Fine-scale movements and habitat selection of eastern wild turkeys in Mississippi

By

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An important theme of wildlife ecology is understanding how animals move through their landscapes and inferring the strategies of resource acquisition. Eastern wild turkeys (*Meleagris gallopavo silvestris*) are a model species for evaluating the responses of movements and habitat selection to spatiotemporal variability of resources. I hypothesized that scales of area-restricted search (ARS) would change with variation in the landscape. I identified the ARS locations of high first passage time values using segmentation algorithms and hidden Markov models, and evaluated spatial variations in habitat selection for foraging-like activities of wild turkeys using Dirichlet multinomial models. The ARS scale for daily movement paths did not change over time substantially. Wild turkeys placed home ranges in heterogeneous landscapes to maximize forage availability. However, continuous-time Markov chain models demonstrated that habitat selection varied between individuals indicating that fine-scale selection may depend on the local resource availability and status of individuals.
DEDICATION

I would like to dedicate my thesis to my family for their full support throughout my undergraduate and graduate degree. Without their patience and support, I could not have accomplished any of this and I am forever grateful.
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CHAPTER I
INTRODUCTION

1.1 Introduction

An important theme of ecology is understanding how animals move through a landscape and inferring the strategies of resource acquisition for fitness enhancement. Resources are distributed in a scale-dependent hierarchy, meaning patches of resources at a small scale are nested within patches at a larger scale (Wiens 1976, Johnson et al. 1992). Additionally, there may be patches across a landscape that vary in suitability for use by an organism due to different levels of resource availability, various degrees of exposure to predation, or different opportunities for mating and probabilities of reproduction (Milne et al. 1989, Wiens 1992). Senft et al. (1987) suggested that an ecological hierarchy within ecosystems may describe the different scales at which a generalist herbivore selects resources, such as the specific plant species in a community, the plant communities on the landscape, and the different landscapes within a region. As a result, researchers now recognize habitat selection as a scale-sensitive process (Mayor et al. 2009).

Multi-scale research refers to any study attempting to identify the scale at which an organism interacts with its environment, and despite a call for multi-scale studies, a large majority of research has failed to address multiple spatial and temporal scales, as well as scale optimization (McGarigal et al. 2016). However, a challenge arises when trying to understand what factors are important at different scales and trying to identify the underlying ecological
processes associated with multi-scale selection (Turner et al. 1989, Laforge et al. 2015, McGarigal et al. 2016). Therefore, to truly understand the spatial variation in animal movements we must shed our conception of the environment and concentrate on the organism’s perspective (Wiens 1976). In the context of movements related to resource consumption, a foraging spatial scale can give us an insight into the organism’s perception of available resources across domains of scale.

1.2 Spatial and temporal scales of resource availability and habitat selection

The spatial scale of an organism’s movements refers to the specific extent and resolution of resources and space used. Extent describes the geographic scope of the study, while resolution describes the smallest area that is perceived or measured by the researchers (Hobbs 2003). When analyzing movement data, spatial resolution is often described as the grid cell (or pixel) size used to map available and used locations (Anderson et al. 2005, Meyer and Thuiller 2006). Multi-grain (resolution) studies have shown that outcomes of resource selection changes with resolution and depends on the resource as well as the season (Laforge et al. 2015). Johnson (1980) proposed four hierarchal orders of selection that incorporate components of spatial scale. First order refers to the geographical range of the species. Second order refers to the location of a home range within the geographical range. Third order pertains to the resources available within the home range. Finally, fourth order refers to the procurement of resources available within the third order. With this hierarchy of selection, we can describe the resources available to an organism. For example, when assessing second order selection the resources available will be encompassed in all the organism’s movements on the landscape, whereas, third order selection would encompass only resources that fall within the home range of the organism. Resource availability varies simultaneously across space and time, or spatiotemporally, and can influence
the spatial scale at which an individual will forage. However, movement and even the
distribution of a species is determined by not only the landscape heterogeneity and resource
availability, but also other factors such as predator avoidance, conspecific interactions, and

Resource availability can vary as much in time as it can in space (Mayor et al. 2009). The
temporal scale of an organism’s movements refers to a time frame of space use patterns. This
could mean a daily, monthly, seasonal, or yearly scale. Determining how animals react to
temporally changing environments can be beneficial to understanding their foraging behavior.
For example, in highly productive environments, rapid fine-scale temporal changes in resource
availability may result in more frequent animal movements, provided an animal perceives the
changing resources. However, in less variable environments, slower changes in resource
availability result in less frequent movements (Van Moorter et al. 2013). Additionally, seasonal
variation due to plant senescence, hard mast availability, annual variation due to prevailing
weather conditions are likely to affect habitat selection (Mobaek et al. 2009). Van Moorter et al.
(2009) suggests that animals will forage optimally and then return to a patch to allow for renewal
during a growing season, meaning that animals will forage until the patch is depleted but will
return once the resource has replenished. However, Seidel and Boyce (2015) proposed optimal
foraging behavior can also occur at a temporal scale smaller than a growing season in elk (*Cervus
canadensis*), which were observed returning to identified forage patches on average 9 to 23 days
within the same season. Moreover, home range size is also dependent upon the spatiotemporal
changes in the quantity and the quality of forage patches, and can change with resource
availability (Tufto et al. 1996, van Beest et al. 2011). Understanding how resource availability
changes temporally on a heterogenous landscape allows researchers to predict how animals will react to changing environments inferring from changes in resource selection.

The spatial scale at which researchers quantify an animal’s movement can influence our understanding of how individuals select for resources (Wiens 1976, Addicott et al. 1987, Wheatley and Johnson 2009). For example, yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) build nests where food abundance is greater at large spatial scales, but when observed at a smaller scale, they place nests where cover is greater (Orians and Wittenberger 1991). We may analyze and interpret results at a specific spatial scale, but an animal may perceive its landscape across multiple spatial and temporal dimensions (Wiens 1989, Orians and Wittenberger 1991, Levin 1992, Fauchald et al. 2000, Laforge et al. 2015). An example described by Fauchald et al. (2000), is the multi-scale predator-prey relationship of murres and capelin. Murres (*Urias spp.*) search at large scales to find patches, and once found search in smaller scale patches using shorter travel distances and higher turn frequencies. There are multiple factors affecting the scale of daily foraging movements (Fig.1). Multi-scale, spatially replicated studies demonstrate inferences regarding spatiotemporal variation in habitat selection that are valuable to wildlife management and conservation over broad extents in heterogeneous landscapes (Shirk et al. 2014). Still, few studies attempt to identify the optimal spatial and temporal scale at which an organism interacts with its environment or attempt to explain which environmental variables influence scale (McGarigal et al. 2016).

