7%) was positively related to later hatch date and increased daily movements. Daily poult survival during the first four days of life was positively related to nest-site selection for nests being closer to paths or roads. Ultimately, we found that all reproductive parameters were lesser than estimates from studies of stable or increasing populations and that seasonal productivity was affected by each stage of the nesting and brooding cycle. Based on our results,

we provided habitat recommendations at landscape and site-specific scales to positively affect both nesting, poult survival, and ultimately seasonal productivity.

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Part I: Introduction

By 1920 the wild turkey (*Meleagris gallapavo*) was no longer found in 18 of the original 38 states of its ancestral range (Mosby and Handley 1943). By the 1940's, wild turkeys had disappeared from 33 counties in Tennessee (Lewis 1964). Through an initiative with Tennessee Wildlife Resource Agency (TWRA), the National Wild Turkey Federation (NWTF) and other partners, there was a large restoration effort of wild turkeys in Tennessee that started in 1940 (Lewis 1964). During the restoration period there was minimal research being done on the turkeys being introduced in Tennessee. Studies done on the Natchez Trace Wildlife Management Area documented reproductive success of translocated turkeys (McGuiness et al. 1990, McGuiness and Smith 1990). Little turkey research has been done since the end of the restoration period (2005) in Tennessee. Currently, Tennessee has about 120,000 turkey hunters with a statewide harvest of ~30,000 birds per year (Schexnayder et al. 2013). The turkey population and harvest have been monitored annually through mandatory hunter harvest reporting and observational data by TWRA. Annual harvest in the state peaked in 2010, but since then harvest has declined. This decline has been most pronounced in middle Tennessee (TWRA Region 2), where harvest has decline by 25%. Within Region 2, some of the counties that once had the greatest harvest in the state have now declined by ~50%. The entire southeastern United States also has been experiencing turkey harvest declines and have also reported declines in annual poult/hen ratios in recent years (Byrne et al. 2016). The recent decline has sparked concern by Tennessee hunters and wildlife managers, prompting the formation of this study to identify the potential causal factors leading to the decline in harvest and apparent decline in population.

Reasonable rates of nest and poult survival have been found elsewhere to be very important to sustaining wild turkeys populations (Roberts et al. 1995, Vangilder and Kurzejeski 1995, Isabelle et al. 2016). Therefore, we studied nest and brood survival and resource-selection of turkeys in south-central Tennessee to better understand the underlying causes related to harvest and ultimately population declines. Our objectives were to:

1. Document nesting ecology, success and habitat use of the nesting hens.
2. Document poult ecology, survival and habitat use.
3. Document seasonal productivity and compare reproductive parameters to parameters documented in other studies with stable/increasing vs. declining populations.

Nesting Ecology and Resource-Selection

Knowledge of the productivity of a turkey population is necessary to effectively manage that population. In recent years, Tennessee has had a relatively abundant turkey population but has not extensively studied the nesting ecology within the state. Reproductive parameters and productivity have been studied extensively elsewhere within the southeastern United States (Exum et al. 1987, Still and Baumann 1990, Palmer et al. 1993, , Miller et al. 1998, Norman et al. 2001), although there is no way of knowing whether these studies are representative of the Tennessee turkey population. Studying hen nesting ecology involves collecting data on nest initiation, success, renesting, clutch size and hatching rates. Nesting parameters can then be used to determine seasonal productivity (the number of poults produced per hen per breeding season) and allow managers to understand which factors may be limiting turkey populations.

One of the most important parameters that affect turkey population size is nest success (Roberts et al. 1995), such that the availability of quality nesting habitat is important (Thogmartin 1999). Quality nesting habitat is important for the success of a nesting hen to avoid predation (Badyaev 1995) and to supply an abundant insect food source for hens and poults (Healy 1985). Nest-site selection has been studied to better understand what characteristics hens may be choosing for nesting compared to availability, and how that selection influences success. High visual obstruction is often reported as an important attribute of a good nesting site (Holbrook et al. 1987, Badyaev 1995, Badyaev et al. 1996, Spears et al. 2007, Fuller et al. 2013). Nest sites with greater visual obstruction at the 0-1 m range have been shown to be selected for compared to available habitat (Badyaev 1995).

Landscape-scale characteristics may also be important in nest-site selection and nest survival. Shrubland and young regenerating forest cover types may be selected for compared to mature forest stands with little structure in the understory (Still and Baumann 1990, Streich et al. 2015). Shrubland and young forest cover types also correlate with the microhabitat characteristics that hens select for that provide greater visual obstruction. Landscape fragmentation can also influence nest-site selection and success as long as the fragmentation is not caused by human development, because more fragmented landscapes have greater amounts of edge (Laurance 2001). Edges, however, have also been shown to have greater densities of nest predators, which could have a negative effect on nest success (Thogmartin 1999). If the survival implications of nest-site selection can be determined, then better habitat management prescriptions may be developed to improve nest success.

We gathered data to gain insight into how nesting parameters and nest-site selection may be influencing the population trend in south-central Tennessee (Chapter Two). We will compare these parameters to past research associated with declining or stable/increasing populations.

Brooding Ecology and Resource-Selection

Poult survival is an important component of seasonal productivity, but it has been given relatively little research attention compared to the number of studies on nesting ecology.

Currently, state agencies are using poult per hen ratios and the proportion of hens with broods as indices of seasonal productivity in their populations (Byrne et al. 2016). Tennessee has had almost a 30% decline in the number of hens reported with poults from 1983-2012, based on summer productivity surveys (Byrne et al. 2016). Without studying brood resource-selection and poult survival, a key aspect of seasonal productivity is being overlooked which may lead to misappropriate management decisions. The first two weeks after hatching are generally the most vulnerable times for poults (Peoples et al. 1995, Miller et al. 1998, Paisley et al. 1998, Spears et al. 2007), with predation documented as the top cause of poult mortality (Speake et al. 1985). Understanding what areas broods are selecting for and how survival is being influenced by resource selection during the critical first few weeks of life is crucial to effective turkey management.

Limited research has been done on the relationships between movements, landscape and site-specific vegetative characteristics and daily poult survival. Brood habitat has been characterized as areas with abundant forb cover associated with abundant insects for food, overhead cover for concealment from predators, and open structure at ground level for easy movement (Healy 1985). The spatial arrangement and availability of cover type patches that provide these structural components must be studied to understand how brood habitat availability affects hen resource selection and brood survival.

Increased movement of broods was positively related to poult survival in one study in Virginia (Godfrey and Norman 1999), but had no measurable effect on survival in another study in Alabama (Peoples et al. 1996). These contradictory results lead to alternative hypotheses relating brood habitat availability to movements and ultimately survival. In one scenario, brood habitat, as defined by the availability of herbaceous cover, should be negatively related to movements, such that more herbaceous cover leads to less movements. Alternatively, if hens are predisposed to move broods to avoid predators associated with the nest site, regardless of brood habitat availability, the amount of herbaceous cover should be unrelated to the amount of movements. An understanding of which of the above hypotheses is best supported is critical to effective management of brood habitat and ultimately brood survival.

In theory, nest-site selection and brood-site selection should be linked to optimize poult production through successful nesting and poult survival. An understanding of this relationship would be critical for effective management of turkey seasonal productivity (Streby et al. 2016). Although there have been many turkey nesting studies and a few poult studies (see above), we did not find any published studies that documented the linkage of these two critical stages of seasonal productivity for wild turkeys. Nesting cover is normally very dense and may not provide quality brood habitat, such that hens have to move broods from nest sites to find appropriate brood habitat. An understanding of where, how, and why hens move broods is critical to understanding factors limiting seasonal productivity. Ultimately, brood resource-selection and poult survival play key roles in determining seasonal productivity of wild turkeys. The data we gathered will allow us to better understand and ultimately manage for increased poult survival during the critical stage of their life cycle.

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Part II: Nest-site Selection and Nest Survival of Eastern Wild Turkeys in South-Central Tennessee

Abstract

Since 2010 there has been a decline in the spring wild turkey (*Meleagris gallopavo silvestris*) harvest in many eastern states, including Tennessee. To understand if turkey productivity could be contributing to population declines, we radio-tagged 206 hens in 2017 and 2018 with VHF transmitters and tracked them throughout the nesting season. We documented nest-site selection, nesting rate, clutch size, hatching rate, renesting rate, and daily nest survival. We used conditional logistic regression to determine which landscape-scale and nest-site vegetative characteristics were most related to nest-site selection by hens. We used program RMARK to determine which temporal, rainfall, landscape-scale, and site-specific vegetation characteristics were most related to daily nest survival. An average of 75.7% of the hens attempted to nest in 2017-2018. We monitored 204 nests, and documented an average clutch size of 9.3 from successful nests, with an overall nest success of 33.9% during the nest-incubation stage. Nest-site selection was positively associated with the amount of early succession/pasture and shrubland cover types available in pre-nesting home ranges. Nest-site selection also was positively associated with visual obstruction (0-50 cm above ground-level and 101-200 cm) and percent vegetative cover above the nest, but negatively associated with distance from trails or roads. The best-supported model for daily nest survival included percent vegetative cover above the nest as the most influential covariate. Ultimately, hens selected for greater vegetative cover around the nest, which was associated with greater survivability of the nest. Habitat management prescriptions that promote favorable nesting covers could lead to increased nest success.

Introduction

In recent years there has been a documented decline in annual reproductive indices of eastern wild turkeys (hereafter "turkey") (*Meleagris gallopavo silvestris*) in many areas of the southeastern United States (Byrne et al. 2016). Reproductive parameters have been studied extensively within this region (Exum et al. 1987, Palmer et al. 1993, Thogmartin and Johnson 1999, Norman et al. 2001, Isabelle et al. 2016), but a contemporary study on nesting ecology of wild turkeys is lacking in Tennessee. Limited research done during the restoration phase (1988) provides the only comparison with contemporary data (McGuiness and Smith 1990). With a documented significant decline in harvest in the south-central portion of Tennessee, reproductive parameters of the turkey population need to be studied to better understand the potential factors affecting recruitment into the population. Poor recruitment coupled with "average" hen survival could lead to local extirpation within 10 years (Miller et al. 1998). In Arkansas, low nest initiation rates (62%), nest success (16.5%), and small clutch size (9 eggs) were speculated to be the main cause for the population decline; hen survival (75%) and poult survival (~34%) were typical of a stable population (Thogmartin and Johnson 1999). A current study in Louisiana showed similarly low initial nest success (15.6%) (Yeldell et al. 2017a), which may be linked to a population decline. By understanding the reproductive parameters in Tennessee and comparing them to known stable/increasing or declining populations, we will have a better understanding of which parameters could be causing the apparent decline.

Ideally, if there is a relationship between hen nest success and habitat characteristics, then managers may be able to effectively increase nest success through habitat management. Predation is typically the primary cause of nest failures accounting for 51 – 93% of all nest failures (Vangilder et al. 1987, Palmer et al. 1993, Thogmartin and Johnson 1999, Kiss 2015).

Habitat characteristics may be important for providing appropriate nest cover to avoid predation (Badyaev 1995), and to supply an abundant insect food source (Healy 1985). Visual obstruction has been reported as influential on nest-site selection (Holbrook et al. 1987, Badyaev et al. 1996, Spears et al. 2007, Fuller et al. 2013, Wood et al. 2019). Sites with greater visual obstruction in the 0-1 m range typically are selected for nesting (Badyaev 1995). Concealment is important but so is the ability to escape when confronted by a predator. Nesting habitat that has increased visual obstruction but has lower woody stem densities around the nest provide quality cover and do not limit the escapability of the hen.

Hen nest-site selection, and ultimately nest survival may be related to habitat characteristics at multiple spatial scales. Shrubland, old field or young regenerating forest cover types may be highly selected for nest sites compared to mature forest stands with little understory structure (Still and Baumann 1990, Streich et al. 2015). Selection for nest sites in shrubland or young regenerating forest likely correlate with the microhabitat characteristics that hens select for that provide greater visual concealment. In Mississippi, nests were more successful as distance to man-made edges decreased, because edges provided more suitable structure compared to the interior of the cover types (Seiss et al. 1990). Understanding the nature of nest-site selection at the landscape level and identifying which characteristics are linked to nest survival may help managers and private landowners positively influence nesting success in their area.

Turkey populations in the Southeast may be exhibiting a density-dependent response whereby seasonal productivity is decreasing where populations have reached carrying capacity (Byrne et al. 2016). Byrne et al (2016) demonstrated a possible negative correlation between population and decreasing poult per hen ratios and increasing percent of hens without poults.

This could indicate reproduction is influenced by density dependence. Density dependence on production has been documented in both ring-necked pheasants (*Phasianus colchicus*; Einarsen 1945) and northern bobwhites (*Colinus virginianus*; Cookingham and Ripley 1964). Both studies documented increased growth rates until a certain level was reached, then productivity began to decrease, causing stability (pheasants), or a decline until stable levels were reached (northern bobwhite).

We gathered information on nest-site selection and nest survival to understand how nesting may contribute to turkey harvest declines. Turkey harvest declines could be an indicator of an overall population decline, so our objectives allowed us to analyze nesting parameters, nest-site selection and nest survival to see how they compared to increasing, stable, or decreasing populations. Specific objectives were to: (1) Document current nesting parameters for turkeys in south-central Tennessee, (2) identify nest-site selection compared to availability, (3) determine relationships between daily nest survival and temporal, spatial, and site-specific vegetative covariates, and (4) evaluate evidence to support a density-dependent response in reproduction.

Study Area

The study was conducted in 5 counties of south-central Tennessee (Maury, Lawrence, Wayne, Bedford and Giles). Via contacts with private landowners, we gained access to 26,007 ha of private land and also worked on 10,846 ha of public land. Each of the five counties was dominated by varying amounts of deciduous forest and hay/pasture cover types (USDA National Agricultural Statistics Service Cropland Data Layer 2017; Figure 2.1). Ten study sites (two per county) were used as focal points for the study (Figure 2.2). These sites were located on private (n = 9) and public (n = 1) land and had turkey densities that were sufficient to obtain the target sample size (n = 10 hens per site) for the nesting study. Each site had a range of turkey densities, hunter densities and land cover compositions.

Lawrence County was predominantly deciduous forest (44.7%) with substantial agricultural land use (grasslands and pastures, 27.4%; row crops, 13.12%; Figure 2.3). The study sites were on private land where we acquired land access from 40 private landowners (3,944 ha) at the southern site and 37 (36 private and 1 public) landowners (8,952 ha; 3,287 ha of private and 5,665 ha of public) at the northern site. Both sites were similarly dominated by deciduous forests, but the northern site had a greater amount of hay/pasture. The northern and southern sites both had rivers flowing through them, creating steep hillsides for roosting habitat and fertile river bottoms for row crop agriculture and grazing.

Giles County was predominantly deciduous forest (47.5%) with agricultural land cover in the river valleys (Figure 2.4). Both study sites were located on private land, located in the northern and southern sections of the county, respectively. The northern site was located close to the border of Giles and Marshall counties with access from 29 landowners (4,163 ha). A total of 22 landowners in the southern study site provided access (1,672 ha). The northern site had many properties that were managed for wildlife and consisted of deciduous forests, old fields and pastures throughout the area. Deciduous forest dominated the northern section of the southern site with some pastures, unlike the southern portion which was heavily row crop agriculture.

Maury County was predominantly deciduous forest (44.5%), and hayfield/pasture (31.3%) cover types (Figure 2.5). The southeastern site was located within Yanahli Wildlife Management Area (WMA). Yanahli is a 5,180 ha WMA dominated by mixed cedar (*Juniperus* spp.) and oak (*Quercus* spp.) -hickory (*Carya* spp.) forests. There were row crop fields along the Duck River that was either privately owned or leased out by the state. We gained access from 9 private landowners, which increased our total land access by 657 ha. Both of the sites had some type of wildlife-based management practices being implemented on them. The northwestern site was dominated by deciduous forest, with a lake in the middle of the property. There was row crop agriculture and hayfields/pastures to the west and south of the main trap site. In total we acquired access to 19 properties (2,280 ha) at the northern site.

Wayne County was more forested than the other counties (61.7% deciduous and 8.6% evergreen; Figure 2.6). Timber companies owned much of the accessible land (5,281 ha) in the southern site, but 14 landowners also granted access to another 388 ha. This site was dominated by evergreen and mixed forests with minimal hayfield/pasture and row crop agriculture located to the south. The northern site was dominated by deciduous and mixed forests. There were managed agricultural fields in the area but most of the agriculture was to the north of the trap site. We acquired access from 11 landowners that totaled 1,096 ha.

Bedford County was dominated by hayfields and pastures (47.5%), with less deciduous forest than the other counties (26.6%; Figure 2.7). The northern site was dominated by deciduous forest and hayfield/pasture cover types. We gained access from 24 landowners (1,748 ha). The southern site adjoined Marshall County. The site was very flat and was heavily in row crops with forests in the site that were either deciduous or cedars growing on poor soils. We gained access from 22 private landowners (1,491 ha).

Methods

Field Methods

Trapping: Each study site was baited with corn (cracked or whole kernel) to attract turkeys for trapping. Sites were monitored for turkey activity with a Moultrie A-30i (PRADCO

Outdoor Brands, Birmingham, AL) motion-sensing camera to monitor turkey activity at the trap site prior to trapping. Turkeys were trapped with rocket-nets (box set) based on the methods of Delahunt (2011b). Each bird caught was placed in a standard holding box in the shade away from the net to await processing. The goal for each site was to trap 10 hens (> 5 adults), yielding ~100 hens in the monitored sample. Once captured, every bird was fitted with an individually-numbered metal leg band. The first 10 hens and males on each site were fitted with a backpack-style VHF radio transmitter (Advanced Telemetry Systems [ATS] Isanti, MN). The transmitters weighed an average of 80 g, ~2% of the hen's body weight and <1% of the male's body weight. Each transmitter was equipped with an 8 h mortality switch and a motion sensing switch. Without the motion sensing switch, transmitters were designed to last ~7.5 years; the motion sensing switch reduced battery life by an unknown amount. Each turkey was weighed and the keel examined and scored for body condition (Robins 1998). The birds were then released on site.

Monitoring: Each hen was monitored around 3 times per week prior to nesting by triangulation with three intersecting compass bearings from fixed locations (Vangilder et al. 1987). Each bearing and base station location was put into LOAS version 4.0.3.8 (Ecological Software Solutions, Urnäsch, Switzerland) to determine an estimated location and error polygon. Beginning April 1st we began monitoring hens every other day to detect the initiation of incubation (Vangilder et al. 1987, Norman et al. 2001). We noted hen activity (active/inactive) and used those data along with localized movement data to determine if the hen had begun egg incubation. If a hen had been located in the same approximate location on two consecutive days, had prolonged periods of inactivity (e. g., 1 hour) based on the motion sensor or was sending out a mortality signal, it was assumed to be incubating. An estimated location was acquired by circling the hen (Vangilder et al. 1987, Miller et al. 1998, Thogmartin and Johnson 1999). An estimated hatch date was then calculated by adding 28 days to the incubation date.

Nesting hens were monitored every 1-2 days. If a hen was off the nest for >3 hours, or was >200 m from the estimated nest location, we searched for the nest. Once found, the nest location was recorded by GPS and nest fate was determined as either still active, hatched, abandoned, or depredated. If depredation was the apparent fate, we looked for tracks, scat, and other field sign to determine which species possibly predated the nest. When a hen lost or abandoned a nest, we monitored her subsequent activity every 1-2 days to document renesting. Successful nest were those with ≥1 eggs hatched (Vangilder et al. 1987, Miller et al. 1998, Thogmartin and Johnson 1999). A hatch was determined if the eggs shells still had a membrane attached and by the general appearance of the shells and nest (tops pecked off or eggshells still all within or on edge of the nest bowl). We recorded the number of hatched and unhatched eggs, the hatch date and the exact nest location. The nest was then marked with flagging tape for later habitat analysis. In cases where we could not definitively determine if a nest hatched or was predated (<10% of nest fates), we continued to monitor hen activity to determine if poults were present. If we determined poults were present, we classified the nesting attempt as successful.

Nest-site Evaluation: A habitat evaluation of each nest site was conducted within 4 weeks after the nest was either abandoned, hatched or depredated. A paired random site was sampled for each nest to represent available habitat. To determine the area from which to randomly select points for comparison, we first calculated home ranges from 95% convex polygons in ArcGIS 10.4.1 (ESRI, Redlands, California). We used the HRT 2.0 package (Rodgers et al. 2015) for calculating home-ranges of hens during the pre-nesting period (the time when winter flocks were dispersing, breeding was occurring and hens were assessing habitat for nesting). We only used hens that had ≥10 locations during February and March to run home range analysis. We then averaged the home ranges across the two years of the study for all hens with at least 10 locations during the pre-nesting period to represent the general area a given hen had available for nest-site selection. We used the average radius of the home-range circle (779 m) as the maximum distance and arbitrarily set the minimum distance at 40 m from which to select random points. We also generated a random azimuth from the nest and with that information generated a random location. The random locations were checked on ArcGIS 10.4.1 (ESRI, Redlands, California) to confirm that they were located in potential nesting habitat (i. e., not human developed or water land cover types) and accessible (permission of the landowner). Vegetative structure and composition at each nest and associated random point were measured within a 11.3-m radius plot (Badyaev 1995). We located perimeter points in each cardinal direction 11.3 m from plot center. The density of the cover over the nest (nest cover) was measured using a spherical densitometer held at a height of 0.46 m (Seiss et al. 1990). We used a vegetation profile board (Nudds 1977) divided into 3 height classes (0-50 cm- VORlow; 51-100 cm- VORmedium; 101-200 cm- VORhigh) to measure understory cover (Badyaev 1995). The percent of cover was broken into 6 classes (Badyaev 1995): (1) <2.5%, (2) 2.5-25%, (3) 26-50%, (4) 51-75%, (5) 76-95%, (6) >95%. We placed the profile board on the nest (or plot center) and viewed the board from the plot perimeter at the cardinal directions. We counted stems of shrubs, saplings and brambles within a 5-m-radius plot for stems >1.37 m tall and ≤11.4 cm dbh (Brooke et al. 2016). The basal area of overstory trees within three size classes (<25 cm, 25-45 cm, >45 cm diameter breast height [DBH]) was measured with a 2.5 m^2/ha-factor prism (Bidwell et al. 1989) centered at the nest. Cover type was assigned to one of the following categories: deciduous forest, evergreen forest, shrubland, early succession/pasture, row crop and water/developed (Table 2.2). Other general characteristics of the nest site were recorded (slope, aspect, elevation, dominant nest plant, distance to paths or roads and distance to nearest edge). Edge was defined as a change between two cover types. If nest sites were on a property that we did not have access too, we assumed incubation if the hen was at the same bearings each day and inactive. Once the hen began moving, we would calculate days of inactivity and then would flush her once she was on accessible property to confirm hatch by the presence of poults.

Landcover Data: We chose relevant landscape metrics to quantify based on the literature for wild turkeys. We acquired 30-m land cover data from the United States Department of Agriculture (National Agriculture Statistical Services; 2017) to determine land cover for the study sites. We grouped land cover into six types; deciduous forest, evergreen/mixed forest, shrubland, fallow field/pasture/old field/grassland (ES/pasture), row crop, and water/human developed (Table 2.1). We calculated distance to cover types from each nest and random point using ArcGIS 10.4. The distance to the cover type that the nest or point was located in was recorded as 0 m. We measured distance to nearest cover type edge and road (primary and secondary roads) for the nest and associated random point (Seiss et al. 1990, Still and Baumann 1990, Badyaev 1995, Yeldell et al. 2017a, Wood et al. 2019). We used FRAGSTATS 4.1 (McGarigal et al. 2012) to quantify five landscape metrics. Clumpiness (CLUMPY) was an index of the dispersion of individual cover types; as CLUMPY approaches 1 for a given cover type, the cover type patches were highly aggregated. The percent cover of each cover type (PLAND) was calculated as the # of pixels of a given cover type divided by the total # of pixels. Edge density was the total amount of edge between all the cover types (Edge). Contagion (CONTAG) was a measure of dispersion where large values of contagion occurred when patches were highly aggregated. The Interspersion and Juxtaposition Index (IJI) measured the extent to which the landscape was intermixed with different patch types.

Data Analysis

Nesting rate of the hens was determined by the proportion of females alive and available on April 1st that were documented incubating a nest (Miller et al. 1998, Norman et al. 2001, Lehman et al. 2008). Renesting rate was the number of hens that attempted a second nest divided by the number of hens that were unsuccessful in their first attempt. Female success was the number of hens that ultimately hatched ≥1 egg (initial nests and re-nests) divided by the total number of hens alive and available on April 1st (Vangilder et al. 1987, Paisley et al. 1998, Lehman et al. 2008). We recorded minimum clutch size of each nest that was examined but the average clutch was calculated from successful nests because depredated nests usually had shells scattered making it difficult to accurately count the clutch (Palmer et al. 1993). We also calculated hatchability as the number of poults that hatched from each successful nest divided by the clutch size. We used chi-square contingency tests to measure the relationship between year, county and hen age with nesting rate, renest rate, nest success, and female success (Isabelle et al. 2016). We used univariate analysis of variance (ANOVA; JMP Pro; SAS software; version 14.0; SAS, Institute, Cary, NC) to compare clutch size and hatchability by year, county and hen age. Statistical significance was set at $\alpha = 0.05$.

Density Dependency: We used trail camera photos during the winter trapping season to estimate turkey relative abundance at each site within the five counties. The number of turkeys, per photo, was counted and the photo that had the greatest number of individuals was used as an abundance estimate at that site. Site estimates were averaged for each county to generate a county abundance estimate each year. We then regressed the abundance for each county with reproductive parameters: nesting rate, renest rate, nest success, female success, clutch size, poults hatched and poult per hen ratios each year.

Resource Selection: We evaluated resource selection at two spatial scales (2nd and 3rd order; Johnson 1980). We used a case-control resource selection function (RSF) of use versus availability (Johnson et al. 2006, Pollentier et al. 2017) modeled with conditional logistic regression in package Survival (Therneau 2015) in program R version 3.5. (R Core Team 2018). In our analysis, the nest was the case and random locations were the controls (Yeldell et al. 2017a, Wood et al. 2019). We assumed nest-site selection during renesting was independent of the initial nest-site selection (Yeldell et al. 2017b). We conducted model selection in an information-theoretic framework (Burnham and Anderson 2004). For the measure of available habitat at the nest site, we used the habitat metrics at the paired random point described above. To determine available habitat for landscape metrics, we generated five random points within a hens' pre-nesting home range to represent an area that she could have chosen a nest site from based on her movements. We followed the protocol of Yeldell et al. (2017a) and Wood et al. (2018) and randomly selected 5 points within each area of use around the nest. We then placed a buffer, of the same size, around each random point and that was used as the area of availability for landscape metrics for random points. Explanatory variables (Table 2.1) used in the analysis were checked for correlation using Pearson's correlation (r; Fuller et al. 2013). We eliminated edge density from the landscape models and the visual obstruction reading from 51-100 cm from the nest-site models because they were highly correlated ($r > 0.7$) with other covariates. Before modeling habitat selection, we scaled distance variables by dividing each value by 100 m to provide easier interpretation of the Beta parameter estimates. The null model was that nest-site selection was not related to any covariate. Row crop and water/development cover types had too few observations during the selection function analysis so were removed from analysis.

Daily Nest Survival: We used the nest-survival model (Dinsmore et al. 2002) in Program RMARK (Laake 2013) to calculate the daily survival rate (DSR) of each nest and to determine whether DSR was related to specific covariates. We created model suites based on *a priori* hypotheses involving the potential relationships of temporal, rainfall, and landscape and nest-site specific vegetation covariates (Table 2.1). We followed a similar model protocol used by Fuller et al. (2013) that involved the creation of model suites that moved from a larger, non-manageable covariate suite, to covariates that could be managed. We standardized April 8th as the first day of the nesting season (first nest incubated) and standardized distances by dividing each value by 100 m but left the rest of the data unstandardized. Adult and juvenile nests were pooled together because juvenile hen nest sample sizes were too sparse to warrant standalone analysis. The best-supported model was chosen by using Akaike's Information Criterion adjusted for small sample sizes and we accepted all models that had a $\Delta AIC_c \leq 2$ for evaluation (AIC_c; Burnham and Anderson 2002). If any of the Beta estimates in the top models had a 95% confidence interval that did not overlap 0, then it was considered a "strong" relationship, whereas Beta estimates with 95% confidence intervals which overlapped 0 where considered "weak" (Kilburg et al. 2014a). The null model contained constant daily survival.

