TRANSLOCATION AND REPRODUCTIVE ECOLOGY OF WILD TURKEYS (*MELEAGRIS GALLOPAVO*) IN EAST TEXAS

by

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(Under the Direction of Michael J. Chamberlain)

ABSTRACT

Eastern wild turkey restoration efforts in east Texas have been extensive since the early 1940's. However, restoration efforts have yielded mixed success, resulting in fragmented turkey populations across east Texas. In recent years, the primary objective of restoration has been to reconnect and supplement fragmented populations through continued use of translocation. Translocation is the process where an animal is captured in its current endemic habitat, transported, and then released into a new landscape. Restoration success is dependent on the ability of translocated wild turkeys to adapt and survive in this new landscape. Individual adaptation and survival are influenced by a suite of confounding biotic and abiotic factors (*e.g.*, habitat types and availability, presence of conspecifics, reproduction, spatial structure, prescribed fire). This study investigated how these factors influenced translocation success of eastern wild turkeys. Furthermore, because restoration success is also dependent on fitness, and because translocation may influence reproduction, this study assessed reproductive ecology of translocated eastern wild turkeys. Therefore, results of this study increase our theoretical and applied knowledge of translocation and reproductive ecology of eastern wild turkeys in east Texas.

INDEX WORDS: Eastern wild turkey, *Meleagris gallopavo silvestris*, translocation, prescribed fire, GPS telemetry, survival, habitat selection, nest activity, nest characteristics, brood parasitism

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A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2019

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August 2019

DEDICATION

This dissertation is dedicated to Amy Fortener. Words cannot express the deep gratitude I have for your enduring support, motivation, patience, and love for me. We have made this journey together, next to each other, partners in crime, during the dark times and the brightest of times. You are my rock when I need a stable place, my wind when I need my sails to move me in the right direction, you believe in me when nobody else does, you are my everything. I will always relish our time together and look forward to seeing what our bright future has in store for our beautiful, crazy life. I love you.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to Dr. Michael Chamberlain for his mentorship and giving me the opportunity to conduct this research. No one else can tell a scientific story the way that you can, and I can only hope to be a scientific troubadour like you someday. I would like to acknowledge and thank my committee members, Drs. Mike Conner, Guha Dharmarajan, and Garett Street for their mentorship and guidance in developing this dissertation and my career as a wildlife ecologist.

Likewise, I would like to thank my technicians Connor Almond, Kandis Cazenave, and Evan Donoso for working long days and tirelessly in hot, humid, bug infested conditions to collect sound scientific data that was used in this research. Without your efforts, I would still be collecting data somewhere along the Neches River. I would also like to acknowledge Drs. Joey Hinton, Mike Hooker, Andy Little, and Brad Cohen for their analytical guidance and friendship. I also want to acknowledge the many other friendships I have earned over the last few years with other graduate students in the turkey lab, specifically Nathan Yeldell, Jeremy Wood, Patrick Wightman, Nick Bakner, Calvin Wakefield, and Ashley Lohr. I have enjoyed our many deep (sometimes shallow), philosophical discussions that have often caused headaches, but mostly laughter of the best kind. I hope our friendships will continue to flourish for a lifetime.

I also want to acknowledge and thank Gene Miller, Dan Johnson, Annie Farrell, Craig White and the awesome members of the Texas Chapter of the National Wild Turkey Federation for their support of this research in east Texas. Likewise, I want to acknowledge the support provided to our research team by the many United States Forest Service personnel that allowed

our research crew open access to Angelina National Forest. We enjoyed its beauty behind locked gates. I would like to thank Jason Hardin, Micah Poteet, Sean Willis, and staff of the Texas Parks and Wildlife (TPWD) for their support and funding of this research. Without you, this project would have never lifted off the ground, thank you. I want to thank TPWD and the Warnell School of Forestry, and Natural Resources at the University of Georgia for funding and logistical support.

TABLE OF CONTENTS

Page

CHAPTER

APPENDICES

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

Translocation is the process whereby an animal is captured in its current habitat, transported, and then released into a new landscape (Seddon et al. 2007). Translocation is used by managers to reintroduce flora and fauna to historic ranges where respective populations once existed (IUCN 1998). Although translocation is widely accepted as an important tool for conservation, translocations can be risky and often fail (IUCN 1987, Lyles and May 1987, Fischer and Lindenmayer 2000). Translocation success is dependent on the ability of animals to adapt and survive in new habitat, where the animal possesses no prior knowledge of how abiotic (e.g., climate, spatial structure, prescribed fire) and biotic factors (e.g., forage types and availability, predator type and density) vary across the landscape (IUCN 1998, Caughley 1994, Armstrong and Seddon 2007).

In addition to abiotic and biotic factors, translocation success is dependent on mating strategies and the ability of each individual to reach a point of stability prior to the reproductive period, a point thought to have positive influence on population fitness (Armstrong et al. 1994). Furthermore, translocation success depends greatly on pre- and post-release management. Release locations must be determined based on whether availability and structure of suitable habitat will support the population (IUCN 1998, Armstrong and Seddon 2007). If not, habitat must be manipulated to favor survival and fitness based on life history strategies prior to reintroduction (IUCN 1998). Managers also must determine an adequate number of animals to translocate to an area (Armstrong and Seddon 2007, Miller et al. 1999, Lopez et al. 2000). If the initial translocated population is too small, greater dispersal and mortality rates may result in an Allee effect, preventing an individual from finding mates as they become isolated on the landscape, thereby negatively influencing mating and fitness (Allee 1931). Following release, biologists must continue to monitor the newly translocated population and decide whether to supplement stock as mortality and emigration occurs (Armstrong and Seddon 2007, Lopez et al. 2000).

Translocation success is dependent on an animal's ability to acclimate to its new habitat and survive post-release (Rittenhouse et al. 2007, Hamilton et al. 2010). Previous studies have suggested that survival of translocated animals is influenced by the extent of post-release movements when exhibiting exploratory behavior (Curtis et al. 1988, Spinola et al. 2008, Berger-Tal et al. 2014). The exploratory phase is characterized by an initial increase in space use and wide-ranging movements, which decrease as animals shift to resource exploitation (Berger-Tal and Saltz 2014, Cohen et al. 2015). Translocated individuals exhibiting wide-ranging movements and increased space use are susceptible to experiencing greater mortality than those capable of quickly reducing space use and movements post-release (Curtis et al. 1988, Sisson et al. 2000, Clapp et al. 2014). Animals that transition quickly from exploration to exploitation also are able to better optimize energy costs associated with foraging and fitness (Charnov 1976, Berger-Tal et al. 2014). Therefore, animals capable of acclimating quickly to their new habitat post-release have the greatest propensity to survive, thus increasing translocation success (Letty et al. 2007, Dickens et al. 2009, Clapp et al. 2014).

Translocation success also can be influenced by presence of conspecifics at or near the release site, influencing translocated animals to move less and increase fidelity to release sites, which can positively influence survival. Previous research has shown that the presence of conspecifics can positively influence a suite of species such as Northern bobwhite (*Colinus virginianus*, Jones et al. 1999), water voles (*Arvicola terrestris*, Fisher et al. 2008), black rhinoceros (*Diceros bicornis*, Linklater et al. 2006, Linklater and Swaisgood 2008), and African elephants (*Loxodonta Africana*, Pinter-Wollman et al. 2009). Therefore, presence of conspecifics at or near release sites is an important consideration when restoring species through translocation (Martin et al. 2017).

An excellent model species for reintroduction using translocation in North America is the wild turkey (*Meleagris gallopavo*). The 5 wild turkey subspecies in North America (Eastern—*M. g. silvestris*, Merriam's—*M. g. merriami*, Osceola—*M. g. osceola*, Rio Grande—*M. g. intermedia*, and Gould's—*M. g. mexicana*) were once common and abundant throughout their native ranges prior to colonial establishment. However, by 1920 nearly all populations of eastern wild turkeys (hereafter, wild turkeys) were extirpated primarily because of habitat destruction and overharvest by unregulated subsistence hunting (Kennamer et al. 1992, Mosby and Handley 1943). Following the Great Depression, agricultural landscapes were transformed to forested landscapes, leading to an increase in sustainable habitat for wild turkeys (Shands 1992). Because of habitat restoration, federal and state management agencies along with hunting and conservation stakeholder groups undertook great effort to restore sustainable wild turkey populations across the nation from the 1930's thru the early 1990's (Mosby 1975, Kennamer and Kennamer 1990). Throughout this period, translocations of wild turkeys faced unique challenges across all respective states involved in reintroduction efforts, despite being largely successful.

Texas has faced an arduous battle to restore wild turkeys to east Texas (Newman 1945). East Texas represents the western extent at which wild turkeys were distributed throughout the southern pine belt (Newman 1945, Kennamer and Kennamer 1990, Figure 1.1). Historically, the fire-dependent longleaf pine (*Pinus palustris*) ecosystem occupied approximately 30 million ha in the southeastern United States and was distributed from Virginia to east Texas (Frost 1993). Because of longleaf pine and hardwood drainage systems, wild turkey populations were able to disperse from the east coast emigrating westward to east Texas until reaching habitat not suitable for supporting further expansion into Texas (Newman 1945). As human development continued to increase in east Texas in the early 1900's, longleaf pine savanna and hardwood drainages were harvested and replaced by lower quality habitat represented by faster growing loblolly (*Pinus taeda*) and slash pine (*Pinus elliotti*) for timber production (Pyne 1982, Frost 1993, Alavalapati et al. 2002). The removal of longleaf pine savannas and hardwoods, coupled with subsistence hunting, lead to the extirpation of wild turkeys from the Pineywoods of east Texas by 1940 (Newman 1945).

The early 1940s saw new restoration efforts by the Texas Game, Fish and Oyster Commission (present-day Texas Parks and Wildlife Department, TPWD) to translocate wild turkeys from Mississippi and Alabama for pen-rearing and release at locations within 3 counties in east Texas (Newman 1945). The early pen-raised reintroductions were unsuccessful, and it was not until 1979 and 1980 when east Texas observed its first 2 successful translocations of wild-trapped wild turkeys from Mississippi and Louisiana (Campo et al. 1984). Since then, restoration efforts have continued with mixed success as biologists from TPWD moved from a block stocking strategy of 12 adult females and 3 adult males (Campo et al. 1984) to super-stocking 60 mixed-aged females and 20 mixed-aged males from states such as Iowa, Missouri, Tennessee, and West Virginia (Lopez et al. 2000). Translocations using the super-stocking strategy have produced greater survival and reproduction compared to block stocking. However, not all translocations using super-stocking have been successful, as survival and reproduction are dependent on adaptability of the animal and availability of suitable habitat in their new home (Conway et al. 2010).

Notably, habitat that wild turkeys translocated to east Texas encounter in their new home is mostly comprised of upland-pine savanna managed with frequent prescribed fire. Disturbance events such as prescribed fire can influence a species ecology (White and Pickett 1985, Wong and Candolin 2015). Since frequently burned upland-pine savannas constitute important habitat for wild turkey populations in east Texas and across the southeastern United States, there have been increasing efforts to understand the effects of prescribed fire on population dynamics of wild turkeys (Streich et al. 2015, Little et al. 2015, Yeldell et al. 2017, Wood et al. 2018*a,b*). Previous studies have aimed to elucidate the direct (e.g., nest loss to fire) and indirect (e.g., nest- and brood site selection) effects of prescribed fire (Sisson et al. 1990, Martin et al. 2012, Little et al. 2016, Wood et al. 2008*a,b*), but little is known about how wild turkeys are influenced by the spatial scale and shape of prescribed fires. Therefore, additional research is needed to understand how the spatial scale and shape of prescribed fire influence landscape use by wild turkeys. Likewise, alternative reproductive strategies can also influence a species ecology (Payne 1977). One such alternative nesting strategy, brood parasitism, can play an important role in processes regulating a species reproductive fitness and population dynamics (Robinson et al. 1995, Cichoń 1996). Recently, managers have observed reduced productivity resulting in population declines across the southeastern United States (Byrne et al. 2015, Eriksen et al. 2015). Productivity manifested via nest success, is the driver of population sustainability in both translocated and resident wild turkey populations (Vangilder 1992). However, the potential for brood parasitism to serve as an alternative reproductive strategy by wild turkeys (*Meleagris gallopavo*) is poorly understood. Therefore, further research is needed to increase our basic understanding of the prevalence of brood parasitism and how it may influence productivity of wild turkey populations across the southeastern United States.

Previous studies investigating reproductive behavior of translocated wild turkeys in east Texas relied upon VHF transmitters to determine nesting behavior and nest success (Isabelle et al. 2015, 2016). The advent of GPS transmitters for wild turkeys has allowed researchers to more appropriately describe various behaviors of wild turkeys, including nesting and movement ecology (Guthrie et al. 2011). Notably, contemporary research on both resident and translocated wild turkeys using GPS telemetry has demonstrated improved inferences relative to estimating various demographic parameters (Collier and Chamberlain 2011, Cohen et al. 2015, Yeldell et al. 2017, Wood et al. 2018*a*,*b*). Since TPWD and other management agencies will continue to translocate wild turkeys for restoration efforts across the United States, additional research is needed to evaluate current practices guiding translocation and ecological responses of translocated wild turkeys to new habitats. Therefore, I conducted research in east Texas aimed at increasing our theoretical and applied knowledge of translocation and reproductive ecology of wild turkeys to promote success of future wild turkey restoration efforts. My objectives were to 1) examine and characterize nesting activity and success of translocated GPS-marked wild turkeys, 2) describe space use, movements, and survival of translocated wild turkeys, 3) describe habitat selection of translocated wild turkeys and generate predictive maps of habitat selection, 4) assess and quantify the relationship between scale and shape of prescribed burn units and their effect on landscape use by wild turkeys, and 5) describe instances of brood parasitism using both GPS telemetry data and photographic evidence, and illustrate the potential extent of conspecific brood parasitism in wild turkeys.