1.3 **Geographic and environmental space use of animals**

When analyzing an organism’s scale of daily foraging movements, we need to understand the factors that influence foraging behavior. Animal space use can be addressed in two aspects: geographic and environmental space use (Van Moorter et al. 2016). The geographic space refers
to the home range and spatial distribution of animals (Moorcroft 2012). A marked animal’s space-use pattern in geographic space emerges from all of its relocations (Van Moorter et al. 2016). Geographic space can be influenced by the intrinsic state of the individual, such as sex, age, body condition, and mating system (Greenwood 1980, Dobson 1982). The resource dispersion hypothesis (RDH) states that resources distributed patchily over space and time require animals to use the same resource patch without cooperation between social units and predicts that as resource patches become more dispersed, the home range size increases to obtain the sparse resources (Johnson et al. 2002, Macdonald and Johnson 2015). However, RDH does not specifically relate to the intrinsic state of the individual. RDH relates to the distribution of animals on heterogeneous landscapes, but does not explain why animals select a certain resource. Ideal free distribution (IFD) states that animals are distributed proportionally to resource availability to maximize energy intake (Fretwell and Lucas 1969). According to IFD, animals will move freely to where they can take advantage of a high-quality patch based on resource availability without any exclusion from conspecifics, while RDH relates to the how resources are configured on the landscape and an animal’s distribution and home range size on the landscape.

Environmental space refers to the environmental factors influencing resource use and selection, and changes in location are in response to changes in environmental conditions (Manly et al. 2002, Van Moorter et al. 2016). We can infer that both resource heterogeneity (associated with RDH) and resource availability (associated with IFD) are instrumental factors in the foraging spatial scale of an organism. There are other factors that affect space use. One example, Beest et al. (2011), showed that the most influential factor on home range size at the individual-level for moose (Alces alces) was reproductive status, where females with calves had smaller home range across all scales. Depending on the community structure, interference competition or
despotic distribution is also a factor for conspecifics as well, where individuals defend territories and expel others to suboptimal habitat (Fretwell 1972, Rosenzweig 1981). Furthermore, optimal foraging theory states that an individual will forage in a patch for an optimal amount of time and leave the patch once the trade-off between energy uptake and risk of predation or starvation becomes detrimental to the survival of the individual (Charnov 1976). As most organisms occupy heterogenous landscapes, it is important to understand how they move in accordance with availability and distribution of resources and infer how the scale at which they select resources effects their fitness (Mayor et al. 2009).

1.4 Species Literature Review

The Eastern wild turkey (*Meleagris gallapavo silvestris*; hereafter, wild turkey) is an important game species in the United States, especially in Mississippi. However, there has been a nationwide decline (5.96–7.52%) in population over most of their native range for the past 10 years (Eriksen et al. 2016). Understanding the small-scale foraging ecology of the wild turkey will further advance appropriate management of this species and promoting stable populations in Mississippi. If we can identify how turkeys move and how much space wild turkeys use for foraging on a heterogenous landscape, we can better understand how to properly manage for the species.

Resource selection by wild turkeys fluctuates seasonally. During winter and fall, turkeys utilize diverse hardwoods interspersed with multiple species as well as forest edges however, the use of open areas decreased compared to spring and summer (Porter 1992). In the spring, breeding takes place with males developing a hierarchal pecking order established by fighting in late fall when birds flock together (Healy 1992). Spring wild turkey home ranges are associated with breeding and nesting, with male habitat selection being related to nesting habitat of females
(Badyaev et al. 1996a). However, nest-site selection precedes mate selection (Healy 1992). Dominance also plays an important role in male spring/breeding habitat selection. Older, larger males occupy smaller fall/winter home ranges closer to high quality nesting ranges to increase chances for breeding (Badyaev et al. 1996b). Nesting females select for upland habitat structure that will better conceal nests, such as clear cuts, overgrown old fields, and pine stands with dense herbaceous understory (Badyaev 1995, Miller and Conner 2005). Open areas are used for courtship and foraging opportunities throughout the spring and summer months (Hurst and Dickson 1992). Brooding females utilize habitat with greater ground-level vegetation cover to increase poult survival during summer months (Spears et al. 2007). Females often move to bottomland hardwoods during fall/winter to take advantage of hard mast production (Stys 1992, Miller and Conner 2005, 2007). Home range size of wild turkeys seem to be a function of age, body mass, reproductive status and the habitats selected (Badyaev et al. 1996a, Thogmartin 2001).

Previous studies relied on limited technology to understand how wild turkeys utilize landscapes. Location data was previously collected using very-high frequency (VHF) resulting in datasets presumed to not be correlating spatiotemporally and low accuracy (Cohen et al. 2017). Results of previous habitat selection studies could be an artifact of low temporal resolution in movement data. Davis et al. (2017) found that turkey abundance increases with landscape interspersion, which requires a better understanding of landscape use and movement to determine population abundance outcomes. Therefore, determining wild turkey space use at high temporal resolution so that we can have a true representation of actual wild turkey movements is crucial to understanding what affects abundance.
1.5 Objectives

My first objective is to determine the area-restricted search (ARS) scale of the eastern wild turkey and how both resource availability and landscape heterogeneity influences ARS scale. My second objective is to determine 2nd order habitat selection for both ARS and non-ARS locations, as well as fine-scale habitat selection in 4 regions of Mississippi to identify important habitat characteristics of wild turkeys. I will account for how seasonality affects both objectives.

In my first objective, I will test the hypotheses that the daily area-restricted search scale will change throughout the year (H1). I predict that as resources change temporally, wild turkeys will need to change their search strategy, which will cause a change in area restricted search scale. If available resources increase, then the search scale will decrease because the individual does not need to travel large distances to find resources. However, if available resources decrease then the search scale will increase due to the individual needing to travel larger distances to find resources.