The first model suite included temporal variables including time (linear change in DSR), quadratic time (curvilinear change in DSR), nest age (the number of days since the nesting period began), year, and an interaction term between time and year (Table 2.3). We expected that as the nesting season continued, DSR may increase as vegetation continued to develop providing more concealment for the nests. DSR could also vary with the year as well because of variation in weather, predator communities or other broad-scale factors. As the nesting season progressed, there could be changes in the predator community, so we included quadratic time to track fluctuations in DSR caused by changes in predator populations or predator activity. Nest age was included because as a nest progressed, the hens may spend more time off the nest foraging, which may increase nest vulnerability to predation (Thogmartin and Johnson 1999).

The second suite of models included two variables that measured different rain events during the nesting season (Table 2.3). Thogmartin and Johnson (1999) reported rain was one of the main reasons for the variation of nesting success between years, and other studies have demonstrated that rain can lead to lesser nest survival (Lavoie et al. 2017). We hypothesized that storm events led to greater nest failure within 3 days of the event and that a lesser rain event led to greater nest failure within 2 days of the event. We calculated the mean daily rainfall (PRISM Climate Group 2017) during the nesting period (April-July) for each year and defined a storm event as any 24-h rainfall total that was ≥16.1 mm, which was 1 standard deviation greater than the daily average. Lesser rain events were defined as 24-h totals which ranged between 1 mm and 16 mm (Carlzon et al. 2018).

The third suite of models were landscape covariates used in the resource selection analysis (Table 2.3). We hypothesized that shrubland would provide more protection for nesting hens and therefore increase their nest survival if they chose shrub cover to nest in compared to other vegetation types. We hypothesized that DSR could also vary in relation to the distance to specific cover type edges. We included CONTAG, CLUMPY, PLAND, and IJI in the third suite of models because we wanted to assess whether DSR was related to broader landscape context and configuration. DSR has been reported to vary with distance to edge (Seiss et al. 1990) and other landscape metrics (Lehman et al. 2008).

The fourth model suite included all the top covariates from the first three suites and the nest-site-specific covariates. We included a selection model in this suite that included each variable that hens selected for compared to available habitat. We also included a global concealment model that included nest cover, stem density, VOR low and VOR high (Table 2.3) which described the horizontal and vertical cover associated with the nest. We identified the best-supported model and then ran it with counties and year as group variables to allow estimation of DSR for each county in each year.

Results

During the two years of the study we caught 235 hens (191 adult, 81.3% and 44 juvenile, 18.7%) using rocket nets (Table 2.4); 152 of the females were radio-tagged (130 adult, 85.5% and 22 juvenile, 14.5%). We standardized the beginning of the nesting period as 1 April for both 2017 and 2018 and by that date we had 107 (95 adult and 12 juvenile) and 99 hens (92 adult and 7 juvenile), respectively, alive and radio-tagged (Table 2.5). The median nest initiation dates were similar between both years ($Z = 1.27$, $P = 0.203$). The earliest nest that was initiated first for both years was 8 April; the combined median date of incubation was 27 April (Table 2.5). In total, we monitored 204 nests (194 adult and 10 juvenile), an average nesting rate of 75.7% (78.1% adult and 47.4 % juvenile) and 29.4% (60/204) of the nests were successful. Adult hens had 28.4% (55/194) successful nests and juveniles had 40.0% (4/10) successful nests. The overall female success rate was 29.1% (29.4% adult, 21.1% juvenile; Table 2.5). Successful hens had an average clutch size of 9.3 (9.3 adult, 9.6 juvenile; first nest attempt). Average clutch size estimated for all nests (depredated, hatched or abandoned) was 8.92 and average clutch size of nests that were abandoned was 11.5.

Nesting rate varied by age (χ^2 = 5.332, P = 0.021); nesting rate of adult hens (78.1%) was much greater than nesting rate of juvenile hens (47.4%; Table 2.5). Adult nesting rate was greater in 2018 (84.8%) than 2017 (71.6%; Table 2.5) (χ^2 = 4.831, P = 0.028) but it did not vary by years for juvenile hens (χ^2 = .091, P = 0.763). Neither adult (χ^2 = 4.322, P = 0.364) nor juvenile (χ^2 = 9.423, P = 0.051) hen nesting rates varied between counties (Table 2.6).

Renesting rate did not vary by age class (χ^2 = 1.985, P = 0.159) although juvenile sample sizes were limited; adult renesting rate was 40.2% (n = 41) and juvenile renesting rate was 20.0% (n = 1; Table 2.5). Pooled across years, the overall renesting rate was 39.3% (n = 42; Table 2.5). Renesting rate did not differ by county (χ^2 = 9.007, P = 0.061; Table 2.6).

Nest success of adult hens (28.4%) and juvenile hens (40.0%; Table 2.5) did not vary with age (χ^2 = 1.458, P = 0.227) although juvenile sample sizes were very limited. Female success (χ^2 = .661, P = .416), also did not vary with age (adult 29.4%, juvenile 21.1%; Table 2.5). Nest success did not differ by year (χ^2 = 2.550, P = 0.110), nor county (χ^2 = 9.007, P = 0.061; Table 2.6). Female success also did not differ by year (χ^2 = .317, P = 0.573), nor county (χ^2 = 4.051, P = 0.399; Table 2.6).

Clutch size and number of poults hatched per nest did not differ by hen age (clutch P = 0.632, hatched P = 0.293) or year (clutch P = 0.736, hatched P = 0.525) (Table 2.7). Clutch size ($\bar{x}$ = 9.31 initial, $\bar{x}$ = 7.64 renest) did not vary between attempts (P = 0.055) but the number of poults hatched per nest decreased from the initial nesting attempt ($\bar{x}$ = 8.48 hatched) to renesting attempts ($\bar{x}$ = 6.45 hatched, P = 0.026; Table 2.7). The number of poults hatched per nest did vary by county (P = 0.031) with Wayne County having the fewest poults hatched per nest ($\bar{x}$ = 5.16, SE = 1.031) and Maury County having the greatest ($\bar{x}$ = 9.55, SE = 0.084; Table 2.7).

Density-Dependency: We collected 16,582 photos (2017 = 13,036; 2018 = 3,456) for the 2017-2018 trapping season. Maury (2017 = 136, 2018 = 82) and Bedford (2017 = 106, 2018 = 80) counties had the greatest abundances with Wayne (2017 = 49, 2018 = 31) having the lowest abundance (Table 2.8). Based on linear regression, there were no significant relationships between density and the reproductive parameters at the county-level ($P > 0.05$, Table 2.8).

Nest-site Selection: Nest-site selection analysis was done on 189 nest locations in 2017 and 2018; 15 nests were censored because they were on properties we did not have access to for habitat mensuration. Based on landscape covariates, four models showed strong support (i.e., $\Delta AIC_c \leq 2$; Table 2.9). The best-supported model ($K = 3$, $\Delta AIC_c = 0$, $w_i = 0.25$; Table 2.9) for relating landscape covariates to nest-site selection included three cover types: evergreen forest, shrublands and ES/pasture. Evergreen forest ($\beta = 0.89$; SE = .28; $P = \leq 0.01$), ES/pasture ($\beta = 1.01$; SE = .21; $P = \leq 0.01$) and shrubland ($\beta = 1.45$; SE = .24; $P = \leq 0.01$) were all positively associated with selection, the other top models all included these three covariates but the additional covariates in the models were not significant (Table 2.10). A female that was selecting a nest-site was 2.44, 2.75 and 4.27 times more likely to choose evergreen forest, ES/pasture and shrubland, respectively, compared to the availability of those cover types on the landscape. For further analysis, we split ES/pasture into two categories (pasture/hay and old/fallow field) to determine if selection varied between these separate grass-dominated cover types. Old field was positively associated with selection ($\beta = 0.61$; SE = 0.29; $P = 0.03$), and pasture/hay was selected against (marginally; $\beta = -0.92$; SE = 0.48; $P = 0.06$).

Two models with support related nest-site-specific covariates to nest-site selection (i.e., $\Delta AIC_c \leq 2$; Table 2.11). The best-supported model ($K = 5$, $\Delta AIC_c = 0$, $w_i = 0.47$) contained the covariates visual obstruction (0-50 cm), cover above the nest, slope, distance to nearest path or road, and the quadratic function of distance to nearest path or road (Table 2.11). Nearest path was negatively associated with nest-site selection ($\beta = -0.02$; SE = ≤ 0.01; P = 0.01; Table 2.12). Slope was negatively related to nest-site selection ($\beta = -0.07$; SE = 0.03; P = 0.01) and both cover above the nest ($\beta = 0.02$; SE = 0.00; P = ≤ 0.01) and visual obstruction ($\beta = 0.79$; SE = 0.15; P = ≤ 0.01; Table 2.12) were positively associated with nest-site selection. With every 10% increase in visual obstruction at 0-50 cm the site was 2.21 times more likely to be selected, which was the most influential covariate related to selection (Table 2.12). Slope, nearest path, the quadratic function for nearest path and cover above the nest had odds ratios very close to 1, which indicated relatively weak selection compared to availability (Table 2.12). Thirty percent of the random points had both visual obstruction at 0 – 50 cm values, and percent vegetative cover above the nest values within one standard deviation of the mean for nest sites. The second supported model did not include either path variables but contained the quadratic function for slope, which was positively associated with selection ($\beta = 0.01$; SE = ≤ 0.01; P = 0.02; Table 2.12).

Daily Nest Survival: We modeled nest survival using 188 nests from 2017 and 2018; 16 nests were censored from the analysis because of observer-caused abandonment (n = 10) or the nests were on properties we could not gain access to (n= 6). The best-supported model in the first suite with temporal covariates was constant daily survival ($K = 1$, $\Delta AIC_c = 0$, $w_i = 0.20$). All other models with temporal covariates had less support than the constant survival model, so these covariates did not receive further consideration (Table 2.10). The precipitation covariates also did not improve model performance over the constant daily survival, so those covariates also were excluded from further consideration (Table 2.11).

When the landscape covariates were included in the model suite, two models were supported above the null model of constant daily survival ($\Delta AIC_c \leq 2$). The best-supported model contained distance to evergreen cover ($K = 2$, $\Delta AIC_c = 0$, $w_i = 0.18$; Table 2.15). The second best-supported model contained distance to nearest road or path ($K = 2$, $\Delta AIC_c = 0.70$, $w_i = 0.13$; Table 2.15). Beta parameter estimates for both distance to evergreen cover ($\beta = 0.003$, CI = -0.0005 to 0.006) and distance to nearest road or path ($\beta = 0.010$, CI = -0.004 to 0.023) had confidence intervals that overlapped 0, suggestive of weak relationships. In spite of the weak relationships, distance to the evergreen cover and distance to the nearest road or path were included with the nest-site specific model suite.

Three models were supported in the final model set ($\Delta AIC_c \leq 2$; Table 2.16). The best-supported model contained nest cover and distance to evergreen cover ($K = 3$, $\Delta AIC_c = 0$, $w_i = 0.17$; Table 2.16), but distance to evergreen cover ($\beta = 0.003$, CI = -7.480^{-4} to 0.006; Table 2.17) Beta estimate confidence intervals overlapped zero. The next best-supported model in the suite included just nest cover ($K = 2$, $\Delta AIC_c = 0.35$, $w_i = 0.14$; Table 2.16); Beta estimate confidence intervals did not overlap zero ($\beta = 0.005$, CI = 7.112^{-4} to 0.009; Table 2.17). DSR was positively associated with cover above the nest (Figure 2.8). An additional model with support contained distance to nearest path or road ($\beta = 0.008$, CI = -0.005 to 0.021; Table 2.17) and nest cover ($\beta = 0.005$, CI = 6.110^{-4} to 0.009; $K = 3$, $\Delta AIC_c = 0.95$, $w_i = 0.11$; Table 2.17), although the Beta estimate confidence interval for distance to the nearest path overlapped 0. The DSR estimate from the best-supported model was 0.962105 (SE = .003299). The probability that a nest survived to hatching once it reached the incubation stage was 33.9%.

Discussion

The key parameter estimates for the factors that determine successful nesting in our study were all lesser than the estimates from the only other detailed nesting study in Tennessee during the turkey restoration phase. Incubation rate of radio-tagged hens was 86.7% (initial) and 60.0% (renesting; McGuiness and Smith 1990), compared to our rates of 75.7% and 39.3%. Nest success was about twice as great as nest success in our study (61.5% in 1988; 30.9% 2017-18). Our initial and renesting rates (75.7%; 39.3%), in contrast, were very similar to the rates from declining populations; 72.3% and 34.8% (Miller et al. 1998), and much less than rates from stable/increasing populations; 98.5% and 75.6% (Delahunt 2011a). Generally, our total nest success (29.4%) was also similar to that of declining populations; 26.8% (Pittman and Krementz 2016) and 31.0% (Palmer et al. 1993) compared to nest success from stable/increasing populations; 38.2% (Paisley et al. 1998) and 37.9% (Roberts et al. 1995).

Clutch size in birds is generally genetically determined although local environmental conditions including nutrition available to the hens may modify the clutch size in turkeys (Price and Liou 1989). Clutch size significantly differed between studies from increasing/stable populations and studies from declining populations (Table 2.18). A stable/increasing population in Missouri (Vangilder and Kurzejeski 1993) had an average clutch size of 11.1, whereas our clutch size of 9.3, was similar to a clutch size of 9.1 that Miller et al. (1998) reported for a declining turkey population in Mississippi. Reporting clutch size from successful nests, however, may be somewhat misleading because of the potential for loss of eggs during the laying and incubation stages from partial nest predation. Nests that were abandoned in our study had an average clutch size of 11.5, which suggests that hens may not be nutritionally limited leading to reduced initial clutches but instead may be experiencing partial nest predation. Nevertheless, the clutch size at hatching ultimately determines poult production. The number of poults that were hatched (n= 427) per successful female (n = 60) for our study (7.12) was much lower than poult per hen ratios for studies of stable/increasing populations; 9.96 (Vangilder and Kurzejeski 1995) and 12.76 (Roberts et al. 1995).

We found no evidence to support the hypothesis that the reproductive rates documented in our study were density-dependent when examined at the county level. In addition to reproductive rates, density-dependent processes could also affect adult survival. Hens are at a greater risk of mortality while nesting (Palmer et al. 1993), so lower nesting rates could be a tradeoff with greater hen survival. Population modeling which includes hen survival is needed to ultimately understand the role of density-dependence in wild turkey population regulation.

Hen turkeys selected cover types and site-specific structural conditions related to cover at the nest site which were linked to greater nest survival. Evergreen (pine) forests were selected for and these forests were usually managed for timber production, where thinning led to increased vegetation growth (cover) in the understory. Managed pine forests have been reported to have dense understories (Miller and Conner 2007), which provide concealment from predators during the nesting season and improved nest-site selection (Lehman et al. 2008, Little et al. 2016). ES/pasture and shrubland cover types, occurred infrequently on our study sites but were strongly selected for nesting. When old fields were analyzed separately from pasture/hay fields, hens were positively selecting for old fields and showed no selection for pasture and hay fields. Selection of old field and shrubland cover types have been consistently documented for nesting regardless of population trend (Still and Baumann 1990, Thogmartin 1999, Streich et al. 2015), although the limited relative availability of these cover types still could be important in determining successful nesting.

Hens were selecting nest sites with increased visual obstruction to provide greater concealment and protection from predators. Selection for increased visual obstruction and cover at nest sites have been commonly reported regardless of population trend (Fuller et al. 2013, Kilburg et al. 2014a, Streich et al. 2015, Yeldell et al. 2017a, Wood et al. 2019). Avian species choose areas to nest with greater cover to minimize visual and olfactory cues of nest predators and increase predator search effort (Martin 1993). Ground nests that have increased nest concealment and vegetation structure heterogeneity generally have decreased risk of predation by mammals (Bowman and Harris 1980). Our results showing nest sites closer to paths/roads than expected by chance have been reported elsewhere (Badyaev 1995, Kilburg et al. 2014, Yeldell et al. 2017b, Wood et al. 2019) in both stable (Still and Baumann 1990) and decreasing populations (Thogmartin 1999). Nests may be located near trails or roads to allow broods to move more easily to ideal brooding habitat (Moore et al. 2010), or because paths and roads have openings in the canopy, providing more light and increasing cover along the edges. Both percent vegetative cover above the nest and distance to path/road covariates also occurred in one top daily nest survival model, suggesting that selection for these covariates may have nest survival implications.

Hen nest-site selection has not changed as population sizes vary when our study is compared to other studies with stable/increasing populations. This suggests that density-dependent processes apparently are not causing hens to nest in marginal habitat. Females, regardless of population trend, selected both landscape and site-specific covariates that provided an increased amount of understory cover, which improved concealment from predators. An estimated 30.0% of random points were within one standard deviation from the mean for visual obstruction at the nets site and percent cover above the nest, suggesting that the availability of quality nesting habitat may not be limiting in our study.

Daily nest survival was related to both landscape and site-specific covariates, although these covariates accounted for relatively little variation in survival beyond the null model (constant daily survival). Percent vegetative cover above the nest was the most influential covariate in the nest survival models, similar to other studies (Delahunt 2011a, Fuller et al. 2013, Yeldell et al. 2017a). Denser vegetation around a nest may decrease the ability of nest predators to locate nests based on visual and olfactory cues (Bowman and Harris 1980, Martin 1993). Increasing the availability of vegetative cover on the landscape may increase quality nesting habitat, decrease predation events, and ultimately have a positive impact on poult production. Testing these relationships empirically through management experiments would be required to provide definitive causal relationships.

Management Implications

Management for wild turkey nesting habitat may begin at the landscape scale by providing more old field and shrubland cover. Although these cover types were not necessarily driving nest survival, their limited availability on the landscape was strongly selected for and could be enhanced through management. Management to improve nesting success needs to concentrate at the site-specific scale by providing increased visual obstruction in the understory within the selected cover types. Thinning mature forests and letting fallow fields and pasture/hayfields undergo succession would increase availability of quality nesting habitat. Once created/restored, quality nesting areas will need to be maintained via periodic disturbance such as prescribed burning or thinning.

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Appendix

Table 2. 1**:** Variables used to describe nest-site selection and nest survival for hen wild turkeys in south-central, Tennessee, USA 2017-2018. The descriptions are based on NASS recommendations.

Variable	Abbreviation	Survival	Selection
Rain that occurred day prior of fate (mm)	RDPrior	Y	N
Rain that occurred day of fate (mm)	Rfate	Y	N
Distance (m) to			
Deciduous	DistDecid	Y	Y
Evergreen	DistEver	N	Y
Shrubland	DistS	Y	Y
ES/pasture	DistES	Y	Y
Row crop	DistRow	N	Y
Water/developed	DistWater	N	Y
Nearest edge	NearE	Y	Y
Nearest path or road	NearP	Y	Y
Total edge	TE	Y	Y
Contagion index	CONTAG	Y	Y
Interspersion and juxtaposition	IJI	Y	Y
Clumpiness index	CLUMPY		
ES/pasture	CES	Y	Y
Landscape make-up of a cover type (%)	PLAND		
ES/pasture	PES	Y	Y
Visual obstruction at 0-50 cm	VORlow	Y	Y
Visual obstruction at 101-200 cm	VORhigh	Y	Y
Number of woody stems in 5 m radius circle	Stem	Y	Y
Slope at brood site	Slope	Y	Y
Basal area of trees that are <25 cm DBH	BasalLow	Y	Y
Basal area of trees that are 25-45 cm DBH	BasalMed	Y	Y
Basal area of trees that are >45 cm DBH	BasalHigh	Y	Y
Abundance of plant groups			
Forbs	Forbs	Y	Y
Grasses	Grass	Y	Y
Brambles	Bram	Y	Y
Shrubs	Shrub	Y	Y
Daily Movement (m)	Move	Y	N
Julian Capture Date	CaptDate	Y	N

Table 2. 2**:** Descriptions and abbreviations for the six cover type categories for south-central, Tennessee, USA 2017-2018.

Variable	Abbreviation	Description
Deciduous forest	Deciduous	More than 75% of the trees are deciduous hardwoods that shed their leaves as the season change. The area is more than 25% trees that are over 5 meters tall.
Evergreen forest	Evergreen	More than 75% of the trees are conifers that never lose their leaves. The area is more than 25% trees that are over 5 meters tall.
Shrubland	Shrubland	An area that is dominated by shrubs shorter than 5 meters tall. This consisted of shrubs and young trees in an early successional stage.
Early Succession & Pasture	ES/Pasture	An area that is dominated by grasses and can include oldfield, fallow ag fields, hayfields and grasslands. Pasture includes areas that are grazed but are not planted or cultivated.
Row crop	Row crop	Any area that is planted or actively tilled producing harvestable products.
Water & Developed	Water/Developed	Any area that is a water source or is developed land that would not be considered potential nesting habitat.

Table 2. 3: List of models that were used to determine how variables affected daily nest survival for hen wild turkeys in south-central, Tennessee, USA 2017-2018.

Model Suites	Model	Notation
Temporal and Group Models	Constant DSR	S(.)
	Linear Time	S(T)
	Quadratic Time	S(T+TT)
	Year	S(Year)
	County	S(County)
	Year by Linear Time	S(Year + T)
	Hen Age	S(Adult)
	Nest Age	S(Age)
Environmental Variables	Storm 3 Days Prior to Nest Fate	S(Storm3DFate)
	Rain 2 Days Prior to Nest Fate	S(Rain2DFate)
Landscape Variables	Selection	S(Deciduous + ES/Pasture + Shrubland + RowDist + NearPath)
	Cover Type	S(CoverType)
	Distance to Cover Types	
	Deciduous	S(DecidDist)
	Evergreen	S(EverDist)
	Shrubland	S(ShrubDist)
	ES/Pasture	S(ESDist)
	RowDist	S(RowDist
	WaterDist	S(WaterDist)
	Contagion	S(CONTAG)
	Interspersion & Juxtapostion	S(IJI)
	Nearest Path & Road	S(NearestPath)
	Nearest Edge	S(NearEdge)
	Clumpiness	S(CLUMPY)
	Patch Type Percentage	S(PLAND)
Nest-Site Specific Variables	Selection	S(NestCover + VORlow + VORhigh + NearPath)
	% Nest Covered	S(NestCover)
	Woody Stem Density	S(Stem)
	Visual Obstruction (0-50 cm)	S(VORlow)
	Visual Obstruction (101-200 cm)	S(VORhigh)
	Basal Area of Small Trees	S(Basal25cm)
	Basal Area of Medium Trees	S(Basal25to45cm)
	Basal Area of Large Trees	S(Basal45cm)
	Nest Concealment	S(NestCover + Stem + VORlow + VORhigh)

Table 2. 4: The number of hen wild turkeys trapped and radio-tagged in south-central, Tennessee, USA 2017-2018.

Year	County	Site	# Adult Hens	# Juv Hens	Total
2017	Bedford	North	16	4	20
	Bedford	South	16	1	17
	Giles	North	20	6	26
	Giles	South	7	0	7
	Lawrence	South	15	2	17
	Lawrence	North	30	1	31
	Maury	South	7	3	10
	Maury	North	10	4	14
	Wayne	North	6	0	6
	Wayne	South	13	2	15
	All	All	140	23	163
Tagged	All	All	92	13	105
2018	Bedford	North	5	3	8
	Bedford	South	5	6	11
	Giles	North	12	12	24
	Giles	South	0	0	0
	Lawrence	South	0	0	0
	Lawrence	North	0	0	0
	Maury	South	9	0	9
	Maury	North	13	0	13
	Wayne	North	3	0	3
	Wayne	South	4	0	4
	All	All	51	21	72
Tagged	All	All	32	9	41
Tagged 17&18	All	All	124	22	146
Both	All	All	191	44	235

Table 2. 5: Reproductive parameters of adult (Ad) and juvenile (Juv) hen wild turkeys in south-central, Tennessee, USA 2017-2018.

Year	Hen age	Date first nest incubated	Median nest incubation date	n[a]	% initial nesting (n)[b]	% initial nest success (n)[c]	% renest (n)[d]	% renest success (n)[e]	% third nest (n)[f]	% third nest success (n)[g]	% successful nests (n)[h]	% female success (n)[i]	Intial clutch size
2017	Ad Hen	8-Apr	28-Apr	95	71.6 (68)	35.3 (24)	31.8 (14)	35.7 (5)	22.2 (2)	50.0 (1)	35.7 (30)	31.6 (30)	9.1
	Juv Hen	19-Apr	23-Apr	12	50.0 (6)	25.0 (3)	11.1 (1)	0.0 (0)	0.0 (0)	0.0 (0)	42.9 (3)	25.0 (3)	9.7
2018	Ad Hen	9-Apr	26-Apr	92	84.8 (78)	21.7 (20)	37.5 (27)	18.5 (5)	22.7 (5)	0.0 (0)	23.6 (26)	28.2 (26)	9.5
	Juv Hen	26-Apr	28-Apr	7	42.9 (3)	33.3 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	33.3 (1)	14.3 (1)	0.0
Both	Ad Hen	8-Apr	27-Apr	187	78.1 (146)	30.1 (44)	40.2 (41)	24.4 (10)	22.6 (7)	14.3 (1)	28.4 (55)	29.4 (55)	9.3
	Juv Hen	19-Apr	27-Apr	19	47.4 (9)	44.4 (4)	20.0 (1)	0.0 (0)	0.0 (0)	0.0 (0)	40.0 (4)	21.1 (4)	9.7
Both	Both	8-Apr	27-Apr	206	75.7 (155)	31.0 (48)	39.3 (42)	23.8 (10)	21.9 (7)	14.3 (1)	28.9 (59)	28.6 (59)	9.3

[a] The number of hens available as of 1-April.

[b] The number of hens that incubatd ≥1 nest.

[c] The number of hens that hatched ≥1 egg in the first attempt.

[d] The number of hens with potential to renest after a first nest failure.

[e] The number of hens that hatched ≥1 egg in their second attempt.

[f] The number of hens with potential to renest after a second nest failure.

[g] The number of hens that hatched ≥1 egg in their third attempt.

[h] The number of nests that were successful between all attempts.

[i] The number of hens that hatched ≥1 egg in any attempt.

Table 2. 6: Contingency tests to compare the reproductive parameters between hen age, year, and county for south-central, Tennessee, USA 2017-2018.

Models	ChiSquare	P
Nesting rate + age	5.332	0.0209
Nesting rate + year + adult	4.831	0.0279
Nesting rate + year + juvenile	0.091	0.7633
Nesting rate + county + adult	4.322	0.3642
Nesting rate + county + juvenile	9.423	0.0514
Renest rate + age	1.985	0.1589
Renest rate + year	3.803	0.0512
Renest rate + county	4.020	0.4033
Nest success + age	1.458	0.2273
Nest success + year	2.550	0.1103
Nest success + county	9.007	0.0609
Femal success + age	0.661	0.4162
Female success + year	0.317	0.5730
Female success + county	4.051	0.3992

Table 2. 7: The variability of clutch size and number of poults hatched per wild turkey nest as female age, county, year, and nesting attempt changes in south-central Tennessee, USA 2017-2018.

Model	Categories	n[a]	$\bar{x}$	SE	lower 95%	upper 95%	P
Clutch + age	Adult	50	8.92	0.369	8.180	9.660	0.6319
	Juvenile	3	9.67	1.505	6.646	12.687	
Clutch + county	Bedford	9	9.00	0.842	7.307	10.693	0.1812
	Giles	11	8.91	0.762	7.378	10.440	
	Lawrence	18	9.06	0.595	7.859	10.253	
	Maury	9	10.22	0.842	8.529	11.915	
	Wayne	6	6.83	1.031	4.760	8.907	
Clutch + year	2017	31	9.06	0.469	8.124	10.005	0.7362
	2018	22	8.82	0.556	7.702	9.935	
Clutch + attempt	Initial	42	9.31	0.389	8.529	10.090	0.0553
	Renest	11	7.64	0.759	6.112	9.161	
Hatched + age	Adult	50	7.96	0.038	7.193	8.727	0.2931
	Juvenile	3	9.66	1.561	6.534	12.800	
Hatched + county	Bedford	9	8.33	0.842	6.640	10.026	0.0306
	Giles	11	8.55	0.762	7.014	10.077	
	Lawrence	18	7.83	0.595	6.636	9.030	
	Maury	9	9.55	0.084	7.863	11.249	
	Wayne	6	5.16	1.031	3.093	7.240	
Hatched + year	2017	31	8.26	0.489	7.277	9.239	0.5253
	2018	22	7.77	0.580	6.608	8.938	
Hatched + attempt	Initial	42	8.48	0.401	7.670	9.282	0.026
	Renest	11	6.45	0.784	4.880	8.029	

[a] The number of successful nests that hatched ≥1 egg.

Table 2. 8: Comparison between abundance and reproductive parameters at the county-level for hen wild turkeys in south-central, Tennessee, USA 2017-2018.