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CHAPTER 2

NESTING ACTIVITY AND NEST SITE CHARACTERISTICS OF A TRANSLOCATED EASTERN WILD TURKEY POPULATION IN EAST TEXAS[1]

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[1] Sullivan, D. J., M. L. Poteet, B. A. Collier, and M. J. Chamberlain. 2019. To be submitted to the Journal of the Southeastern Association of Fish and Wildlife Agencies.

ABSTRACT

Sustainability of Eastern wild turkey (*Meleagris gallopavo silvestris*, hereafter turkey) populations following translocation is dependent on reproductive success. Extensive efforts to restore turkeys to east Texas using translocation have yielded mixed results, leading to low-density, fragmented populations. Dynamics of a translocated turkey population are dependent on the outcome of nesting activity and nest success, which can be influenced by vegetation characteristics selected by females when nesting. Because translocated turkeys transition from natal to new habitats, understanding patterns of nesting activity and vegetation characteristics selected by nesting females are important to continued restoration of turkey populations. We translocated 78 female and 23 male turkeys to southern Angelina National Forest near Zavalla, Texas during 2016-2017. In 2017, we recaptured 8 translocated and 3 resident females. We used GPS telemetry to monitor nesting behavior and evaluated vegetation characteristics at nest sites. Initial nesting rates of translocated females varied from 74% to 82%, whereas renesting rates ranged from 21% to 74% between years; both rates were 100% for resident turkeys. Only 2 of 31 initial nests (7%) were successful, whereas no renests were successful. We documented only 1 brood surviving 28 days after hatching. Translocated turkeys selected nest sites with more woody cover and greater vegetation height, whereas resident turkeys selected nest sites with more vine cover and lower vegetation height. The observed rates of nest initiation and success for translocated birds suggest that multiple releases across years may be necessary to ensure establishment and success of translocated populations in east Texas.

INTRODUCTION

Translocations are used to reintroduce species to historic ranges and have been an important tool for species conservation (IUCN 1987, Lyles and May 1987, Fischer and

Lindenmayer 2000). Translocation success hinges on a species' ability to adapt to potentially new habitat conditions, and in the ability of individuals to reach stability in behaviors to where fitness can be maximized (Armstrong and McLean 1995, Pople et al. 2001). Successful translocations require successful reproduction during the year of translocation or in subsequent years (De Leo et al. 2004, Baxter et al. 2010). For translocated birds, species capable of nesting successfully in a variety of vegetation conditions are more likely to be successful relative to more specialized species (Sol et al. 2002).

Eastern wild turkey (*Meleagris gallopavo silvestris*; hereafter turkey) populations have been restored throughout their historic geographic range using translocations of wild caught birds. Restoration of wild turkey populations is considered one of the great success stories in North American wildlife conservation (Mosby 1975, Kennamer and Kennamer 1990, Shands 1992). However, restorations have not been uniformly successful, with one notable example occurring in east Texas (Newman 1945, Campo et al. 1984). Despite the release of >7,000 turkeys since the 1970s (Seidel et al. 2013), turkey density in east Texas remains low, driven by poor reproduction following translocation (Lopez et al. 2000, Conway et al. 2010, Isabelle et al. 2016). Early translocation attempts in east Texas used block stocking (< 20 birds released), but simulation models indicated potential benefit of using a super stocking approach (> 70 birds released, Lopez et al. 2000).

Reproductive success is the primary driver of population dynamics for wild turkeys (hereafter turkey; Vangilder and Kurzejeski 1995, Pollentier et al. 2014). Productivity of turkey populations throughout the southeastern United States has declined during the past two decades, potentially from reductions in nest success (Byrne et al. 2015). Nest success can be influenced by a variety of environmental parameters, such as temperature, precipitation, and vegetation characteristics, each which may influence nest predation risk (Bowman and Harris 1980). Turkeys exhibit considerable plasticity in nest selection, using a diversity of cover types throughout the species range (Martin et al. 2012, Conley et al. 2016). Likewise, across the range, predation is the primary cause of nest loss (Palmer et al. 1993, Miller and Leopold 1992, Miller et al. 1998), with numerous studies noting extensive loss to predation of nests and nesting females (Vangilder et al. 1987, Badyaev 1995, Miller et al. 1998, Isabelle et al. 2016).

Turkeys nest in a wide range of vegetation types, and although characteristics at nest sites have potential to influence reproductive success (Badyaev et al. 1996, Fuller et al. 2013), translocated birds must select nest sites with no prior experience of where to find vegetation that most influences nest success. Indeed, Isabelle et al. (2016) noted that translocated turkeys in east Texas used diverse habitat types for nesting but failed to note relationships between vegetation at nests and nest success. Previous studies investigating reproductive behavior of translocated turkeys in east Texas relied upon VHF transmitters to determine nesting behavior and nest success (Isabelle et al. 2016). The advent of GPS transmitters for turkeys has allowed researchers to more appropriately describe various behaviors of turkeys, including nesting and movement ecology (Guthrie et al. 2011). Notably, contemporary research on both resident and translocated turkeys using GPS telemetry has demonstrated improved inferences relative to estimating various demographic parameters with VHF data (Collier and Chamberlain 2011, Cohen et al. 2015, Yeldell et al. 2017, Wood et al. 2018*a*). Hence, our objectives were to examine and characterize nesting activity and success of GPS-marked turkeys translocated to east Texas during 2016-2017. We also evaluated vegetation characteristics of nest sites between translocated and resident turkeys.

STUDY AREA

We conducted our research in and around the southern portion of Angelina National Forest (hereafter ANF, Figure 2.1) located near the town of Zavalla in the Pineywoods eco-region of east Texas. The southern shoreline of Sam Rayburn reservoir served as the northern boundary of ANF, whereas the Neches River formed the southern boundary. The western boundary of ANF was Shawnee Creek and Farm to Market (hereafter; FM) 69, and the eastern portion was bounded by the Angelina River and FM 255. The ANF was approximately 18,751 ha and comprised mostly of mature longleaf pine (*Pinus palustris*) managed by large-scale prescribed fires (≥ 600 ha), with hardwood drainages near streamside management zones and other riparian areas. We released turkeys at a single release site near Boykin Springs Campground due south of FM 63, and near the bisection of Angelina and Jasper counties. The release site was predetermined by Texas Parks and Wildlife Department biologists and selected to promote safe flight of turkeys as they were released from transport boxes.

METHODS

We released 78 female and 23 male wild turkeys captured in Iowa and West Virginia on the ANF during 2016-2017. In addition to releasing translocated turkeys, we captured 3 female turkeys using rocket nets in February 2017. Prior to release, we classified each turkey as adult or subadult based on barring of ninth and tenth primary feathers (Pelham and Dickson 1992) and affixed backpack-style GPS transmitters equipped with VHF weighing approximately 88-g (Lotek-Biotrack LTD: Wareham, Dorset, UK). We programmed transmitters to record hourly locations from 0800 to 1700 hours post-release to 1 March. Beginning 1 March, transmitters recorded hourly locations from 0700 to 1800 hours, along with a roost location at 2330 hours (Cohen et al. 2018). All capture and handling procedures were approved by the University of

Georgia Institutional Animal Care and Use Committee (Approval number A2015 07-009-Y1-A0).

We monitored wild turkeys daily by locating individuals with VHF and remotely-downloaded GPS data ≥ 1 time/week post-release to end of February. When mortality events were detected, we recovered transmitters and assessed causes of mortality. Beginning 1 March, we began remotely-downloading GPS data ≥ 2 times per week as nesting activity began. Using GPS locations, we determined when a female was incubating a nest when locations became clustered around a single point (Yeldell et al. 2017, Wood et al. 2018*b*). Once females were observed away from the nest site for > 1 day, we examined nests to determine the outcome (failure or success). We determined the nest to be successful if evidence of ≥ 1 hatched egg was found at the nest site, or by relocating females after they left the nest site and confirming presence of a brood. We classified nests as failed if we found eggshell fragments in and around the nest bowl and there was clear evidence of a predation event on either the nest or the incubating female (Yeldell et al. 2017, Wood et al. 2018*b*).

To describe nesting ecology, we assessed nesting rates and nest success following methods outlined in Melton et al. (2011). We defined initial nesting rate as the proportion of females that initiated ≥ 1 nest. Likewise, we defined second, third, and fourth nesting rates as the proportion of females initiating second, third, and fourth nests following loss of an earlier nest. We defined nest success rate for each nesting attempt as the proportion of nests producing ≥ 1 hatched egg (Yeldell et al. 2017). Nesting behavior of female turkeys cycles annually (Kurzejeski and Lewis 1990), hence we considered translocated females who survived into their second nesting season to be residents whereas females nesting in the year of translocation were considered translocated.

We examined vegetation characteristics within 15-m radius circular plots (Streich et al. 2015, Little et al. 2016, Yeldell et al. 2017) at the nest site and in each cardinal direction from the nest site for comparison of vegetation characteristics between translocated and resident female turkeys. We estimated percent ground cover for 8 ground cover types (woody, grass, forbs, vine, fern, moss, debris, bare), maximum vegetation height (cm), mean vegetation height (cm), visual obstruction (cm), canopy cover (% covered), understory cover (% covered), basal area (m^2 per ha). We estimated percent ground cover using a modified 1-m^2 Daubenmire frame (Daubenmire 1959) centered over the nest site and in each cardinal direction 15-m from the nest. We measured maximum and mean vegetation height in addition to visual obstruction by placing a 2-m Robel pole (Robel et al. 1970) at the nest site and 15-m in each cardinal direction and viewing it at approximately 1-m above ground to simulate the height of a turkey (Pelham and Dickson 1992). We determined visual obstruction as the lowest point on the Robel pole obscured by vegetation viewed from 1-m above the ground. We followed methods outlined by Yeldell et al. (2017) to estimate maximum vegetation height, mean vegetation height, and mean visual obstruction. We measured understory cover 1-m above ground and canopy cover at breast height of the observer at the nest site and in each cardinal direction 15-m from the nest site using a convex densiometer (Lemmon 1956). Mean percent cover for understory and canopy cover was calculated by taking the mean of 5 readings at the nest site and in each cardinal direction. To estimate tree density, we recorded basal area using a 10-basal area factor (BAF) prism centered on the nest site.

We calculated mean date for onset of incubation using Julian dates when females were observed to initiate incubation divided by the total number of incubated nests and renests. Ranges of incubation dates were represented by the temporal period between the earliest date when onset of incubation occurred and the last date of incubation for nesting and renesting attempts. Nesting rates were estimated using the proportion of females that initiated ≥1 nest (Yeldell et al. 2017). We estimated renesting rates for subsequent nests using the proportion of females that initiated a second nest following the loss of the first or antecedent nest. We described vegetation characteristics of nest sites by 2 classes of nest types; translocated and residents. We compared vegetation characteristics at each nest site between classes using a one-way analysis of variance (ANOVA) for unbalanced designs because of uneven sample sizes. If results of the ANOVA indicated significance between the 2 classes, we conducted a Tukey HSD post-hoc test to determine which vegetation characteristics differed at $\alpha = 0.05$. We conducted all analyses using software program R (R Core Team 2013).

RESULTS

During 2016, 56 and 4 female turkeys were translocated to ANF from Iowa and West Virginia, respectively. Of those 60 females, 35 (21 adults, 14 subadults) were available to nest, as the remaining 25 females were lost to mortalities ($n = 13$) or transmitter failure ($n = 12$; Table 2.1, Figure 2.1) prior to first nest initiation. Causes of mortality included predation ($n = 11$) and vehicle collision ($n = 2$). We observed an initial nesting rate of 74% comprised of 15 and 11 nests by adult and subadults, respectively (Table 2.1). Collectively, adult and subadult female turkeys attempted 31 nests and 5 renests in 2016 (Figure 2.1). Mean incubation start date of initial nests was 5 May, ranging from 13 April to 9 June. Only 2 initial nests were successful hatching ≥ 1 egg, and 1 brood survived until 28 days after hatch. Renesting rates for second and third nest attempts in 2016 were 21% and 25%, respectively, but no renests were successful (Table 2.1).

We translocated 18 additional females from Iowa (*n* = 7) and Missouri (*n* = 11) to ANF in 2017 and recaptured 8 females originally translocated in 2016, as well as 3 resident females (from unknown origin) on private lands within ANF. Of these 29 females, 7 were lost before nesting to mortality (*n* = 2) or transmitter failures (*n* = 5). The remaining 22 females (20 adults, 2 subadults) included 12 translocated females (10 adults, 2 subadults) and 10 (adult) resident females (Tables 2.1 and 2.2). Mean date of onset of incubation for initial nests was 23 April, ranging from 31 March to 12 June. Initial nesting rates were 67% and 100% for translocated and resident females, respectively (Table 2.2). Renesting rates were 29% for translocated females and 100% for resident females (Table 2.2). We noted that 3 resident females attempted a third nest, and a single resident female attempted a fourth nest. No nests were successful in 2017. Overall, causes of nest failure included mortality of the incubating female (*n* = 9), prescribed fire (*n* =2), flooding (*n* = 2), and nest predation (*n* = 48).

Vegetation characteristics at nest sites were generally similar between translocated and resident females (Table 2.3). Translocated females tended to select nests with a greater percentage of woody ground cover ($\bar{x}$ = 27.44%, SE ± 2.13%, $F_{1,60}$ = 6.63, *P* = 0.01), whereas resident females tended to select nests with greater percentage of vine cover ($\bar{x}$ = 9.31%, SE ± 3.24%, $F_{1,60}$ = 4.99, *P* = 0.03). We noted that maximum vegetation height ($F_{1,60}$ = 3.01, *P* = 0.09) was similar at all nests (translocated; $\bar{x}$ = 168.70 cm, SE ± 5.46 cm, resident; $\bar{x}$ = 152.34 cm, SE ± 9.19 cm) but mean vegetation height was greater at nests of translocated females ($\bar{x}$ = 118.77 cm, SE ± 6.24 cm, $F_{1,60}$ = 6.78, *P* = 0.01) than nests of resident females ($\bar{x}$ = 91.00 cm, SE ± 7.86 cm). No other vegetation characteristics differed between nests of translocated and resident females.