In my second objective, I will test the hypothesis that at a landscape scale, wild turkeys would select for forested heterogeneous landscapes (H2). Therefore, I predict birds will select for hardwood, pine and mixed forest more than other landcover types. I will also test the hypothesis that at a fine scale, wild turkeys will select for open areas which are important breeding, brood rearing, and bugging habitat (H3). Therefore, I predict birds will select grass areas at a fine scale at the individual level more than other landcover types.
CHAPTER II
FINE TEMPORAL SCALE MOVEMENTS OF WILD TURKEYS ACROSS MISSISSIPPI

2.1 Introduction

Understanding animal movements at fine scale can help us understand ecological processes underlying resource selection and acquisition, especially for a habitat generalist species such as wild turkeys. Recent advances in transmitter technology have allowed for higher temporal resolution in movement data. As the temporal resolution of data on individual movement trajectories becomes more detailed, we may better understand how organisms utilize resources in a heterogeneous landscape (Gaillard et al. 2010, Van Moorter et al. 2013, Byrne et al. 2014). Wild turkeys may have movement behaviors that have previously not been recorded with low temporal resolution in the movement data and understanding where turkeys concentrate their use or spend more time will allow researchers identify those areas of importance (Byrne et al. 2014, Cohen et al. 2017).

Analysis of spatiotemporal patch dynamics of space use at a fine scale can reveal specific information as to when animals could be foraging or utilizing a biologically important patch compared to movement bouts between patches (Le Corre et al. 2008). Previous studies have focused on a hierarchal analysis of resource selection and landscape use, such as 2nd and 3rd order habitat selection (Johnson 1980, Laforge et al. 2015, 2016). While it is important to understand resource selection processes at multiple scales, organisms may not perceive this type of hierarchical spatial structure and/or perceptions of spatial structure and scale may change over
time (Levin 1992, Le Corre et al. 2008). Animals may form a home range under 2nd order selection processes; however, animals may have areas of concentrated use that are the more important for resource acquisition more than the other areas within the home range – a 3rd order selection process (Don and Rennolls 1983, Van Moorter et al. 2009). Using fine scale movement data, we can now associate these areas of concentrated use with resources that may be important to a species, as well as observe how individuals of this species change their strategies as resources change spatiotemporally.

According to Marginal Value Theorem and Optimal Foraging Theory, an animal should spend more time in a patch when the resource value is high (Krebs et al. 1974, Charnov 1976). Therefore, in a heterogeneous landscape a highly mobile generalist should exhibit slower, more diffusive movements when encountering many patches of high resource value (Van Moorter et al. 2013). Fine scale data allow for the ability to discern where animals could potentially be foraging and better understand foraging patterns over time. However, one challenge in determining exploitation tactics of patches, or areas of concentrated use, within an animal’s home range is identifying scales at which individuals perceive resources (Levin 1992, Le Corre et al. 2008).

First Passage Time (FPT) is a method for measuring area restricted search (ARS) effort along a given pathway (Fauchald and and Tveraa 2003, Pinaud 2008). FPT analysis is based on measuring the time taken by an animal to cross (i.e., first enter and first exit) a circle with a given radius. These measurements are repeated over tracked locations along a given path by moving the circle at increasing radii increments. The variance of FPT is then calculated for the whole path with a given radius size and is log-transformed to make the variance independent of the magnitude of the mean FPT (Fauchald and and Tveraa 2003). The peak radius would suggest
that the animal is exhibiting ARS at the spatial scale at which an animal is increasing search effort (Fauchald and Tveraa 2003, Pinaud and Weimerskirch 2005). ARS scale is related to individual forage pattern and success as well as the spatial distribution of resources (Pinaud and Weimerskirch 2005). A small ARS scale may suggest that an individual encounters high resource density relatively quickly without much search effort, as in a generalist (Fauchald and Tveraa 2006). However, a small ARS scale could also indicate that the resource is distributed within relatively small patches (Fauchald and Tveraa 2006). High FPT values can be used to correspond to intensive use (Pinaud 2008). Using FPT, we can identify the areas of concentrated use in order to observe how wild turkeys utilize patches when resources are distributed spatiotemporally on a landscape (Hamer et al. 2009, Bennison et al. 2018). However, previous studies have compared FPT with methods such as Hidden Markov Movement (HMM) models, a state-switch model, to evaluate their respective performances in estimating foraging activities (Gurarie et al. 2016, Bennison et al. 2018, Hurme et al. 2019). Because HMM models can have some technical constraints, FPT can be a good compliment as a simple but comparably accurate method (Hurme et al. 2019). Nonetheless, lack of high temporal resolution (e.g., sub-hourly) location data has hindered FPT analysis for fine-scale spatiotemporal dynamics of space use until recent advances in Global Positioning System (GPS) or satellite tracking technology became available.

FPT is a non-parametric method that allows researchers to make no assumptions of statistical distributions; however, there is no certainty of the validity of the ARS scale size. Using a HMM model, we can estimate the number of behavior states for a given movement trajectory and estimate the parameters of step length and relative turning angle for each state (Franke et al. 2004, Morales et al. 2004). A HMM model is a state space model which describes how an
observation (i.e., movement pattern) is generated from a state or behavior (Rabiner 1989, Patterson et al. 2008). Using step length and turning angle parameters estimated with HMM models, I can identify the state of each discrete location. Typically, an encamping state is associated with short step lengths and large turning angles, and a taxing state is associated with large step lengths and small relative turning angles (Guilford et al. 2004, Morales et al. 2004). The encamping state could be characterized as a foraging-like state, while the taxing state is characterized as long-distance movements between patches. Comparing the encamping state step lengths with the ARS scale sizes allows more certainty that the ARS scale size encompasses those foraging-like locations.

I predict that daily ARS scale will change temporally and spatially. The ARS scale could change temporally due to differences in resource availability or changes in life history events throughout the year. I also predict the ARS scale to change spatially among wild turkey management zones in Mississippi, due to the different landscape compositions.

2.2 Methods
2.2.1 Study Sites

I conducted GPS tracking of wild turkeys on 4 study sites, located within a county in 4 out of the 5 wild turkey management zones in Mississippi (Fig. 2.1). This including trapping on 2 private properties at the Atalla County site (Table 2.1). Vegetation in Atalla was mostly comprised of planted pine stands and mixed pine-hardwood stands. The Copiah County site was located in the Copiah County Wildlife Management Area and was mainly comprised of managed hardwood and mixed forested areas. The Lamar County site also included 2 private properties and was primarily comprised of planted longleaf pine managed for pine straw production and
hardwood drainages. The Marshall County site included 1 private property and is comprised of planted pine, mixed forest, and hardwood forests.