Year	County	Relative Abundance	Nesting Rate	Renest Rate	Nest Success	Hen Success	Clutch	Poults Hatched	Poults: Hen
2017	Bedford	106	81.0	40.0	34.8	38.1	9.1	69	8.6
	Giles	68	82.4	50.0	36.8	41.2	8.0	57	8.1
	Lawrence	38	54.8	33.3	45.0	29.0	10.3	76	8.4
	Maury	136	83.3	27.3	27.8	27.8	10.7	36	7.2
	Wayne	49	55.0	0.0	36.4	10.0	6.7	18	4.5
2018	Bedford	80	68.2	25.0	16.7	13.6	6.0	6	2.0
	Giles	77	82.4	33.3	27.8	29.4	10.0	37	7.4
	Lawrence	63	80.0	44.4	45.0	50.0	9.7	65	6.5
	Maury	82	81.8	71.4	16.7	22.7	10.8	50	10.0
	Wayne	31	100.0	46.7	14.8	27.3	7.0	13	3.3
	P-Value		0.57	0.93	0.71	0.80	0.25	0.81	0.86

Table 2. 9: Model selection using conditional logistic regression with matched-pairs case-control sampling that used nests as the case and random sites as the controls for hen wild turkey nest-site selection based on landscape variables in south-central Tennessee, USA, 2017-2018.

Models	K	AICc	ΔAIC_c	AICc Weight	LL
CoverEver + CoverGrass + CoverShrub	3	644.5299	0.0000	0.2515	-319.2545
CoverEver + CoverGrass + CoverShrub + Rowcrop + RowQuad	5	645.1677	0.6378	0.1828	-317.5576
CoverEver + CoverGrass + CoverShrub + NEAR_DIST_Rd + RoadQuad	5	645.6545	1.1246	0.1433	-317.8010
CoverEver + CoverGrass + CoverShrub + GrasslandPasture + GrassQuad	5	645.9263	1.3964	0.1251	-317.9369
CoverEver + CoverGrass + CoverShrub + Shrubland +ShrubQuad	5	647.2245	2.6946	0.0654	-318.5860
CoverEver + CoverGrass + CoverShrub + NEAR_DIST_Edge + EdgeQuad	5	647.3271	2.7972	0.0621	-318.6373
CoverEver + CoverGrass + CoverShrub + GrasslandPasture + Rowcrop	5	647.6816	3.1518	0.0520	-318.8146
CoverEver + CoverGrass + CoverShrub + Evergreen + EverQuad	5	647.8224	3.2925	0.0485	-318.8849
CoverEver + CoverGrass + CoverShrub + AWaterDeveloped + WaterQuad	5	648.4435	3.9137	0.0355	-319.1955
CoverEver + CoverGrass + CoverShrub + Deciduous + DecidQuad	5	648.5531	4.0233	0.0336	-319.2503
Null	1	1032.0874	387.5575	0.0000	-515.0420

Table 2. 10: Parameter estimates of the models that were predicting site-specific variables selected for at nest sites by hen wild turkeys in south-central, Tennessee, USA, 2017-2018. Positive values for distance variables indicate negative association with the variable.

							Odds ratio CI	
Model	Covariates	β	SE	Z	P	Odds ratio	Lower 95%	Upper 95%
CoverEver + CoverGrass + CoverShrub	CoverEver	0.89	0.28	3.12	≤.01	2.44	1.40	4.26
	CoverGrass	1.01	0.21	5.54	≤.01	2.75	1.84	4.11
	CoverShrub	1.45	0.24	6.30	≤.01	4.27	2.68	6.80
CoverEver + CoverGrass + CoverShrub+ DistRow + RowQuad	CoverEver	0.92	0.28	3.22	≤.01	2.50	1.43	4.36
	CoverGrass	1.02	0.21	4.96	≤.01	2.78	1.86	4.17
	CoverShrub	1.48	0.24	6.21	≤.01	4.39	2.75	7.00
	DistRow	-0.16	0.10	-1.65	0.10	0.85	0.70	1.03
	RowQuad*	0.02	0.01	1.85	0.06	1.02	1.00	1.03
CoverEver + CoverGrass + CoverShrub + NearPath + PathQuad	CoverEver	0.91	0.29	3.18	≤.01	2.48	1.42	4.33
	CoverGrass	1.01	0.21	5.10	≤.01	2.90	1.93	4.38
	CoverShrub	1.48	0.24	6.16	≤.01	4.38	2.74	7.01
	NearPath	0.16	0.10	1.57	0.12	1.17	0.96	1.43
	PathQuad*	-0.01	0.01	-1.16	0.25	0.99	0.97	1.01
CoverEver + CoverGrass + CoverShrub + DistGrass + GrassQuad	CoverEver	0.94	0.29	3.30	≤.01	2.56	1.47	4.48
	CoverGrass	0.93	0.21	4.36	≤.01	2.52	1.66	3.82
	CoverShrub	1.40	0.24	5.85	≤.01	4.06	2.54	6.50
	DistGrass	-0.31	0.19	-1.64	0.10	0.73	0.50	1.06
	GrassQuad*	0.06	0.04	1.43	0.15	1.06	0.98	1.15

* Quadratic function for the distance to each cover type that is indicated.

Table 2. 11: Model selection using conditional logistic regression with matched-pairs case-control sampling that used nests as the case and random sites as the controls for hen wild turkey nest-site selection based on site-specific variables in south-central Tennessee, USA, 2017-2018.

Models	K	AICc	ΔAICc	AICc Weight	LL
VORlow + PercentCover + Slope + NearestPath + PathQuad	5	157.12	0	0.47	-73.48
VORlow + PercentCover + Slope + SlopeQuad	4	157.77	0.65	0.34	-74.83
VORlow + PercentCover + Slope + NearestPath	4	160.84	3.72	0.07	-76.36
VORlow + PercentCover + Slope	3	162.00	4.87	0.04	-77.96
VORlow + PercentCover + Slope + UTMY	4	163.33	6.21	0.02	-77.61
VORlow + PercentCover + Slope + StemCount + StemQuad	5	163.34	6.22	0.02	-76.59
VORlow + PercentCover + Slope + StemCount	4	163.80	6.68	0.02	-77.84
VORlow + PercentCover + Slope + EdgeDist	4	164.04	6.92	0.01	-77.96
VORlow + PercentCover + Slope + EdgeDist + EdgeQuad	5	166.09	8.97	0.01	-77.96
VORlow*County + PercentCover*County + Slope*County	19	167.44	10.32	0.00	-63.60
VORlow*CoverType + PercentCover*CoverType + Slope*CoverType	23	177.92	20.80	0.00	-64.32
Null	1	335.14	178.01	0.00	-166.56

Table 2. 12: Parameter estimates of the site-specific variables selected for at nest sites by hen wild turkeys in south-central, Tennessee, USA, 2017-2018. Positive values for distance variables indicate negative association with the variable.

							Odds ratio CI	
Model	Parameters	β	SE	Z	P	Odds ratio	Lower 95%	Upper 95%
VORlow + PercentCover + Slope + NearestPath + PathQuad	Slope	-0.07	0.03	-2.59	0.01	0.93	0.88	0.98
	Nearest path or road	-0.02	≤.01	-2.6	0.01	0.98	0.97	1
	Nearest path or road ^2	≤.01	≤.01	2.15	0.03	1	1	1.0001
	Percent cover	0.02	≤.01	3.43	≤.01	1.02	1.01	1.03
	VOR low	0.79	0.15	5.25	≤.01	2.21	1.64	2.96
VORlow + PercentCover + Slope + SlopeQuad	Slope	-0.22	0.07	-3.16	≤.01	0.8	0.69	0.91
	Slope ^2	0.01	≤.01	2.31	0.02	1.01	1	1.01
	Percent cover	0.02	≤.01	3.59	≤.01	1.02	1.01	1.03
	VOR low	0.86	0.16	5.05	≤.01	2.38	1.75	3.24

Table 2. 13: Model selection results for temporal covariates related to daily survival rate of hen wild turkey nests in south-central, Tennessee, USA, 2017-2018.

Model	K	AICc	ΔAICc	AIC_c weight	Deviance
Constant daily survival	1	838.05	0.00	0.20	836.05
Year	2	838.18	0.13	0.19	834.18
Age of nest	2	838.46	0.41	0.17	834.46
County	5	839.43	1.38	0.10	829.41
Quadratic time trend	2	839.47	1.42	0.10	835.46
Hen age	2	839.51	1.46	0.10	835.51
Time	2	839.73	1.68	0.09	835.72
Year and time interaction	4	840.71	2.66	0.05	832.70

Table 2. 14: Model selection results for rainfall covariates related to daily survival rate of hen wild turkey nests in south-central, Tennessee, USA, 2017-2018.

Model	K	AICc	ΔAICc	AIC_c weight	Deviance
Constant daily survival	1	838.05	0.00	0.64	836.05
Rain2DFate	3	840.43	2.39	0.19	834.43
Storm3DFate	3	840.66	2.61	0.17	834.65

Table 2. 15: Model selection results for landscape covariates related to daily survival rate of hen wild turkey nests in south-central, Tennessee, USA, 2017-2018.

Model	K	AICc	ΔAICc	AIC_c weight	Deviance
S(~EverDist)	2	837.32	0.00	0.18	833.31
S(~NearPath)	2	838.01	0.70	0.13	834.01
S(~1)	1	838.05	0.73	0.12	836.05
S(~GrassDist)	2	838.23	0.91	0.11	834.22
S(~NearEdge)	2	838.86	1.54	0.08	834.85
S(~CONTAG)	2	839.00	1.69	0.08	835.00
S(~ShrubDist)	2	839.56	2.24	0.06	835.55
S(~DecidDist)	2	839.93	2.61	0.05	835.92
S(~RowDist)	2	840.02	2.71	0.05	836.02
S(~CoverType)	5	840.04	2.72	0.05	830.02
S(~IJI)	2	840.05	2.73	0.05	836.05
S(~Selection)	4	840.99	3.68	0.03	832.98
S(~CLUMPY)	6	842.56	5.25	0.01	830.54
S(~PLAND)	6	843.89	6.57	0.01	831.86

Table 2. 16: Model selection results for nest-site covariates related to daily survival rate of hen wild turkey nests in south-central, Tennessee, USA, 2017-2018.

Model	K	AIC$_c$	ΔAIC$_c$	AIC weights	Deviance
S(~NestCover + EverDist)	3	834.73	0.00	0.17	828.72
S(~NestCover)	2	835.08	0.35	0.14	831.08
S(~NestCover + NearPath)	3	835.68	0.95	0.11	829.67
S(~EverDist)	2	837.32	2.59	0.05	833.31
S(~NestCover + VORlow + Slope + EverDist)	5	837.58	2.85	0.04	827.56
S(~NearPath)	2	838.01	3.28	0.03	834.01
S(~1)	1	838.05	3.32	0.03	836.05
S(~NestCover + VORlow + Slope + NearPath)	5	838.09	3.36	0.03	828.07
S(~Stem + EverDist)	3	838.22	3.49	0.03	832.21
S(~Slope + EverDist)	3	838.71	3.98	0.02	832.70
S(~BasalHigh + EverDist)	3	838.75	4.02	0.02	832.74
S(~Stem)	2	838.76	4.03	0.02	834.76
S(~BasalLow + EverDist)	3	838.76	4.03	0.02	832.76
S(~VORhigh + EverDist)	3	839.07	4.34	0.02	833.07
S(~BasalMed + EverDist)	3	839.20	4.47	0.02	833.19
S(~Stem + NearPath)	3	839.24	4.51	0.02	833.23
S(~VORlow + EverDist)	3	839.29	4.56	0.02	833.28
S(~Slope + NearPath)	3	839.49	4.76	0.02	833.48
S(~VORlow + NearPath)	3	839.58	4.85	0.02	833.57
S(~BasalHigh + NearPath)	3	839.61	4.88	0.01	833.60
S(~VORhigh)	2	839.61	4.88	0.01	835.61
S(~BasalLow + NearPath)	3	839.63	4.90	0.01	833.62
S(~BasalMed + NearPath)	3	839.65	4.92	0.01	833.64
S(~Slope)	2	839.70	4.97	0.01	835.70
S(~BasalHigh)	2	839.70	4.97	0.01	835.70
S(~BasalMed)	2	839.71	4.98	0.01	835.71
S(~VORhigh + NearPath)	3	839.81	5.08	0.01	833.80
S(~VORlow)	2	839.92	5.19	0.01	835.92
S(~Concealment)	5	840.01	5.28	0.01	829.99
S(~Concealment + EverDist)	6	840.09	5.36	0.01	828.07
S(~Concealment + NearPath)	6	840.45	5.72	0.01	828.42

Table 2. 17: Parameter estimates and 95% confidence intervals (CI) for the top three models in the final model suite for nest survival of hen wild turkeys in south-central, Tennessee, USA 2017-2018.

Model	Parameter	Estimate	SE	95% CI	
				Lower	Upper
NestCover and EverDist	Intercept	2.7171	0.2042	2.3169	3.1172
	NestCover	0.0048	0.0022	0.0004	0.0091
	EverDist	0.0027	0.0017	-0.0007	0.0061
NestCover	Intercept	2.9142	0.1621	2.5965	3.2320
	NestCover	0.0049	0.0022	0.0006	0.0093
NestCover and NearPath	Intercept	2.7577	0.2056	2.3547	3.1607
	NestCover	0.0046	0.0022	0.0003	0.0090
	NearPath	0.0081	0.0068	-0.0053	0.0215

Table 2. 18: Reproductive parameters from studies in states with either stable/increasing populations or declining populations of hen wild turkeys that can be compared to the parameters that were collected in south-central, Tennessee, USA, 2017-2018.

Population Growth	Author	Year	Initial nesting rate	Initial nest success	Renesting rate	Renesting success	% Nest success	Average clutch size
Stable/Increasing	Vangilder and Kurzejeski 1993	1981-88	96.0%	56.3%	40.6%	30.2%	47.6%	11.08
	Rumble and Hodruff	1986-91	97.0%	27.0%	59.6%	35.0%	32.0%	9.20
	Paisley et al. 1998	1989-92	92.7%	13.6%	55.1%	21.0%	38.2%	11.20
	Roberts et al.	1990-93	98.5%	37.4%	67.2%	45.8%	37.9%	12.04
	Delahunt 2008	2008-10	98.5%	23.0%	75.6%	16.0%	35.4%	13.10
Declining	Pittman and Krementz 2016	2012-13	92.0%	26.5%	37.5%	7.0%	26.8%	10.00
	Miller et al. 1998	1984-96	72.3%	27.9%	34.8%	24.6%	29.7%	9.40
	Palmer et al. 1993	1984-1992	74.0%	30.8%	34.8%	26.1%	31.0%	9.10
	Thogmartin and Johnson 1999	1993-96	62.2%	16.5%	35.0%	36.0%	13.6%	8.43
	Current Study	**2017-18**	**75.7%**	**31.0%**	**39.3%**	**26.2%**	**29.4%**	**9.30**

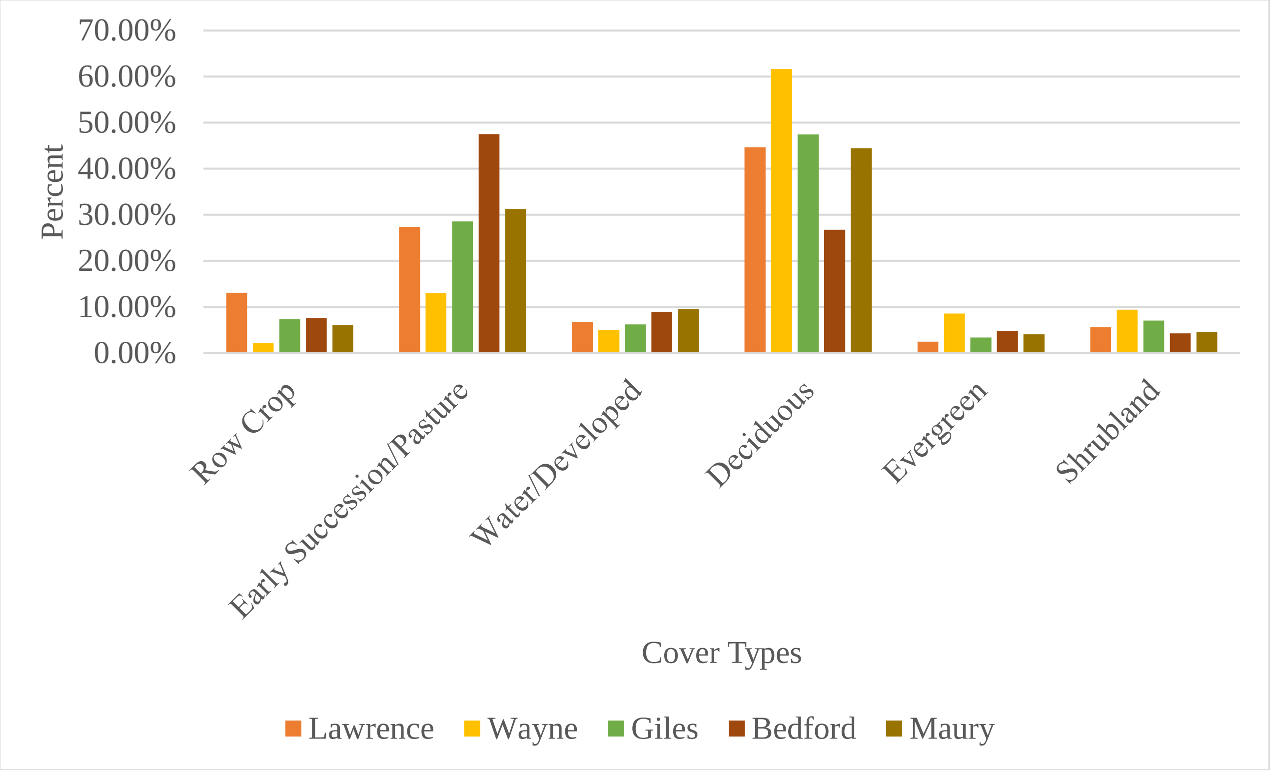

Figure 2. 1**:** Cover type composition (%) of the five study counties in south-central, Tennessee, USA, 2017-2018.

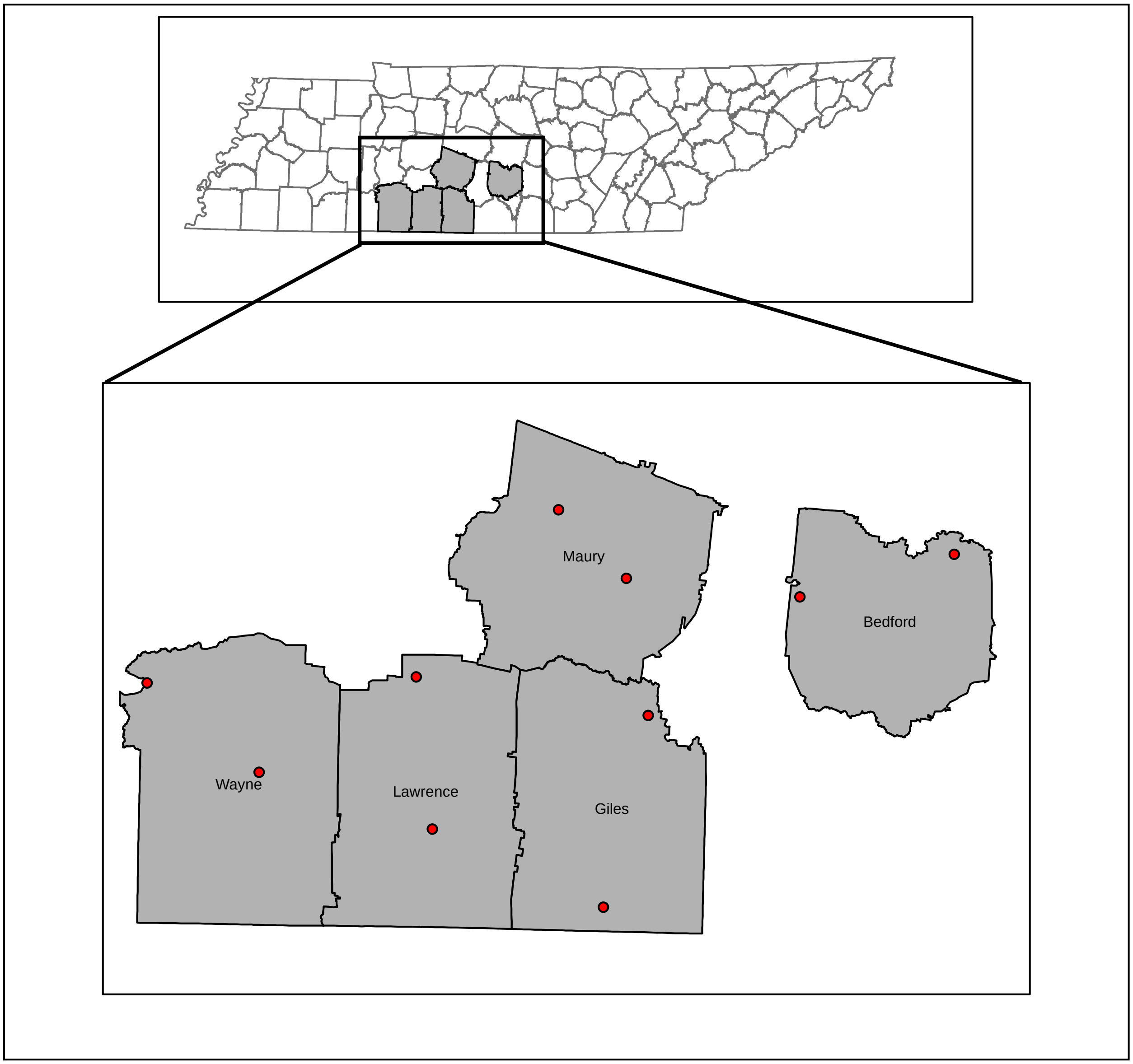

Figure 2. 2: Map of the study area and study site locations within each county of south-central, Tennessee, USA, 2017-2018.

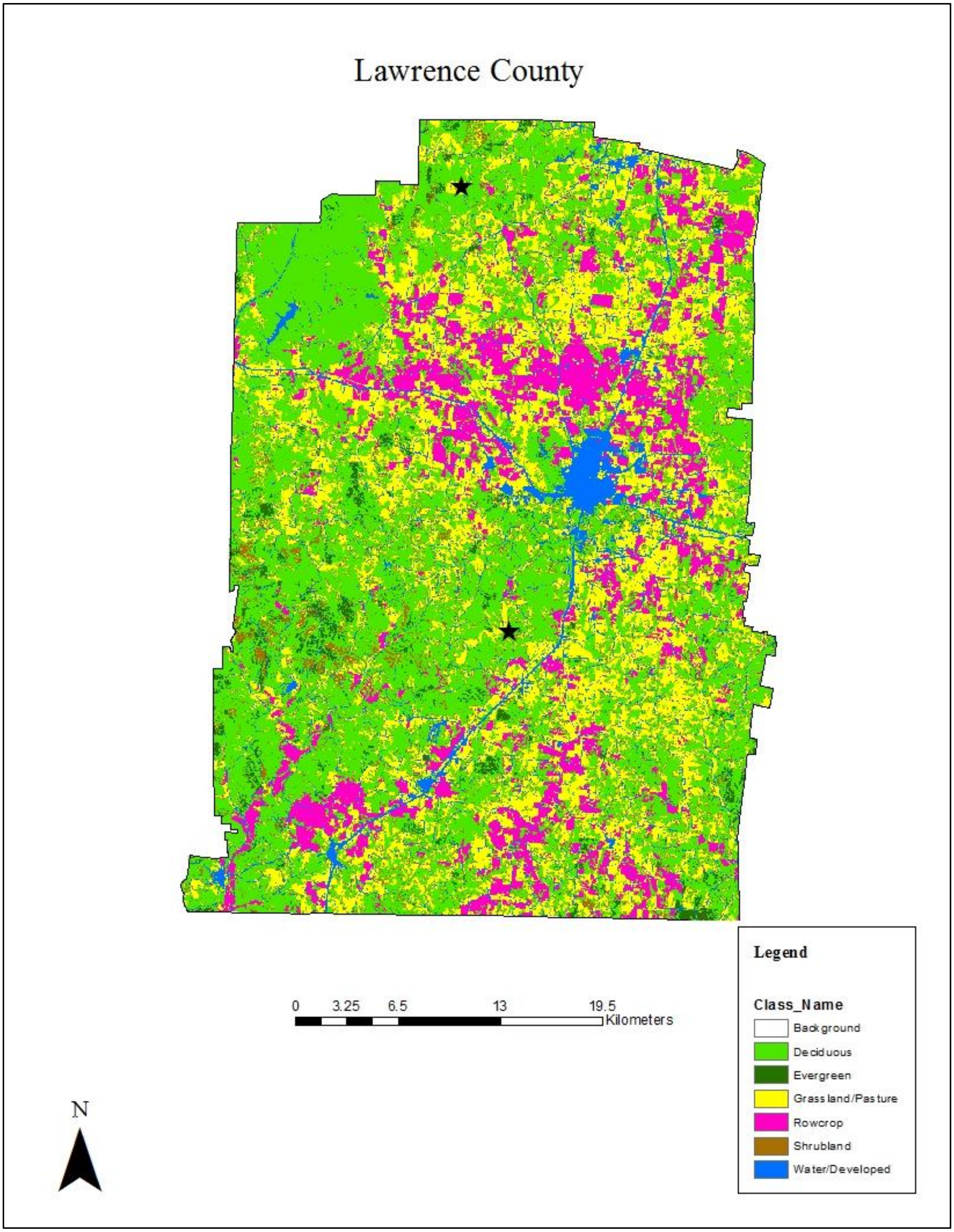

Figure 2. 3: Cover type map of Lawrence County, TN with study site locations, 2017-2018.

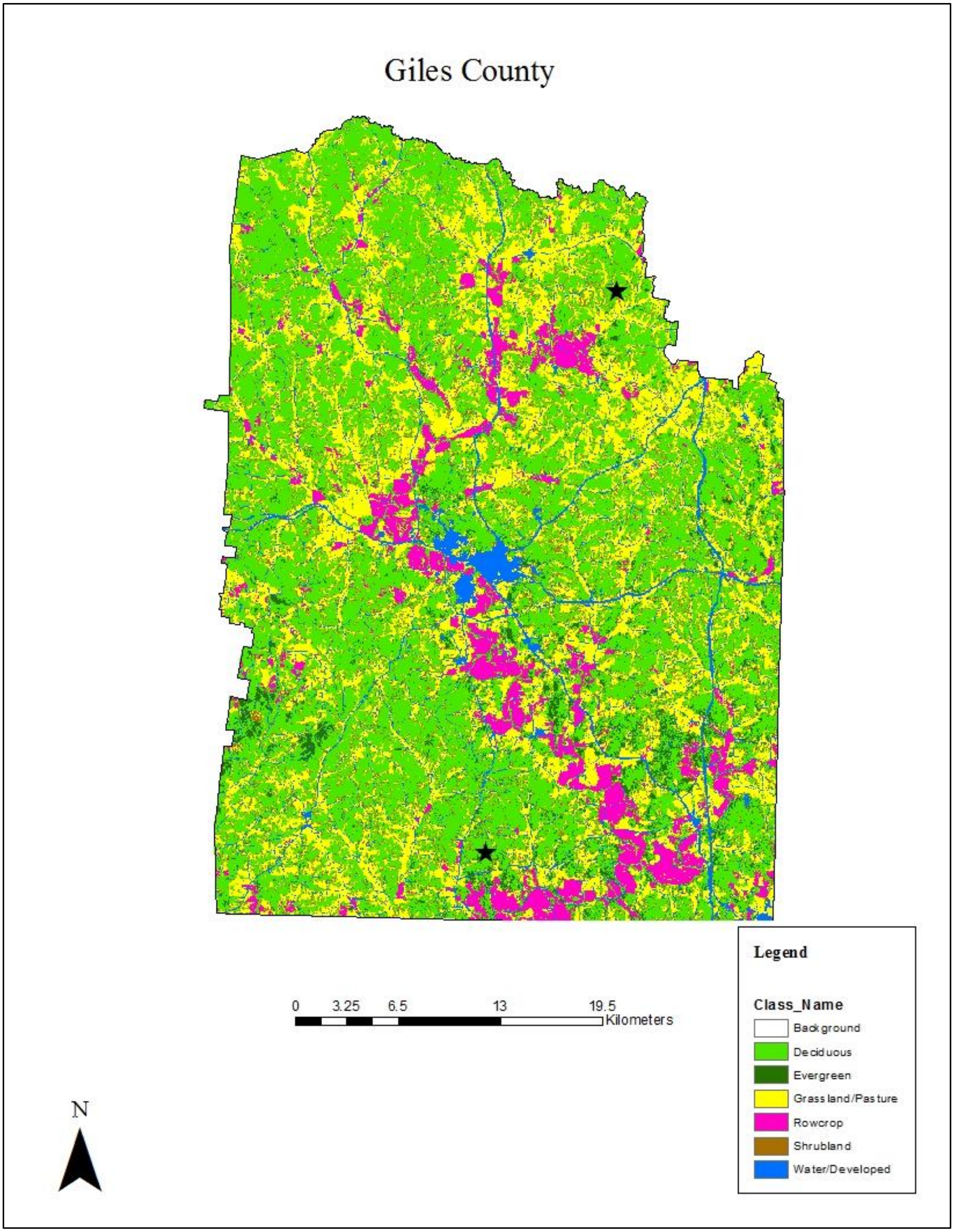

Figure 2. 4: Cover type map for Giles County, TN and the study site locations, 2017-2018.