DISCUSSION

We observed that translocated wild turkeys suffered substantive mortality following release and prior to nesting. Translocated animals are confronted with the necessity to adjust to new landscapes that often differ in predator abundance relative to natal habitats (Chivers et al. 2014, Ferrari et al. 2015, Kenison and Williams 2018). Although quantifying predator abundance was beyond the scope of our work, richness of predator species in east Texas was likely higher than at all natal sites, given known latitudinal gradients in predator richness and abundance (Gaston 2000, Willig et al. 2003). For wild turkeys and other ground nesting birds, excessive mortalities immediately after translocation can compromise translocation success through reductions in fitness potential (Kelly 2001, Whiting et al. 2005, Martin et al. 2017). Conversely, we observed greater initial nesting rates than those previously reported for translocated turkeys in east Texas (see Isabelle et al. 2016). Our results indicate that the use of GPS telemetry allowed for a more precise assessment of nest initiation rates via improved abilities to monitor reproductive behaviors and movements associated with nesting (Collier and Chamberlain 2011, Yeldell et al. 2017).

We observed rates of nest success well below those necessary to ensure sustainable populations (Vangilder et al. 1987, Wood et al. 2018b). Furthermore, nest success was poor for females translocated during 2016 that survived and attempted to nest during 2017. Notably, we observed average nest success for both translocated and resident birds on ANF lower than that reported for any population of wild turkeys in the southeastern United States, regardless of whether the population consisted of resident or translocated birds (Vangilder et al. 1987, Thogmartin and Johnson 1999, Miller et al. 1995, Yeldell et al. 2017), including previously reported estimates for translocated turkeys in east Texas (Campo et al. 1984, Isabelle et al.

2016). We suggest that greater nest success rates reported in previous studies in east Texas may be attributed to natal habitats where birds were captured for translocation. Previous translocations used wild turkeys from similar forested habitats (e.g., Louisiana and Mississippi, Campo et al. 1984; South Carolina and Tennessee, Isabelle et al. 2016). Conversely, translocated turkeys in our study originated from open, agricultural landscapes and fragmented hardwood forests, which may have influenced their ability to identify nest sites offering reduced predation risk (irrespective of vegetation) during the initial nesting season after translocation.

Translocation presents a unique opportunity to study nest site selection and vegetation characteristics associated with nest sites because translocated female turkeys do not have predisposed knowledge of the landscape prior to release. Therefore, we would expect that as females increase their knowledge of the landscape, changes in nest-site selection would be observed. Although we noted subtle differences in vegetation characteristics at nest sites between resident and translocated females, these characteristics collectively were consistent with what is observed at nest sites throughout pine-dominated forests of the southeastern United States (Moore et al. 2010, Streich et al. 2015, Yeldell et al. 2017, Wood et al. 2018*b*). The consistency of vegetation characteristics observed at nest sites is reasonable when considering nest selection of birds is evolutionarily linked to the habitats they inhabit (Joyce 1993, Verlando and Márquez 2002) and thus requires an innate understanding of basic materials to construct nests capable of mitigating thermoregulation and protecting the attending female from predatory risks (Collias 1964, Heenan 2013, Mainwaring et al. 2014).

MANAGEMENT IMPLICATIONS

The success of a translocation depends on the ability of translocated individuals to quickly adapt to new habitat conditions, thereby maximizing individual fitness and positively influencing fecundity. Given the low nest success we observed, we suggest that multiple years of translocations will be necessary to establish a sustainable population of turkeys on ANF. We note that Lopez et al. (2000) suggested multi-year efforts may be good management practice in the process of restoring turkey populations, with a plan to supplement initial super stocked populations. Furthermore, managers in east Texas should consider translocating turkeys from natal habitat representative of the new habitat conditions at the release site.

ACKNOWLEDGEMENTS

We appreciate funding and support provided by Texas Parks and Wildlife Department, and the Warnell School of Forestry and Natural Resources at the University of Georgia. Funding for this research was provided in part by TPWD and U.S. Fish and Wildlife Service through the Federal Aid in Wildlife Restoration Act (Pittman-Robertson) program, Grant number TX-W-164-R-1.

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Table 2.1. Nesting rate and success by year (2016 vs. 2017) and age (adult vs. subadult) of available female wild turkeys affixed with µGPS telemetry transmitters. All 2016 female wild turkeys were translocated to Angelina National Forest, Texas, USA.

Year	1st Nest Attempt			2nd Nest Attempt			3rd Nest Attempt			4th Nest Attempt		
2016	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)
Adult	21	71	1	13	23	0	3	33	0	–	–	–
Subadult	14	79	1	6	17	0	1	0	0	–	–	–
Overall	35	74	2	19	21	0	4	25	0	–	–	–
2017	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)
Adult	20	85	0	14	71	0	8	25	0	2	50	0
Subadult	2	50	0	1	0	0	–	–	–	–	–	–
Overall	22	82	0	15	67	0	8	25	0	2	50	0

Table 2.2. Nesting rate and success of available translocated and resident female wild turkeys by class and age (adult vs. subadult) affixed with µGPS telemetry transmitters in Angelina National Forest, Texas, USA during 2017.

Class	1st Nest Attempt			2nd Nest Attempt			3rd Nest Attempt			4th Nest Attempt		
Translocated	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)
Adult	10	70	0	6	33	0	2	0	0	–	–	–
Subadult	2	50	0	1	0	0	–	–	0	–	–	–
Combined	12	67	0	7	29	0	2	0	0	–	–	–
Residents	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)	Available (n)	Rate (%)	Success (n)
Adult	10	100	0	8	100	0	6	33	0	2	50	0
Total	22	82	0	15	67	0	8	25	0	2	50	0

Table 2.3. Vegetation characteristics for each nest site by class (Translocated = 41 nest attempts, Residents = 21 nest attempts) representing percent ground cover for 8 ground cover types, maximum vegetation height (cm), mean vegetation height (cm), visual obstruction (cm), understory cover (% covered), canopy cover (% covered), and basal area (m^2 per ha) for translocated (n = 34 individuals) and resident (*n* = 10 individuals) female wild turkeys in Angelina National Forest, Texas, USA during 2017. Data is mean ± 1 SE.

Vegetation Characteristics	Vegetation by Class ($\bar{x}$ ± 1 *SE)*	
Type	Translocated (n = 34)	Residents (n = 10)
Woody (%)	27.44 ± 2.13	14.88 ± 2.77
Grass (%)	19.84 ± 2.81	28.88 ± 5.95
Forbs (%)	4.90 ± 1.01	6.44 ± 1.15
Vine (%)	3.54 ± 0.77	9.31 ± 3.24
Fern (%)	3.17 ± 1.11	0.31 ± 2.53
Moss (%)	0.24 ± 0.13	0
Debris (%)	34.92 ± 3.40	30.44 ± 5.63
Bare (%)	3.51 ± 1.09	9.75 ± 3.32
Maximum Vegetation Height (cm)	168.70 ± 5.46	152.34 ± 9.19
Mean Vegetation Height (cm)	118.77 ± 6.24	91.00 ± 7.86
Visual Obstruction (cm)	98.40 ± 7.02	96.44 ± 11.09
Understory Cover (%)	68.50 ± 3.71	72.61 ± 6.17
Canopy Cover (%)	78.13 ± 22.89	68.61 ± 6.26
Basal Area (M^2 per^{-ha})	54.41 ± 54.44	44.44 ± 6.38

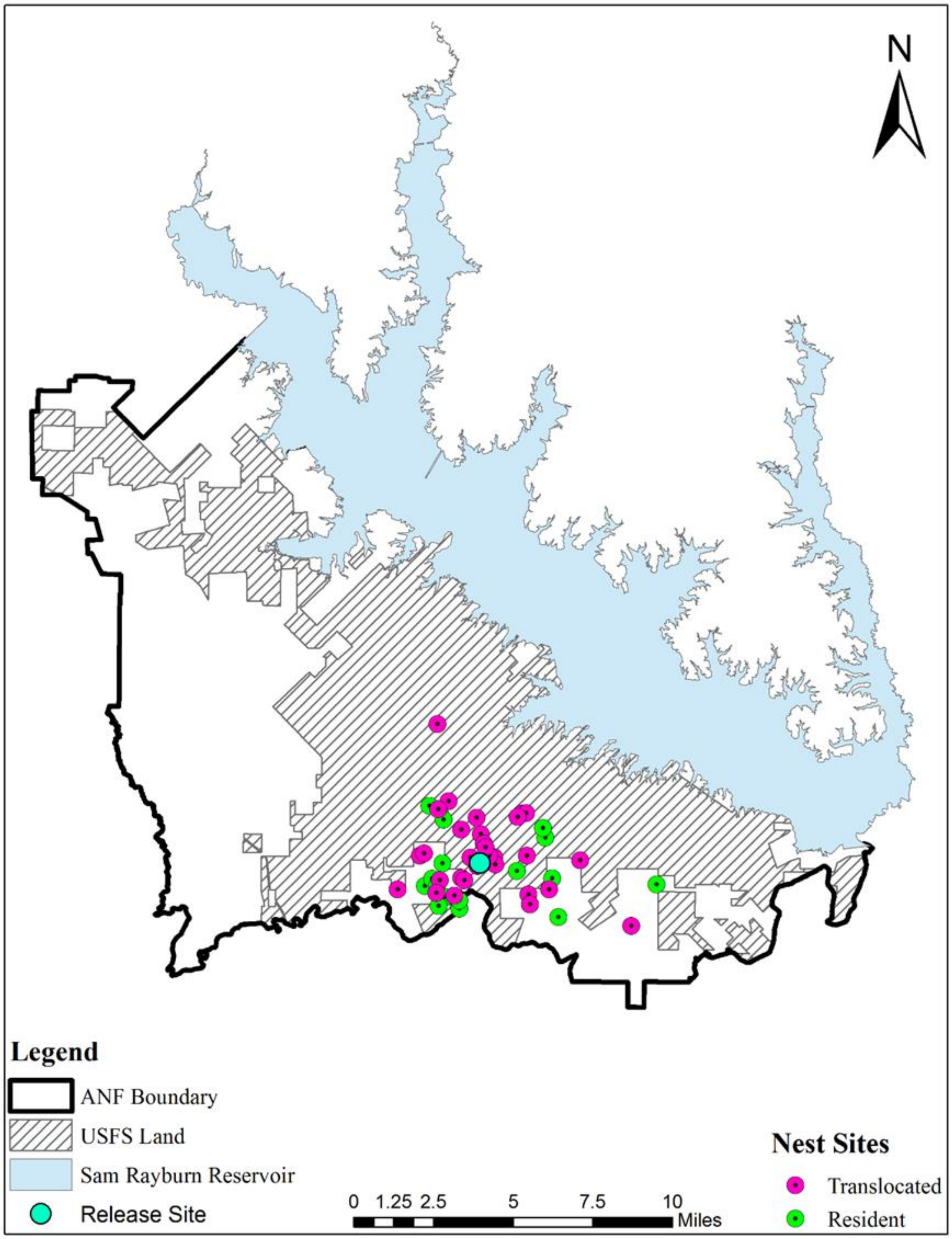

Figure 2.1. Nest sites of translocated and resident female eastern wild turkeys in Angelina National Forest, Texas, USA during 2016–2017.

CHAPTER 3

SPACE-USE, MOVEMENTS, AND SURVIVAL OF TRANSLOCATED EASTERN WILD TURKEYS IN EAST TEXAS[1]

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[1] Sullivan, D. J., B. S. Cohen, B. A. Collier, and M. J. Chamberlain. To be submitted to the Journal of Wildlife Management.

ABSTRACT

Translocation failures are driven by the inability of individuals to adapt to abiotic and biotic factors occurring in the new landscape. Translocated animals typically prospect the local landscape post-release and the presence of conspecifics positively influences translocation success via reductions in post-release movements. Extensive efforts to restore Eastern wild turkeys (*Meleagris gallopavo silvestris*) to east Texas have yielded mixed results, leading to low-density, fragmented populations. Thus, increased information on space use, movements, and survival of translocated turkeys will improve translocation success in east Texas. We translocated 78 female and 23 male wild turkeys to Angelina National Forest, TX USA during 2016─2017. We monitored translocated individuals using GPS telemetry and observed a noticeable decline in space use and movements at approximately 20 days post-release for turkeys translocated in 2016. Turkeys translocated in 2016 in the absence of conspecifics maintained larger mean daily core area and home range sizes, and moved greater daily distances from the release site and between roosts during days 1-20 than days 21-80. Conversely, females translocated in the presence of conspecifics (during 2017) used smaller daily core areas and home range sizes and moved shorter distances. We modelled survival using Cox proportional hazards models and found survival was negatively influenced by increasing daily core area size and daily distance travelled during year 1, but the effect of daily distance travelled was not found when conspecifics were present in year 2. Our findings suggest that translocations to areas with wild turkeys present may be a strategy to minimize movements and improve survival, thereby increasing translocation success.

INTRODUCTION

A central question in ecology is the role various disturbance characteristics (e.g., distribution, frequency, size, severity; White and Pickett 1985) play in affecting resource availability and animal response, as behavioral responses of animals are mediated by severity of the disturbance (Wong and Candolin 2015). When changes in ecosystem processes are unpredictable (Beever et al. 2017), individuals must possess the behavioral plasticity to adapt to unpredictable environments (Renn and Schumer 2013, Bhat et al. 2015). When some species are unable to respond to rapid changes and their populations decline, conservationists and managers must decide whether to intervene to facilitate population recovery. One common practice to aid in population re-establishment is translocation, wherein animals from one part of their geographic distribution are moved to another where the species historically occurred or exists at low abundance (IUCN 1998 Seddon et al. 2007).