2.2.2 Wild Turkey Captures

I captured turkeys using rocket nets from December to March 2016-2018 (Delahunt et al. n.d., Bailey et al. 1980). Birds were baited using wheat and corn at 2-3 locations in areas previously identified as having turkey presence based on the tracks and visual spotting of wild turkeys. I set up Browning Strike Force HD Cameras at a height of 0.5 - 1 m above the ground and about 3 - 5 m from a baiting location to monitor bait use prior to trapping. Once activity was confirmed, I set up a 30 × 50 ft rocket net (Memphis Net and Twine Co, Memphis, TN) at baiting locations after birds were captured by cameras the previous evening. I conducted trapping from 0400 to 1100 hours to capture birds coming off of roost. I fitted “backpack style” transmitters using parachute chord on each captured bird using 70-g Advanced Telemetry System (ATS) GPS transmitters with built-in mortality sensor (Model W500, ATS, Isanti, MN). I released captured birds immediately after handling at capture site. Capture and handling of wild turkeys followed a protocol approved by Mississippi State University Institutional Animal Care and Use Committee (IACUC; protocol number: IACUC-17-482).

2.2.3 GPS Tracking

I tracked tagged birds using two different relocation schedules. Schedule 1 recorded fixes every 30 minutes from 0500 - 1900 daily. Schedule 2 recorded one fix daily at different hours of the day for 3 weeks and took fixes every 15 minutes from 0600 to 1900 on the 4th week of a month. Schedule 1 was intended to capture continuous fine-scale movements. Schedule 2 was intended to capture fine-scale movement changes throughout the year. I remotely downloaded
data directly onto a laptop computer using a downloading module (Model Wildlink W100, ATS, Isanti, MN) and ultra-high frequency (UHF) antenna. A very high frequency (VHF) radio signal was set to be omit during 1800 - 2300 each day when tagged birds were on the roost. With the aid of VHF signals, I downloaded GPS location data from each tagged bird at a distance of <100 m during the roosting hours.

Using this approach, I downloaded transmitter data every 2 months to save battery life; however, birds were checked for the status of the individual using VHF relocation every 2 weeks. Nest locations were excluded from all analysis. I identified nests by visually examining GPS locations and determining areas hens used approximately 28 consecutive days. The area used was determined to be less than 20m and also had characteristic foraging trips within the incubation period.

2.2.4 Statistical Analysis

2.2.4.1 First Passage Time Method

I conducted first passage time (FPT) analysis on daily movement segments of GPS locations for locations where birds were not roosting. I interpolated each movement segment into 5 m segments (Fig. 2.2) using the function redisltraj with R package adehabitatLT. Byrne et al. 2014 used 1 m segments; however, my data could not be interpolated into segments of this size due to transmitter GPS error of about 3 m. I ran FPT at varying radii from 10 -1000 m along the segmented locations using functions as.ltraj, fpt, and varlogfpt with R package adehabitatLT (Calange 2006). The daily movement trajectory was classified into K segments using the Lavaille’s non-parametric classification algorithm with function lavaille within R package adehabitatLT (Lavielle 1999, 2005). The number of segments K was determined by the elbow method using the R function chooseseg to find the precipitous decrease or break point (like an
elbow curve) of the contrast function JK (Figs 2.3-2.5). I then took the variance in the log transformed FPT to obtain the optimal radius at which individuals are intensively using or exhibiting ARS on a daily basis (Fig. 2.3). I used the daily optimal radius to run FPT again along the same trajectory to measure time spent within that radius. This allows me to identify locations where individuals are intensively using areas as opposed to locations where individuals are more likely moving quickly (ARS vs. non-ARS). I randomly selected 3 days from each month to determine the number of clusters and were selected by using the lavielle function (Fig. 2.4). Using the randomly elected days, I determined a threshold that encompasses all differences in the data determined by the lavielle function which would describes high FPT and low FPT. Once the threshold was determined, it was applied to all days for that month. This process was repeated for all individuals and for each month to account for behavioral variation between seasons and between individuals. The threshold of high and low FPT distinguishes between ARS and non-ARS locations for future analysis.

Scale size change for ARS was determined as both the most frequently selected daily ARS scale size as well as the mean variance in log transformed FPT for each month and the total time period analyzed. Daily ARS scale size indicates any changes in daily movement strategies, while the peak mean variance in log transformed FPT can indicate the extent of area searched for any temporal scales.

2.2.4.2 Discrete Time Hidden Markov Movement Model Method

I examined all movement data according to the weekly 15 min schedule. I interpolated the movement trajectory to fill in overnight location gaps between daily locations using the crawl function in the R package crawl (Johnson et al. 2008, Johnson and London 2018). To train the model and ensure accuracy of the model I set initial values based on parameters estimated by
fitting Von Mises distributions for turning angles and Weibull distributions for step length.

Fitting of the Von Mises distribution estimates parameters of mean relative turning angle and kappa (i.e., a dispersion parameter). Fitting of the Weibull distribution estimates the parameters of scale and shape which coincide with step length and variance in the step length. Using those values obtained from the two distribution fittings, I set initial values for the HMM model and ensured model optimization and convergence. Based on observed step length and turning angle, the HMM model estimated the state-specific parameters of step length and turning angle for each week of the individual. I fit two- and three-state models to each data set, respectively, using R package Template Model Builder (TMB) and R function optim() to maximize the likelihood function (Langrock et al. 2012, Kristensen et al. 2016). The two-state model consisted of an encamping state and a taxing state, and the thee-state model included encamping, taxing and an intermediate state. The intermediate state was characterized by a step length in between those of encamping and taxing state and a narrow relative turning angle. The intermediate state may be used to depict the loafing movement of wild turkeys. I conducted model selection using information-theoretic approaches with Akaike information criterion corrected for small sample size (AICc) (Burnham and Anderson 2002). The best model has the lowest AICc values between the two candidate models with competing models being $<$2 ΔAIC.

2.3 Results

I ran FPT analysis on 31 individual’s daily movement trajectories ($n =2,747$). The duration of GPS tracking for most individuals lasted from March to September. Due to transmitters technical issues and mortality, mean time period of transmitters was only 133 days (Table 2.2). Nesting days for all hens were excluded from analysis. The mean variance of log transformed FPT for each study site peaked at 10m for Atalla and Lamar, while it peaked at 20m
for Copiah and Marshall (Fig. 2.6). The daily ARS scale radius or distance ranged from 10m to 30m for all sites (Table 2.3). The annual mean variance peaked at 40m for males and 20m for females (Fig. 2.7). The mean ARS scale identified by the peak variance changed slightly per month and the daily ARS scale most frequently selected per month changed slightly (Table 2.3). Using FPT time values, I identified 50,307 ARS locations to use in future habitat analysis.

Both 2 and 3-state HMM models were able to estimate differences in step lengths (Fig. 2.8). I used the state 1 step lengths from both the 2 and 3-state HMM models to ensure the ARS scales encompassed the foraging-like movements. The mean weekly step lengths for state 1 in the 2-state model was 10.9 ± 0.8. The mean weekly step lengths for state 1 in the 3-state model was 7.4 ± 0.5. Depending on the model selected, the foraging-like state tends to be encompassed by the ARS scale size (Table 2.4).