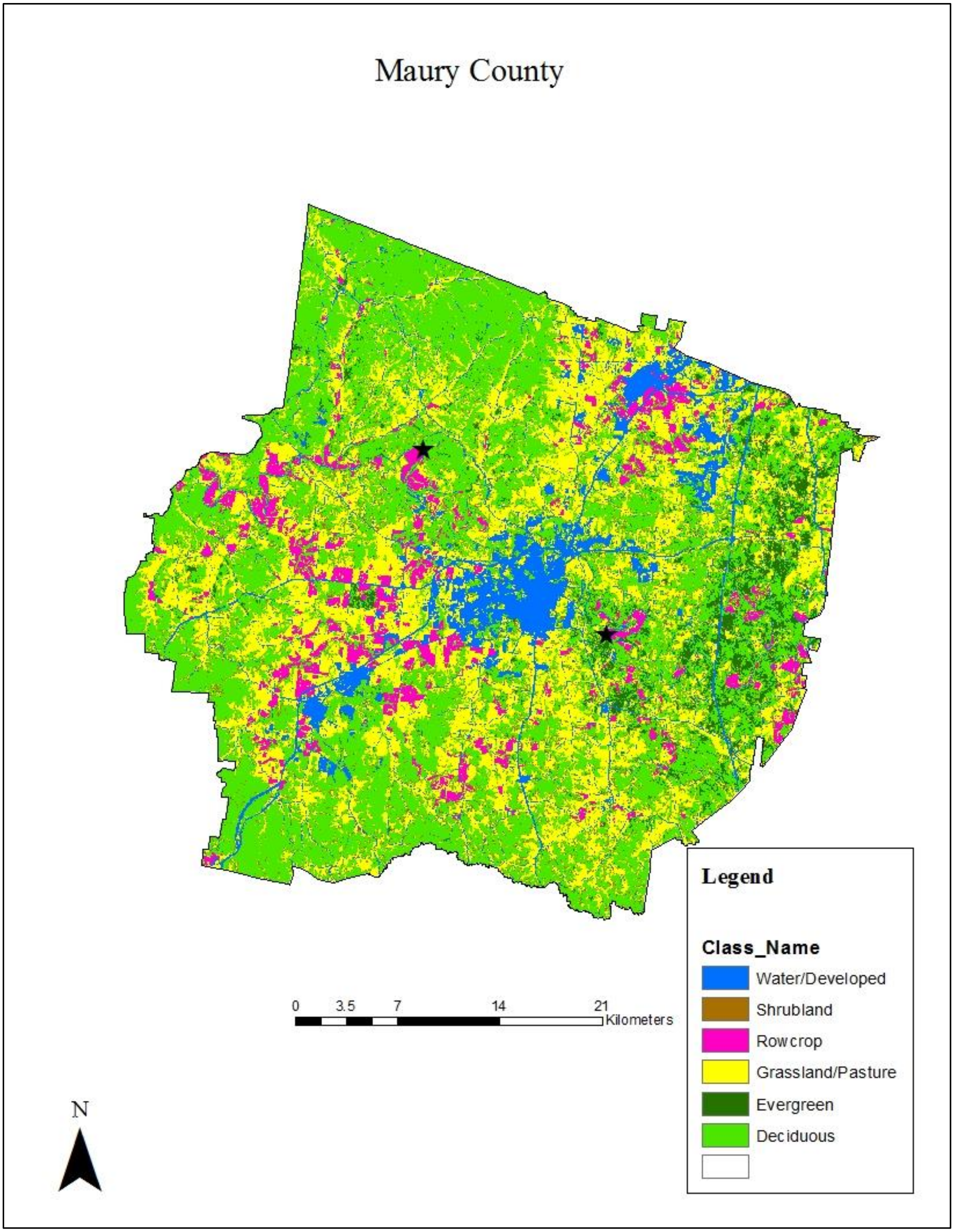

Figure 2. 5: Cover type map of Maury County, TN with study site locations, 2017-2018.

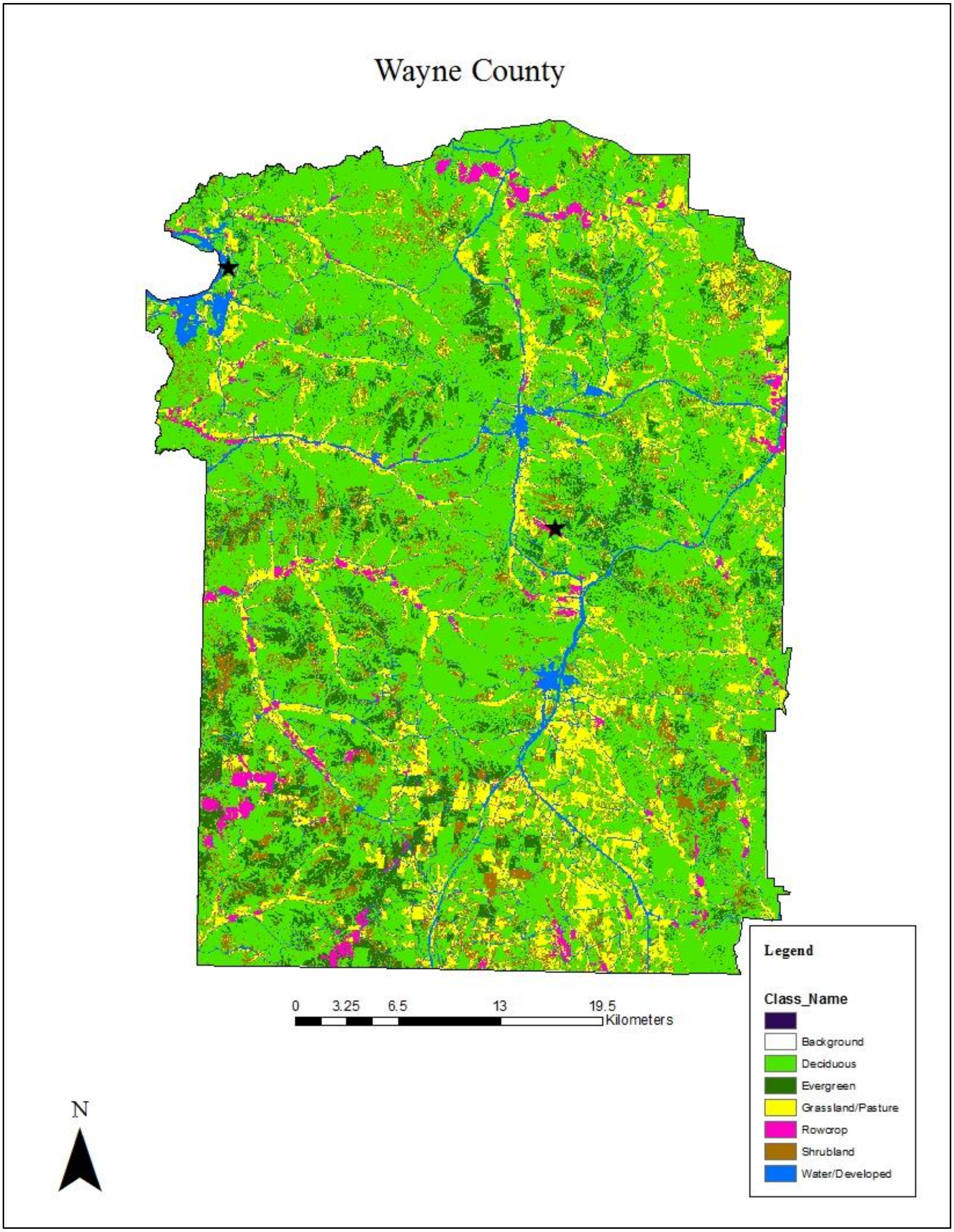

Figure 2. 6**:** Cover type map of Wayne County, TN with study site locations, 2017-2018.

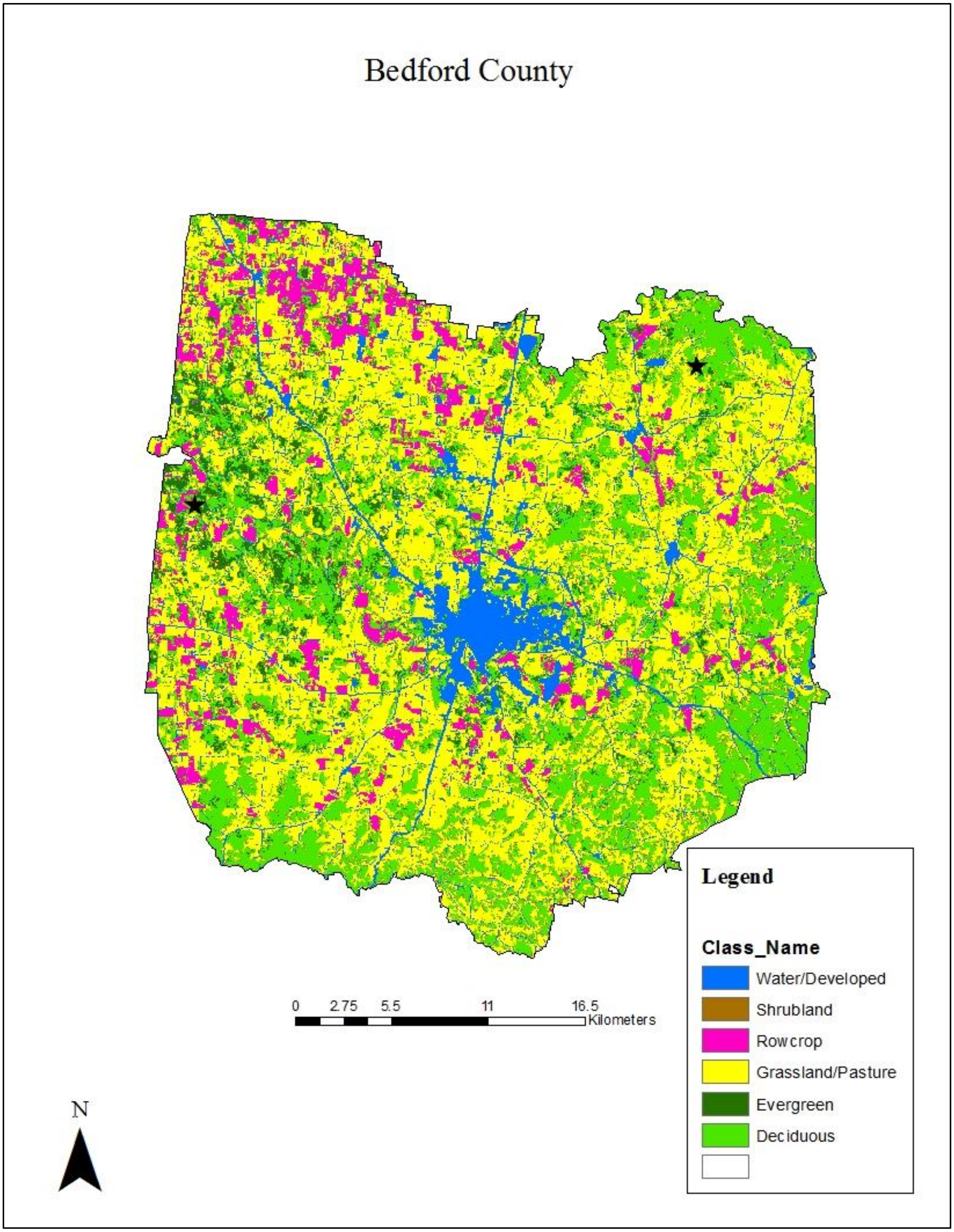

Figure 2. 7**:** Cover type map for Bedford County, TN with study site locations, 2017-2018.

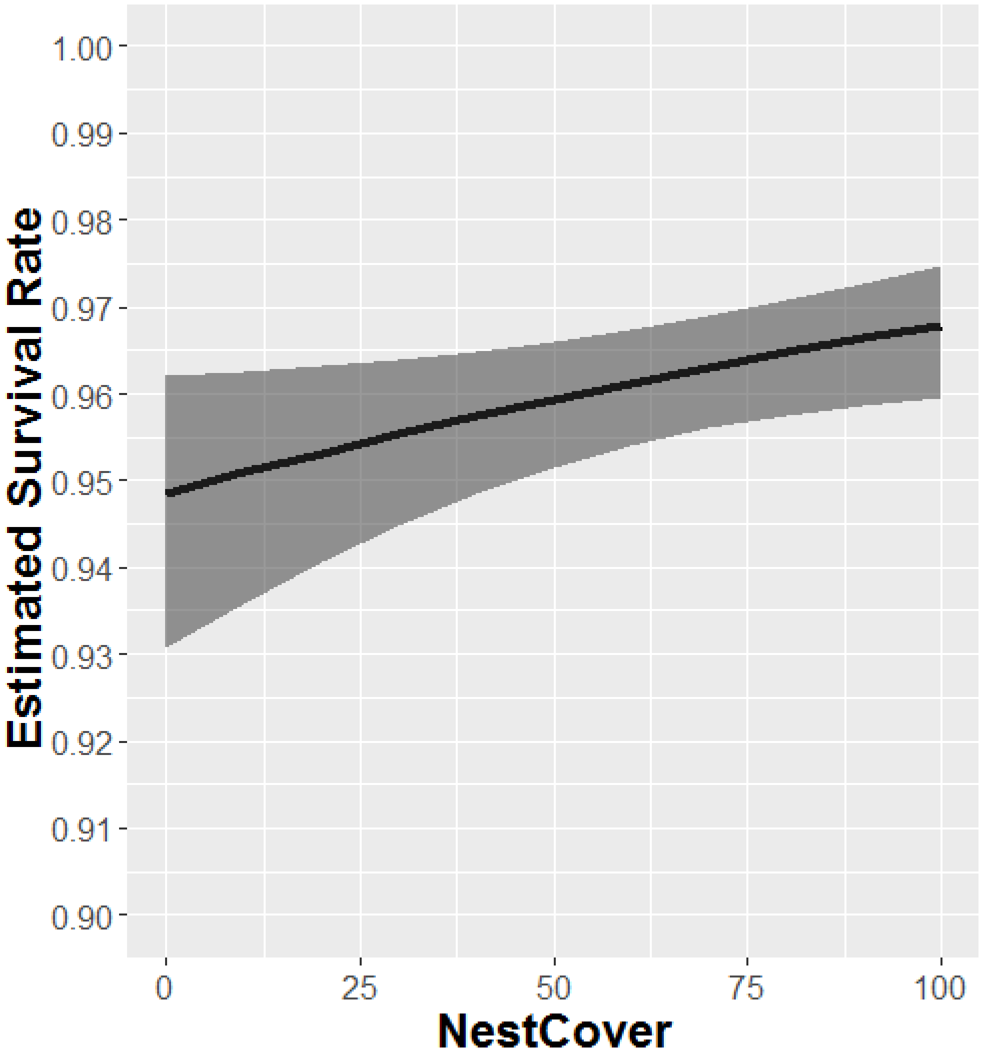

Figure 2. 8**:** Top model for wild turkey daily nest survival that shows how the changes in percent cover above the nest are related to nest survival in south-central, Tennessee, USA, 2017-2018.

Part III: Brood-Site Selection and Daily Poult Survival of Eastern Wild Turkeys in South-Central Tennessee

Abstract

Restoration efforts for the eastern wild turkey (*Meleagris gallopavo silvestris*) ended in 2005 in Tennessee, but since 2010 the spring wild turkey harvest has declined significantly in many Tennessee counties. Documented declines in poult/hen indices in Tennessee and elsewhere in the southeastern U. S. warranted new research on nesting and brooding ecology. In 2017-18 we radio-tagged 83 poults to document resource-selection, movements, and survival of turkey poults through the critical first 30 days of their life. We used conditional logistic regression to determine which landscape-scale and site-specific vegetative characteristics were most related to brood-site selection. We used program RMARK to evaluate temporal, rainfall, landscape-scale, and vegetative site-specific characteristics related to poult survival. Brood-site selection at the landscape level was negatively associated with distance to shrub cover, deciduous forest and clumpiness index of herbaceous-dominated plant communities. Site-specific selection was positively associated with percent cover of forbs compared to what was available on the landscape. The best-supported model for daily poult survival included daily movement and hatch date as the most influential covariates. Greater daily brood movements and later hatch dates were linked to increased likelihood of poult survival. Daily poult survival of the top model during days 1-3, 4-7, 8-14 and 15-30 was: 0.987579 (SE = 0.013), 0.906445 (SE = 0.022), 0.810470 (SE = 0.033) and 0.902000 (SE = 0.038), respectively. Using the top model, there was 1.5% and 9.7% poult survival in 2017 and 2018, respectively, during the first 30 days of life. Flush count survival estimates of poults for solitary hens were 6.1% (2017) and 24.1% (2018). Management that increases forb abundance and facilitates movements on the landscape may increase poult survival during the critical first 30 days of life and ultimately mitigate apparent population declines.

Introduction

From 1983 to 2012, there has been a documented decline in annual reproductive indices (ie., poults/hen, % hens with poults) of eastern wild turkey (hereafter “turkey”) (*Meleagris gallopavo silvestris*) in many areas of the southeastern United States (Byrne et al. 2016). With a documented significant decline in harvest in the south-central Tennessee since 2010, state turkey biologists and managers need a better understanding of the limiting factors affecting both populations and harvest. Wild turkey brood productivity is a key parameter of recruitment (Vangilder and Kurzejeski 1995) and because population growth is a balance between recruitment and survival, various combinations of these two parameters could lead to stable populations; e. g., hen survival 75% and poult survival ~34% in Arkansas (Thogmartin and Johnson 1999). Studies with declining populations have shown relatively poor poult survival; Florida ~10% (Peoples et al. 1995) and Virginia ~20% (Norman et al. 2001), indicative of poor recruitment. Other studies with stable or increasing populations have documented the upper limits of poult survival; Texas (27%-40%) (Spears et al. 2007); Alabama (~30%) (Speake et al. 1985); New York (>20%) (Glidden and Austin 1975). More research on how poult survival affects population growth for declining populations is needed by identifying key factors that are linked to poult survival. If habitat covariates that affect poult survival can be identified, then focused brood habitat management may have a positive impact on recruitment, and ultimately population growth.

Researchers have documented poult survival using different methods (telemetry, flush counts, road surveys, infrared cameras and poult calls). Flush counts, paired with radio-telemetry have been used to document poult survival (Hubbard et al 1999, Peoples et al. 1995). Both Hubbard et al. (1999) and Peoples et al. (1995) reported no difference between the survival estimates of the flushed and radio-tagged poults. Both methods have their strengths and weaknesses. Flush counts can bias estimates because of brood flocking, poults cryptic appearance/behaviour and possibly poult swapping while they are flocked together causing uncertainty in assigning individual poults to specific hens (Orange et al 2016). Transmitter attachment methods have improved and have no apparent effect on the growth of the chicks (Larson et al. 2001), but can bias estimates if transmitters fall off or inhibit movement. Burkepile et al. (2002) used the suture method for radio-tag attachment on one-day-old sage grouse and reported no effect on growth and < 10% transmitter loss.

The greatest poult mortality is thought to happen in the first 14 days of life (Peoples et al. 1995), with survivability increasing with the development of flight and tree roosting (Holbrook et al. 1987, Spears et al. 2005). Predation is one of the greatest causes of mortality for a brood (Speake et al. 1985, Hubbard et al. 1999), but other factors can correlate with brood mortality. Greater daily precipitation has been associated with decreased survival during the second week after hatch apparently because the larger poults cannot be properly brooded during rain events (Roberts and Porter 1998). Greater brood movements have also been associated with greater survivability in poults within the first week after hatch as broods leave areas of apparently poor brooding cover and move towards habitat with better cover and nutrition (Godfrey and Norman 1999).

Documenting poult resource use may enable managers to identify and enhance available brood habitat, increase the survivability of turkey poults, and ultimately enhance recruitment. Habitat for broods can be characterized as well-developed and diverse herbaceous cover (forbs, graminoids, and ferns), abundant invertebrates, and sparse woody ground cover (Healy 1985, Ross and Wunz 1990, Godfrey and Norman 1999). Brood habitat requirements change to more forested areas as poults are able to roost after ~14 d (Ross and Wunz 1990).

Brood movements may reflect habitat quality and influence survival. Greater movements have been linked to greater survival (Godfrey and Norman 1999), but have also been shown to have no measurable effect (Peoples et al. 1996). It is unclear whether movements reflect inadequate brood cover near or the inherent tendency to disperse from the nest site to avoid potential predators keying in on scent or activity associated with the nest site at hatching. The availability of herbaceous cover (i. e., brood habitat) also may be correlated with movements and poult survival. We hypothesized that broods select areas with greater herbaceous cover and that selection is negatively correlated with movement. If brood movement is negatively related to herbaceous cover, and the amount of herbaceous cover is related to poult survival, then survival will increase with a decrease in brood movement and an increase in herbaceous cover.

Little research has linked turkey hen nest-site selection to increased poult survival, but nest-site selection by greater sage-grouse (*Centrocercus urophasianus)* improved chick survival and ultimately seasonal productivity (Gibson et al. 2016). The spatial relationships between nest sites, brood habitat, and the movements tying these two habitat components together have important implications for understanding factors limiting recruitment and for developing effective habitat management prescriptions. If hen nest-site selection correlates with poult survival, then managers could improve the quality of potential nest sites and poult survival. We hypothesized hens selected nest sites to improve poult survival by being near high-quality brood cover and/or selected areas with travel corridors leading to high-quality brood cover. In theory, hens should select nest sites near open cover types that will support insect abundance and nest sites that facilitate travel to such areas.

We monitored daily poult survival, movements, rain events and resource selection to ultimately identify the characteristics of brood habitat, to understand the relationship between nest-site selection and brood habitat availability, and to understand how poult survival is related to brood habitat characteristics and availability. Our overall goal was to understand how brood habitat availability and survival were related to recent declines in harvest and populations in south-central Tennessee. Our main objectives were to: (1) document daily poult survival of marked individuals and bi-weekly survival of unmarked individuals, (2) identify resource selection compared to availability and determine if movement was related to brood habitat availability, (3) determine relationships between daily poult survival and movement, rainfall, landscape covariates and site-specific vegetation covariates, and (4) determine if there was a relationship between nest-site selection and poult survival.

Study Area

The study was conducted in 5 counties of south-central Tennessee (Maury, Lawrence, Wayne, Bedford and Giles). Via contacts with private landowners, we gained access to 26,007 ha of private land, and worked on 10,846 ha of public land. Each of the five counties was dominated by varying amounts of deciduous forest and herbaceous-dominated cover types (USDA National Agricultural Statistics Service Cropland Data Layer 2017; Figure 3.1). Ten study sites (two per county) were used as focal points for the study (Figure 3.2). These sites were located on private (n = 9) and public (n = 1) land and had turkey densities that were sufficient to obtain the target sample size (n = 10 hens per site) for the nesting and brooding studies. Each site had a range of turkey densities, hunter densities and land cover compositions.

Lawrence County was predominantly deciduous forest (44.7%) with substantial agricultural land use (grasslands and pastures, 27.4%; row crops, 13.12%; Figure 3.3). The study sites were on private land where we acquired land access from 40 private landowners (3,944 hectares) at the southern site and 37 (36 private and 1 public) landowners (8,952 ha; 3,287 ha of private and 5,665 ha of public) at the northern site. Both sites were similarly dominated by deciduous forests, but the northern site had a greater amount of hayfield/pasture.

Giles County was predominantly deciduous forest (47.5%) and had agricultural land in the river valleys (Figure 3.4). Both study sites were located on private land, located in the northern and southern sections of the county, respectively. The northern site was located close to the border of Giles and Marshal counties and we had access from 29 landowners (4,163 ha). A total of 22 landowners in the southern study site provided access (1,672 ha). Deciduous forest dominated the northern section of the southern site with some pastures, unlike the southern portion which was heavily row crop agriculture.

Maury County was predominantly deciduous forest (44.5%), and hayfields/pasture (31.3%) cover types (Figure 3.5). The southeastern site was located within Yanahli (WMA), a 5,180 ha WMA dominated by a mixed cedar (*Juniperus* spp.) and oak (*Quercus* spp.) -hickory (*Carya* spp.) forest landscape. We gained access from 9 private landowners which increased our total land access by 657 ha. Both sites had wildlife management practices implemented on them. The northern site was a large property that was dominated by deciduous forest, with a lake in the middle of the property. There was row crop agriculture and hayfield/pasture to the west and south of the main trap site. In total we acquired access from 19 landowners (2,280 ha) at the northern site.

Wayne County was more forested than the other counties (61.7% deciduous and 8.6% evergreen; Figure 3.6). Timber companies owned much of the accessible land (5,281 ha) in the southern site, but 14 landowners also granted us access to another 388 ha. This site was dominated by evergreen and mixed forests with minimal hayfield/pasture and row crop agriculture located to the south. The northern site was dominated by deciduous and mixed forests. We acquired access from 11 landowners (1,096 ha).

Bedford County was dominated by hayfield/pasture (47.5%) with less deciduous forest than the other counties (26.6%; Figure 3.7). The northern site was dominated by deciduous forest and hayfield/pasture cover types. We gained access from 24 different landowners (1,748 ha). The southern site was very flat with extensive row crops with deciduous forests and cedars growing on shallow soils. We gained access from 22 private landowners (1,491 ha).

Methods

Field Methods

Trapping: Each study site was baited with corn (cracked or whole kernel) to attract turkeys for trapping. Sites were monitored for turkey activity with a Moultrie A-30i (PRADCO Outdoor Brands, Birmingham, AL) motion-sensing camera to monitor turkey activity at the trap site prior to trapping. Turkeys were trapped with rocket-nets (box set) based on the methods of Delahunt (2011b). The goal of each site was to trap 10 hens (> 5 adults), yielding ~100 hens in the monitored sample. Once captured, every bird was fitted with an individually-numbered metal leg band. The first 10 hens and males on each site were fitted with a backpack-style VHF radio transmitter (Advanced Telemetry Systems [ATS] Isanti, MN). The transmitters weighed an average of 80 g, ~2% of the hen’s body weight and <1% of the male’s body weight. Each transmitter was equipped with an 8 h mortality switch and a motion sensing switch. Each turkey was weighed and the keel examined and scored for body condition (Robins 1998). The birds were then released on site.

Hen Monitoring: Each hen was monitored around 3 times per week prior to nesting by triangulation with three intersecting compass bearings from fixed locations (Vangilder et al. 1987). Each bearing and base station location was put into LOAS version 4.0.3.8 (Ecological Software Solutions, Urnäsch, Switzerland) to determine an estimated location and error polygon. Beginning April 1st we began monitoring hens every other day to detect the initiation of incubation (Vangilder et al. 1987, Norman et al. 2001). If a hen had been located in the same approximate location on two consecutive days, had prolonged periods of inactivity (e. g., 1 hour) based on the motion sensor or was sending out a mortality signal, it was assumed to be incubating. An estimated location was acquired by circling the hen (Vangilder et al. 1987, Miller et al. 1998, Thogmartin and Johnson 1999). An estimated hatch date was then calculated by adding 28 days to the incubation date.

Nesting hens were monitored every 1-2 days. If a hen was off the nest for >3 h, or was >200 m from the estimated nest location, we searched for the nest. Once found, the nest location was recorded by GPS and nest fate was determined as either still active, hatched, abandoned, or depredated. When a hen lost or abandoned a nest, we monitored her subsequent activity every 1-2 days to document re-nesting. Successful nest were those with ≥1 egg hatched (Vangilder et al. 1987, Miller et al. 1998, Thogmartin and Johnson 1999). A hatch was determined if the eggshells still had a membrane attached and by the general appearance of the shells and nest (tops pecked off or eggshells still all within or on edge of the nest bowl). In cases where we could not definitively determine if a nest hatched or was predated (<10% of nest fates), we continued to monitor hen activity to determine if poults were present. If we determined poults were present, we classified the nesting attempt as successful.