Translocations are a widely accepted conservation tool; however, they regularly fail (IUCN 1987, Lyles and May 1987, Fischer and Lindenmayer 2000), as individuals are unable to adapt and survive in an environment where the animal possesses no prior knowledge of how abiotic and biotic factors vary across the landscape (IUCN 1998, Caughley 1994, Armstrong and Seddon 2007). In addition to abiotic and biotic drivers, translocation success depends on the ability of individuals to reach a point of stability in their behaviors prior to the reproductive period, a point thought to positively influence population fitness (Armstrong et al. 1994). Furthermore, translocation success depends on whether availability and structure of suitable habitats will support an adequate number of animals (Armstrong and Seddon 2007, Miller et al. 1999, Lopez et al. 2000) deemed necessary for restoration (IUCN 1998, Armstrong and Seddon 2007).

Translocation utility is dependent on an animal’s ability to acclimate to its new habitat and survive post-release (Rittenhouse et al. 2007, Hamilton et al. 2010). Translocated individuals use different behavioral strategies during an exploratory phase to identify resources post-release (Berger-Tal et al. 2014). Behaviors during the exploratory phase are characterized by increased space use that declines as animals identify and shift to individual maintenance (Berger-Tal and Saltz 2014, Cohen et al. 2015). Previous studies have suggested that survival of translocated animals is influenced by the extent of post-release movements (Curtis et al. 1988, Spinola et al. 2008) wherein those that rapidly reduce space use post-release have increased survival (Curtis et al. 1988, Sisson et al. 2000, Clapp et al. 2014). Hence, acclimation rate post-release increases survival, and thus translocation success (Letty et al. 2007, Dickens et al. 2009, Clapp et al. 2014). Presence of conspecifics may reduce acclimation times, and has been shown to influence translocation success for species such as Northern bobwhite (*Colinus virginianus*, Jones et al. 1999), water voles (*Arvicola terrestris*, Fisher et al. 2008), black rhinoceros (*Diceros bicornis*, Linklater et al. 2006, Linklater and Swaisgood 2008), and African elephants (*Loxodonta Africana*, Pinter-Wollman et al. 2009). Therefore, presence of conspecifics at or near release sites is an additional consideration when restoring species through translocation (Martin et al. 2017).

Eastern wild turkeys (*Meleagris gallopavo silvestris*, hereafter turkey) were once abundant in the southeastern United States, however, by 1920 turkeys were extirpated from most of their historic range (Mosby and Handley 1943), largely due to habitat degradation and overharvest (Kennamer et al. 1992, Mosby and Handley 1943). Harvest restrictions combined with habitat restoration and translocation activities were used to restore wild turkeys across the United States (Mosby 1975, Kennamer and Kennamer 1990). Although largely successful, restoration has faced challenges, particularly in east Texas (Newman 1945). East Texas is recognized as the historical western boundary of the subspecies range with an estimated population of 3,000 individuals in 1989 (Kennamer and Kennamer 1990).

Efforts to restore turkeys to east Texas have resulted in fragmented populations across the landscape. Confounding factors such as stocking strategy, resource availability, and predation risk have all been hypothesized to have impacted restoration success (Newman 1945, Lopez et al 2000, Conway et al 2010). As managers continue working toward establishing a sustainable turkey population in east Texas, information on movements, spatial ecology, and survival of translocated turkeys would improve the efficiency of translocations in east Texas. Hence, our objectives were to monitor post-release behaviors and survival of turkeys translocated to east Texas. We hypothesized that translocated individuals would exhibit greater space use and movements during an initial exploratory phase, followed by a reduction in both as they gained knowledge of the new landscape. We also hypothesized that space use and movements of turkeys translocated after the initial year of stocking would stabilize more rapidly in the presence of conspecifics, and would converge on results from previous works on stable, non-translocated studies. Finally, we hypothesized that increased space use and movements post translocation would negatively impact survival.

STUDY AREA

We conducted our research on Angelina National Forest (hereafter; ANF), located in the Pineywoods ecoregion of east Texas and separated by Sam Rayburn Reservoir (46,336 ha) into northern and southern management sections. Our research focused around the southern management section of ANF (18,751 ha, Figure 1). The northern boundary of ANF was the southern shore of Sam Rayburn Reservoir, whereas the Neches River formed its southern boundary. The western and eastern boundaries of ANF were denoted by Shawnee Creek and Angelina River, respectively. Habitat characteristics on ANF were dominated by longleaf pine (*Pinus palustris*) and was partially managed for red-cockaded woodpeckers (*Picoides borealis*). Understory ground cover was characterized by dense yaupon (*Ilex vomitoria)* and American beautyberry (*Callicarpa americana*) with a midstory dominated by sweetgum (*Liquidambar styraciflua*), shortleaf pine (*P. echinata*), loblolly pine (*P. taeda*) and longleaf pine. Hardwood riparian areas were found throughout the pine-dominated system, and consisted of post-oak (*Quercus stellata*), various oaks (Quercus *spp.*), elm (*Ulmus spp*.), maple (*Acer spp*.), hickory (*Carya spp.*), magnolia (*Magnolia spp*.), and American beech (*Fagus grandifolia*).

METHODS

We used the super-stocking technique (Lopez et al. 2000) to reintroduce turkeys into ANF in January–February 2016 (Year 1) and March 2017 (Year 2). Reintroductions were conducted using translocated turkeys captured in Iowa, Missouri, and West Virginia and transported immediately to the Texas Parks and Wildlife Department (TPWD) office in Lufkin, Texas. There, we sexed and classified each turkey as adult or subadult based on barring of ninth and tenth primary feathers (Pelham and Dickson 1992). We affixed each turkey with a backpack style GPS transmitter (Lotek-Biotrack LTD: Wareham, Dorset, UK, Guthrie et al. 2011) weighing approximately 88 grams with remote-download capabilities. To reduce handling time following processing, groups of turkeys were released immediately after delivery to TPWD. All translocated turkeys were released at a single release site predetermined by TPWD biologists in the southeastern portion of ANF (Figure 3.1).

To delineate and compare behavioral shifts associated with translocation (Cohen et al. 2015) and to ensure adequate data for estimates of space use (Cohen et al. 2018), we programmed transmitters to record hourly locations from 0800 to 1700 hours post-release to 1 March. Beginning 1 March, transmitters recorded hourly locations from 0700 to 1800 hours, along with a roost location at 2330 hours. All capture and handling procedures were approved by the Institutional Animal Care and Use Committee at the University of Georgia (Approval number: A2015 07-009-Y1-A0).

Animals translocated to new environments may exhibit behavioral shifts in space-use and movement as they transition from exploration of their new range to settling and exploiting resources within their new range following knowledge accrual (Kemink and Kesler 2013, Berger-Tal et al. 2014, Cohen et al. 2015). Further, other studies of translocated animals have indicated that decreasing core area and home range sizes can also improve survival and positively influence translocation success (Curtis et al. 1988, Sisson et al. 2000). Hence, we evaluated temporal shifts in space use post-release by estimating daily 50% (core area, hereafter CA) and 95% (home range, hereafter HR) utilization distributions (hereafter; UDs) using dynamic Brownian Bridge Movement Modelling (dBBMM, Kranstauber et al. 2012, Byrne et al. 2014). We also estimated a suite of movement metrics for each individual to explore behavioral changes in fidelity to the release site, daily distance travelled, and daily distance between consecutive roosts as these parameters could be important to individual survival and translocation success.

The location of a release site is an important consideration for restoring a local population. If wild turkeys disperse from the release site due to lack of available resources, other release sites should be considered (Terhune et al. 2005). Hence, we estimated site fidelity as daily distance to release site (m) by calculating mean distance of GPS locations collected daily compared to the original release site. Furthermore, because long movements require greater energy demands (Shields 1987) while increasing susceptibility of individuals to predation (Holdstock et al. 2006), we evaluated daily distance travelled (m) by calculating mean distance of all GPS locations collected each day post-release. Lastly, because familiarity with roost sites may influence survival (Byrne et al. 2015*a*), we estimated distance between roosts (m) by calculating a mean daily distance between consecutive roost sites.

We observed an obvious change in space use and movements at approximately day 20 (Figures 3.2 and 3.3). Hence, to test the hypothesis that translocated turkeys would have greater space use and movements during exploratory phases after release, we compared space use and movements by sex and year (male 2016 and female 2016-2017) for 2 periods (days 1-20 versus days 21-80) using an analysis of variance (ANOVA). To test our hypothesis that space use and movements of turkeys translocated 1 year after initial stocking would stabilize in the presence of conspecifics, we used ANOVA to compare females translocated in 2016 to those translocated in 2017. If results of the ANOVAs indicated significance, we conducted Tukey HSD post-hoc tests to identify which means were statistically different at $\alpha = 0.05$. We visualized our data using ggplot2 (Wickham 2016) and performed all analyses using program R (R Core Team 2013).

We modeled survival with Cox proportional hazards models (hereafter; CPH) using package ‘survival’ (Cox 1972, Therneau and Grambsch 2000). The CPH models provide hazard ratios >1.0 indicating increasing probability of a mortality event and <1.0 indicating decreasing probability of mortality. We examined pairwise correlation between explanatory variables using Pearson correlation. We considered variables highly correlated at $r > 0.7$ and retained the variable with the simplest biological interpretation (Dormann et al. 2013). Likewise, we evaluated variance inflation factors of each explanatory variable to test for remaining multicollinearity (Zuur et al. 2009). We assessed the proportional hazards assumption prior to calculating hazard ratios from CPH models using the cox.zph function recommended by Therneau and Grambsch (2000).

We hypothesized that survival of translocated turkeys would be influenced by sex and estimates of daily space use and movements when conspecifics were absent the first year. Therefore, we constructed 9 a priori models using additive explanatory variables of movement and space use for turkeys translocated in 2016 (Table 3.2; Burnham and Anderson 2002). Likewise, we hypothesized that survival of translocated turkeys in the second year would be influenced by the presence of conspecifics and estimates of mean daily space use and movements. Therefore, we constructed 9 a priori models using additive explanatory variables of movement and space use along with year (2016 - conspecifics absent, 2017 - conspecifics present) to model potential influences of conspecifics and movement parameters on survival. We scaled all movement covariates by 100-m to aid in model convergence but did not scale covariates of space use. We assessed model support by calculating corrected AIC values (AIC_c) and considered the most plausible model to have the lowest AIC_c value. We calculated ΔAIC_c values and adjusted Akaike weights (w_i) for each model. We considered models within ≤ 2 ΔAIC_c values equally plausible as the top model. We then calculated parameter estimates (β), standard errors, test statistics (Z), and P-values, along with hazard ratios, and hazard ratio confidence intervals for all covariates in the top-performing models. We considered covariates statistically significant and to influence survival at $P < 0.05$.

RESULTS

We translocated 83 wild turkeys (60 females and 23 males) in 2016 and 18 females in 2017. We radio-tagged 94 (78 females, 16 males) of 101 translocated turkeys, but because of mortality and radio failures, we excluded 8 females and 2 males translocated in 2016, and 3 females translocated in 2017, from analysis. Thus, we used 52 females and 14 males translocated during 2016 and 15 females in 2017 to describe space use and movements.

Space Use and Movement

We observed a noticeable decline in space use and movements at approximately 20 days post-release for both females and males translocated in 2016 (Table 3.1, Figures 3.2 and 3.3). During the first 20 days post-release, we observed exploratory behavior represented by wide-ranging movements by both sexes. We found that females maintained larger mean daily core areas and home ranges, and moved greater distances from the release site and between roosts during days 1-20 than days 21-80 (Table 3.1, Figures 3.2 and 3.3). However, mean daily distance travelled did not differ between days 1-20 and days 21-80. Males maintained larger mean daily core areas, moved greater distances from the release site with increasing mean daily distance travelled during days 1-20 than days 21-80 (Table 3.1, Figures 3.2 and 3.3). However, estimates of mean daily home range and distance between roosts did not differ (Table 3.1). Females translocated in 2017 maintained smaller mean daily core areas, moved less distances from the release site and between roosts, and travelled less daily during days 1-20 than days 21-80 (Table 3.1, Figures 3.4 and 3.5). Conversely, females translocated in 2017 maintained similar mean daily home ranges during days 1-20 and days 21-80 (Table 3.1, Figures 3.4 and 3.5).

During days 1-20, females translocated in 2017 maintained smaller core areas and home ranges than females translocated in 2016 (Table 3.1, Figures 3.4 and 3.5). Likewise, females translocated in 2017 moved less distances from the release site and between roosts, and travelled less daily compared to females translocated in 2016. During days 21-80, females translocated in 2017 maintained slightly larger core areas than females translocated in 2016, and these females moved less distances from the release site and between roosts. Home range sizes and daily distance travelled were similar (Table 3.1, Figures 3.5 and 3.5).

Survival Models

During 2016, 38% (*n* = 9) of males and 19% (*n* = 11) of females died within 80 days of release. One male and 2 females died within the first 20 days, and 8 males and 9 females died between days 21 and 80. During 2017, 27% (*n* = 5) of 18 females died within 80 days of release. One female died within the first 20 days and 4 females died between days 21 and 80.

No covariates were correlated, and none violated the assumption of proportionality. Therefore, we used all covariates (sex, mean daily core area size, mean daily home range size, mean daily distance to release site, mean daily distance travelled, mean daily distance between roosts, and year) in subsequent models (Table 3.3). Our first set of models evaluated potential relationships between survival following translocation and metrics of space use and movement. The best approximating space use model (core area model; $AIC_c = 176.42$, $w_i = 0.66$) suggested survival was not influenced by sex (β = -0.648, Hazard Ratio = 0.523, $P = 0.204$; Table 3.4), but was negatively influenced by increasing mean daily core area size (β = 0.067, Hazard Ratio = 1.069, $P < 0.01$). The second best approximating model was the global model ($AIC_c = 177.90$, $w_i = 0.31$), which suggested that survival was not influenced by sex (β = -0.662, Hazard Ratio = 0.516, $P = 0.516$) or mean daily home range size (β = -0.002, Hazard Ratio = 0.998, $P = 0.210$) but was influenced by increasing mean daily core area size (β = -0.077, Hazard Ratio = 0.1080, $P < 0.01$). The best approximating movement model was the distance travelled model ($AIC_c = 174.00$, $w_i = 0.85$), which suggested that survival was not influenced by sex (β = -0.983, Hazard Ratio = 0.974, $P = 0.056$; Table 3.4) but was negatively influenced by mean daily distance travelled (β = 1.778, Hazard Ratio = 5.913, $P < 0.01$).