2.4 Discussion

Using fine scale data, I have been able to demonstrate the spatial scales of wild turkey intensive use or (i.e., 10-30m radius), identified the locations of concentrated use, and how that changes over time. Mortality and transmitters difficulties only allowed data analysis to occur from early spring to early fall. A small overall ARS scale indicates that wild turkeys tend to forage as they move. Animals that exhibit small foraging scales are more than likely encountering resources more frequently (Fauchald and Tveraa 2006), which describes a generalist in a heterogeneous landscape such as wild turkeys.

The foraging scale also changed over time, likely because of seasonal variation in resource availability and spatial heterogeneity (Dé et al. 2008, Pinaud 2008, Henry et al. 2016). The scale was larger in the spring during the breeding season while birds, especially males, are searching for mates. In spring, resources may be more spatially heterogenous with more
variation in food resources across space than in summer. Marable et al. (2012) demonstrated that wild turkeys increased their movement distance with increasing landscape heterogeneity in the Mississippi Alluvial Valley. The ARS scale tended to decrease during summer months most likely due to decreased search effort. A decrease in search effort is likely due to an increase in available resources on the landscape. The ARS scale in late summer increased as resources started to senesce and birds needed to increase their search effort to maintain net energy intake.

Mcnab (1963) hypothesized that spacing extent and home range of animals would decrease with increased available energy or food resource of habitat. Marshall, Copiah, and Atalla sites demonstrated an immediate increase in foraging scale in August and September, this may be due to limited hard mast availability and late season senescence of summer resources (Table 2.3).

Essentially, wild turkeys will move to take advantage of spatiotemporal changes in resources on heterogenous landscapes. Le Corre et al. (2008) introduced a second scale of use, finer than that of a home range for roe deer that described a scale of focus within a home range, similar to that of the ARS scale. The ARS scale could be characterized as the scale at which the home range is perceived at a given time, while the extent of the home range is used to fulfill life history activities, an animal will focus its search effort on a smaller scale depending on the seasonal needs at that time. Additionally, it may be a more logical approach to use the ARS scale size within the home range to understand the perception of an organism when analyzing habitat selection, rather than the ordered selection hierarchy or availability proposed by Johnson (1980).

Hidden Markov Models demonstrated that movement distance of foraging-like state was comparable to the ARS scale size, ensuring that when using a daily scale size across a movement trajectory all foraging-like movements are evaluated. ARS locations focused around forest edges, small open fields, and powerline-like strips of open areas. We have shown that birds will also
walk and forage along roads and trails. Forest edge creates high vegetation diversity while also providing escape routes for predator avoidance, both of which could be drivers of intensive use for wild turkeys. Davis et al. (2017) and Farrell et al. (2019) demonstrated that habitat suitability and male wild turkey relative abundance were positively related to forest edge density at landscape scales. Moving forward, turkey management practices may want to focus on creating more foraging opportunities by increasing heterogeneity in small openings and perceived escape routes with forest edges. Wild turkeys forage on such a small scale that birds may avoid large areas of continuous similar habitat. Management practices should shift focus to enhancing habitat structure and creating heterogeneity on the landscape rather than habitat type.

### Tables and Figures

#### Table 2.1  Trapping sites of wild turkeys in four counties of Mississippi from 2016-2018.

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>Trapping Sites</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atalla</td>
<td>33.149064°, -89.771474°</td>
<td>Private Property</td>
<td>3</td>
</tr>
<tr>
<td>Atalla</td>
<td>33.073278°, -89.795655°</td>
<td>Private Property</td>
<td>3</td>
</tr>
<tr>
<td>Copiah</td>
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<td>Copiah County WMA</td>
<td>4</td>
</tr>
<tr>
<td>Lamar</td>
<td>31.234932°, -89.615676°</td>
<td>Soterra Forestry Property</td>
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</tr>
<tr>
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<td>Private Property</td>
<td>5</td>
</tr>
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<td>Marshall</td>
<td>34.613536°, -89.658781°</td>
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Table 2.2 List of GPS-tracked individual wild turkeys used in daily first passage time analysis for all four sites

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<th>ID</th>
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<th>Schedule (min)</th>
<th>Site</th>
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<th>Data end date</th>
<th>Total GPS locations</th>
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Table 2.3 Mean foraging scales (or radii) determined by the peak mean variance of log transformed first passage time (mean varfpt) and the most frequently selected forage scales for daily movement segments.

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<th>July</th>
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Table 2.4  Mean step lengths of foraging-like state in 2- and 3-state hidden Markov models and most frequently selected radius of daily area restricted search per month

<table>
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<th>3-state</th>
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<td>10</td>
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</table>
Figure 2.1  Four study sites in Atalla (3), Copiah (4), Marshall (1), and Lamar County (5) within wild turkey management zones in Mississippi. The counties of study sites are marked by red color.
Figure 2.2  Interpolated daily movement trajectory (every 5 m) of wild turkey M38092 in Atalla County, Mississippi June 6th, 2017. The y axis is the northing coordinate (m) and the x axis is the easting coordinate (m). The blue triangle and red square are the starting and ending location of the movement trajectory.
Figure 2.3  Estimation of the radius size \((m)\) (x axis) of area restricted search (ARS) by using the peak variance (y axis) of log transformed first passage time (FPT) from previous trajectory.
Figure 2.4  Determination of the number of clusters of the first passage time of daily movement trajectory by the Lavielle algorithm. The x axis is the number of clusters and the y axis is the goodness-of-fit statistic-contrast function-(Jk) of clustering fit to data.
Figure 2.5  Segmentation of daily movement trajectory based on the clustering of first passage time (FPT). Segments or clusters are delimited by red vertical lines. Clusters or segments of high FPT values (y axis) are GPS location segments (indexed from 1 to 350 on the axis) where birds exhibited area-restricted search.
Figure 2.6  The peak mean variance (y axis) of log transformed first passage time. Atalla was 10m, Lamar was 10m, Copiah 20m, and Marshall 20m. The x axis is radius size (m).
Figure 2.7  Peak in mean variance (y axis) of log transformed first passage time by sex, males at 40m and females at 10m. The x axis is radius size (m).
Figure 2.8  Weibull distribution of step lengths (the first and second columns of panels) and von Mises distributions of relative turning angles (the third and fourth columns of panels) for 2- and 3-state hidden Markov movement models for wild turkeys in March (top row), April (middle row), and May (bottom row) in Atalla County. The first column and third column are for the step length and turning angles of 2-state HMMs, respectively. The second column and the fourth column for turning angle are for the step lengths and turning angles 3-state HMMs, respectively.
Figure 2.9  High first passage time locations for male wild turkey M39560 (top) in Copiah and female wild turkey F38082 (bottom) in Atalla in July 2018.
Figure 2.10  High first passage time of male wild turkey M39560 (top) in Copiah and female wild turkey F38082 (bottom) in Atalla in April of 2018.
CHAPTER III
FINE-SCALE RESOURCE SELECTION BY WILD TURKEYS ACROSS MISSISSIPPI