Poult Trapping and Monitoring: Once a nest had successfully hatched, poults were captured to enable monitoring of daily survival and resource selection. Poults were generally caught 1-2 days after hatching to enable efficient capture and to avoid missing potential mortality events during the first days of life (Spears et al. 2002). We tracked to within 100 m of the hen an hour before sunrise, and positioned 2-4 people around the hen at ~15 m so the hen could be flushed and the poults caught by hand (Hubbard et al. 1999). We attempted to capture all poults present but only radio-tagged 1-5 poults per brood. Once captured, poults were placed inside an insulated cooler with a warm water bottle to maintain their body heat (Hubbard et al. 1999, Spears et al. 2002). Captured poults were processed ~30 m from the point of capture (opposite direction of where the hen flushed to) so any poults that were not caught did not experience increased stress from our presence (Spears et al. 2007). We weighed each poult in a cloth bag with a 100-g spring scale. We attached a 1.5-g transmitter (Advanced Telemetry Systems ATS Isanti, MN) along the midline of the back using a glue method in 2017 (Spears et al. 2002) and a suture method in 2018 (Burkepile et al. 2002). For the glue method, we shaved a ~1 cm x 1 cm patch of feathers. We then applied 2-3 drops of super glue gel on a ~1 cm x 1 cm piece of cheese cloth and applied that to the shaved patch on the poult. Once the glue on the cheese cloth was dried on the back of the poult, we added 2-3 drops of glue to the transmitter and held it on the cheese cloth until it was dry and secure. Because ~25% of radios dropped off poults prematurely in 2017, we changed methodologies in 2018 to a suture method. To attach the transmitters, we inserted two individually prepackaged sterile 20-gauge needles subcutaneously between the wings of the poult, allowing for ~5 mm of skin between where the needle entered and exited and

19 mm perpendicular distance between the two needles. We then threaded monofilament suture material (3-0 black braided silk, non-absorbable and non-sterile) through both needles and then pulled both needles out, leaving the suture material under the skin. Then we threaded both ends of the suture material through the mounting holes on the transmitter and tied a square knot on top of the front of the transmitter (avoiding feathers) and tied a square knot under the antenna at the rear of the transmitter (avoiding feathers). We clipped off ~2.50 cm of the antenna in both years to decrease transmitter interference with poult movements. Once our sample of poults were radio-tagged and the other poults were weighed, we released them at the trap location. We captured 1-7 poults per brood and radio-tagged 1-5 poults per brood.

We used homing to circled the hen and poults to within 30-50 m 1x/d for the first 7 d of the brood period (Spears et al. 2007). While we circled the hen, we verified that the radio-tagged poults were still with the brood. We turned on the tracks feature on our hand-held Global Positioning System (GPS) device to record our path and provide a means of estimating the brood's central location ±15 m. When >1 radio-tagged poult was present in a brood, each poult was assigned the same brood location. At the end of the 7-d period, we monitored broods every other day until 30 days of life. When a poult mortality occurred, we located the transmitter and examined the area for field sign, such as a carcass, scat, hair, tracks, feathers, mode of death and means of hiding the kill to determine the likely cause of death (Speake et al. 1985, Peoples et al. 1995). If a transmitter was no longer detected with the brood and was not located through a systematic search from the previous brood location to the current brood location, then we assumed the poult was predated (Orange et al. 2016). Each brood of radio-tagged hens was flushed at 2 and 4 weeks of age to count the number of marked and unmarked poults (Peoples et al. 1995, Hubbard et al. 1999). If there was >1 hen during the time of the flush count, then that value was not used in the survival percentage (Isabelle et al. 2016). In 2017 we monitored 24 broods for flush counts and 9 of them were used to estimate survival for solitary hens, whereas in 2018 we monitored 19 broods and used 7 for the analysis of solitary hens. Individual poult monitoring ceased after 30 days; the expected life of the transmitters was 34-58 days according to the manufacturer. We tested battery life on 2 units which lasted ~60 days.

Brood Habitat Evaluation: An analysis of each brood location was conducted within 4 weeks after the brood was located. A paired random site was sampled for each location to evaluate selection. To determine the area from which to randomly select points for comparison, we first calculated average daily movement for all broods with radio-tagged poults. We used the average daily movement (277 m) as the maximum distance and arbitrarily set the minimum distance at 20 m from which to select random points. We generated a random azimuth from the location and with a random distance generated a random point. The random points were checked with United States Department of Agriculture (USDA) land cover data (National Agricultural Statistics Service; 2017) in ArcGIS 10.4.1 (ESRI, Redlands, California) to confirm that they were in potential habitat (i.e., not human-developed or water cover types) and in areas where we had access. Habitat assessment was based on a 30-m transect that was centered on the brood or random location (Brooke et al. 2016). A random bearing was generated to determine the orientation of the transect. To determine plant composition and coverage, at every 1-m on the transect we identified the presence of each individual plant that was <1.37 m tall that touched a 2.54-cm diameter pole. Each plant was identified at least to genus and placed into one of the following categories: grasses, forbs, brambles, shrubs, vines, saplings and ferns. If no plants were present, the category was entered as either litter or bare ground. Vegetative structure at each location and associated random point were measured within a 11.3-m-radius plot (Badyaev

1995). We used a vegetation profile board (Nudds 1977) divided into 3 height classes (0-50 cm; VORlow; 51-100 cm- VORmedium; 101-200 cm-VORhigh) to measure understory cover (Badyaev 1995). Percent cover was broken into 6 classes, as outlined in Badyaev (1995): (1) <2.5%, (2) 2.5-25%, (3) 26-50%, (4) 51-75%, (5) 76-95%, (6) >95%. We placed the profile board on the plot center and read the board 11.3 m from the plot perimeter in the cardinal directions. We counted stems of shrubs, tree saplings, and brambles (combined) within a 5-m-radius plot by counting the number of stems >1.37 m tall and ≤11.4 cm dbh (Brooke et al. 2016). We measured the basal area of trees within three size classes (<25 cm, 25-45 cm, >45 cm diameter breast height [DBH]) with a 2.5 m^2/ha-factor prism (Bidwell et al. 1989) at plot center. We measured openness at ground level at 15.2 cm aboveground with a ground-sighting tube (Gruchy and Harper 2014). We placed the sighting tube at the center point of the plot and at 1-m intervals starting a plot center along the 30-m transect, we placed a 2.54-cm-diameter pole. If the pole was no longer visible through the sighting tube, we measured that distance from plot center. Based on visual evaluation, we assigned cover type at plot center to one of the following categories: deciduous forest, evergreen forest, shrubland, early succession (>50 % herbaceous vegetation, < 50% woody material lower than 1.37 m in height), pasture, hay field, row crop and water/developed (Table 3.1). Other general characteristics of the site were recorded (slope, aspect, elevation, distance to paths or roads and distance to nearest edge- defined as a change between two cover types).

Landcover Data: We chose relevant landscape metrics to quantify based on previous literature for wild turkeys (Bowling et al. 2016, Wood et al. 2019). We acquired 30-m land cover data from the USDA (National Agricultural Statistics Service; 2017) to determine land cover for the study sites. We grouped land cover into six types; deciduous forest, evergreen/mixed forest, shrubland, fallow field/pasture/old field/grassland (ES/pasture), row crop, and water/human developed (Table 3.2). We calculated distance to cover types from each brood location and random point using ArcGIS 10.4 (ESRI, Redlands, CA). We used FRAGSTATS 4.1 (McGarigal and Marks 1995) to quantify five landscape metrics. Clumpiness (CLUMPY) was an index of the dispersion of individual cover types; as CLUMPY approached 1 for a given cover type, the cover type patches were more aggregated. The percent cover of each cover type (PLAND) was calculated as the number of pixels of a given cover type divided by the total number of pixels. Total edge was the total amount of edge between all the cover types (TE). Contagion (CONTAG) was a measure of dispersion and interspersion of patches regardless of patch cover type identity. Large values of contagion occurred when patches were highly aggregated (one patch dominating the landscape). The Interspersion and Juxtaposition Index (IJI) measured the extent to which the landscape was intermixed with different patch cover types.

Data Analysis

Resource Selection: We evaluated resource selection at two spatial scales (2nd and 3rd order; Johnson 1980). We used a case-control resource selection function (RSF) of use versus availability (Johnson et al. 2006, Pollentier et al. 2017) modeled with conditional logistic regression in package Survival (Therneau 2015) in program R version 3.5. (R Core Team 2018). In our analysis, the hen/brood location (not individual poult) was the case and random locations were the controls (Yeldell et al. 2017a, Wood et al. 2019). We conducted model selection in an information-theoretic framework (Burnham and Anderson 2004). For the measure of available habitat at the brood site, we used the characteristics at the paired random point described above. A buffer based on the average daily movement (277 m) was created around each brood location to define the area used. We then randomly assigned 5 points within each area of use around the brood location following the protocol of Yeldell et al. (2017a) and Wood et al. (2018). We then placed a 277-m buffer around each random point which defined the area of availability. Explanatory variables (Table 3.2) used in the analysis were checked for correlation using Pearson's correlation (r, Fuller et al. 2013). We eliminated visual obstruction reading from 51-100 cm from the analysis because it was highly correlated ($r > 0.7$) with other VOR covariates. The null model was that site selection was unrelated to any covariate.

The average daily movement of an individual brood during days 1-3, 4-7, 8-14, and 15-30 was compared to average percentage of the landscape that was early succession, and pastures and hay fields using linear regression. An analysis of variance (ANOVA) was used to compare the average daily movements between each time-interval and was also used for comparing the herbaceous cover types used. ANOVA was also used to compare visual obstruction, openness at ground-level, percent overhead cover and herbaceous cover between each vegetation cover type selected. We used $a < 0.05$ to determine statistical significance. When $0.05 – a – 0.10$, we termed statistical significance as 'marginal'.

Daily Poult Survival: We used the known-fate model in Program MARK (White and Burnham 1999) using the RMark interface (Laake, 2013) to calculate daily poult survival rate (DSR) and to determine to what extent DSR was associated with covariates. We created model suites based on *a priori* hypotheses involving the influence of temporal, movement, rainfall, and landscape and site-specific vegetation covariates (Table 3.1). We followed a similar model protocol used by Fuller et al. (2013) that involved the creation of model suites that moved from a larger-scale, non-manageable covariate set to a set of vegetation covariates that could be managed. We identified the best model(s) based on Akaike's Information Criterion adjusted for small sample sizes ($\mathrm{AIC_c}$); models that had a $\Delta\mathrm{AIC_c} \leq 2$ were deemed as having "support"

(Burnham and Anderson 2002) and covariate Beta estimates with 95% confidence intervals that did not overlap 0 were considered “strong” relationships (Kilburg et al. 2014). The null model assumed constant daily survival.

The first model suite included temporal variables including time (linear change in DSR), hatch data, quadratic time trend, time periods (days 1-3, 4-7, 8-14 and 15-30) and year (Table 3.3). We ran linear time, quadratic, and the time period models first to determine the most appropriate way to group the time-varying covariates. We created time intervals that corresponded to biologically relevant time periods in the poult life cycle. We averaged the time-varying covariates (i. e., vegetative, movement, and rainfall) during those time intervals to run through the survival models to determine if those covariates were related to interval survival. We expected DSR to decline until poults could tree roost around day 14 of life. DSR could also vary with the year as well because of variation in weather, predator populations or other broad-scale phenomena. As the brood-rearing period progressed, we hypothesized that changes in the structure of the ground cover and insect abundance may lead to greater survival and be correlated with hatch date.

The second suite of models (movement and rainfall) included three variables; two that measured rainfall in different ways and one that accounted for daily movements (Table 3.3). Rainfall has been linked to negative productivity in hens in other studies; we wanted to see if it was directly related to poult survival (Bowling et al. 2016). We hypothesized that large rainfall events would increase poult mortality during the early stages of their life. We acquired rain totals (PRISM Climate Group 2017) for the day prior and the day of poult fate to see if greater rain events were linked to increased mortality. We averaged daily movements into the four-time intervals mentioned above to determine if the patterns of movement were linked to survival.

The third suite of models were landscape variables that were used in the resource-selection analysis (Table 3.3). We hypothesized that an herbaceous cover type, dominated by forbs, would provide suitable cover and food, and therefore increase poult survival if the hen chose to spend more time in proximity to this cover type compared to other cover types. We included CONTAG, CLUMPY, PLAND, and IJI in the third suite of models because we wanted to assess whether DSR was related to broader landscape context and configuration. Others have suggested that maintaining a variety of well-dispersed cover types may be beneficial for brood survival (Speake et al. 1985, Lehman et al. 2008).

The fourth model suite included all the top covariates from the first three suites and the site-specific vegetation covariates. We included a selection model in this suite that included each covariate that broods selected for compared to available habitat. We also included a global model that included all covariates that were used in the models (Table 3.3). We hypothesized that abundance of forbs and greater openness at ground level would be positively correlated with poult survival.

To evaluate whether nest-site selection was related to poult survival, we truncated the encounter history to include only the first 4 days of life. We developed 13 *a priori* models that included both landscape and site-specific covariates in biologically relevant combinations to assess whether hens were selecting certain covariates for nesting that were linked to greater poult survival post-hatching. The models included the landscape covariates distances to early succession/pasture, deciduous forest, shrublands, nearest path and nearest edge, IJI, percentage of the landscape made up of early succession/pastures and deciduous forests. Models also included the nest-site specific covariates of visual obstruction from 0-50 cm, slope and percent cover above the nest.

Results

We trapped a total of 98 (63, 2017; 35, 2018) poults and radio-tagged 83 (53, 2017; 30, 2018) from 22 broods in 2017 and 11 broods in 2018 (Table 3.4). During the two years, we made 40 attempts to trap poults, with 33 attempts successful (82.5%). During four attempts the hen was flushed and no poults were trapped; the remaining 3 unsuccessful attempts resulted from hens taking broods to properties where we did not have access. We averaged 2.65 and 2.33 poults trapped per attempt during 2017 and 2018, respectively (Table 3.4). We right censored survival data from 12 poults in 2017 because the transmitters fell off prior to end of radio life without sign of predation or other source of mortality. We removed 5 poults from the 2018 dataset because they immediately entered property that we had no access to and right censored survival data from one poult because of transmitter failure. One poult was censored because mortality occurred within 24 hours of trapping and was likely related to capture/handling. We used a total of 77 radio-tagged poults (663 exposure days) in the daily survival analysis (both years combined). No radio-tagged poults survived the 30-day period in 2017; 15 mortalities-source undetermined, 12 transmitters fell off, and 25 known mortalities (11 mammalian, 8 avian, 6 exposure). Seven poults survived the 30-day period during 2018; 16 mortalities-source undetermined, 1 transmitter failure, and 6 known mortalities (5 mammalian, 1 avian).

Broods used deciduous forests (38.7%), evergreen forests (21.2%), hay fields (7.5%), old fields (17.9%), pasture (10.4%), and shrubland (4.2%). The nearest adjacent cover type to a brood location was deciduous forests (42.0%), evergreen forests (6.6%), hay fields (9.0%), old fields (26.9%), pasture (7.5%), shrubland (3.3%), row crop (2.4%) and developed (2.4%). Visual obstruction from 0-50 cm differed among all cover types ($F = 11.5$, $P < 0.01$, df = 5 and 200). For the pairwise comparison of visual obstruction between cover types we found that pastures ($\bar{x}$

= 2.7, SE = 0.31) vs. hay fields ($\bar{x}$ = 3.0, SE = 0.44) (P = 0.56); deciduous forest ($\bar{x}$ = 4.1, SE = 0.16) vs. evergreen forest ($\bar{x}$ = 3.9, SE = 0.21) (P = 0.47); and old field ($\bar{x}$ = 5.2, SE = 0.24) vs. shrubland ($\bar{x}$ = 5.7, SE = 0.49) (P = 0.36) were the only cover types that did not differ. Openness at ground level differed between cover types (F = 3.7, P < 0.01, df = 5 and 199). Old fields differed ($\bar{x}$ = 6.1 m, SE = 1.44) from most other cover types: deciduous forest ($\bar{x}$ = 11.6 m, SE = 0.97, P < 0.01), evergreen forest ($\bar{x}$ = 12.8 m, SE = 1.30, P < 0.01), hay field ($\bar{x}$ = 15.4 m, SE = 2.76, P < 0.01),and pasture ($\bar{x}$ = 13.68 m, SE = 1.86, P < 0.01) , but not shrubland ($\bar{x}$ = 11.4 m, SE = 2.91, P = 0.10). Percent grass cover differed between cover types (F = 11.5, P < 0.01, df = 5 and 203) and was greater in hay fields ($\bar{x}$ = 0.70, SE = 0.08), pastures ($\bar{x}$ = 0.78, SE = 0.06), and old fields ($\bar{x}$ = 0.56, SE = 0.05) compared to forest cover types (deciduous; $\bar{x}$ = 0.36, SE = 0.03, P < 0.01; and evergreen; $\bar{x}$ = 0.31, SE = 0.04, P < 0.01). Percent forb cover differed between cover types (F = 20.4, P < 0.01, df = 5 and 203). Percent forb cover in pastures ($\bar{x}$ = 0.24, SE = 0.05) did not differ from forb cover in shrubland ($\bar{x}$ = 0.37, SE = 0.07, P = 0.16), hay field ($\bar{x}$ = 0.34, SE = 0.06, P = 0.18), or deciduous forest ($\bar{x}$ = 0.20, SE = 0.02, P = 0.38). Also, percent forb cover did not differ between shrubland and hay field (P = 0.81). Patch size differed greatly among herbaceous cover types selected for (F = 20.4, P < 0.01, df = 5 and 203), with patch size smallest in old fields ($\bar{x}$ = 6.9 ha, SE = 3.8), intermediate in pastures ($\bar{x}$ = 10.3 ha, SE = 4.8) and greatest in hay fields ($\bar{x}$ = 34.9 ha, SE = 5.6)

Brood Resource Selection: Brood resource selection was analyzed using (n = 217) brood locations from 2017 and 2018 combined. Modeling landscape covariates for selection produced 4 models with the strongest support (i. e., $\Delta AIC_c \leq 2$; Table 3.5). The best-supported model (K = 4, $\Delta AIC_c = 0$, $w_i = 0.32$; Table 3.5) included the covariates distance to shrub cover, distance to deciduous forest, clumpiness of herbaceous cover, and percent cover in row crop. When the selection coefficients for the top model were reviewed, percent cover of row crops had a P-value > 0.05 ($\beta = 0.010$; $P = 0.56$; OR =1.01; Table 3.6). Broods selected areas that were closer to shrub cover ($\beta = -0.006$; $P \leq 0.01$; OR = 0.99; Table 3.6) and deciduous forests ($\beta = -0.011$; $P = 0.01$; OR = 0.99; Table 3.6), and selected areas that had a lesser clumpiness index for herbaceous cover ($\beta = -0.69$; $P = 0.03$; OR = 0.50; Table 3.6). The lesser clumpiness index indicated broods were choosing areas where herbaceous cover patches were highly fragmented. Broods were 0.5 times less likely to choose an area with every 10% increase in clumpiness index of herbaceous cover and only 0.01 times more likely to choose a site with every 100-m decrease in distance from shrubland and deciduous forest cover types.

Three models were supported for brood-site selection (i.e., $\Delta AIC_c \leq 2$; Table 3.7). The best-supported model ($K = 4$, $\Delta AIC_c = 0$, $w_i = 0.37$; Table 3.7) included forb cover, distance to nearest edge, basal area of trees 25-45 cm, and openness at ground level. Although four covariates were included in the model, distance to nearest edge ($\beta = -0.459$; $P = 0.10$; OR = 0.63; Table 3.8), basal area ($\beta = -0.006$; $P = 0.05$; OR = 0.99; Table 3.8) and openness ($\beta = 0.010$; $P = 0.48$; OR = 1.01; Table 3.8), were not individually significant in the selection model ($P > 0.05$). Forb cover was positively associated with brood use ($\beta = 1.320$; $P = 0.02$; OR = 3.74; Table 3.8); a brood was 3.74 times more likely to utilize a site with every 10% increase in forb abundance.

Percent cover of ES/pasture was positively associated with average movements during the 1-3 day interval ($\beta = 0.084$; SE = 0.018; $P \leq 0.01$), but was negatively associated with average movements during the 15-30 day interval ($\beta = -0.019$; SE = 0.007; $P = 0.01$; Table 3.9). Movements during the time intervals 4-7 and 8-14 days were not related to percent cover of ES/pasture. Percent herbaceous cover did not differ ($P > 0.05$) among the four-time intervals

(Table 3.10). Percent herbaceous cover was not correlated with average daily movement during days 1-3 or 15-30 but was correlated for the other two-time intervals. Average daily movement was positively associated with percent herbaceous cover during the 4-7-day time interval (β= 1.483; SE = 0.537; $P \leq 0.01$; Table 3.9) and negatively associated with the time interval 8-14 days (β= -1.809; SE = 0.407; $P \leq 0.01$; Table 3.9). Average daily movement decreased (marginally) between each time-interval (1-3 = 348 m, 4-7 = 308 m, 8-14 = 250 m, 15-30 = 195 m; P = 0.06; Table 3.10). Average brood home-range was 48.7 ha (95% MCP) and core range was 9.7 ha (50% MCP).

Poult Survival: We modeled daily survival based on data from 77 poults from a total of 33 broods during the 2017-18 seasons. The best-supported models from analysis of the first model suite (temporal covariates) contained hatch date (K = 2, $\Delta AIC_c = 0$, $w_i = 0.50$; Table 3.11) and year (K = 2, $\Delta AIC_c = 1.13$, $w_i = 0.30$; Table 3.11). Both hatch date (β = 0.021, CI = 1.250^{-3} to 0.042) and year (β = 0.602, CI = -0.011 to 1.215) were positively associated with survival but Beta coefficient confidence interval for year overlapped 0, suggesting a weak relationship. Models with the other temporal covariates lacked support so those covariates were excluded from subsequent model sets (Table 3.11). Both hatch date and year were then combined with rainfall and movement covariates in the next model suite; the additive model of hatch date and movement was the best-supported model (K = 3, $\Delta AIC_c = 0$, $w_i = 0.67$; Table 3.12). Covariates from the other models were not considered in subsequent model sets (Table 3.12). Both movement (β = 0.334, CI = 0.067 to 0.601) and hatch date (β = 0.029, CI = 0.008 to 0.050) were positively associated with survival.

When hatch date and movements were added to landscape covariates, 9 models had some support ($\Delta AICc \leq 2$; Table 3.13). None of the landscape covariates improved model performance over the model with hatch date and movements (K = 3, $\Delta AIC_c = 0$, $w_i = 0.20$; Table 3.13) The confidence intervals for Beta coefficients for the landscape covariates in the other 8 models all overlapped 0, suggesting that the relationships between landscape covariates with daily survival were weak. For the sake of consistency in approach, however, all 8 models were included in the final model suite which included site-specific covariates.

Twelve models were supported in the final model suite ($\Delta AICc \leq 2$; Table 3.14). The best-supported model (K = 3, $\Delta AIC_c = 0$, $w_i = 0.06$; Table 3.14) was the same model as from the previous two suites that included both hatch date ($\beta = 0.029$, CI = 0.008 to 0.050) and movement ($\beta = 0.003$, CI = 6.657^{-4} to 6.009^{-3}). The additional 11 models included grass abundance, IJI, distance to herbaceous cover, clumpiness of herbaceous cover, distance to shrubland, forb abundance, percent herbaceous cover, distance to shrublands, bramble cover, distance to deciduous forest and basal area as single covariates added to movement and capture date (Table 3.14). The 95% confidence intervals for Beta coefficients for these covariates all overlapped 0, suggesting weak relationships. Ultimately, the best-supported model indicated poults survived longer with increased daily movements (Figure 3.8) and if they hatched later in the nesting season (Figure 3.8). The survival estimates for each time interval for the best-supported model was: 0.903560 (days 1-3; SE = 0.01592), 0.903020 (days 4-7; SE = 0.015865), 0.874444 (days 8-14; SE = 0.016000) and 0.855792 (days 15-30; SE = 0.020234) (Table 3.15).

During 2017, the daily poult survival estimate for each time interval was: 0.97841 (1-3; SE = 0.02141), 0.87824 (4-7; SE = 0.02621), 0.79546 (8-14; SE = 0.03789) and 0.87382 (15-30; SE = 0.05457), with interval survival probabilities of 93.7%, 59.7%, 20.2%, and 13.2%, respectively (Table 3.16). Daily poult survival during the 2018 season was 0.98837 (1-3; SE = 0.01197), 0.93119 (4-7; SE = 0.02339), 0.87946 (8-14; SE = 0.03334), and 0.92853 (15-30; SE =

0.02895), with interval survival probabilities of 96.6%, 75.2%, 40.7%, and 32.9%, respectively (Table 3.16). Based on the best-supported model, the 30-day survival was 1.5% and 9.7 % for 2017, and 2018, respectively. Poult survival did not differ between radio-tagged poults in broods that were flushed and non-radio-tagged poults in those same broods for 2017 (F = 0.02, df = 1 and 16, P = 0.89), nor for radio-tagged poults and non-radio-tagged poults in 2018 (F = 2.27, df = 1 and 8, P = 0.17).

Nest-Site Selection and Poult Survival: Two models had the best support for explaining daily poult survival related to nest-site selection covariates (i.e.,$\Delta AIC_c \leq 2$; Table 3.17). The top model held 34.4% of the model weight and included distance to herbaceous cover and distance to nearest path or road covariates. Distance to nearest path or road was negatively correlated with survival (β = -0.208, CI = -0.0367 to -0.0048; Table 3.18); hens that nested closer to paths or roads had increased poult survival during the first four days post-hatching. The 95% confidence interval for the Beta coefficient for the distance to herbaceous cover covariate overlapped 0, suggesting a weak relationship (β = -0.0013, CI = -0.0110 to 0.0084; Table 3.18).

Flush Counts: Poult survival based on flush counts including multiple hens/broods were 24.3% and 23.4% survival for the 2- and 4-week flush counts in 2017, whereas poult survival in 2018 was 52.9% and 32.6% for the 2- and 4-week flush counts. Poult survival of solitary hens was 7.6% and 6.1% for the 2- and 4-week flush counts in 2017, whereas poult survival during the 2- and 4-week flush counts in 2018 was 58.6% and 24.1%, respectively. The poult per hen ratio based on solitary hens at the 4-week flush count for 2017 was 0.67 and was 2.8 for 2018.

Discussion

We hypothesized that brood-rearing sites would be in close proximity to herbaceous cover types (pastures, hay fields, fallow fields and old fields) because of the increased availability of appropriate cover and available food resources but our results did not support this hypothesis. Old fields, hay fields and pastures were not highly selected for possibly because the structure of these herbaceous cover types were inappropriate for selection by broods. Herbaceous cover types are often referenced in the literature as important brood habitat but can be of limited value if the ground-level structure is not open and if there is a lack of overhead protection. Hay fields, for example, could be too thick at ground level for poults to move through and pastures could have too sparse of cover for concealment, depending on the grazing intensity. Old fields also may be too dense for poult movement and limit hen visibility if succession results in dense cover higher than the height of the hen and dominated by briars and grasses.

Greater forb cover at sites used by broods compared to available habitat provided movement ability, hen visibility, and likely abundant food sources. Brood-site selection can be comprised of various cover types that provide security from predation and access to food including soft mast, seeds and invertebrates (McCord et al. 2014). Habitat patches with greater forb cover require the appropriate structure to be frequently selected; just the presence of forbs alone does not make the site ideal. Old fields and pastures had greater abundance of forbs but apparently inappropriate structure compared to deciduous forest, hence brood locations were found in deciduous forest with forb cover in the understory. If structure is not ideal in the interior of herbaceous cover patches, then broods likely will stay along the edges (Everett et al. 1980), or stay within the forest. Broods used the edges of pastures, old fields, and hayfields apparently because structure was either too open or too dense in the interior of these open cover types or for larger fields, field interiors were too far from escape cover.

Hens selected for heterogeneity in landscape structure and chose areas where the landscape was fragmented between open and closed-canopy cover types. This is contrary to what Wood et al. (2018) found in which there was no association between site-selection and landscape heterogeneity. Heterogeneity on the landscape could allow for greater availability of a variety of resources that would benefit poults as they grow and develop flight abilities.

Poult survival in our study was linked to increased daily movements in part in response to limited availability of high-quality habitat. Similar to our results, Godfrey and Norman (1999) found a link between increased movement and increased survival, but they speculated that poor brood habitat near nest sites caused hens to move broods in search of sufficient food resources to increase poult survival. Our results demonstrated that daily movement was greatest during days 1-3, as was the presence of herbaceous cover types. The structure of these herbaceous patches, however, was apparently unsuitable, which would explain why daily movements were still high during days 4-14 as hens with broods continued to move to find better vegetative structure. Once they located a suitable area, however, movements generally decreased, especially during days 15-30. Once poults developed flight capabilities, not only did survival increase but daily movements also declined.

Poult daily survival was strongly linked to hatch date, with poults hatched later during the nesting season have greater survival. The radio-tagged broods from 2017 generally hatched earlier (late May) than the broods from 2018 (early June), which correlated with increased survival in 2018 versus 2017. We assume that hatch date had a positive effect on survival because poults that hatched later in the season had greater cover for concealment available to them and an increase in forbs that would attract greater insect abundance (Healy 1985). A study of northern bobwhite (*Colinus virginianus)* also indicated that chick DSR increased with later hatch dates and cited better cover and food resources as the likely causal factors (Terhune II et al. 2019).