Our second set of models evaluated potential relationships between survival following translocation and metrics of space use and movement in the presence of conspecifics. The best approximating space use model was the core area model (AIC_c = 209.28, w_i = 0.55, Table 3.3), which indicated survival was not influenced by year (β = 0.493, Hazard Ratio = 1.637, P = 0.253), but was negatively influenced by increasing mean daily core area size (β = 0.056, Hazard Ratio = 1.058, $P < 0.01$; Table 3.4). The second-best approximating space use model (global; AIC_c = 210.05, w_i = 0.37) suggested survival was not influenced by year (β = 0.428, Hazard Ratio = 1.534, P = 0.327) and mean daily home range size (β = -0.005, Hazard Ratio = 0.995, P = 0.238) but was negatively influenced by mean daily core area size (β = 0.080, Hazard Ratio = 1.084, $P < 0.01$). The best approximating movement model (Distance Travelled; AIC_c = 213.72, w_i = 0.18) suggested that survival of translocated females was not influenced by either year (β = 0.341, Hazard Ratio = 1.406, P = 0.425) or mean daily distance travelled (β = 0.904, Hazard Ratio = 2.468, P = 0.145), although we noted considerable model uncertainty among competing models (Table 3.4).

DISCUSSION

Translocated turkeys exhibited exploratory behaviors up to day 20, at which point we observed noticeable declines as turkeys settled in their new landscape. Our findings support our hypothesis that translocated turkeys would exhibit greater space use and movements during an initial exploratory phase, before decreasing both as they acquired knowledge post-release. Our results differ slightly from previous works that have reported exploratory behaviors well beyond 20 days post-release (Marable et al. 2012, Isabelle et al. 2015), and Cohen et al. (2015) observed increased space-use and movement of translocated turkeys between days 60 and 80 following release. We note that Isabelle et al. (2015) was a VHF study and while Cohen et al. (2015) used

GPS, their inferences were based on a smaller sample with fewer daily relocations on individual birds, and turkeys were translocated to habitats essentially identical to their former ranges.

The presence of conspecifics has potential to affect translocation success, primarily by impacting individual behaviors following release (Linklater and Swaisgood 2008, Weilenmann et al. 2011). We observed that female turkeys translocated into areas with conspecifics failed to exhibit an obvious exploratory phase after release, which supported our hypothesis that space use and movements of translocated individuals would differ relative to birds translocated in absence of conspecifics. We recognize that movement behaviors observed during the second year of our study may have been confounded by subtle differences in timing of release and weather conditions post-release. Nonetheless, our results indicate that conspecifics can positively influence behaviors exhibited by turkeys released in subsequent years by reducing space use and movements. During 2017, females appeared to settle almost immediately after translocation, before gradually increasing space use and movements as spring progressed. Gradually increasing movements and space use corresponding with onset of reproductive behaviors has been widely described for turkeys, as females depart winter flocks and enter into laying and incubation phases (Kurzejeski and Lewis 1990, Thogmartin 2001, Yeldell et al. 2017, Wood et al. 2018).

Managers using translocation as a conservation tool often seek ways to increase site fidelity and improve the likelihood that individuals will remain at or close to release sites (Larkin et al. 2004, Tuberville et al. 2006). Indeed, we found that female turkeys translocated in the presence of conspecifics showed greater fidelity to the release site, used less space, and generally moved less than females translocated initially. The presence of previously released turkeys could be an important determinant of settling behavior, and coupled with greater site fidelity, points to the importance of multiple releases at the same site to establish extant populations, particularly given poor reproduction reported in translocated populations in east Texas (Lopez 1998, Isabelle et al. 2016, Sullivan et al. 2019). Historically, translocations of turkeys to other regions of the United States often facilitated rapid population growth, as released birds reproduced successfully following translocation (Kennamer and Kennamer 1990, Kennamer et al. 1992). However, results from contemporary translocation attempts in east Texas suggests that managers can no longer depend on reproductive success as a primary determinant of translocation success. Rather, managers may need to more carefully consider adult female survival as determinants of translocation success (IUCN 1998, Armstrong and Seddon 2007).

Translocated animals that can quickly identify usable habitat, use less space, and minimize movement are less susceptible to mortality and more likely to influence establishment of an extant population post-release (Curtis et al. 1988, Sisson et al. 2000, Clapp et al. 2014). We noted that increased core area size influenced survival, but the effect was weak. Conversely, we found a strong negative relationship between mean daily distance travelled and survival for turkeys when translocated in absence of conspecifics. Notably, the negative effect of daily distance travelled on survival did not occur during the second year, when turkeys were translocated where conspecifics were available. Our findings support our hypothesis that survival would be negatively influenced by increased space use and movement after translocation, and provides further support that presence of conspecifics on the landscape is important to the survival and establishment of translocated populations (Jones et al. 1999, Martin et al. 2017). Similar to translocations where the abundance of conspecifics at or near release sites have been considered prior to release (Fisher et al. 2008, Linklater et al. 2006, Linklater and Swaisgood 2008), managers translocating turkeys should consider focusing translocation efforts to sites where turkeys already occur, thus reducing exploratory behaviors, increasing survival, and allow individuals to naturally disperse to other areas as the existing population grows.

MANAGEMENT IMPLICATIONS

Our findings suggest that conspecifics are an important driver of space use, movement, and survival of translocated turkeys. Hence, we encourage managers charged with conducting translocations consider the distribution of resident conspecifics, particularly in areas where translocation success has been variable. If conspecifics are not initially present, agency biologists should plan to translocate individuals over multiple years as conspecifics appear to positively influence space use and movement. Multi-year translocations should be conducted as suggested by Lopez et al. (2000) to replace individuals lost to mortality the first year, and to bolster population numbers during subsequent years.

ACKNOWLEDGEMENTS

We thank K. Cazenave, C. Almond, and E. Donoso for their assistance with data collection and analysis. We thank the staff of the Texas Parks and Wildlife Department, United States Forest Service, and the Warnell School of Forestry, and Natural Resources at the University of Georgia for funding and logistical support. Funding for this research was provided in part by Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service through the Federal Aid in Wildlife Restoration Act (Pittman-Robertson) program, Grant number TX-W-164-R-1.

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Table 3.1. Mean (± 1 SE) daily space-use [core area (CA) and range (HR) size] and movement metrics (mean daily distance to release site, mean daily distance travelled, and mean daily distance between roosts) during 2 periods (Days 1–20, 21–80) for female and male wild turkeys translocated to Angelina National Forest, TX, USA during 2016–2017.

Period	**Sex**	**Year**	**50% CA (ha)**	**95% HR (ha)**	**Distance to Release Site (m)**	**Distance Travelled (m)**	**Distance Between Roosts (m)**
Days 1-20	Female	2016	21.57 ± 1.26	127.86 ± 6.42	3112.22 ± 58.43	3273.63 ± 69.95	969.06 ± 34.52
	Male	2016	33.22 ± 3.13	185.82 ± 14.56	2867.74 ± 94.07	4546.20 ± 185.65	1286.35 ± 77.53
	Female	2017	13.52 ± 0.98	94.45 ± 7.80	2002.22 ± 94.30	3014.87 ± 110.74	979.27 ± 66.30
Days 21-80	Female	2016	16.31 ± 0.41	101.89 ± 2.46	4134.72 ± 78.95	3296.47 ± 39.02	792.16 ± 19.19
	Male	2016	24.69 ± 1.06	154.80 ± 6.31	3795.79 ± 47.70	3985.78 ± 92.65	1182.69 ± 47.29
	Female	2017	17.03 ± 0.85	102.47 ± 5.50	2416.39 ± 77.41	3280.05 ± 72.45	627.98 ± 29.65

Table 3.2. Hypotheses and associated conditional logistic regression models used to evaluate effects of mean daily space use and movement, sex, and year on survival of male and female eastern wild turkeys translocated to Angelina National Forest, TX, USA during 2016–2017.

Model Name	Hypothesis	Model
Translocation Space Use Models		
Global	Survival is influenced by all covariates	y = S[1] + CA[2] + HR[3]
Core Area (CA)	Survival is influenced by sex and CA size	y = S + CA
Home Range (HR)	Survival is influenced by sex and HR size	y = S + HR
Null	Survival is influenced by random covariates of turkey	y = 0
Translocation Movement Models		
Global	Survival is influenced by all covariates	y = S[1] + DRS[4] + DT[5] + DBR[6]
Distance to Release Site (DRS)	Survival is influenced by sex and DRS	y = S + DRS
Distance Travelled (DT)	Survival is influenced by sex and DT	y = S + DT
Distance between Roosts (DBR)	Survival is influenced by sex and DBR	y = S + DBR
Null	Survival is influenced by random covariates of turkey	y = 0
Conspecific Space Use Models		
Global	Survival is influenced by all covariates	y = YR[6] + CA[2] + HR[3]
Core Area	Survival is influenced by year and CA size	y = YR + CA
Home Range	Survival is influenced by year and HR size	y = YR + HR
Null	Survival is influenced by random covariates of turkey	y = 0
Conspecific Movement Models		
Global	Survival is influenced by all covariates	y = YR[7] + DRS[4] + DT[5] + DBR[6]
Distance to Release Site	Survival is influenced by year and DRS	y = YR + DRS
Distance Travelled	Survival is influenced by year and DT	y = YR + DT
Distance between Roosts	Survival is influenced by year and DBR	y = YR + DBR
Null	Survival is influenced by random covariates of turkey	y = 0

[1] Sex
[2] Core Area
[3] Home Range
[4] Distance to Release Site
[5] Distance Travelled
[6] Distance between Roosts
[7] Year

Table 3.3. Akaike's Information Criterion (AIC) with small sample adjustment (AICc), number of parameters (*K*), **Δ**AICc, adjusted Akaike weights (w_i) in support of model, and log-likelihood (LL) for Cox proportional hazard models used to evaluate influences of mean daily space use and movement, sex, and year on survival of male and female wild turkeys translocated to Angelina National Forest, TX, USA during 2016─2017.

Model Name	Rank	*K*	AIC	AICc	**Δ**AICc	Adjusted w_i	LL
Translocation Space Use Models							
Global	2	3	177.53	177.90	1.49	0.31	-86.12
Core Area	1	2	176.23	176.42	0.00	0.66	-86.12
Home Range	3	2	186.54	186.73	10.31	0.00	-91.27
Translocation Movement Models							
Global	2	4	177.34	177.98	3.98	0.12	-84.67
Distance to Release Site	4	2	186.65	186.83	12.83	0.00	-91.32
Distance Travelled	1	2	173.81	174.00	0.00	0.85	-84.91
Distance between Roosts	3	2	180.98	181.17	7.17	0.02	-88.49
Conspecific Space Use Models							
Global	2	3	209.73	210.05	0.77	0.37	-101.87
Core Area	1	2	209.12	209.28	0.00	0.55	-102.56
Home Range	3	2	217.20	217.35	8.08	0.01	-106.77
Conspecific Movement Models							
Global	2	4	214.97	215.51	1.98	0.14	-103.49
Distance to Release Site	3	2	217.09	217.25	3.72	0.06	-106.55
Distance Travelled	1	2	213.56	213.72	0.18	0.35	-104.78
Distance between Roosts	4	2	217.21	217.37	3.84	0.06	-106.61

Table 3.4. Results of Cox proportional hazards models evaluating influences of mean daily space use and movement, sex, and year on survival of translocated male and female wild turkeys in Angelina National Forest, TX USA during 2016─2017.

Model Name	Covariates	β^1	SE	*Z*	*P*	Hazard Ratios	Hazard Ratios CI	
							95% Lower	95% Upper
Translocation Space Use Models								
Global	Sex	-0.662	0.538	-1.281	0.200	0.516	0.187	1.420
	CA (ha)	0.077	0.029	4.103	<0.001	1.080	1.041	1.121
	HR (ha)	-0.002	0.003	-1.255	0.210	0.998	0.995	1.001
Core Area	Sex	-0.648	0.535	-1.270	0.204	0.523	0.192	1.423
	CA (ha)	0.067	0.023	3.828	<0.001	1.069	1.033	1.107
Translocation Movement Model								
Distance Travelled	Sex	-0.983	0.546	-1.910	0.056	0.974	0.137	1.026
	DT (m)	1.778	0.473	3.491	<0.001	5.913	2.180	16.038
Conspecific Space Use Models								
Global	Year	0.428	0.449	0.980	0.327	1.534	0.652	3.612
	CA (ha)	0.080	0.045	4.663	<0.001	1.084	1.048	1.121
	HR (ha)	-0.005	0.008	-1.180	0.238	0.995	0.988	1.003
Core Area	Year	0.493	0.445	1.144	0.253	1.637	0.703	3.811
	CA (ha)	0.056	0.019	3.908	<0.001	1.058	1.028	1.088
Conspecific Movement Models								
Global	Year	0.224	0.463	0.450	0.618	1.251	0.518	3.022
	DRS (m)	0.003	0.006	0.501	0.616	1.003	0.990	1.017
	DT (m)	1.541	0.576	2.333	0.020	4.668	1.280	17.031
	DBR (m)	-0.148	0.094	-1.652	0.100	0.862	0.723	1.028
Distance Travelled	Year	0.341	0.436	0.797	0.425	1.406	0.608	3.250
	DT (m)	0.904	0.448	1.458	0.145	2.468	0.733	8.317

[1] Movement covariates scaled by 100-m

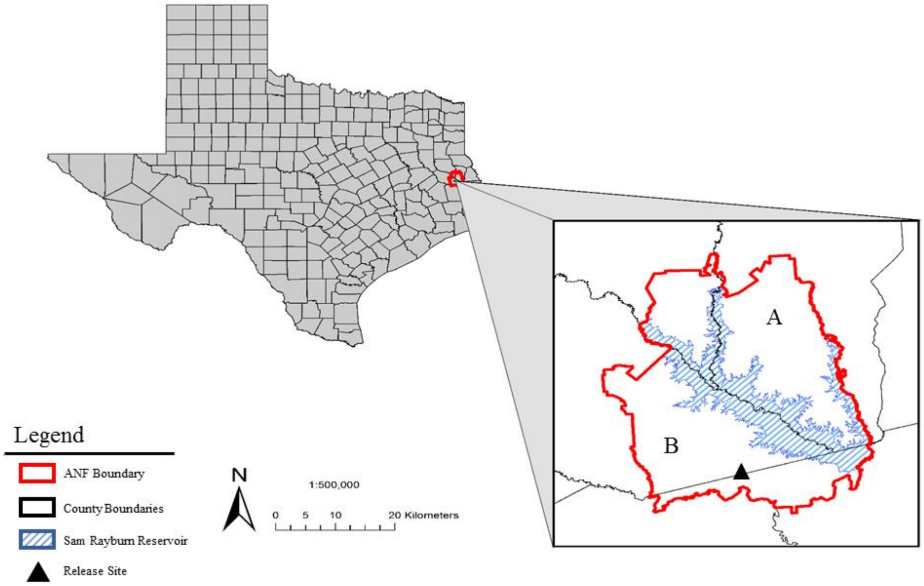

Figure 3.1. Location of Angelina National Forest, TX, USA with boundary indicated by red line. Sam Rayburn Reservoir divided ANF into northern (A) and southern (B) sections. We conducted research in and around the southern section at the intersection of Angelina and Jasper Counties (black lines), south of Sam Rayburn Reservoir (blue-dashed lines). The release site (black triangle) where all turkeys were translocated was in proximal distance to Boykin Springs Campground.