3.1 Introduction

A foundation in ecological studies is the evaluation of how animals use their surrounding environment and select the habitats they occupy (Johnson 1980). Understanding the landscape conditions and habitats species occupy can provide researchers and wildlife managers insights into the ecological processes underlying resource requirements for species. Additionally, analysis of space use by wildlife across multiple spatial scales may help us to understand the appropriate scales at which animals perceive and interact with their environments (Levin 1992, Anderson et al. 2005, Boyce 2006, Laforge et al. 2016). The Eastern wild turkey (*Meleagris gallopavo silvestris*) is an important game species in the United States, especially Mississippi, and adaptive management of the species requires understanding of spatiotemporal variation in its habitat requirements.

Habitat selection of wild turkeys has been well documented. Habitat selection by wild turkeys fluctuates seasonally due to the temporal variation in resource availability. Wild turkeys tend to select for hardwoods during fall and winter (Porter 1992, Miller et al. 1999, Miller and Conner 2007). Spring home ranges of female wild turkeys are associated with breeding and nesting, while male habitat selection is related to nesting habitat of females (Badyaev et al. 1996a). Nesting females select for upland habitat structures that will better conceal nests, including managed pine stands with dense herbaceous understory (Miller and Conner 2005,
2007, Little et al. 2014). Additionally, females tend to associate their fall-winter habitat selection with adjacent nesting and brooding areas available (Badyaev 1995, Miller and Conner 2007). Female summer habitat selection is conditional upon brood status; however, they tend to forage in areas with low, abundant herbaceous vegetation and along road edges that provide vegetation heterogeneity (Hurst and Dickson 1992, Porter 1992, Miller and Conner 2007). Male summer habitat selection tends to be associated with pine and areas with high resource availability (Miller et al. 1999). Nevertheless, few studies have investigated behavioral-specific (e.g., foraging vs. non-foraging) habitat selection by wild turkeys.

Fine-scale habitat selection of wild turkeys may be dependent upon distributions of available resources within a close proximity to the individual at a given time (Hanks et al. 2015). Therefore, wild turkeys may establish their home ranges and demonstrate second order selection where seasonal resources are most abundant and most apparent to an individual (Johnson 1980). Previous studies have primarily analyzed habitat selection in a hierarchical structure of second order (i.e., placement of home range) and third order selection (i.e., selection within a home range); however, wild turkeys may only be able to perceive their environment beyond their immediate surroundings when making a behavioral decision (Mueller and Fagan 2008, Beyer et al. 2010). Habitat selection has previously been analyzed using use-availability or presence-absence ratios, where random locations are used as a gauge of (pseudo-) absence or resource availability (Lele et al. 2013, Northrup et al. 2013). However, it is unknown if random locations are representative of true absence or resource availability. Additionally, availability at random locations, especially within a home range, may not be logically viable as an assumption because at any point in time an individual’s available resources could be limited by its immediate
surroundings. Fine-scale resource selection may need to be analyzed on a smaller scale than home ranges.

In this study I analyzed second order habitat selection for wild turkeys using Dirichlet-multinomial distribution models at the population level. Dirichlet-multinomial distribution models do not utilize pseudo-absence locations (de Valpine and Harmon-Threatt 2013). I also used a continuous-time discrete-space movement model to analyze fine-scale habitat selection at an individual level (Hanks et al. 2015). Fine-scale resource availability in the latter was measured within the immediate micro-setting (i.e., 4 surrounding 150-m grid cells) of an individual’s current location. With this method an individual will likely spend more time in desirable habitat when surrounded by less desirable habitat. A CTDS method is a continuous time Markov chain movement model for resource selection inferred from a space-time series of location data. CTDS models also allow for modelling of both location-based (e.g., animal’s mobility and residence time in a grid cell) and directional drivers of movement. This is an ideal approach for modelling fine-scale habitat selection with the assumption that not all resources within a home range are available at a given time.

I tested the prediction that landscape mixed pine would determine second order habitat selection. Diversity of resources in mixed pine and temporal variation in resource availability may encourage an individual to place a home range in an area with high vegetation diversity, such as mixed pine. Because temporal variation in resource availability occurs throughout the year, wild turkeys will change their fine-scale habitat selection based on resource availability. I predicted that in spring, wild turkeys will choose to move slower in (i.e., select) open/grassland and shrub areas as associated with breeding and courtship behaviors. During summer, I predicted that wild turkeys will move slower through pine, mixed, and hardwood because of resource
availability and predator avoidance. I also expected individual variation in fine scale resource selection because of differences in resource availability among different movement routes.

3.2 Methods

3.2.1 Landcover Classification

I used the 2016 30m National Landcover Database to classify land use and landcovers (LULCs). I used open water, developed, hardwood forest, pine forest, mixed forest, shrub, grass, agriculture, woody wetland, and herbaceous wetland. I reclassified developed open space, developed low intensity, developed medium intensity, developed high intensity, and barren land into developed. I reclassified grassland and pasture/hay into grass. I used program CircAn to obtain the proportion of each LULC for each cell by using the mean hourly step length of turkeys (150m) as the radius size surrounding each cell to analyze.