Movement may not be only associated with finding quality brood habitat but could also be a means of predator avoidance. Predation has been documented as the number one cause of poult mortality: 66% (Speake et al. 1985), 92.9% (Hubbard et al. 1999), 88% (Peoples et al. 1995); 59.4%, this study. Although attributing poult predation events to even the appropriate class of predators (avian, mammalian, etc) based on field sign at radio-tag recovery sites is problematic (Larson et al. 2001), predation events in our study appeared to be dominated by mammals (43.8%). Snake predation did not appear to be a common mode of mortality in that we never recovered a poult transmitter in a snake unlike a spot-fledging songbird study where recovery of transmitters in snakes was a common occurrence (Lehman 2017). Since predation was the most common means of poult mortality, broods that moved greater distances were more likely to avoid predation. Broods moved greater distances earlier in life to find quality brood habitat also increased the likelihood of not being predated. Poult survival was greater once they developed flight abilities, likely because they avoided ground-based predators and localized on quality brood habitat. Sonerud (1985) noted that ruffed grouse broods, similar to our turkey broods, had large home ranges up to the point of fledging, then the ranges decreased, and the broods remained more sedentary.

An important spatial relationship existed between hen nest-site selection and brood survival. Hens selected nest sites that were located closer to accessible travel corridors to facilitate movements to appropriate brood habitat with an apparent poult survival benefit. Ruffed grouse (*Bonasa umbellus*) hens also selected for logging roads and gated forest roads for travel from nest sites to brood habitat because the well-developed herbaceous layer and greater vertical cover provided both food and cover (Jones et al. 2008). We defined a road or path as a linear feature that was maintained for vehicle or other human uses, including four-wheeler trails, hiking and bridle paths, farm roads, or gravel or paved roads. Paths or roads such as these provided a different type of structure compared to the adjacent cover type patches. These linear features often provided increased cover along the edges for nesting but also were used by poults as travel corridors. Paths and roads may not improve poult survival directly, but the herbaceous plant cover and structure associated with roads/paths may provide better quality habitat for poults than the surrounding areas, which ultimately increased poult survival. Distance to herbaceous cover itself was also in the top model linking nest-site selection to poult survival, but it was not a strong relationship, apparently because the structure of the herbaceous cover types were not consistent with quality brood habitat. Our model results, then, support the hypothesis that hens selected nest sites, not just to improve nest survival, but also to provide access to travel corridors that facilitated poult movement and ultimately poult survival. Selecting nest sites that are linked to increased poult survival would be an important life history trait ultimately linked to maximizing recruitment, as opposed to simply maximizing nest survival (Streby et al. 2016).

Our poult survival estimates were similar to estimates from other studies with declining populations (Table 3.20). Although detailed sensitivity analyses are required to determine which life cycle stages are most limiting, the relatively poor poult survival estimates suggest that this stage of the life cycle may be contributing to the population decline in our study. Other studies have estimated that poult survival between 20% - 30% is needed to support stable populations (Glidden and Austin 1975, Vangilder and Kurzejeski 1995). Given the inherent reproductive potential of wild turkeys, populations may largely be regulated by the balance between boom (i. e., >30% poult survival) and bust (<20% poult survival) years (Cookingham and Ripley 1964, Einarsen 1945, Guthery et al. 1988). Our two-year study was not of sufficient length to document how populations are being regulated among years, but poult survival during 2017 and 2018 were clearly consistent with declining populations. Management focused on improving brood habitat quality and availability may be capable of increasing poult survival to at least stabilize populations.

Survival estimates for radio-tagged poults vs. flush counts varied, with estimates from broods with multiple hens far greater than estimates based on radio-tagged poults. Survival of non-radio-tagged poults with solitary hens, compared to radio-tagged poults during flush counts did not differ. We only had one mortality that was censored because of death within the first 24 hours after release, suggesting that capture and handling did not contribute significantly to radio-tag poult mortalities. The suture method appeared to work well for the study objectives in that radio tags remained attached to the poults for the duration of radio life (>30 d) and did not appear to have any apparent negative effect on survival. We had 3 instances where solitary hens at their 2-week flushes had greater number of poults than what was present at hatching. This discrepancy demonstrated potential poult adoption, which has been cited but other researchers (Mills and Rumble 1991, Metz et al. 2006) and would bias survival estimates high.

Management Implications

Given the poor poult survival in our study, the availability and spatial distribution of quality brood habitat that is linked via travel corridors to quality nesting habitat is likely a limiting factor for population growth. Patches of forb-dominated herbaceous cover with 50-75%

visual obstruction at 0-50 cm above ground level would provide appropriate brood habitat structure and composition. Managing to promote a mosaic of small patches of brood habitat (i. e., clumpiness index values < 0.52) in an average brood home range (95% MCP = 48.7 ha and 50% MCP = 9.7 ha) would also contribute to brood habitat characteristics that hens were selecting for. Although several studies have documented brood habitat characteristics linked to poult survival (i. e., this study), we are aware of no other published studies that have evaluated whether and to what extent purposeful brood habitat management can increase brood survival. Ultimately, managers need to monitor poult survival in response to experimental brood habitat prescriptions to be able to determine the keys to success.

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Appendix

Table 3. 1: Description of cover type classifications used to describe brood-site selection and poult survival for wild turkey broods in south-central, Tennessee, USA 2017-2018. The descriptions are based on NASS recommendations.

Variable	Abbreviation	Description
Deciduous forest	Deciduous	More than 75% of the trees are deciduous hardwoods that shed their leaves as the season change. The area is more than 25% trees that are over 5 meters tall.
Evergreen forest	Evergreen	More than 75% of the trees are conifers that never lose their leaves. The area is more than 25% trees that are over 5 meters tall.
Shrubland	Shrubland	An area that is dominated by shrubs shorter than 5 meters tall. This consisted of shrubs and young trees in an early successional stage.
Early Succession & Pasture	ES/Pasture	An area that is dominated by grasses and can include oldfield, fallow ag fields and grasslands. Pasture includes areas that are grazed but are not planted or cultivated.
Row crop	Row crop	Any area that is planted or actively tilled producing harvestable products.
Water & Developed	Water/Developed	Any area that is a water source or is developed land that would not be considered potential nesting habitat.

Table 3. 2: Variables used to describe brood-site selection and poult survival for wild turkey broods in south-central, Tennessee, USA 2017-2018.

Variable	Abbreviation	Survival	Selection
Rain that occurred day prior of fate (mm)	RDPrior	Y	N
Rain that occurred day of fate (mm)	Rfate	Y	N
Distance (m) to			
Deciduous	DistDecid	Y	Y
Evergreen	DistEver	N	Y
Shrubland	DistS	Y	Y
ES/pasture	DistES	Y	Y
Row crop	DistRow	N	Y
Water/developed	DistWater	N	Y
Nearest edge	NearE	Y	Y
Nearest path or road	NearP	Y	Y
Total edge	TE	Y	Y
Contagion index	CONTAG	Y	Y
Interspersion and juxtaposition	IJI	Y	Y
Clumpiness index	CLUMPY		
ES/pasture	CES	Y	Y
Landscape make-up of a cover type (%)	PLAND		
ES/pasture	PES	Y	Y
Visual obstruction at 0-50 cm	VORlow	Y	Y
Visual obstruction at 101-200 cm	VORhigh	Y	Y
Number of woody stems in 5 m radius circle	Stem	Y	Y
Slope at brood site	Slope	Y	Y
Basal area of trees that are <25 cm DBH	BasalLow	Y	Y
Basal area of trees that are 25-45 cm DBH	BasalMed	Y	Y
Basal area of trees that are >45 cm DBH	BasalHigh	Y	Y
Abundance of plant groups			
Forbs	Forbs	Y	Y
Grasses	Grass	Y	Y
Brambles	Bram	Y	Y
Shrubs	Shrub	Y	Y
Daily Movement (m)	Move	Y	N
Julian Capture Date	CaptDate	Y	N

Table 3. 3: Description of the poult daily survival model suites and the corresponding notation for wild turkey broods in south-central, Tennessee, USA, 2017-2018.

Model	Model	Notation
Temporal and Group Models	Constant DSR	S(.)
	Linear Time	S(T)
	Quadratic Time	S(T+TT)
	Year	S(Year)
	Day 1-3, 4-7, 8-14, 15-30	S(Timebin)
	Hatch Date	S(HatchDate)
Rainfall and MovementVariables*	Rain Day Prior to Fate (mm)	S(RDPrior)
	Rain on Fate Date (mm)	S(Rfate)
	Average Daily Movement	S(AvgMove)
Landscape Variables*	Selection	S(DistS + DistD + CES)
	Distance to Cover Types (m)	
	Shrubland	S(DistS)
	ES/Pasture	S(DistES)
	Deciduous forest	S(DistD)
	Interspersion & Juxtapostion	S(IJI)
	Nearest Path & Road (m)	S(NearestPath)
	Nearest Edge (m)	S(NearEdge)
	Patch Type Percentage	
	ES/Pasture	S(PES)
	Deciduous forest	S(PDecid)
	Clumpiness index ES/Pasture	S(CES)
Brood-Site Specific Variables*	Selection	S(Forbs + NearEdge + Basalmed + SiteTube)
	Openness at Ground Level (m)	S(SiteTube)
	Visual Obstruction (0-50 cm)	S(VORlow)
	Basal Area of Medium Trees	S(Basal25to45cm)
	Plant Coverage	
	Grass	S(Grass)
	Forbs	S(Forbs)
	Shrubs	S(Shrubs)
	Brambles	S(Brambles)
Nest-Site Selection	Nest-site Selection	S(Covertype + EverDist + EverWater + NestCover + NearPath + VORlow + Slope)

*Variables broken up into 4 time intervals (1-3, 4-7, 8-14, 15-30)

Table 3. 4: The number of poults trapped, radio-tagged and success of those trapping attempts of successful hen wild turkeys in south-central, Tennessee, USA, 2017-18.

Year	**2017**	**2018**
Poults Trapped	63	35
Poults Tagged	52	30
Broods	22	11
Attempts	24	16
Success	22	11
Average Caught	2.65	2.33

Table 3. 5: Model selection results for landscape covariates related to resource-selection of wild turkey broods in south-central, Tennessee, USA, 2017-2018.

Models	K	AICc	ΔAICc	AICc Weight	LL
DistShrub + DistDecid + ClumpES + PlandRow	4	792.2628	0.0000	0.3159	-392.1114
DistShrub + DistDecid + ClumpES + PlandRow +PlandDecid	5	792.7647	0.5019	0.2458	-391.3523
DistShrub + DistDecid + ClumpES + PlandRow + TE	5	794.2019	1.9391	0.1198	-392.0709
DistShrub + DistDecid + ClumpES + PlandRow + PlandES	5	794.2376	1.9748	0.1177	-392.0888
DistShrub + DistDecid + ClumpES + PlandRow + IJI	5	794.2782	2.0154	0.1153	-392.1090
DistShrub + DistDecid + ClumpES + PlandRow + IJI + TE	6	796.2150	3.9521	0.0438	-392.0654
DistShrub + DistDecid + ClumpES + ShrubQuad	4	796.7636	4.5008	0.0333	-394.3620
DistShrub + DistDecid + ClumpES	3	802.8909	10.6281	0.0016	-398.4336
DistShrub + DistDecid + ClumpES +DistES + ESQuad	5	803.0437	10.7809	0.0014	-396.4921
DistShrub + DistDecid + ClumpES + DistEver + EverQuad	5	803.6079	11.3451	0.0011	-396.7742
DistShrub + DistDecid + ClumpES +DistES + PlandES + PlandDecid	6	803.6306	11.3678	0.0011	-395.7736
DistShrub + DistDecid + ClumpES + TE	4	804.5120	12.2492	0.0007	-398.2362
DistShrub + DistDecid + ClumpES + RowQuad + DistRow	5	804.7283	12.4655	0.0006	-397.3344
DistShrub + DistDecid + ClumpES + IJI	4	804.8703	12.6075	0.0006	-398.4153
DistShrub + DistDecid + ClumpES + DecidQuad	4	804.906	12.6436	0.00056758	-398.4334
DistShrub + DistDecid + ClumpES + PlandES + PlandDecid + IJI + TE	7	804.935	12.6719	0.00055962	-395.4116
DistShrub + DistDecid + ClumpES +DistES + PlandES	5	806.631	14.3681	0.00023965	-398.2857

Table 3. 6: Parameter estimates of landscape variables selected for brood sites by wild turkeys in south-central, Tennessee, USA, 2017-2018. Negative values for distance variables indicate positive association with the variable.

						Odds ratio CI	
Model	β	SE	Z	P	Odds ratio	Lower 95%	Upper 95%
Distance to Shrubland	-0.006	0.002	-2.90	≤.01	0.99	0.99	1.00
Distance to Deciduous	-0.011	0.004	-2.56	0.01	0.99	0.98	1.00
CLUMPY of ES & pasture	-0.694	0.311	-2.23	0.03	0.50	0.27	0.92
PLAND Row crop	0.010	0.017	0.58	0.56	1.01	0.98	1.05

Table 3. 7: Model selection results for site-specific covariates related to resource-selection of wild turkey broods in south-central, Tennessee, USA, 2017-2018.

Models	K	AICc	ΔAICc	AICc Weight	LL
Forbs + NearEdge + Basalmed + SiteTube	4	278.5031	0.0000	0.3695	-135.2037
Forbs + NearEdge + NearPath + Basalmed + SiteTube	5	280.2838	1.7807	0.1517	-135.0700
Forbs + NearEdge + SiteTube	3	280.3181	1.8150	0.1491	-137.1304
Forbs + NearEdge + CoverType	8	281.1241	2.6210	0.0997	-132.3906
Forbs + NearEdge + NearPath + Basalmed + VORlow + SiteTube	6	282.1116	3.6085	0.0608	-134.9548
Forbs + NearEdge + Basalmed	3	282.4761	3.9730	0.0507	-138.2099
Forbs + NearEdge + QuadEdge	3	283.3102	4.8071	0.0334	-138.6269
Forbs + NearEdge	2	283.8384	5.3352	0.0257	-139.9051
Forbs + NearEdge + NearPath + SiteTube + Grass	5	284.0138	5.5107	0.0235	-136.9350
Forbs + NearEdge + Lat	3	285.3533	6.8501	0.0120	-139.6485
Forbs + NearEdge + NearPath	3	285.6965	7.1933	0.0101	-139.8201
Forbs + NearEdge + QuadPath + NearPath	4	286.0168	7.5137	0.0086	-138.9614
Forbs + NearEdge + NearPath + Grass + Fern	5	288.5887	10.0855	0.0024	-139.2236
Forbs + Grass + Fern	3	288.6434	10.1403	0.0023	-141.2935
Forbs*EdgeChange + NearEdge*EdgeChange	23	292.3016	13.7985	0.0004	-121.7912
Forbs*County + NearEdge*County	14	297.8382	19.3351	0.0000	-134.4131
Forbs*Site + NearEdge*Site	29	314.9309	36.4277	0.0000	-126.2904
Null	1	592.0167	313.5136	0.0000	-295.0037

Table 3. 8: Parameter estimates of site-specific variables selected for brood sites by wild turkeys in south-central, Tennessee, USA, 2017-2018. Negative values for distance variables indicate positive association with the variable.

						Odds ratio CI	
Model	β	SE	Z	P	Odds ratio	Lower 95%	Upper 95%
Forbs	1.320	0.557	2.37	0.018	3.74	1.26	11.13
NearEdge	-0.459	0.282	-1.627	0.104	0.63	0.36	1.01
Basalmed	-0.006	0.003	-1.93	0.053	0.99	0.99	1.00
SiteTube	0.010	0.015	0.7	0.484	1.01	0.98	1.04

Table 3. 9: Linear regression results modeling daily movement in the time-intervals (1 = 1-3, 2 = 4-7, 3 = 8-14 and 5 = 15-30) and the percentage of ES/pasture within 277 m from the location and the abundance of herbaceous material present at wild turkey broods locations during those specific time intervals in south-central, Tennessee, USA, 2017-2018.

Covariate	Estimate	SE	P
PES1	0.084	0.018	≤ 0.01
PES2	-0.008	0.013	0.55
PES3	-0.012	0.014	0.39
PES4	-0.019	0.007	0.01
Herb1	0.988	1.418	0.49
Herb2	1.539	0.542	0.01
Herb3	-1.808	0.407	≤ 0.01
Herb4	1.342	0.679	0.06

Table 3. 10: Analysis of variance and pairwise t-tests for daily movement and abundance of herbaceous material present during the time intervals (1 = 1-3, 2 = 4-7, 3 = 8-14 and 5 = 15-30) for wild turkey broods in south-central, Tennessee, USA, 2017-2018.

ANOVA Analysis					
			95% CI		
Covariate	Mean	SE	lcl	ucl	P-value
Herb1	0.82	0.06	0.71	0.93	0.09
Herb2	0.80	0.04	0.71	0.88	
Herb3	0.80	0.05	0.70	0.91	
Herb4	0.60	0.08	0.45	0.75	
Move1	348	38.14	271.87	424.36	0.06
Move2	308	26.97	253.82	361.64	
Move3	250	36.85	176.66	323.97	
Move4	196	47.57	100.50	290.68	

Pairwise t-test					
Covariates	Difference	SE	lcl	ucl	P-value
Herb1 & Herb4	0.22	0.09	0.04	0.41	0.02
Herb3 & Herb4	0.21	0.09	0.02	0.39	0.03
Herb2 & Herb4	0.20	0.09	0.02	0.37	0.03
Herb1 & Herb2	0.02	0.07	-0.12	0.16	0.73
Herb1 & Herb3	0.02	0.08	-0.13	0.17	0.83
Herb3 & Herb2	0.01	0.07	-0.13	0.14	0.90
Move1 & Move4	152.52	60.97	30.64	274.40	0.02
Move2 & Move4	112.14	54.68	2.83	221.45	0.04
Move1 & Move3	97.80	53.03	-8.21	203.81	0.07
Move2 & Move3	57.42	45.66	-33.86	148.70	0.21
Move3 & Move4	54.72	60.17	-65.56	175.00	0.37
Move1 & Move2	40.39	46.71	-52.99	133.76	0.39

Table 3. 11: Model selection results for temporal covariates related to daily survival rate of wild turkey poults in south-central, Tennessee, USA, 2017-2018.

Model	K	AICc	ΔAICc	AIC_c weight	Deviance
S(~HatchDate)	2	340.8741	0.0000	0.5022	336.8490
S(~Year)	2	341.8475	1.1294	0.2966	70.9268
S(~1)	1	343.7606	3.0425	0.1139	74.8566
S(~Time)	2	344.7978	4.0796	0.0678	73.8770

Table 3. 12: Model selection results for rainfall and movement covariates related to daily survival rate of wild turkey poults in south-central, Tennessee, USA, 2017-2018.

Model	K	AICc	ΔAICc	AIC_c weight	Deviance
S(~HatchDate + Move)	3	335.8569	0	0.6712	329.8064
S(~Year + Move)	3	339.5114	3.6546	0.1080	333.4610
S(~HatchDate)	2	340.8741	5.0173	0.0546	336.8490
S(~HatchDate + Rfate)	3	341.8422	5.9854	0.0337	335.7918
S(~Year)	2	341.8475	5.9907	0.0336	70.9268
S(~Move)	2	342.1564	6.2995	0.0288	338.1312
S(~HatchDate + RDPrior)	3	342.6573	6.8005	0.0224	336.6069
S(~Year + RDPrior)	3	343.7295	7.8727	0.0131	337.6791
S(~1)	1	343.7606	7.9037	0.0129	74.8566
S(~Year + Rfate)	3	343.8727	8.0158	0.0122	337.8222
S(~Rfate)	2	345.7264	9.8696	0.0048	341.7013
S(~RDPrior)	2	345.7710	9.9142	0.0047	341.7459

Table 3. 13: Model selection results for landscape covariates related to daily survival rate of wild turkey poults in south-central, Tennessee, USA, 2017-2018.

Model	K	AICc	ΔAICc	AIC_c weight	Deviance
S(~Move + HatchDate)	3	335.8569	0	0.2023	329.8064
S(~IJI + Move + HatchDate)	4	337.1268	1.2700	0.1072	329.0426
S(~CES + Move + HatchDate)	4	337.3966	1.5398	0.0937	329.3124
S(~DistS + Move + HatchDate)	4	337.4678	1.6110	0.0904	329.3836
S(~DistES + Move + HatchDate)	4	337.4698	1.6129	0.0903	329.3856
S(~PDecid + Move + HatchDate)	4	337.6537	1.7969	0.0824	329.5695
S(~PES + Move + HatchDate)	4	337.8482	1.9913	0.0748	329.7640
S(~DistD + Move + HatchDate)	4	337.8510	1.9941	0.0747	329.7668
S(~NearP + Move + HatchDate)	4	337.8571	2.0002	0.0744	329.7729
S(~NearE + Move + HatchDate)	4	337.8843	2.0275	0.0734	329.8001
S(~Selected + Move + HatchDate)	6	340.8730	5.0161	0.0165	328.6954
S(~1)	1	343.7606	7.9037	0.0039	74.8566
S(~NearP)	2	344.8918	9.0350	0.0022	340.8667
S(~DistD)	2	344.9683	9.1115	0.0021	340.9432
S(~NearE)	2	345.1512	9.2943	0.0019	341.1260
S(~PES)	2	345.2967	9.4398	0.0018	341.2715
S(~DistES)	2	345.5283	9.6715	0.0016	341.5032
S(~IJI)	2	345.6617	9.8049	0.0015	341.6366
S(~CES)	2	345.6948	9.8380	0.0015	341.6697
S(~PDecid)	2	345.7089	9.8521	0.0015	341.6838
S(~DistS)	2	345.7164	9.8595	0.0015	341.6912
S(~Selected)	4	348.9487	13.0919	0.0003	340.8645
S(~Global + Move + HatchDate)	12	352.3231	16.4663	0.0001	327.6550
S(~Global)	10	358.6407	12.7839	0.0000	338.1716

Table 3. 14: Model selection results for site-specific covariates related to daily survival rate of wild turkey poults in south-central, Tennessee, USA, 2017-2018.

Model	K	AICc	ΔAICc	AIC_c weight	Deviance
S(~Move + HatchDate)	3	335.8569	0	0.0622	329.8064
S(~Grass + Move + HatchDate)	4	336.8755	1.0186	0.0374	328.7913
S(~IJI + Move + HatchDate)	4	337.1268	1.2700	0.0330	329.0426
S(~Forbs + Move + HatchDate)	4	337.3232	1.4663	0.0299	329.2390
S(~CES + Move + HatchDate)	4	337.3966	1.5398	0.0288	329.3124
S(~DistS + Move + HatchDate)	4	337.4678	1.6110	0.0278	329.3836
S(~DistES + Move + HatchDate)	4	337.4698	1.6129	0.0278	329.3856
S(~PDecid + Move + HatchDate)	4	337.6537	1.7969	0.0253	329.5695
S(~Bmed + Move + HatchDate)	4	337.8098	1.9530	0.0234	329.7256
S(~Bram + Move + HatchDate)	4	337.8244	1.9676	0.0233	329.7402
S(~PES + Move + HatchDate)	4	337.8482	1.9913	0.0230	329.7640
S(~DistD + Move + HatchDate)	4	337.851	1.9941	0.0230	329.7668
S(~VORlow + Move + HatchDate)	4	337.8813	2.0244	0.0226	329.7970
S(~SiteT + Move + HatchDate)	4	337.8854	2.0285	0.0226	329.8012
S(~Shrubs + Move + HatchDate)	4	337.8895	2.0326	0.0225	329.8053
S(~Grass + DistS + Move + HatchDate)	5	338.1548	2.2980	0.0197	328.0282
S(~Grass + CES + Move + HatchDate)	5	338.2367	2.3799	0.0189	328.1102
S(~Grass + IJI + Move + HatchDate)	5	338.3909	2.5340	0.0175	328.2643
S(~Grass + DistES + Move + HatchDate)	5	338.412	2.5551	0.0173	328.2854
S(~Forbs + DistES + Move + HatchDate)	5	338.422	2.5651	0.0173	328.2954
S(~Forbs + DistS + Move + HatchDate)	5	338.7122	2.8553	0.0149	328.5856
S(~Grass + PDecid + Move + HatchDate)	5	338.7696	2.9127	0.0145	328.6430
S(~Forbs + IJI + Move + HatchDate)	5	338.8561	2.9993	0.0139	328.7295
S(~Grass + DistD + Move + HatchDate)	5	338.8702	3.0134	0.0138	328.7436
S(~Forbs + CES + Move + HatchDate)	5	338.8902	3.0334	0.0137	328.7636
S(~Grass + PES + Move + HatchDate)	5	338.9125	3.0557	0.0135	328.7859
S(~Forbs + PDecid + Move + HatchDate)	5	338.9715	3.1147	0.0131	328.8449
S(~Bram + IJI + Move + HatchDate)	5	339.1048	3.2480	0.0123	328.9782
S(~Bmed + IJI + Move + HatchDate)	5	339.1314	3.2745	0.0121	329.0048
S(~VORlow + IJI + Move + HatchDate)	5	339.1334	3.2766	0.0121	329.0068
S(~Shrubs + IJI + Move + HatchDate)	5	339.1404	3.2836	0.0121	329.0139
S(~SiteT + IJI + Move + HatchDate)	5	339.1692	3.3123	0.0119	329.0426

Table 3. 14: Continued

Model	K	AICc	ΔAICc	AICc weight	Deviance
S(~Forbs + DistD + Move + HatchDate)	5	339.3247	3.4678	0.0110	329.1981
S(~Forbs + PES + Move + HatchDate)	5	339.3654	3.5085	0.0108	329.2388
S(~Bmed + CES + Move + HatchDate)	5	339.4018	3.5450	0.0106	329.2753
S(~VORlow + CES + Move + HatchDate)	5	339.4031	3.5463	0.0106	329.2766
S(~Shrubs + CES + Move + HatchDate)	5	339.4235	3.5667	0.0105	329.2970
S(~SiteT + CES + Move + HatchDate)	5	339.4258	3.5690	0.0104	329.2992
S(~Bram + CES + Move + HatchDate)	5	339.4282	3.5714	0.0104	329.3016
S(~Bram + DistS + Move + HatchDate)	5	339.4819	3.6250	0.0102	329.3553
S(~Shrubs + DistES + Move + HatchDate)	5	339.4824	3.6256	0.0102	329.3559
S(~Bmed + DistS + Move + HatchDate)	5	339.4826	3.6257	0.0102	329.3560
S(~VORlow + DistES + Move + HatchDate)	5	339.4846	3.6277	0.0101	329.3580
S(~Shrubs + DistS + Move + HatchDate)	5	339.4901	3.6332	0.0101	329.3635
S(~VORlow + DistS + Move + HatchDate)	5	339.4926	3.6358	0.0101	329.3661
S(~Bmed + DistES + Move + HatchDate)	5	339.4985	3.6417	0.0101	329.3719
S(~Bram + DistES + Move + HatchDate)	5	339.5031	3.6463	0.0101	329.3765
S(~SiteT + DistS + Move + HatchDate)	5	339.509	3.6522	0.0100	329.3824
S(~SiteT + DistES + Move + HatchDate)	5	339.5104	3.6536	0.0100	329.3839
S(~Bmed + PDecid + Move + HatchDate)	5	339.6383	3.7815	0.0094	329.5117
S(~VORlow + PDecid + Move + HatchDate)	5	339.6666	3.8098	0.0093	329.5401
S(~Bram + PDecid + Move + HatchDate)	5	339.6797	3.8229	0.0092	329.5531
S(~SiteT + PDecid + Move + HatchDate)	5	339.686	3.8291	0.0092	329.5594
S(~Shrubs + PDecid + Move + HatchDate)	5	339.6949	3.8381	0.0091	329.5684
S(~Bram + PES + Move + HatchDate)	5	339.777	3.9201	0.0088	329.6504
S(~Bmed + DistD + Move + HatchDate)	5	339.7935	3.9367	0.0087	329.6669
S(~Bmed + PES + Move + HatchDate)	5	339.8055	3.9486	0.0086	329.6789
S(~Bram + DistD + Move + HatchDate)	5	339.8061	3.9493	0.0086	329.6795
S(~VORlow + PES + Move + HatchDate)	5	339.8832	4.0263	0.0083	329.7566
S(~VORlow + DistD + Move + HatchDate)	5	339.8849	4.0281	0.0083	329.7583
S(~SiteT + PES + Move + HatchDate)	5	339.886	4.0291	0.0083	329.7594
S(~Shrubs + DistD + Move + HatchDate)	5	339.889	4.0322	0.0083	329.7625
S(~SiteT + DistD + Move + HatchDate)	5	339.8904	4.0335	0.0083	329.7638

Table 3. 14: Continued

Model	K	AICc	ΔAICc	AICc weight	Deviance
S(~Shrubs + PES + Move + HatchDate)	5	339.8905	4.0336	0.0083	329.7639
S(~Select + Move + HatchDate)	7	343.07	7.2132	0.0017	328.8327
S(~1)	1	343.7606	7.9037	0.0012	46.0271
S(~Select + DistES + Move + HatchDate)	8	344.0822	8.2253	0.0010	327.7765
S(~Select + DistS + Move + HatchDate)	8	344.4876	8.6307	0.0008	328.1819
S(~Select + Move + HatchDate)	8	344.6738	8.8170	0.0008	328.3681
S(~Select + Move + HatchDate)	8	344.6918	8.8349	0.0008	328.3860
S(~Select + CES + Move + HatchDate)	8	344.7408	8.8840	0.0007	328.4351
S(~VORlow)	2	344.9206	9.0637	0.0007	340.8954
S(~Select + DistD + Move + HatchDate)	8	345.0495	9.1927	0.0006	328.7438
S(~Select + PES + Move + HatchDate)	8	345.1321	9.2752	0.0006	328.8263
S(~Grass)	2	345.2572	9.4004	0.0006	341.2321
S(~Shrubs)	2	345.3716	9.5147	0.0005	341.3464
S(~SiteT)	2	345.4006	9.5437	0.0005	341.3754
S(~Forbs)	2	345.555	9.6982	0.0005	341.5299
S(~Bram)	2	345.7428	9.8859	0.0004	341.7176
S(~Bmed)	2	345.7475	9.8906	0.0004	341.7223
S(~Global + Move + HatchDate)	10	347.4893	11.6324	0.0002	327.0202
S(~Global + DistS + Move + HatchDate)	11	348.5117	12.6549	0.0001	325.9476
S(~Global + DistES + Move + HatchDate)	11	348.5782	12.7213	0.0001	326.0141
S(~Global + CES + Move + HatchDate)	11	349.2016	13.3447	0.0001	326.6375
S(~Global + PDecid + Move + HatchDate)	11	349.3276	13.4707	0.0001	326.7635
S(~Global + IJI + Move + HatchDate)	11	349.4399	13.5830	0.0001	326.8758
S(~Global + DistD + Move + HatchDate)	11	349.4547	13.5979	0.0001	326.8906
S(~Global + PES + Move + HatchDate)	11	349.5444	13.6876	0.0001	326.9803
S(~Select)	5	350.6041	14.7472	0.0000	340.4775
S(~Global)	8	355.5312	19.6743	0.0000	339.2254

Table 3. 15: Daily survival estimates of the top model that included movement and hatch date to explain survival for wild turkey poults in south-central, Tennessee, USA, 2017-2018.