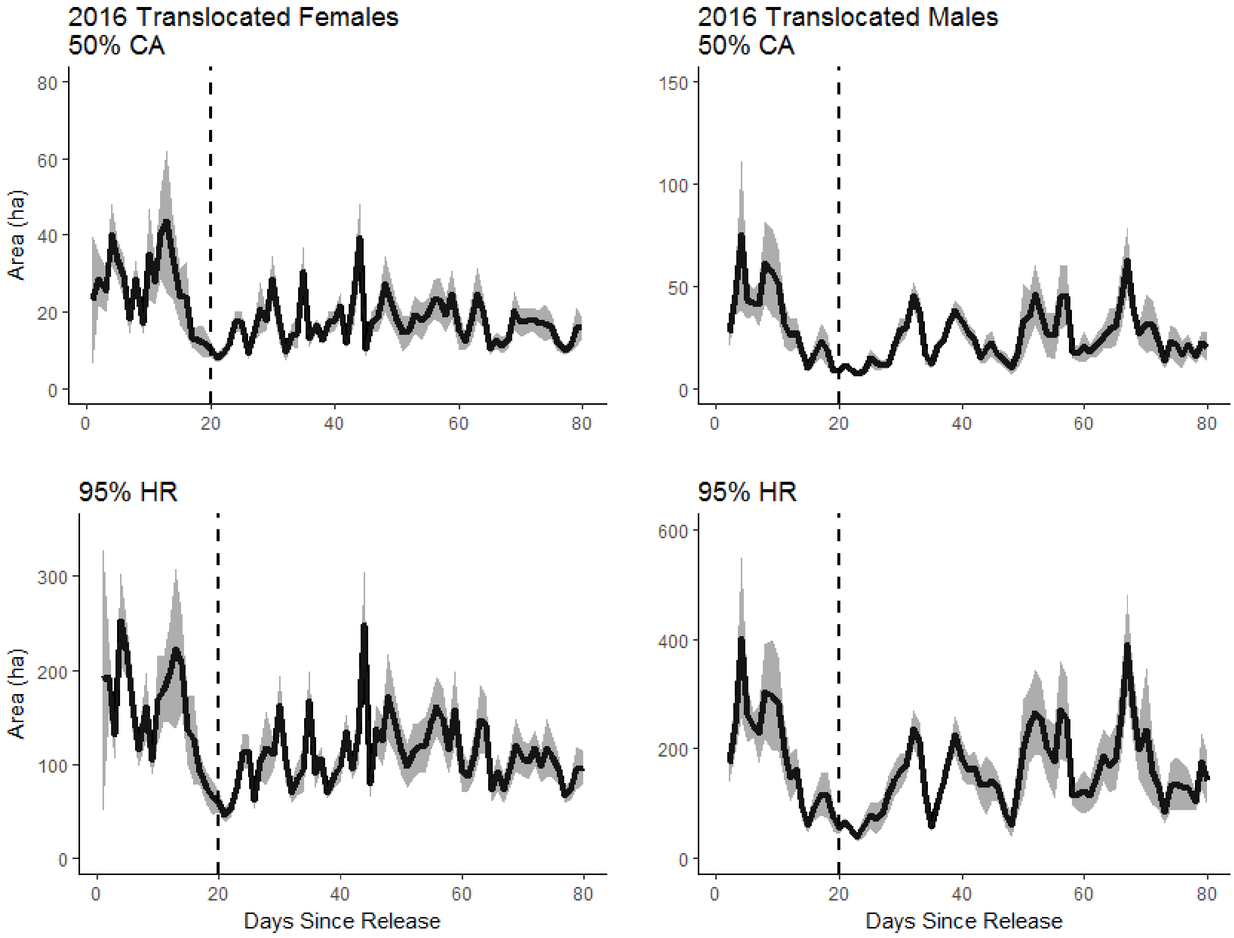

Figure 3.2. Mean daily space use of female and male turkeys translocated to Angelina National Forest, TX, USA in 2016. Mean daily space use represented by 50% core area (CA) and 95% home range (HR) utilization distributions estimated using dynamic Brownian Bridge Movement Modelling (dBBMM). The X-Axis represents number of days post-translocation whereas the Y-Axis represents area in hectares. The vertical dashed line on day 20 represents the approximate time when exploratory movements appeared to decline. Black-colored line represents mean daily space-use with gray-colored shading representing ± 1 standard error (se).

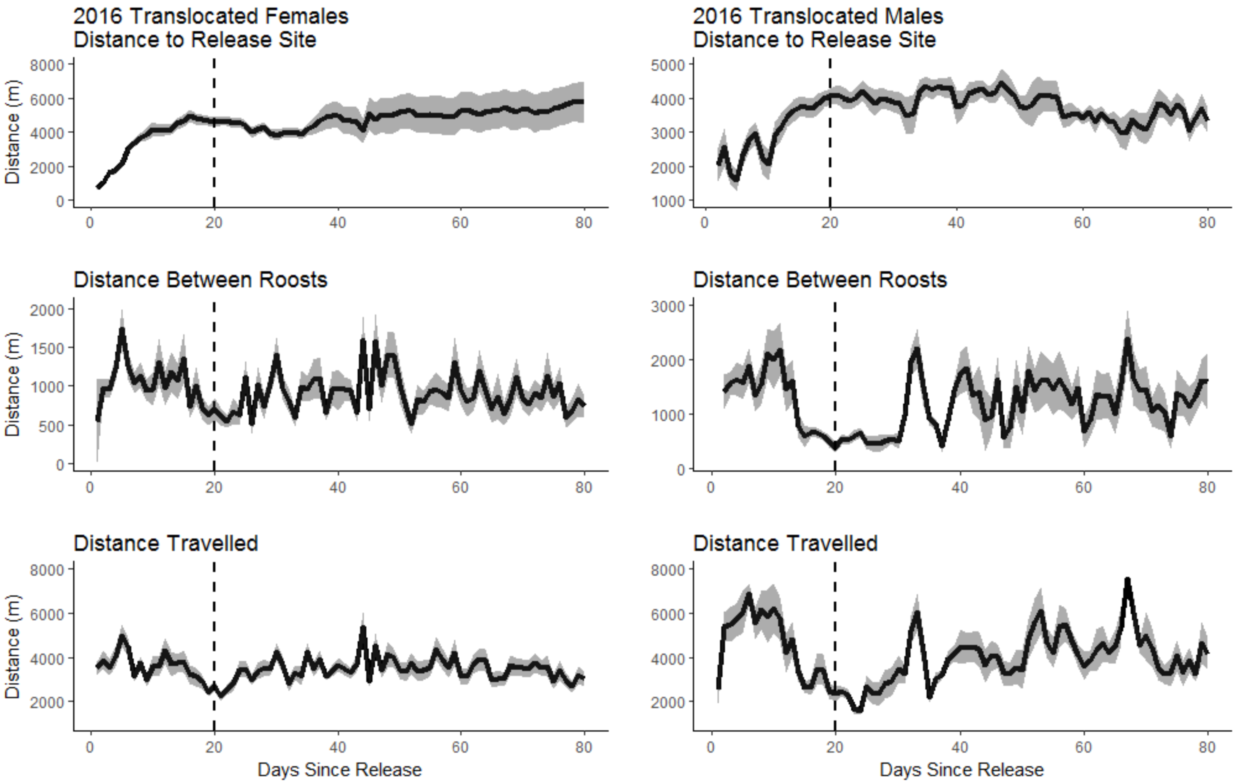

Figure 3.3. Mean daily distance to release site, daily distance between roosts, and daily distance travelled of female and male turkeys translocated to Angelina National Forest, TX, USA in 2016. The X-Axis represents number of days post-translocation whereas the Y-Axis represents distance in meters. The vertical dashed line on day 20 represents the approximate time when exploratory behavior appears to decline. Black-colored line represents mean daily distance to release site, daily distance between roosts, and daily distance travelled with gray-colored shading representing ± 1 standard error (se).

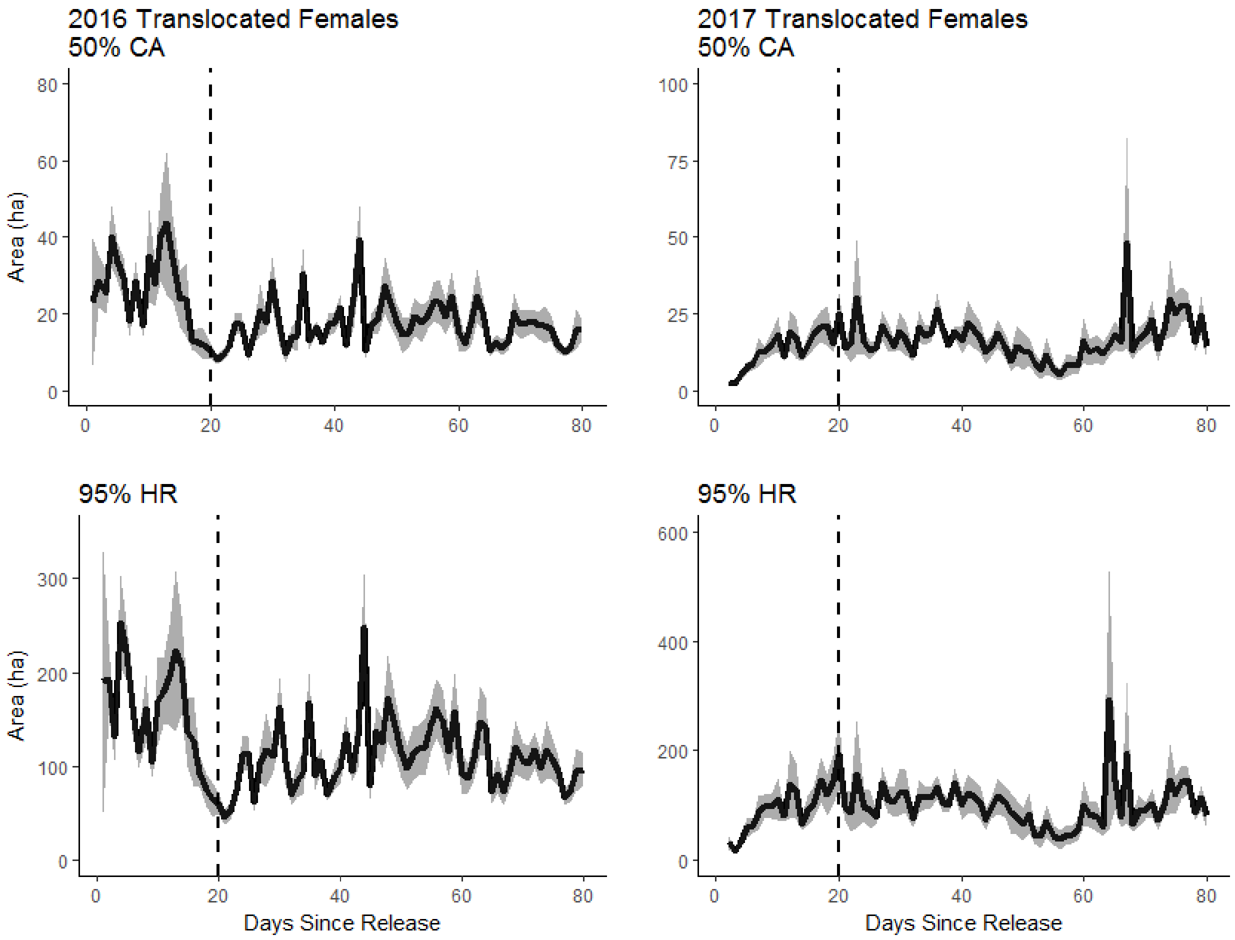

Figure 3.4. Mean daily space use of female turkeys translocated during 2016–2017 to Angelina National Forest, TX, USA. Mean daily space use represented by 50% core area (CA) and 95% home range (HR) utilization distributions estimated using dynamic Brownian Bridge Movement Modelling (dBBMM). The X-Axis represents number of days post-translocation whereas the Y-Axis represents area in hectares. The vertical dashed line on day 20 represents the approximate time when exploratory movements appeared to decline. Black-colored line represents mean daily space-use with gray-colored shading representing ± 1 standard error (se).