3.2.2 LULC Characteristics of high and low first passage time (FTP) locations

I used the function extract () of R package raster to extract proportions of land use and land cover (LULCs) for each of ARS and non-ARS locations (defined in analysis of chapter II), respectively. Land use describes how people use the land that cannot be identified by a satellite, while land cover describes the classification of land using satellite or aerial imagery. I calculated average LULC proportions of LULC classes across each clipped study site raster from the 2016 30m National Land Cover Database (NLCD) of ARS and non-ARS locations by site and season, pooling data over all individuals on a site over a season. I divided the study period into winter (Jan-Mar), Spring (April-Jun), and summer (July-September), I was unable to analyze fall due to data limitations.
3.2.3 Dirichlet-Multinomial Distribution Model

I used Dirichlet-multinomial distribution models to determine seasonal second order habitat selection of wild turkeys at the population level for each study site (de Valpine and Harmon-Threatt 2013). I assumed that the distribution of location counts over the Land Use Landcover Classes (LULC) to follow the multinomial distribution. The distributing probability vector is parameterized as a product of LULC availability and selection coefficient $h$, following a Dirichlet distribution (de Valpine and Harmon-Threatt 2013). The higher the $h$ value, the greater the selection over an LULC type, with the sum of $h$'s over the 10 LULCs being 1.0. Availability was measured by the proportion of LULC classes from the 2016 NLCD. I tallied counts of ARS and non-ARS locations, respectively, for each of the 10 LULC types. Then I estimated selection coefficients $h$ and their standard error (SE) by maximizing the Dirichlet-multinomial distribution implemented with the R TMB (Kristensen et al. 2016). The 95% confidence interval (CI) of coefficient $h$ was estimated as $95\% \text{ CI} = h \pm 1.96*\text{SE}$. I divided seasons into winter (January-March), spring (April-June), and summer (July-September). If the 95% CI of $h$ for an LULC exceeds 0.05, I concluded that selection of LULC is non-negligible.

3.2.4 Continuous-Time Discrete-Space Movement Model

I used a continuous-time discrete-space movement model to analyze fine-scale habitat selection at the individual level. The CTDS method can be characterized as a continues-time Markov chain to model animal movement through a gridded space (Hanks et al. 2015). This method considers motility covariates and directional covariates. Motility covariates pertain to the movement speed through a cell, where an animal would move slower in desirable habitat especially when surrounded by undesirable habitat. Directional covariates pertain to the attraction to neighboring cells due to an improvement in moving to more desirable habitat. As
mentioned earlier, this allows for a more appropriate analysis of available habitat to an individual at a given time. I can estimate a $\beta$ coefficient for each landcover class to provide information about how wild turkeys use available habitat. In this study, I only included motility covariates in the CTDS model focusing on the component of residence time of wild turkey habitat selection, consistent with the FTP analysis of Chapter II.

I used the R package *crawl* (Johnson et al. 2008, Johnson and London 2018) to fit a quasi-Continuous-Time Correlated Random Walk movement path based on collected GPS locations. I simulated 10 CTCRWs for imputation of possible movement trajectory over the entire landscape (Wilson et al. 2018). Hanks et al. (2015) demonstrated that 10 simulated movement trajectories is adequate for regional scale studies of resource utilizations using simulations. I used *path2cmtc()* from the package *ctmcmove* to obtain residence time within each cell along simulated paths (Wilson et al. 2018). Hanks et al. (2015) showed that estimated parameters can be analyzed proportional to a Poisson GLM likelihood. I used the function *ctmc2glm()* to analyze residence time parameters. I used least absolute shrinkage and selection operator (LASSO) to select the relevant coefficients of GLM which were not shrunken to zero using the package *glmnet* (Friedman et al. 2010). LASSO is an approach to variable selection using regularization, which shrinks the coefficients of negligible covariates to 0 (Tibshirani 1996). I divided seasons into winter (January), spring (May), and summer (July).

### 3.3 Results

I analyzed seasonal LULC compositions of ARS and non-ARS locations using for 31 GPS-marked wild turkeys. The LULC composition shared similar pattern between ARS and non-ARS locations (Figs 3.1-3.4). Woody covers such as mixed, pine, and hardwood forests comprised >50% of used LULC of both ARS and non-ARS locations. hardwood forests
constituted <10% of used habitats in the sites in Atalla and Lamar County (Figs 3.1 and 3.4), whereas they comprised 10%-40% of used habitats in Copiah and Marshall County (Figs 3.2-3.3). Therefore, there was a difference in the woody cover compositions of used habitat between study sites.

The 2nd order habitat selection showed wild turkey selected for grass cover ($h > 0.05$) in all sites during all seasons except for spring in Lamar County and winter in Copiah County (Figs 3.5-3.8). Wild turkeys did not select for water and developed areas ($h < 0.05$, horizontal line in each panel of Figs. 3.5-3.8) in all sites and seasons except for Copiah County during spring and summer (Fig. 3.7). Woody cover such as mixed, pine and hardwood forest are all were selected ($h > 0.05$) for all study sites and for all seasons. Shrub and woody wetland selection varied seasonally. In Atalla County, shrub was only selected ($h > 0.05$) in summer, while wild turkey ARS locations selected for woody wetland ($h < 0.05$) in winter and spring. In Marshall County shrub was selected ($h > 0.05$) in winter and spring, while woody wetland was selected ($h > 0.05$) in spring and summer. In Copiah County, shrub was selected ($h > 0.05$) in spring and summer, while woody wetland was only selected in the spring ($h > 0.05$). In Lamar County, shrub was only selected ($h > 0.05$) in winter for non-ARS locations, while woody wetland was selected ($h > 0.05$) in spring and summer. Selection coefficients differed between ARS and non-ARS for one or more LULCs with the 95% CIs of selection coefficient $h$ separating (i.e., not overlapping) between ARS and non-ARS locations, with an exception that there was no difference in ARS and non-ARS for Marshall County in winter and summer (Fig. 3.6).

For individual-level fine-scale habitat selection I analyzed individuals ($n=6$) from Copiah County. Selection coefficients indicate individual and seasonal variation make it difficult to identify any trend or patterns. However, in March wild turkeys moved through developed,
woody wetland, and grass quickly, while moving slowly through hardwood and pine (Table 3.1). In May wild turkeys moved quickly through woody wetland and moved slowly through developed and grass (Table 3.1). In July wild turkeys moved quickly through woody wetland, pine, mixed, and hardwood and moved slowly through developed (Table 3.1).