							95% CI	
Year	Days	Estimate	SE	lcl	ucl	Survival	lcl	ucl
2017-2018	1-3	0.90403	0.01593	0.867948	0.931033	73.88%	65.39%	80.70%
	4-7	0.90349	0.015878	0.867576	0.930443	66.63%	56.65%	74.95%
	8-14	0.87411	0.016044	0.839163	0.902342	38.99%	29.30%	48.71%
	15-30	0.85495	0.020349	0.810359	0.890474	9.53%	4.27%	17.55%

Table 3. 16: Daily survival estimates for year within the time-intervals (1-3, 4-7, 8-14 and 15-30 days) to explain survival for wild turkey poults in south-central, Tennessee, USA, 2017-2018.

							95% CI	
Year	Days	Estimate	SE	lcl	ucl	Survival	lcl	ucl
2017	1-3	0.97841	0.02141	0.86149	0.99698	93.66%	63.94%	99.10%
	4-7	0.87824	0.02621	0.81689	0.92102	59.49%	44.53%	71.96%
	8-14	0.79546	0.03789	0.71130	0.85993	20.15%	9.21%	34.77%
	15-30	0.87382	0.05457	0.72416	0.94810	13.22%	0.79%	44.96%
2018	1-3	0.98837	0.01197	0.91693	0.99847	96.55%	77.09%	99.54%
	4-7	0.93119	0.02339	0.86870	0.96513	75.19%	56.95%	86.76%
	8-14	0.87946	0.03334	0.79752	0.93111	40.69%	20.52%	60.67%
	15-30	0.92853	0.02895	0.84676	0.96830	32.88%	8.25%	61.68%

Table 3. 17: Model selection results for wild turkey nest-site selection covariates related to daily survival rate of wild turkey poults in south-central, Tennessee, USA, 2017-2018.

Models	K	AICc	ΔAICc	AICc Weight	LL
S(~GrassDist + NestP1)	3	44.8767	0.0000	0.3434	38.6187
S(~Nlow1 + NC1 + NestS1)	4	46.3046	1.4278	0.1682	37.8698
S(~1)	1	47.0585	2.1818	0.1153	5.5294
S(~Nlow1 + NestS1 + NestP1 + I(NestP1^2))	5	47.7027	2.8260	0.0836	37.0434
S(~Nlow1 + GrassPland + GrassDist + NestP1)	5	48.1466	3.2699	0.0669	37.4873
S(~Nlow1 + NC1)	3	48.7412	3.8644	0.0497	42.4831
S(~Landscape Variables)	10	49.1620	4.2853	0.0403	26.6039
S(~GrassPland + GrassDist)	3	49.2900	4.4133	0.0378	43.0320
S(~DecPland + DecidDist)	3	50.0187	5.1419	0.0263	43.7606
S(~NearEdge + DecidDist + GrassDist + ShrubDist)	5	50.2171	5.3404	0.0238	39.5578
S(~IJI + DecPland + GrassPland + ShrubPland)	5	50.2897	5.4130	0.0229	39.6304
S(~GrassPland + GrassDist + I(GrassDist^2))	4	51.4667	6.5900	0.0127	43.0320
S(~DecPland + DecidDist + I(DecidDist^2))	4	52.1954	7.3186	0.0088	43.7606
S(~Global)	14	59.4887	14.6119	0.0002	26.3667

Table 3. 18: Parameter estimates of the top wild turkey nest-site selection models that best explained daily survival for wild turkey poults in south-central, Tennessee, USA, 2017-2018.

				95% CI	
Model	Parameter	Estimate	SE	Lower	Upper
GrassDist and NestP1	GrassDist	-0.0013	0.0049	-0.011	0.0084
	NestP1	-0.0208	0.0081	-0.0367	-0.0048
Nlow and NC and NestS	Nlow	0.1832	0.4324	-0.6643	1.0306
	NC	0.0238	0.0377	-0.05	0.0976
	NestS	-0.1428	0.0768	-0.2932	0.0077

Table 3. 19: Wild turkey poult survival estimates using 4-week flush counts from studies of populations that were stable/increasing or decreasing to compare to this study in south-central, Tennessee, USA, 2017-2018.

Population Trend	Author	Year	Survival
Stable	Vangilder et al 1987	1981-85	61.9
Stable	Roberts and Porter 1998	1991-93	44.9
Stable	Delahunt et al. 2011	2008-10	25.4
Stable	Vangilder et al 1987	1986-88	53.4
Declining	Palmer et al. 1993	1984-1992	22.7
Declining	Thogmartin and Johnson 1999	1993-96	23.4
Declining	Peoples et al. 1995	1988-93	9.2
Declining	Isabelle et al. 2016	2017	6
Current	Current	2017	6.1
Current	Current	2018	24.1

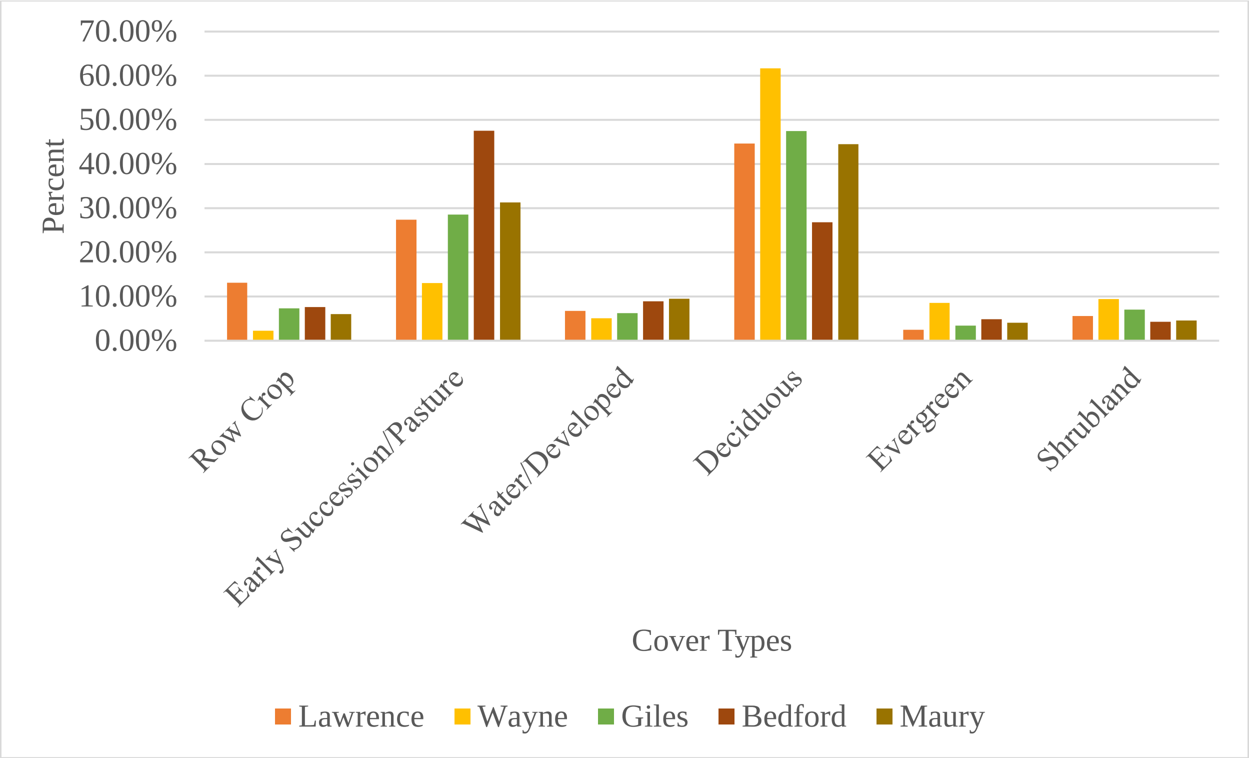

Figure 3. 1: Cover type composition (%) of the five study counties in south-central, Tennessee, USA, 2017-2018.

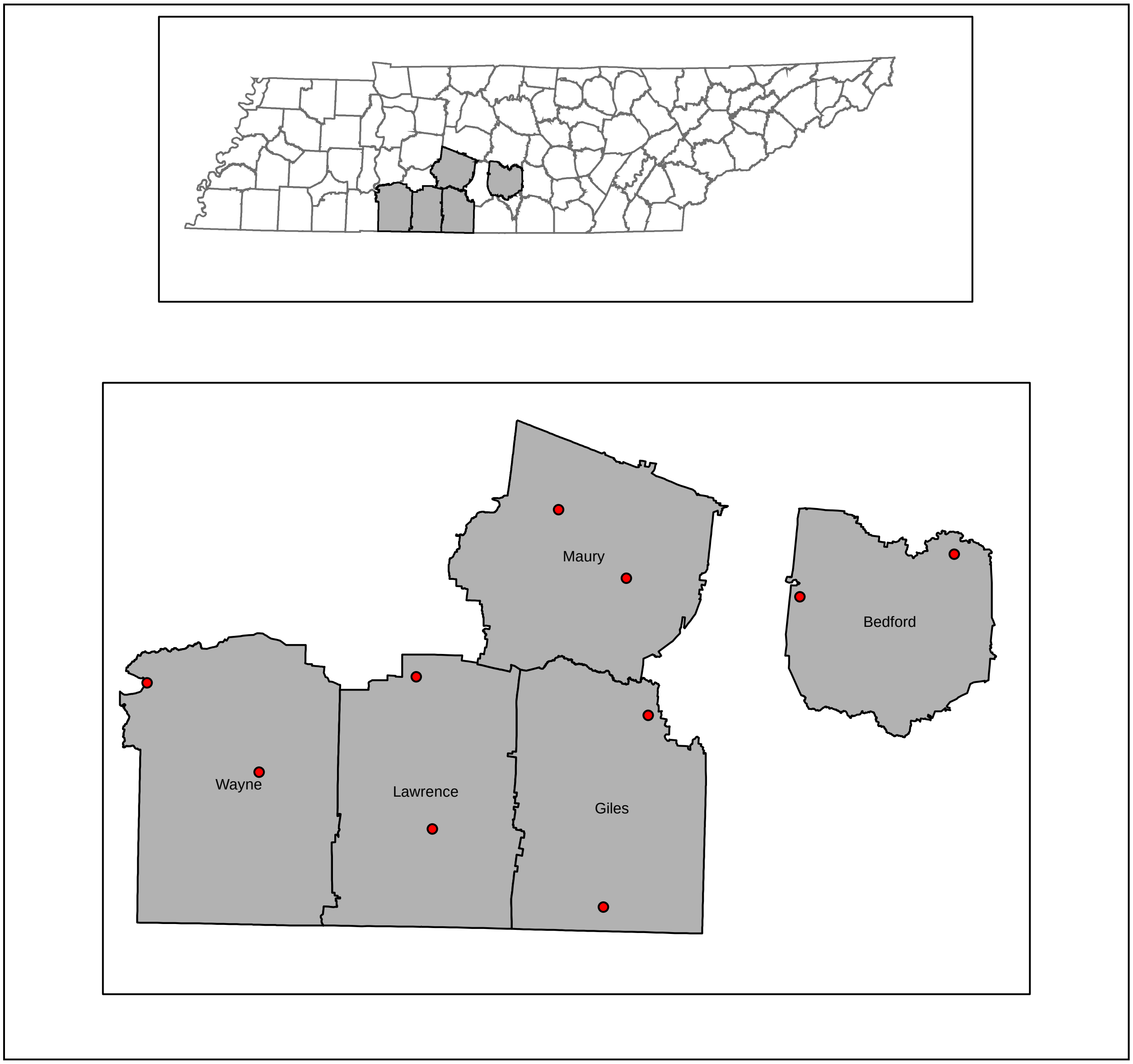

Figure 3. 2: Map of the study area and study site locations within each county of south-central, Tennessee, USA, 2017-2018.

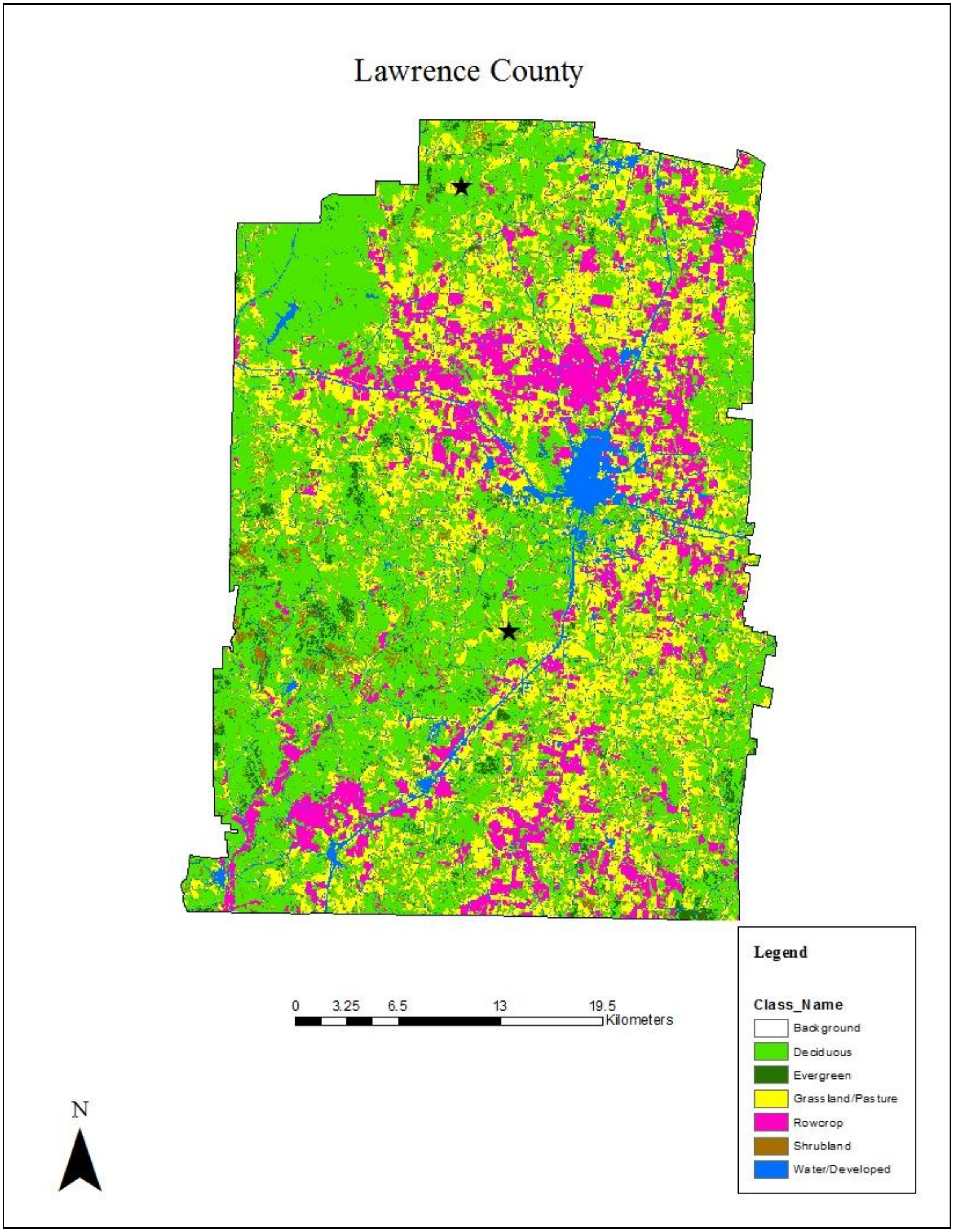

Figure 3. 3: Cover type map of Lawrence County, TN with study site locations, 2017-2018.

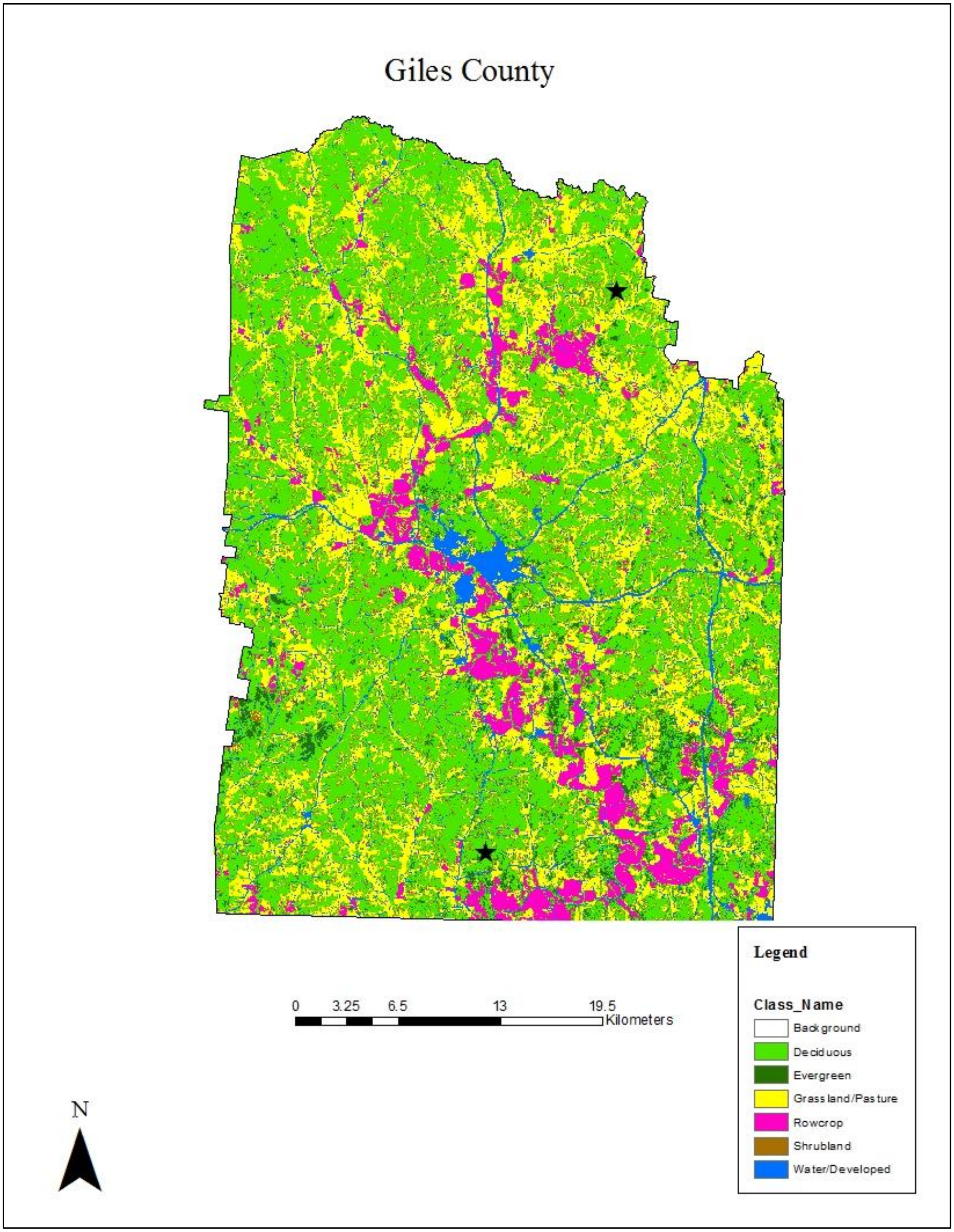

Figure 3. 4: Cover type map for Giles County, TN and the study site locations, 2017-2018.

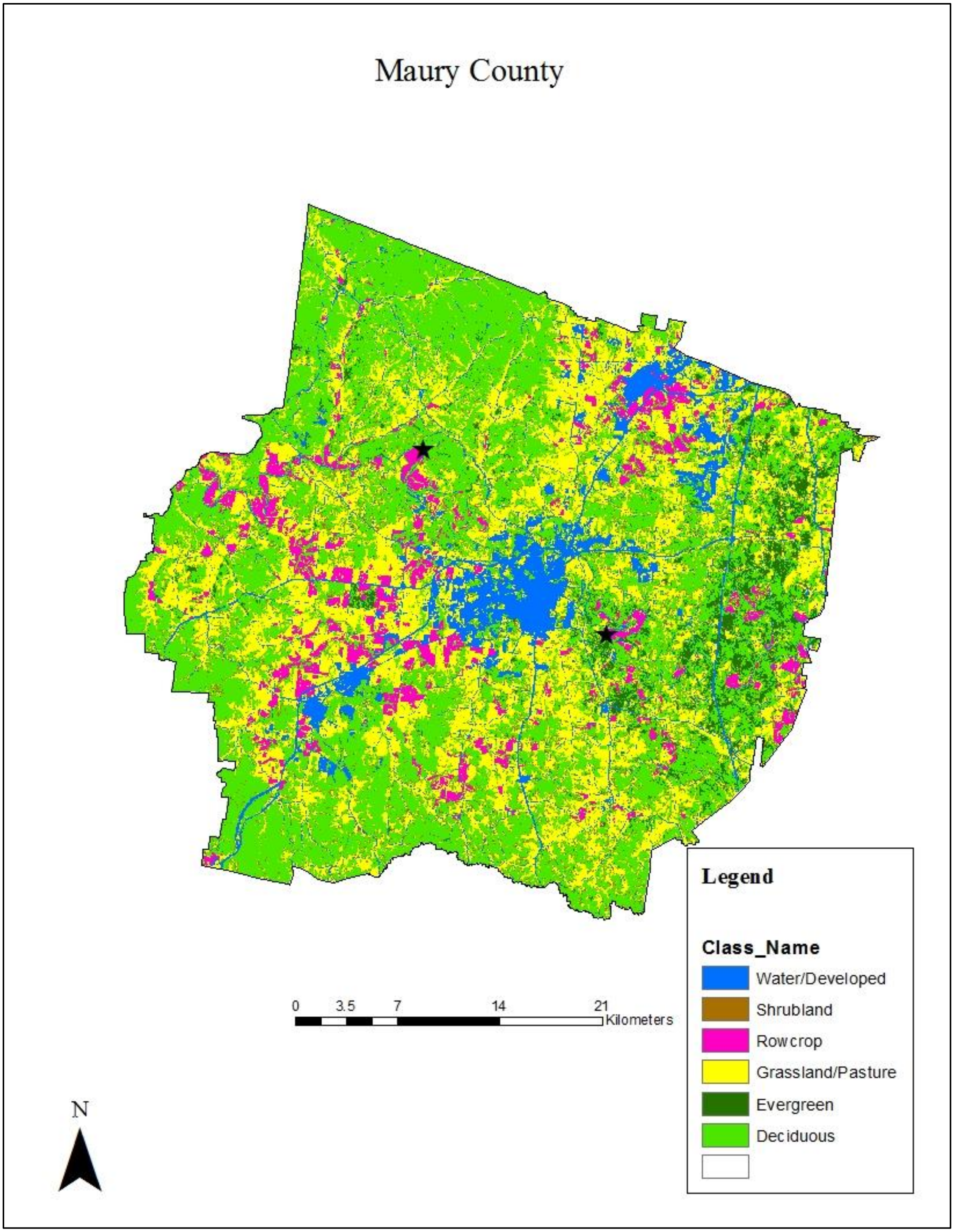

Figure 3. 5: Cover type map of Maury County, TN with study site locations, 2017-2018.

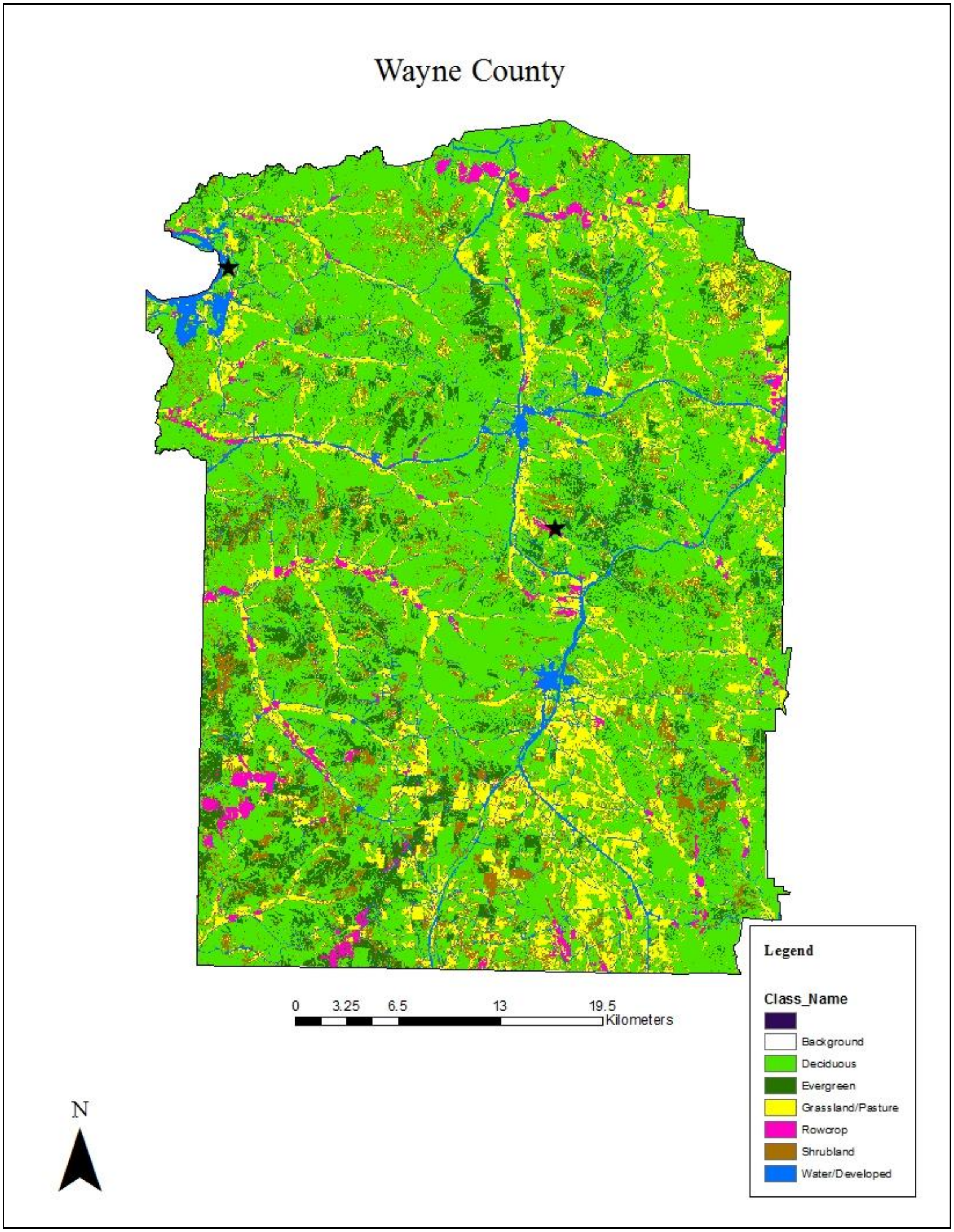

Figure 3. 6: Cover type map of Wayne County, TN with study site locations, 2017-2018.