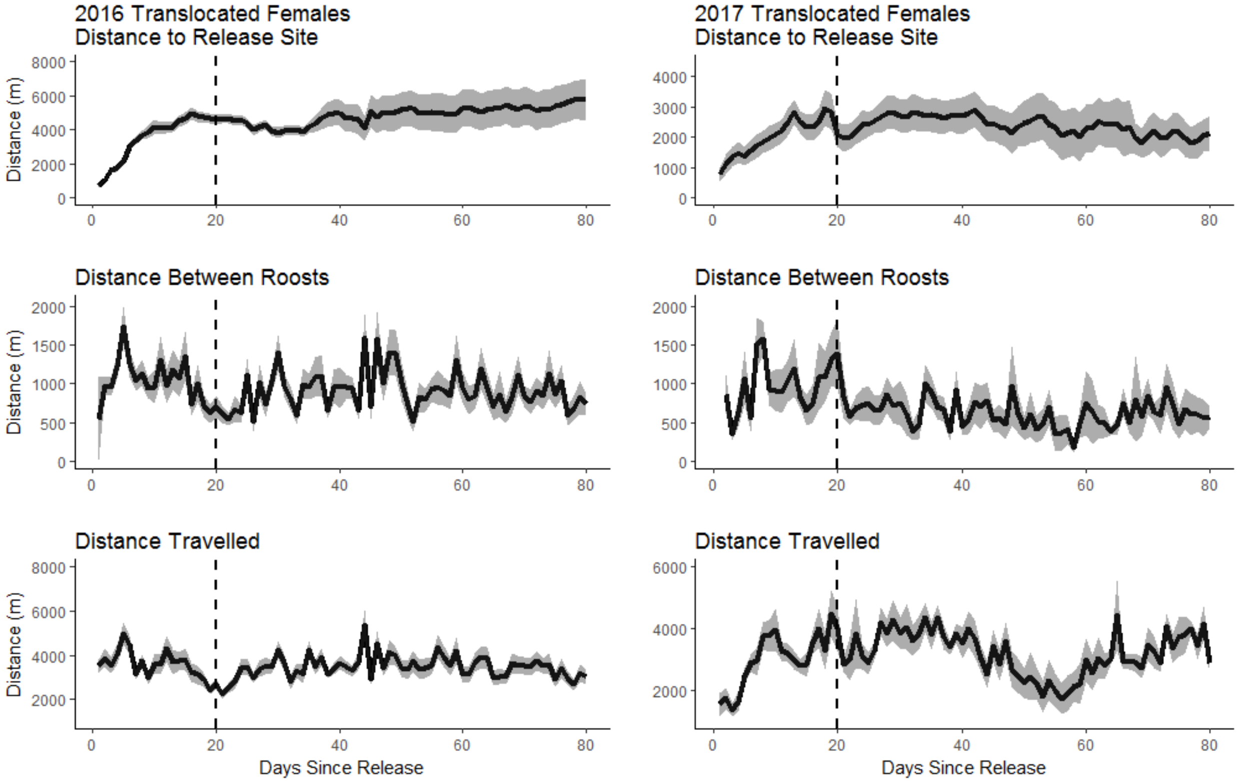

Figure 3.5. Mean daily distance to release site, daily distance between roosts, and daily distance travelled of female turkeys translocated during 2016–2017 to Angelina National Forest, TX, USA. The X-Axis represents number of days post-translocation whereas the Y-Axis represents distance in meters. The vertical dashed line on day 20 represents the approximate time when exploratory behavior appeared to decline. Black-colored line represents mean daily distance to release site, daily distance between roosts, and daily distance travelled with gray-colored shading representing ± 1 standard error (se)

CHAPTER 4

HABITAT SELECTION OF TRANSLOCATED EASTERN WILD TURKEYS IN A DENSELY FORESTED LANDSCAPE

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[1] Sullivan, D. J., A. R. Little, M. L. Poteet, B. A. Collier, and M. J. Chamberlain. To be submitted to PlosOne.

ABSTRACT

Restoration of eastern wild turkeys (*Meleagris gallopavo silvestris*) throughout the United States is among the greatest conservation achievements in North America. However, restoration efforts in east Texas have had variable success, resulting in a fragmented distribution of turkeys across the landscape. Restoration success is largely dependent on the ability of translocated individuals to quickly select the most profitable habitats. Research focused on habitat selection of translocated wild turkeys is important for identifying suitable habitat critical to restoration success, and thereby reducing the probability of translocation failure. Hence, our objective was to describe habitat selection of translocated male and female wild turkeys in a forested landscape of east Texas. During 2016─2017, we translocated 101 GPS-tagged wild turkeys to Angelina National Forest in east Texas. We quantified 3rd-order habitat selection for males and females during 3 temporal periods, which included the exploratory phase (days 1-20), the exploitation phase (days 21-80), and within the annual range. During the exploratory phase, both sexes selected shrub-scrub and open habitats, and females selected linear paths (roads, rights-of-way). During the exploitation phase, both sexes continued to select shrub-scrub and open habitats, whereas males also began selecting deciduous habitats and avoided linear paths. Females selected for mixed habitats and water and did not select for linear paths. On an annual basis, we found that shrub-scrub and open habitats were consistently most important in the densely-forested landscape in and around Angelina National Forest in east Texas. Our findings demonstrate the importance of maintaining early successional and open habitats in forested landscapes where translocated wild turkeys are of management interest.

INTRODUCTION

Restoration of eastern wild turkeys (*Meleagris gallopavo silvestris*, hereafter; turkeys) throughout the United States has been recognized as one of the greatest achievements in the modern history of conservation (Kennamer and Kennamer 1990). Because of extensive restoration efforts, turkey populations have increased from an estimated 500,000 turkeys in 1959 to 4 million (Mosby 1959, Bailey 1980, Kennamer and Kennamer 1990). The native range for turkeys was historically distributed from Maine, south along the eastern seaboard, throughout the southeast to east Texas, and traversing north into the midwest and Great Lakes regions (Mosby and Handley 1943). While restoration efforts have been largely successful, restoration efforts focused in east Texas have had varied in success, resulting in a fragmented distribution across the landscape (Campo 1983, Lopez et al. 2000, Conway et al. 2010).

The landscape of east Texas was once dominated by longleaf pine savannas, mixed-hardwood systems, and expansive grasslands considered high quality habitat for turkeys (Alavalapati et al. 2002, Brockway et al. 2005, Van Lear et al. 2005), but is now predominately characterized by densely forested, fragmented habitat used for timber production (Newman 1945, Campo et al. 1984). Although turkeys are habitat generalists (Hurst 1992), in densely forested landscapes they are inextricably linked to vegetation communities with early successional habitats. Therefore, identifying areas of suitable habitat capable of sustaining and connecting fragmented turkey populations is important for restoration efforts in east Texas (Lopez et al 2000, Conway et al. 2010).

Translocation stocking methods using a variety of source populations with varying stocking numbers have complicated restoration efforts in east Texas (Lopez et al. 2000). Recently, managers began using stocking approaches that incorporate site-specific habitat suitability indices to select stocking sites and super-stocking to improve restoration success (Seidel et al. 2013, Isabelle et al. 2015). Translocation success hinges largely on the ability of individuals to quickly exploit profitable habitats in the novel landscape (Lyles and May 1987, Fischer and Lindenmayer 2000, Berger-Tal and Saltz 2014). However, habitat selection of turkeys following translocation, and knowledge of how selection may change temporally, is poorly understood. Therefore, our objective was to describe habitat selection of male and female turkeys across multiple temporal periods following translocation. Secondarily, we sought to generate sex-specific habitat selection models to be used by managers as a decision-making tool for determining release sites for future restoration efforts.

STUDY AREA

We conducted research on Angelina National Forest (hereafter; ANF), located in the Pineywoods ecoregion of east Texas and separated by Sam Rayburn Reservoir (46,336 ha) into northern and southern management sections. Our research focused around the southern management section of ANF (18,751 ha, Figures 4.1 and 4.2). Habitat around ANF was considered densely-forested as open habitat (e.g., undeveloped fields, fire breaks, gas lines) comprised < 5% of the total available habitat. Habitat characteristics on ANF were dominated by longleaf pine (*Pinus palustris*) which was partially managed for red-cockaded woodpeckers (*Picoides borealis*). Understory ground cover was characterized by yaupon (*Ilex vomitoria)* and American beautyberry (*Callicarpa americana*) with a midstory dominated by sweetgum (*Liquidambar styraciflua*), shortleaf pine (*P. echinata*), loblolly pine (*P. taeda*) and longleaf pine. Hardwood riparian areas were found throughout the pine-dominated system, and consisted of post-oak (*Quercus stellata*), various oaks (*Quercus spp*.), elm (*Ulmus spp*.), maple (*Acer spp*.), hickory (*Carya spp.*), magnolia (*Magnolia spp*.), and American beech (*Fagus grandifolia*).

METHODS

We used the super-stocking technique (Lopez et al. 2000) to reintroduce turkeys into ANF in January and February 2016 and March 2017. Reintroductions were conducted using translocated turkeys captured in Iowa, Missouri, and West Virginia. Turkeys were transported immediately to the Texas Parks and Wildlife Department (hereafter; TPWD) office in Lufkin, Texas. There, we sexed and classified each turkey as either adult or subadult based on barring of ninth and tenth primary feathers (Pelham and Dickson 1992). We fitted each individual with a backpack style µGPS telemetry transmitter (Lotek-Biotrack LTD: Wareham, Dorset, UK, Guthrie et al. 2011) weighing approximately 88 grams with remote-downloadable capabilities. All turkeys were then transported to a single release site that was selected because of available open habitat within a densely forested landscape. To assess habitat selection and ensure adequate data for estimates of space use (Cohen et al. 2018), we programmed GPS transmitters to record hourly locations from 0800 to 1700 hours and a roost location at 2330 hrs. All capture and handling procedures were approved by Institutional Animal Care and Use Committee at the University of Georgia (Approval number: A2015 07-009-Y1-A0).

Translocated turkeys underwent an exploratory phase characterized by extensive movements and larger range sizes during the first 20 days after translocation (Sullivan et al. 2019*a*) and movements declined through 80 days after translocation, presumably as individuals became familiar with the landscape and moved from an exploratory to exploitation phase (Berger-Tal et al. 2014, Cohen et al. 2015). Therefore, we used a distance-based resource selection function (hereafter; RSF) framework (Manly et al. 2002, Boyce et al. 2002, Johnson et al. 2006), and evaluated habitat selection during both periods; days 1-20 and days 21-80. We also evaluated habitat selection throughout the entire period in which birds were monitored, hereafter referred to as annual habitat selection. Within each period, we examined third order habitat selection (Johnson 1980) using 95% utilization distributions (UDs) for each individual. We estimated period-specific 95% UDs using dynamic Brownian Bridge Movement Modelling (dBBMM, Kranstauber et al. 2012, Byrne et al. 2014), and used the UDs to constrain generation of random locations (see below).

To quantify habitat selection, we constructed a 30-m raster layer of habitat types in ArcGIS® 10.3.1 (Environmental Systems Research Institute Inc, Redlands, CA) using National Land Cover Data (NLCD 2011). To simplify the number of habitat types and increase the accuracy of our habitat data from NLCD (Wickham et al. 2013), we reclassified 10 habitat types into 6 habitat categories, including water, open habitats (barren land, grassland/herbaceous, sedge/herbaceous, pasture/hay), deciduous forest, mixed forest, evergreen forest, and shrub-scrub (dwarf scrub, shrub/scrub). To evaluate the importance of roads and other linear paths (e.g., power lines, fire breaks) on habitat selection of turkeys, we extracted road data from TIGER (U.S. Census Bureau 2017) and digitized all linear paths to a 30-m raster grid. We combined all linear paths into a single variable (paths). We calculated distance (m) from every 30-m pixel to the nearest patch of each habitat type using the Euclidean Distance tool in ArcGIS®. We used a distance-based approach because distance-based metrics are not restricted to line and point habitat features, thereby providing more information than categorical-based analyses (Conner et al. 2003). We evaluated non-random habitat selection with a ratio of 1 used location to 5 random (available) locations within each individual's UD (Northrup et al. 2013), and extracted raster habitat values at used and available locations.

To reduce issues with model convergence, we scaled distance values for each habitat covariate by dividing the linear distance by 200-m (during days 1-20 and 21-80) and 500-m for analysis of annual habitat selection. We assessed correlation between model covariates using Pearson correlation and considered any covariates to be highly correlated at $r > 0.7$. We then evaluated multi-collinearity across all covariates using variance inflation factors (Zuur et al. 2009). We constructed a global model of habitat selection for each period and made inference to covariates that were statistically significant at an $\alpha = 0.05$. We modeled non-random habitat selection in a logistic regression framework (Manly et al. 2002) where used and available locations were binomially represented as response variables (1 = used, 0 = random). To account for variability among individual turkeys, we incorporated animal identification as a random effect (Gillies et al. 2006). We modeled the effect of each habitat covariate using a generalized linear mixed-effects model (GLMM) in program R (R Core Team 2013). We inferred selection when used locations were closer to habitat covariates than available locations and inferred avoidance when used locations were farther from habitat variables than available locations (Conner et al. 2005, Hinton et al. 2016). We then used *k*-fold cross validation using 10 folds to estimate performance of our global model. For interpretation, we calculated scaled odds ratios (OR) and 95% confidence intervals for parameter estimates.

We extrapolated β estimates calculated from our model describing annual habitat selection for female turkeys to create a predictive selection layer for the region. We used the Raster Calculator tool in ArcGIS® to scale each habitat covariate from the global model by 500-m. We then created a new raster layer of using Raster Calculator by calculating the annual habitat selection model without a random effect, and exponentiating each habitat covariate by the respective β estimate.

We validated model performance using an independent sample of GPS telemetry relocations collected from 8 female turkeys translocated within the priority region during 2015-

2017 using similar capture and monitoring methodology outlined herein. These females were translocated to 2 privately-owned stocking sites; Brushy Creek (5 females) and Coon Pond (3 females). Coon Pond was an intensively managed property comprised of plantation pine of varying age-classes for timber production with few open habitats (e.g., food plots, right of ways, roads) and streamside management zones. Similar to ANF, Coon Pond lied along the Neches river corridor providing bottomland-hardwood habitat. Brushy Creek was also managed for timber production but was primarily used for agricultural purposes (e.g., cattle operations), hence open habitat was readily available. Common forest management practices (e.g., thinning, fire, herbicidal spraying) were used at both properties for management of understory vegetation and to encourage growth of marketable trees.