3.4 Discussion

In this study, I have shown that wild turkey habitat selection may be conditional on resource availability. I have also shown that 2nd order habitat selection may be used to maximize chances of encountering high availability of temporally varying resources. Overall selection at this scale seems to be associated with a multiple landcover types. Habitat selection changes for both ARS and non-ARS locations between seasons, this could be due to use strategy changes resulting from temporal variability in resource availability as well as variation in resource needs per season. An example of this is during winter in Lamar County, non-ARS selection is associated with habitat available while ARS selection is strictly associated with hardwoods because this is the only habitat with available resources in the form of hard mast (Fig. 3.8) (Porter 1992, Miller et al. 1999, Miller and Conner 2007). However, wild turkeys did tend to select hardwood, pine, and mixed as these are the most common forest landcover types between study sites and have the most forage opportunities. Because wild turkeys were sampled at different study sites with differing landscapes, I can demonstrate 2nd order selection at different habitat availabilities. These results indicate that wild turkeys may place their home ranges in heterogeneous landscapes (Davis et al. 2017), but will implement different use strategies based on temporally varying available resources. A heterogeneous landscape allows individuals to make adjustments and compensate for seasonally limited resources without having to travel large distances.
Analyzing habitat selection at the finest scale possible is important to truly understand how individuals make behavioral decisions on a daily basis. My study has also shown how significant individual variation in movement of wild turkeys can have on statistical analysis. Using a continuous time Markov chain (CTMC) model, individual selection can be analyzed with the surrounding areas (or 150-m grid cells) as the available habitat so that we can understand how wild turkeys make decisions from their perception at fine spatial scales at a given time. Previous studies analyzing habitat selection at the 3rd order must assume that an entire home range’s available habitat is available at any given season or year when using pseudo-absent locations (Johnson 1980). With the CTMC, we can use a more logical assumption that available habitat is conditional on the location of an individual at a given time (1 hour, 30 min, or 15 min). It is plausible that the CTMC model may demonstrate differential selection of the same LULC among different individuals, even with different signs and magnitudes of selection coefficient of the same LULC. Individuals move in different parts of habitats with separate movement trajectories implying different local resource availabilities. It was shown that developed was selected on a fine scale at certain times of the year, developed in Copiah County encompasses roads through the WMA which have wide shoulders creating open areas that are frequently disturbed. Wilson et al. (2018) demonstrated that Steller sea lions (Eumetopias jubatus) in Alaska had differential selection of bathymetry among three sea lions with different signs of selection coefficients and different signs and magnitude for the slope of ocean floor. Furthermore, Johnson et al. (2013) also showed substantial variation in the selection of sea surface temperature among individual northern fur seals (Callorhinus ursinus). For wild turkeys, this may be especially appropriate given the variation in fine-scale habitat selection shown in my
results. However, future research should move to understand an individual’s spatial memory of a landscape and if they make decisions based on their previous knowledge of their home range.

Wild turkeys have a variety of resource needs that need to be met and will concentrate their use in habitats that are lacking within their home range (Glennon and Porter 1999, Farrell et al. 2019). Concentrated use, measured as high FPT and determined to be ARS, may increase depending on current resource availability and a strategy to combat this would be to select areas of high forage diversity and heterogeneous landscapes. Wild turkey 2\textsuperscript{nd} order habitat selection seems to follow this pattern. Additionally, individual fine-scale habitat selection provides evidence that wild turkeys select habitat conditional on the surrounding available resources at that given time. With this we can potentially see a connection between home range placement and fine-scale selection, where 2\textsuperscript{nd} order selection creates the opportunity for adjustments to be made in a stochastic environment and fine-scale selection is the decision to adjust to the abundant seasonal resources available. However, the challenge to account for individual variation in movement and habitat selection remains.

Differences in ARS and non-ARS selection could be due to limitations of availability. As resources become less available in certain landcover types, adopting concentrated use strategies may be required in order to meet energy requirements. However, differences in use as well as overall LULC selection could be due to understory vegetation types and not related to forest or LULC type. In the study I was only able to measure landcover type and not vegetation or understory characteristics. The differences in study site selection compound the evidence that availability of limited resources dictate use and use strategy (ARS or non-ARS). Potentially management may need to become region or area specific to determine resource availability based on LULC type and implement management practices based on availability.
### 3.5 Tables and Figures

Table 3.1  Selection coefficients (β) of seven land use land cover types estimated from a continuous time Markov chain model for 6 individuals in Copiah County during March 2017. Months May and July are found in Fig. A1-A2.

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<th>March ID 39564</th>
<th>March ID 38579</th>
<th>March ID 39560</th>
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Figure 3.1  Seasonal proportions (y axis) of land use and land cover (x axis) at high and low first passage time (FPT) use in Atalla County from 2018 to 2019. Winter is from January to March, spring from April to June, and summer from July to September.
Figure 3.2  Seasonal proportions (y axis) of land use and land cover (x axis) at high and low first passage time (FPT) use in Marshall County from 2018 to 2019. Winter is from January to March, spring from April to June, and summer from July to September.
Figure 3.3  Seasonal proportions (y axis) of land use and land cover (x axis) at high and low first passage time (FPT) use in Copiah County from 2018 to 2019. Winter is from January to March, spring from April to June, and summer from July to September.
Figure 3.4  Seasonal proportions (y axis) of land use and land cover (x axis) at high and low first passage time (FPT) use in Lamar County from 2018 to 2019. Winter is from January to March, spring from April to June, and summer from July to September. Add the definitions of LULCs.
Figure 3.5  Seasonal selection coefficients ($h$) of land cover and land use (LULC) types for high first passage time (FPT) or area-restricted search (ARS) and low FPT or non-area-restricted search (non-ARS) of wild turkeys in the Atalla County. The coefficients were estimated from Dirichlet-multinomial distribution model. Habitat. Availability is measured by the proportions of LULCs (bottom right).
Figure 3.6  Seasonal selection coefficients ($h$) of land cover and land use (LULC) types for high first passage time (FPT) or area-restricted search (ARS) and low FPT or non-area-restricted search (non-ARS) of wild turkeys in the Marshall County. The coefficients were estimated from Dirichlet-multinomial distribution model. Habitat availability is measured by the proportions of LULCs (bottom right).
Figure 3.7 Seasonal selection coefficients ($h$) of land cover and land use (LULC) types for high first passage time (FPT) or area-restricted search (ARS) and low FPT or non-area-restricted search (non-ARS) of wild turkeys in the Copiah County. The coefficients were estimated from Dirichlet-multinomial distribution model. Habitat availability is measured by the proportions of LULCs (bottom right).
Figure 3.8 Create a Seasonal selection coefficients (h) of land cover and land use (LULC) types for high first passage time (FPT) or area-restricted search (ARS) and low FPT or non-area-restricted search (non-ARS) of wild turkeys in the Lamar County. The coefficients were estimated from Dirichlet-multinomial distribution model. Habitat availability is measured by the proportions of LULCs (bottom right).
REFERENCES


APPENDIX A

CONTINUED TABLES
### A.1 Tables

**Table A.1** Selection coefficients ($\beta$) of seven land use land cover types estimated from a continuous time Markov chain model for 5 individuals in Copiah County during May 2017.

<table>
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**Table A.2** Selection coefficients ($\beta$) of seven land use land cover types estimated from a continuous time Markov chain model for 5 individuals in Copiah County during July 2017.

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