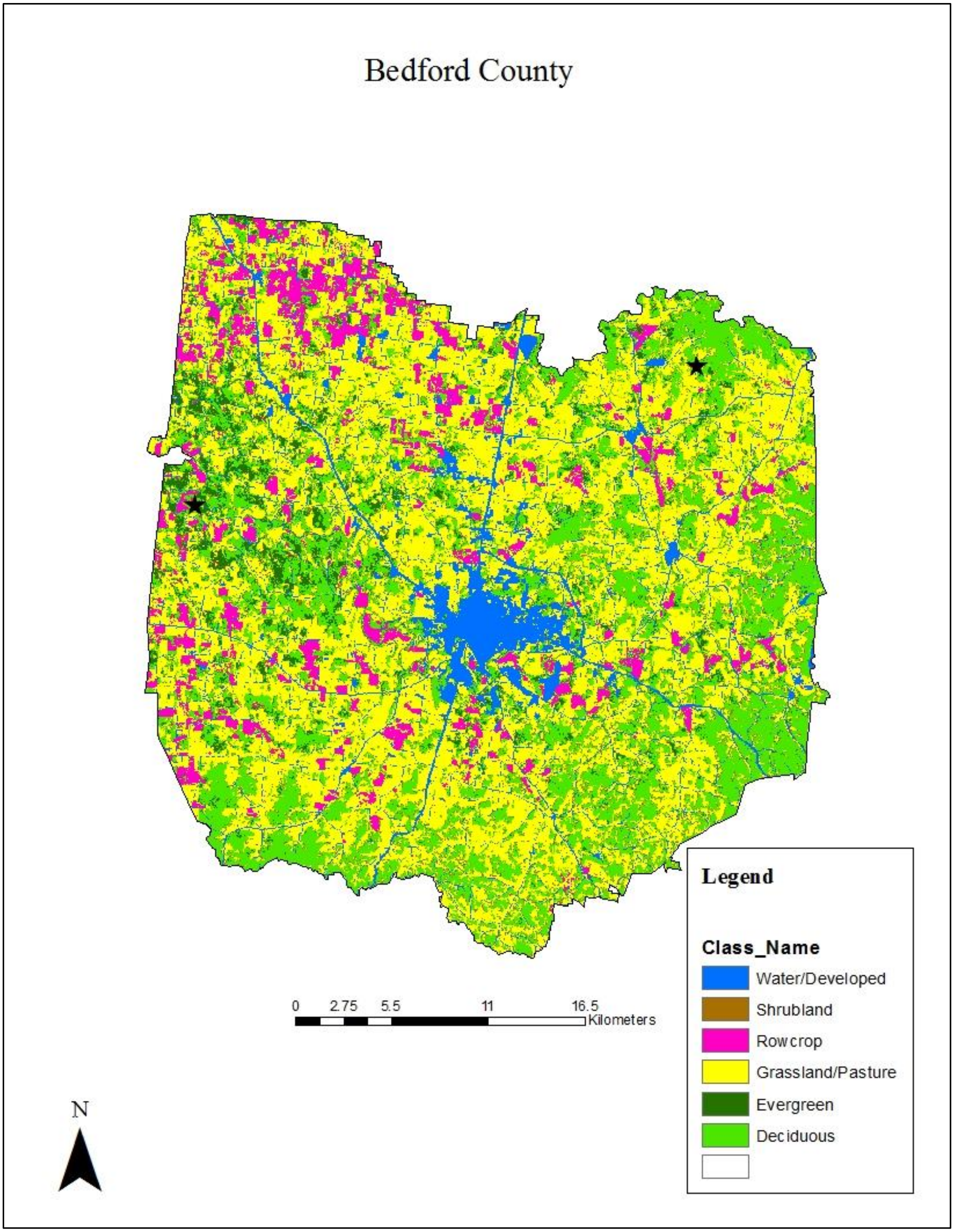

Figure 3. 7: Cover type map for Bedford County, TN with study site locations, 2017-2018.

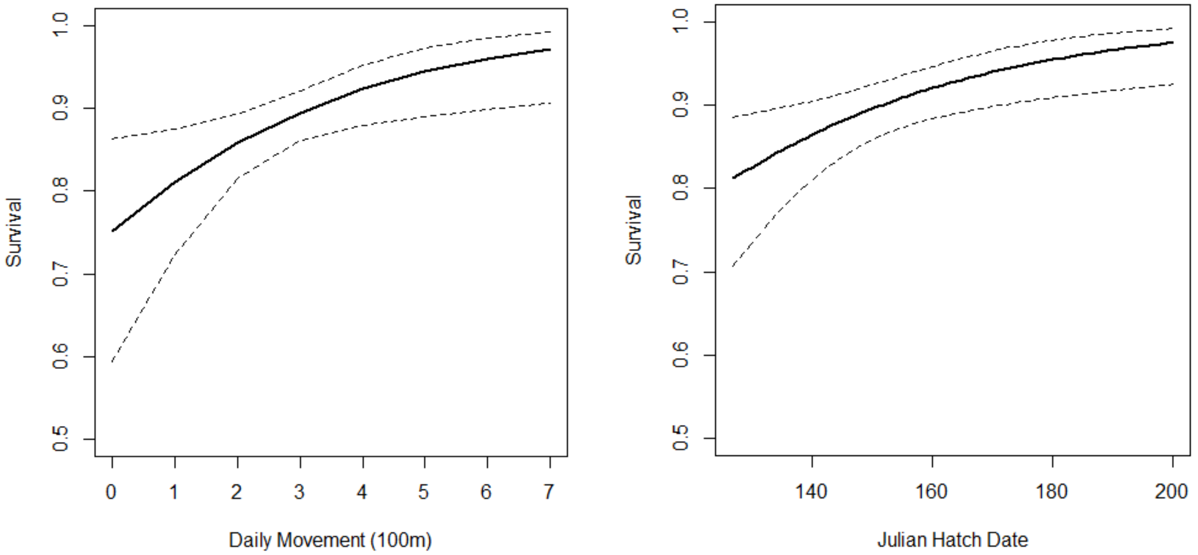

Figure 3. 8: Survival curves for daily movement (100 m) and Julian hatch date for wild turkey poults in south-central Tennessee, USA 2017-2018.

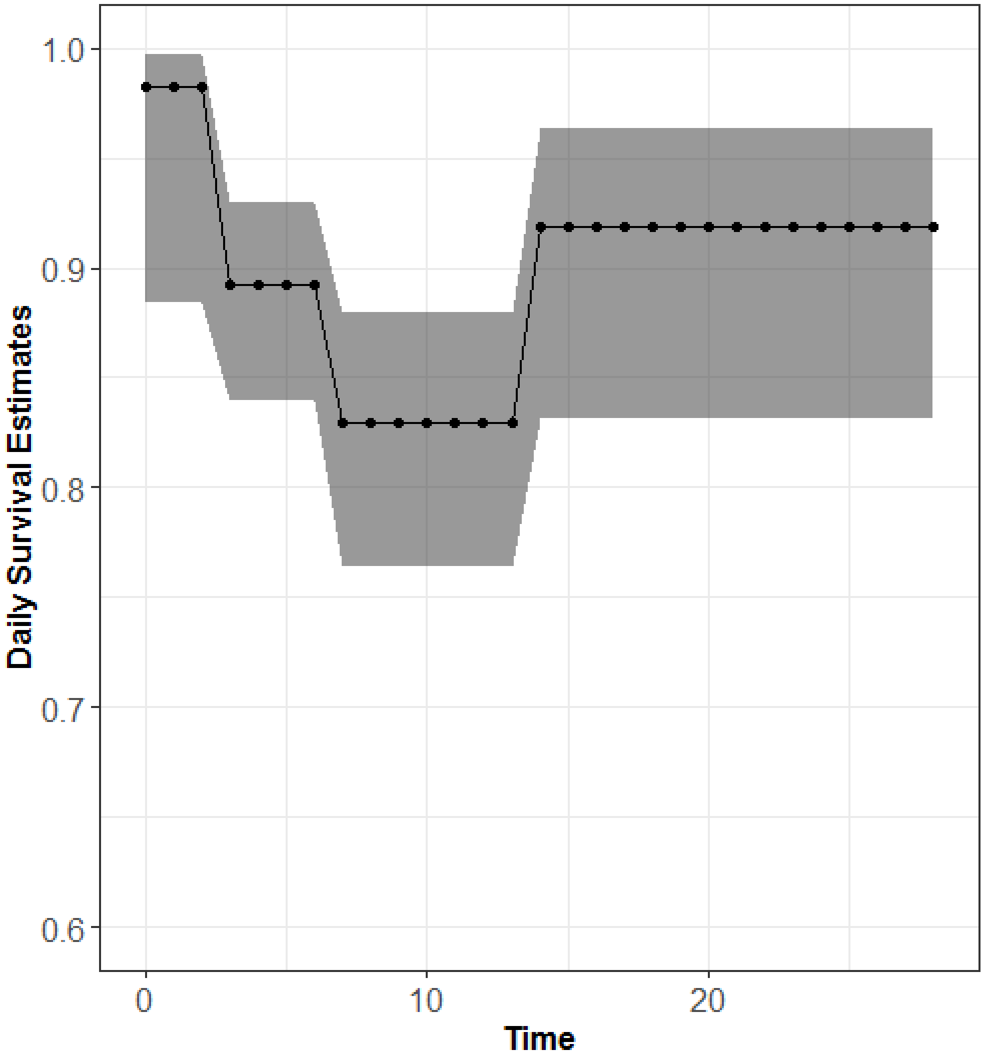

Figure 3. 9: Daily survival during days 1-3, 4-7, 8-14 and 15-30 for wild turkey poults in south-central, Tennessee, USA 2017-2018.

Part IV: Conclusion

Introduction

Recent declines in wild turkey harvest in south-central Tennessee have created the need to better understand whether reproductive parameters are linked to apparent population declines. We collected data on nesting rates, nest success, clutch size, hatching rates and poult survival for two years (2017-2018) in five counties in south-central Tennessee. Our goal was to compare Tennessee reproductive parameters with parameters from studies with comparable data collection and analysis methods where turkey populations were increasing, stable, or decreasing. Seasonal productivity, as measured by poult per hen ratio, has declined in Tennessee (Byrne et al. 2016), such that there is the need to identify the underlying causal factors. If the reproductive parameters which are having the greatest (positive or negative) effect on productivity can be identified, management strategies may be developed to target the deficiencies.

Depending on which reproductive parameters are most limiting, focused management addressing the specific limiting factor(s) would be required on both public and private lands to at least stabilize populations. Predation of nests and poults (this study and others) has been shown to be the single factor most responsible for poor productivity. However, managing predator populations directly through legal trapping and hunting has been shown to be virtually impossible except in very localized and intensely managed situations (Garrettson and Rohwer 2001, Pearse and Ratti 2004). Therefore, the only available management alternative is to improve habitat quality with the goal of making nesting sites and brooding-rearing areas less susceptible to predation. Resource-selection data for both nesting and brood-rearing allows a better understanding of what hens are selecting for and how available nesting and brood-rearing habitat are. Survival analyses show how selection of specific habitat attributes is linked to nest and poult survival. We have shown that nesting and brood-rearing habitat are structurally different, therefore management of each will need separate prescriptions, but ultimately a property likely will need to incorporate management for both nesting and brood-rearing habitat to have a positive impact on the population.

Reproductive Parameters: Stable or Declining?

By comparing reproductive data from 2017 and 2018 to past research, we demonstrated that reproductive parameters for the population in south-central Tennessee are consistent with reproductive parameters of declining populations of wild turkeys elsewhere. Our nesting and renesting rates were very similar to declining populations and were ~20% lower than stable or increasing populations (Figure 4.1). Total nest success was ~10% lower than increasing/stable populations, but comparable again to declining populations (Figure 4.1). Our average clutch size from successful nests (9.3) was also comparable to declining populations that ranged from 10.0 (Pittman and Krementz 2016) to 8.4 (Thogmartin and Johnson 1999) (Figure 4.2). Average clutch size of abandoned nests (11.5), though a small sample size, indicated a more typical clutch size for wild turkeys, suggesting that our low clutch size at hatch likely was caused by partial nest predation. The consistently below average nesting parameters in our population ultimately led to poult production (at hatch) to be 3-5 poults per hen less than poult production from stable or increasing populations. Finally, based on 28-day flush counts of solitary, successful hens (2017 = 6.1%; 2018 = 24.1%), poult survival for the critical first few weeks of life again was consistent with declining populations and less than stable/increasing populations (Figure 4.3). As a result, through every stage of the reproductive life cycle, our parameter estimates were less than parameter estimates from stable/increasing populations and very consistent with parameter estimates from declining populations. Ultimately the population is declining because seasonal productivity is insufficient to offset annual mortality.

Selection, Survival and Habitat Management Recommendations

Based on the data we gathered for resource selection at nesting and brood-rearing sites, and how that affects survival, we can provide habitat recommendations that would increase both nesting and brood-rearing habitat availability. Hens used a large area during pre-nesting (2017 = 196.2 ha; 2018 = 185.4 ha) and a much smaller area during brood-rearing (95% MCP = 48.7 ha and 50% MCP = 9.7 ha), so both landscape and site-specific management prescriptions are needed.

Shrubland and old field cover types were not readily available on the landscape but were strongly selected for as nesting sites. Hens also selected for increased visual obstruction and cover above the nest, and nest sites close to a path or road. Importantly, not only was cover at the nest selected for, but it also had a positive link to nest survival. The availability of quality nesting cover that provides sufficient cover to ensure successful nesting appears to be limited on the landscape through lack of appropriate cover types. As a result, hens place nests in sub-optimal cover types and cover at the nest, leading to an increased risk of nest predation. Management to provide increased availability of shrubland and old field cover types with appropriate site-specific structure, then, would likely enhance nesting habitat quality and availability.

Nest-site selection also had a positive impact on poult survival; nest-sites closer to roads or paths had greater poult survival for the first 4 days of life. Because nest sites and brood-rearing sites have different structural characteristics, a hen must move a brood after hatching some distance to get into appropriate brood habitat. The availability of travel corridors to facilitate this movement thus enhanced poult survival. Provision of such travel corridors strategically located throughout the landscape that link nesting habitat with brood-rearing habitat, then, would likely enhance poult survival hence seasonal productivity.

Hens selected brood-rearing areas on the landscape where herbaceous cover was more dispersed and chose to be closer to deciduous forest and shrubland cover types. The percentage of herbaceous cover increased with movements for the first three days of life, which showed that hens were moving broods towards areas with greater herbaceous cover. Once they arrived at these open patches they did not stay for long, presumably because the structure was inadequate for poults. As a result, hens continued to move greater daily distances, thus improving survival by moving between areas of quality structure. Most open fields in this study had either too dense or too open ground-level structure that would either impede poult movement or provide less than adequate cover, such that hens used field edges or adjacent forests as an alternative. Management prescriptions which led to dispersed, forb-dominated vegetation patches (fields) with greater openness at ground-level could enhance the quality of fields as brood-rearing habitat.

In summary, we have documented that poor seasonal productivity is likely responsible for declining wild turkey populations in south-central Tennessee, We have documented the key habitat characteristics which define nesting and brood-rearing habitat and have documented which habitat characteristics are selected for and are linked to both nest and poult survival. Assuming nesting and brood-rearing habitat quality and availability are key limiting factors, we have developed the following list of management actions to address the assumed deficiencies.

1) Manage to provide increased availability of shrubland and old field cover types with greater visual obstruction and cover at the site-specific scale.

2) Manage the landscape to have more quality brood habitat that is forb dominated, has greater openness at ground-level and is dispersed throughout the average brood-rearing home range (48.7 ha).
3) Provide travel corridors with appropriate structure strategically throughout the landscape to link nesting habitat with brood-rearing habitat, and to facilitate movement from nesting locations to quality brood-rearing habitat.

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Appendix

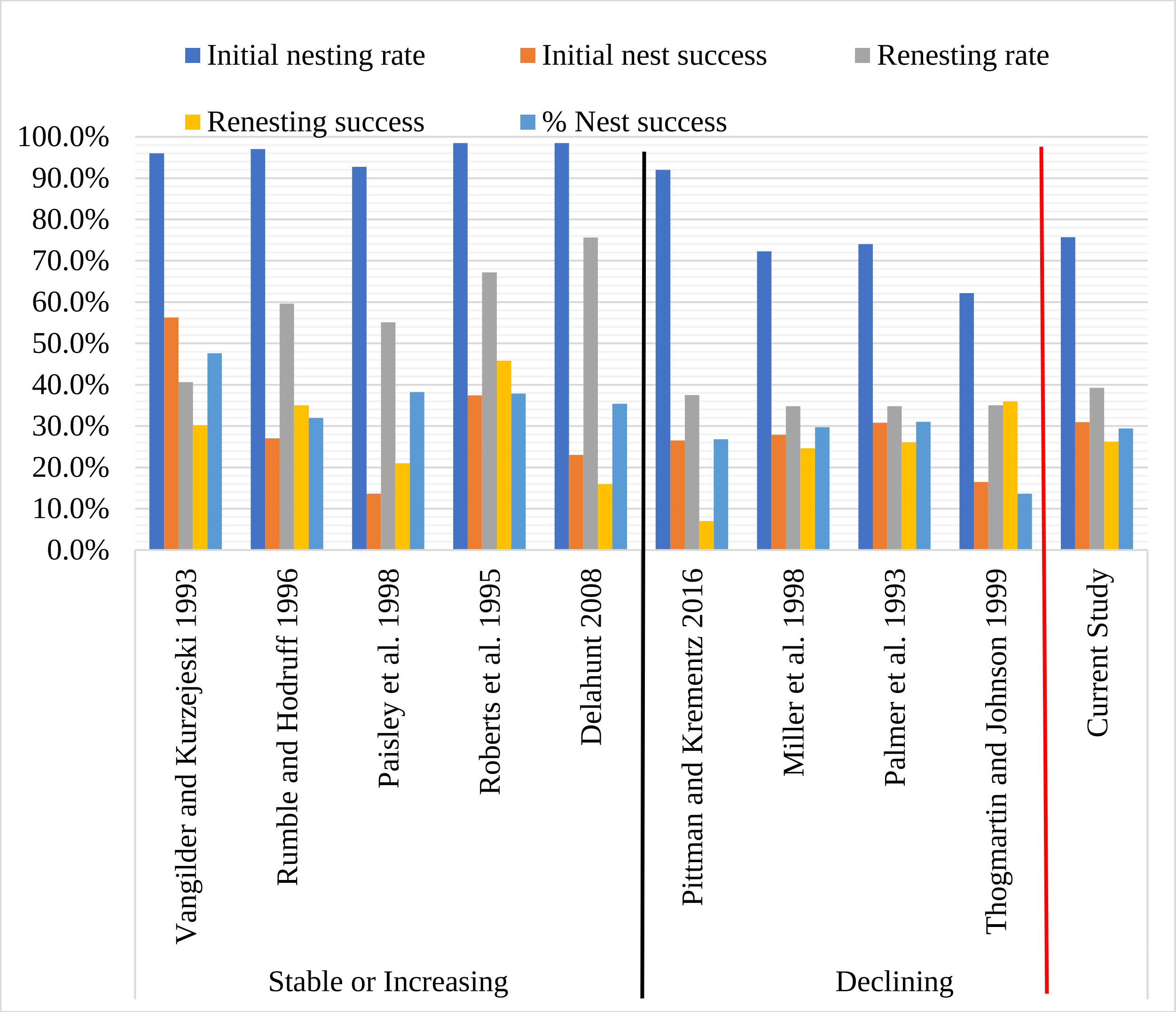

Figure 4. 1: Nesting and nest success rates from studies with stable/increasing or declining populations, compared to the same parameters for a study done on wild turkeys in south-central Tennessee, USA 2017-2018.

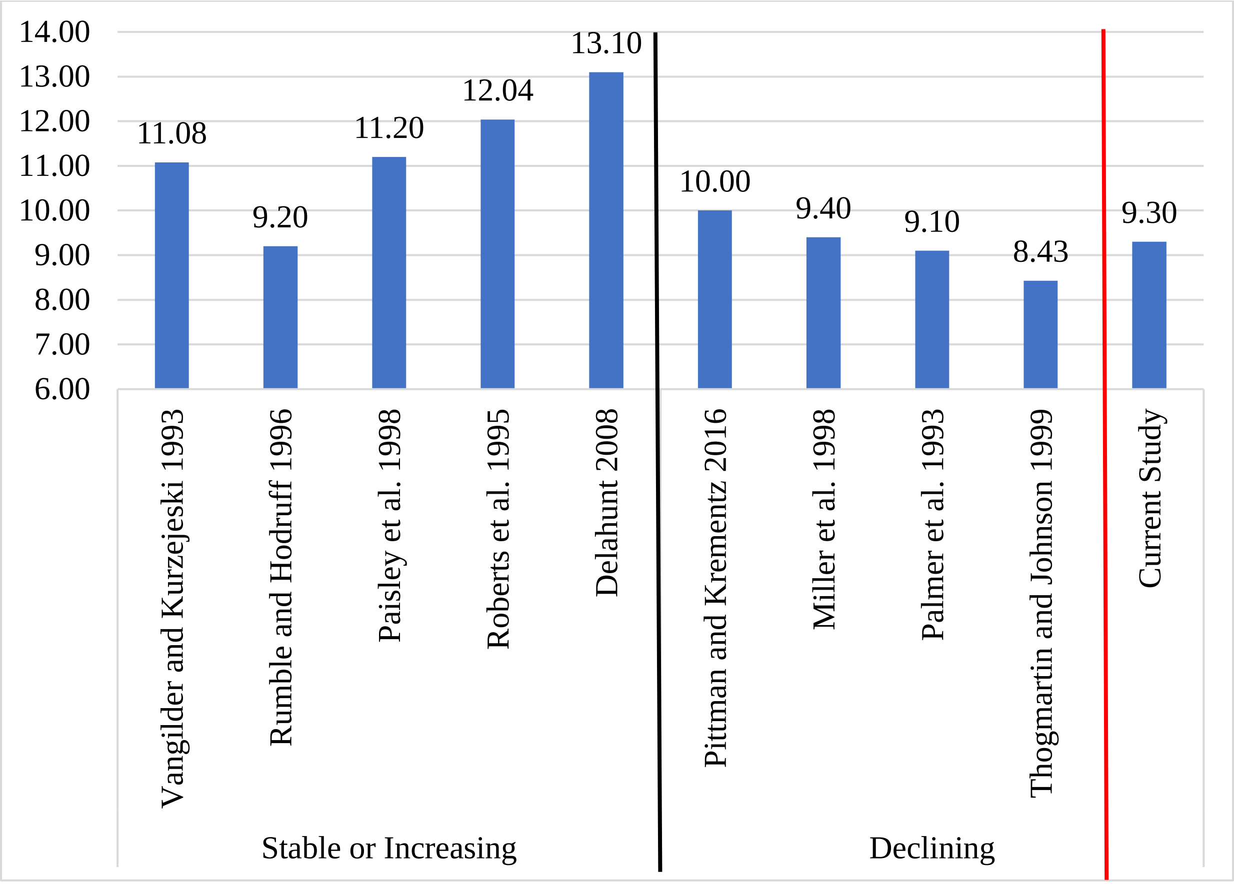

Figure 4. 2: Average clutch size from studies with stable/increasing or declining populations, compared to average clutch size for a study done on wild turkeys in south-central Tennessee, USA 2017-2018.

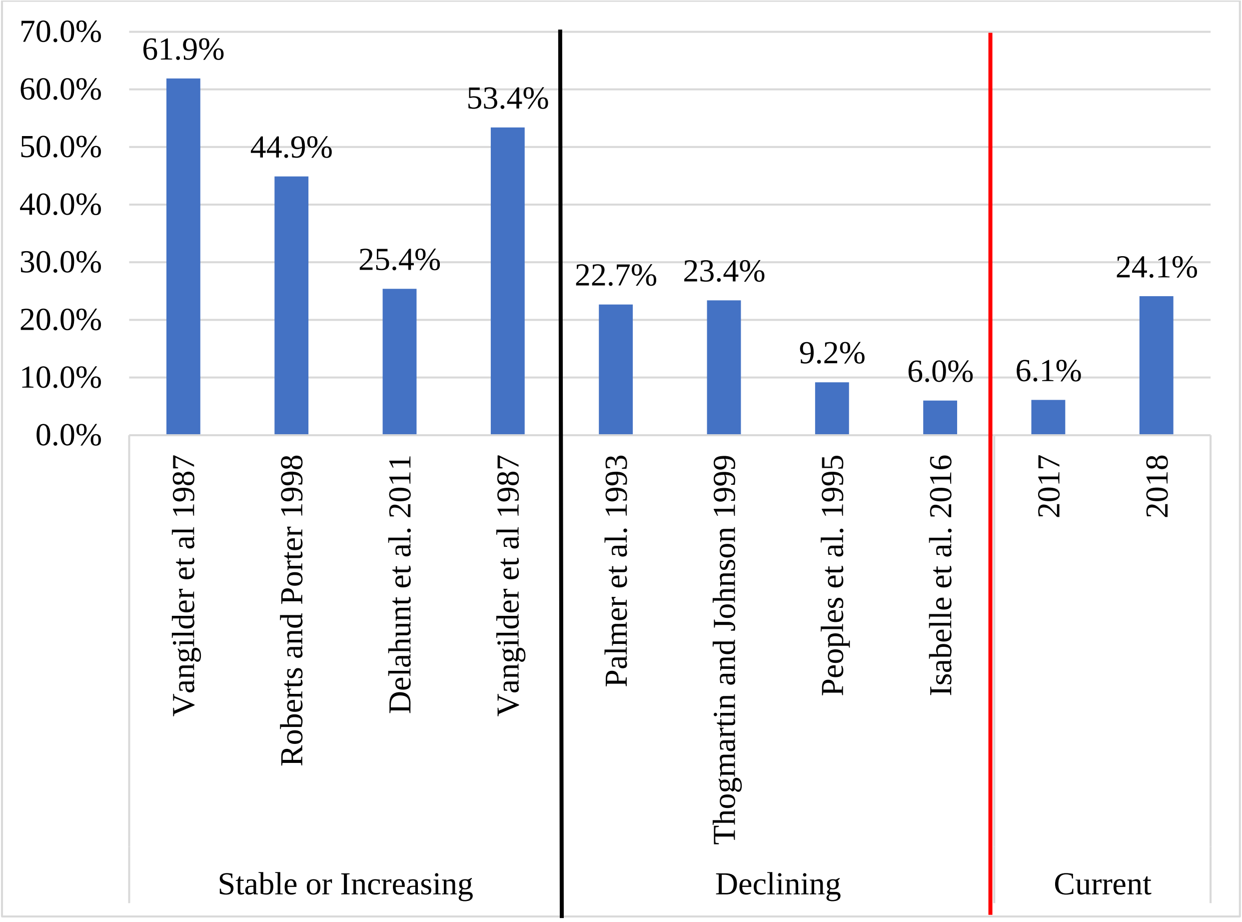

Figure 4. 3: Four-week poult survival estimates based on flush counts from studies with stable/increasing or declining populations, compared to estimates for a study done on wild turkeys in south-central Tennessee, USA 2017-2018.

VITA

Vincent Johnson is from Cuba, New York, where he developed his interest in the outdoors through hiking, hunting and schooling. He acquired a Bachelor of Technology in Wildlife Management at the State University of New York, Cobleskill in 2014 and was heavily involved in the Cobleskill Chapter of The Wildlife Society. After graduation he spent two years traveling the country and working various technician positions that greatly influenced his career goals. He worked with a variety of upland game birds and these jobs took him from the forests of Connecticut to the high plateau region of Colorado. He began working towards his Master of Science degree at the University of Tennessee, Knoxville in 2016, where he worked with his goal species, the eastern wild turkey. He spent a majority of his time at his study sites in south-central, Tennessee.