RESULTS

We translocated 83 turkeys (60 females and 23 males) in 2016 and 18 female turkeys in 2017. We GPS-marked 94 (78 females, 16 males) of the 101 turkeys translocated to ANF. Because of mortality ≤ 7 days after release or radio-failures, we excluded 8 females and 2 males translocated in 2016 and 3 females translocated in 2017. Hence, we present habitat selection of 67 females and 14 males translocated during 2016-2017 (Table 4.1).

Results of Pearson correlation analysis indicated that evergreen forest and deciduous forest were highly correlated in each model ($r > 0.99$). Variance inflation factors indicated that evergreen had an inflation value ≥ 5, so we removed evergreen forest from models. We note that evergreen forest [primarily pine (*Pinus spp.*)] is the dominant habitat type in east Texas, so if a turkey did not select for other habitat types, they presumably were using evergreen forest. Retesting for correlations among remaining covariates revealed no correlations, so we retained the remaining 5 habitat covariates and paths.

Model results for days 1-20 indicated that male turkeys selected for shrub-scrub and open habitats while avoiding water (Table 4.2). Males did not select or avoid paths, mixed forest, or deciduous forest. Likewise, females selected shrub-scrub habitat, open habitat, and paths (Table 4.2). Females avoided water and deciduous forest but did not select or avoid mixed forest.

Model results for days 21-80 indicated male turkeys selected for shrub-scrub and open habitat (Table 4.3). However, in contrast to selection during days 1-20, males selected for deciduous forest while avoiding paths. Likewise, males avoided mixed forest and water. Females selected shrub-scrub habitat, open habitat, mixed forest, and water (Table 4.3), but avoided deciduous forest. Females did not select or avoid paths.

Model results for annual habitat selection indicated males selected open habitats, shrub-scrub, and paths (Table 4.4, Figures 4.3 and 4.4). Conversely, males avoided water, mixed forest, and deciduous forest. Females selected for shrub-scrub, mixed forest, water, open habitats, and paths (Table 4.4, Figures 4.5 and 4.6), and although they also selected deciduous forest, it was the least important habitat.

The *k*-fold cross validation accuracy for males for days 1-20, days 21-80, and annual habitat selections models was 74%, 74% and 76%, respectively. Likewise, *k*-fold cross validation accuracy for females was 70%, 74%, and 81% for days 1-20, days 21-80, and annual habitat selection models, respectively. Validation data from 5 females translocated to Brushy Creek showed that 4.70% and 95.30% of relocations fell within areas of moderate and high probabilities of selection, respectively (Figure 4.7). Validation data indicated there was no habitat at or near Brushy Creek comprised of low probabilities of selection. We found that only 2.96% of relocations for 3 females translocated to Coon Pond fell within areas of low probability of selection, whereas the remaining relocations were within areas of moderate (37.96%) and high probability of selection (59.06%, Figure 4.8).

DISCUSSION

Translocations are a widely accepted conservation practice, with success often hinging on the ability of individuals to locate suitable habitats (IUCN 1998, Caughley 1994, Armstrong et al. 1994, Armstrong and Seddon 2007). Previous authors have noted that translocated turkeys exhibit exploratory behavior before entering into an exploitation phase (Cohen et al. 2015), a similar trend observed in the translocated population we studied (Sullivan et al. 2019*a*). We found that translocated turkeys exhibited differential habitat selection during these initial phases following translocation, although both males and females selected shrub-scrub and open habitats in both phases and annually. Our findings suggest that translocated turkeys in east Texas select a diversity of habitats that change temporally, but that open and early successional habitats are of particular importance in the densely forested landscape of east Texas. Given the highly variable success of translocations in east Texas (Lopez et al. 1998, Lopez et al. 2000, Isabelle et al. 2015), we offer that our results provide relevant information to land managers seeking to restore wild turkey populations to the region.

During the exploratory phase (within 20 days of release), we observed that both male and female turkeys selected shrub-scrub and open habitats, and females selected linear paths. Extensive literature has detailed selection of early successional habitats by turkeys (Sisson et al. 1991, Spears et al. 2007, Yeldell et al. 2017, Wood et al. 2018), and such habitats are particularly important to ground-dwelling birds in densely forested landscapes (Little et al. 2014, Streich et al. 2015, Little et al. 2016). Likewise, roadsides and other linear edges are ecologically important to turkeys (Mosby and Handley 1943, Leedy 1975, Smith et al. 1990), as they can provide herbaceous plant communities with quality foraging opportunities (Hurst and Stringer 1975, Yeldell et al. 2017) and may be used by females as travel routes or predation avoidance (Smith et al. 1990, Badyaev 1995). Previous authors have noted that roads and roadsides within a densely forested area can serve as a proxy for open habitats, and may be used by turkeys in pine-dominated landscapes when open habitats are limited (Smith et al. 1990, Miller and Conner 2007).

Following translocation, individuals shift from exploration to exploitation phases, presumably once they become acclimated to biotic and abiotic factors present at release sites (Berger-Tal et al. 2014, Berger-Tal and Saltz 2014). We observed that turkeys began exhibiting greater plasticity in habitat selection during the exploitation phase, while still exhibiting selection for early successional habitats as noted above. Males continued to avoid water and mixed forest while selecting for deciduous habitat. Conversely, females selected areas closer to water and mixed forest stands, but avoided deciduous habitat. Turkeys require a diverse set of habitats throughout their annual cycle (Porter 1992, Miller et al. 2000, Miller and Conner 2007), hence it is logical that translocated birds in the exploitation phase would exploit diverse habitats as spring transitioned into summer. Indeed, plasticity in habitat selection by turkeys is reflected in results of our annual habitat selection models, which suggest that turkeys exploit multiple habitat types during the annual cycle.

Collectively, our findings indicate the importance of early successional and open habitats, which has been extensively detailed in pine-dominated forests of the southeastern United States (Miller et al. 1999, Streich et al. 2015, Little et al. 2016). Early successional habitats provide critical nesting and brood-rearing sites (Little et al. 2014, Streich et al. 2015, Little et al. 2016), while also ensuring that turkeys have access to dense cover that increases visual obstruction from predators (Sisson et al. 1991, Spears et al. 2007). We propose that female turkeys selected open and shrub-scrub habitats to secure foraging opportunities and reduce predation risk during the nesting season. It is logical that males exhibited similar patterns of habitat selection during temporal periods where breeding opportunities are known to influence male behaviors (Godwin et al. 1992, Miller et al. 1999).

We observed *k*-fold validation accuracies suggesting good predictability of our habitat selection models. Clearly, wild turkeys are a generalist species (Hurst 1992), hence the accuracy we observed was not surprising as higher validation accuracies are regularly found for species with narrow resource requirements (Lobo et al. 2008). Likewise, the predictability of our habitat selection model for female turkeys was positively supported by independent GPS data used for model validation. Our findings suggest that from a habitat perspective, east Texas should provide suitable habitat for turkeys. However, turkey populations in east Texas have generally not persisted despite numerous translocation events, similar to other species that have been reintroduced to the edges of their ranges (Bahn et al. 2006, Bayne et al. 2008).

Turkeys were historically found throughout the extensive longleaf pine systems of east Texas (Kennamer et al. 1992, Conway et al. 2010), but broad expanses of these forests have been converted to short-rotation pine forests or converted to agriculture (Newman 1945, Conway et al 2010). Likewise, predator populations of east Texas have become increasingly more abundant and communities more diverse (Melville 2012). Previous studies have demonstrated that single stocking events typically witness poor success because of high predation rates on adults and nests (Lopez et al. 1998, Lopez et al. 2000, Isabelle et al. 2016). Conversely, recent research has noted that survival of translocated turkeys can be positively influenced by conspecifics at or near the release site (Sullivan et al. 2019*a*). Although our modeling efforts suggest that east Texas is generally comprised of suitable habitat for turkeys, poor reproductive success and loss of adults to predators following earlier translocations suggests that multiple year stocking events at sites where conspecifics are present may be necessary to establish extant turkey populations in east Texas.

ACKNOWLEDGEMENTS

We thank K. Cazenave, C. Almond, E. Donoso, M. Hooker, and J. Hinton for their assistance with data collection and analysis. We thank the staff of the Texas Parks and Wildlife Department, United States Forest Service, and the Warnell School of Forestry, and Natural Resources at the University of Georgia for funding and logistical support. Funding for this research was provided in part by Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service through the Federal Aid in Wildlife Restoration Act (Pittman-Robertson) program, Grant number TX-W-164-R-1. This material is also partially based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, McIntire Stennis project under No. 1005302.

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Table 4.1. Numbers (n), age, sex, and date of release for wild turkeys translocated to Angelina National Forest, Texas, USA upon release in 2016-2017.

Year	**Sex**	**Experience**		**Release (Day 1)**	**Age**	
		Type	**Total (n)**	**Date**	**Adult (n)**	**Subadult (n)**
2016	Female	Translocated	52	01/29/2016	5	1
				02/10/2016	2	2
				02/13/2016	9	9
				02/19/2016	9	13
				02/21/2016	1	1
	Male	Translocated	14	01/21/2016	6	1
				01/22/2016	6	1
2017	Female	Translocated	15	03/02/2017	6	2
				03/12/2017	1	1
				03/16/2017	5	0

Table 4.2. Parameter estimates from habitat selection models for days 1-20 following translocation of male and female turkeys in Angelina National Forest, Texas, USA during 2016-2017.

Covariate[a]	Sex	β	SE	*Z*[b]	*P*	Scaled Odds Ratios[c]	Scaled Lower 95%	Scaled Upper 95%
Path	Male	-0.036	0.022	-1.655	0.098	0.964	0.923	1.007
	Female	-0.018	0.007	-2.456	< 0.001	0.982	0.968	0.996
Water	Male	0.341	0.038	9.036	< 0.001	1.406	1.306	1.514
	Female	0.174	0.018	9.688	<0.001	1.191	1.149	1.233
Open Habitat	Male	-0.031	0.012	-2.606	< 0.001	0.969	0.947	0.992
	Female	-0.035	0.004	-8.543	< 0.001	0.965	0.957	0.973
Mixed Forest	Male	0.033	0.034	0.973	0.331	1.034	0.967	1.104
	Female	-0.010	0.012	-0.789	0.430	0.990	0.967	1.014
Shrub-scrub	Male	-0.247	0.025	-9.820	< 0.001	0.781	0.743	0.820
	Female	-0.217	0.011	-20.021	< 0.001	0.805	0.788	0.822
Deciduous Forest	Male	0.010	0.014	0.679	0.497	1.010	0.982	1.039
	Female	0.018	0.004	4.450	<0.001	1.018	1.010	1.027

[a] Distance to nearest habitat patch (m)

[b] Standardized coefficient estimates

[c] Scalar, 200-m

Table 4.3. Parameter estimates from habitat selection models for days 21-80 following translocation of male and female turkeys in Angelina National Forest, Texas, USA during 2016-2017.

Covariate[a]	Sex	β	SE	*Z*[b]	*P*	Scaled Odds Ratios[c]	Scaled Lower 95%	Scaled Upper 95%
Path	Male	0.026	0.010	2.652	0.008	1.026	1.007	1.046
	Female	0.005	0.005	1.153	0.249	1.005	0.996	1.014
Water	Male	0.302	0.020	15.335	< 0.001	1.353	1.302	1.406
	Female	-0.045	0.012	-3.911	<0.001	0.956	0.934	0.978
Open Habitat	Male	-0.092	0.005	-18.216	< 0.001	0.913	0.904	0.922
	Female	-0.020	0.003	-6.895	< 0.001	0.980	0.974	0.985
Mixed Forest	Male	0.095	0.016	6.118	<0.001	1.100	1.067	1.134
	Female	-0.015	0.007	-2.002	0.045	0.986	0.972	1.000
Shrub-scrub	Male	-0.147	0.015	-10.010	< 0.001	0.863	0.839	0.888
	Female	-0.085	0.007	-11.683	< 0.001	0.919	0.906	0.932
Deciduous Forest	Male	-0.013	0.005	-2.429	0.015	0.987	0.976	0.997
	Female	0.037	0.002	16.240	<0.001	1.037	1.033	1.042

[a] Distance to nearest habitat patch (m)

[b] Standardized coefficient estimates

[c] Scalar, 200-m

Table 4.4. Parameter estimates from habitat selection models for annual period following translocation of male and female turkeys in Angelina National Forest, Texas, USA during 2016-2017.

Covariate[a]	Sex	β	SE	*Z*[b]	*P*	Scaled Odds Ratios[c]	Scaled Lower 95%	Scaled Upper 95%
Path	Male	-0.014	0.005	-2.526	0.012	0.987	0.976	0.997
	Female	-0.062	0.007	-9.069	< 0.001	0.940	0.927	0.952
Water	Male	0.181	0.013	14.065	< 0.001	1.199	1.169	1.229
	Female	-0.074	0.018	-4.000	< 0.001	0.929	0.896	0.963
Open Habitat	Male	-0.090	0.003	-28.380	< 0.001	0.914	0.908	0.920
	Female	-0.074	0.004	-17.374	< 0.001	0.929	0.921	0.936
Mixed Forest	Male	0.041	0.009	4.359	< 0.001	1.042	1.023	1.061
	Female	-0.101	0.012	-8.479	< 0.001	0.904	0.883	0.925
Shrub-scrub	Male	-0.064	0.008	-8.428	< 0.001	0.938	0.92 4	0.952
	Female	-0.114	0.011	-10.562	< 0.001	0.892	0.873	0.911
Deciduous Forest	Male	0.009	0.003	3.537	< 0.001	0.009	1.004	1.014
	Female	0.009	0.003	2.527	0.012	1.009	1.002	1.015

[a] Distance to nearest habitat patch (m)

[b] Standardized coefficient estimates

[c] Scalar, 500-m

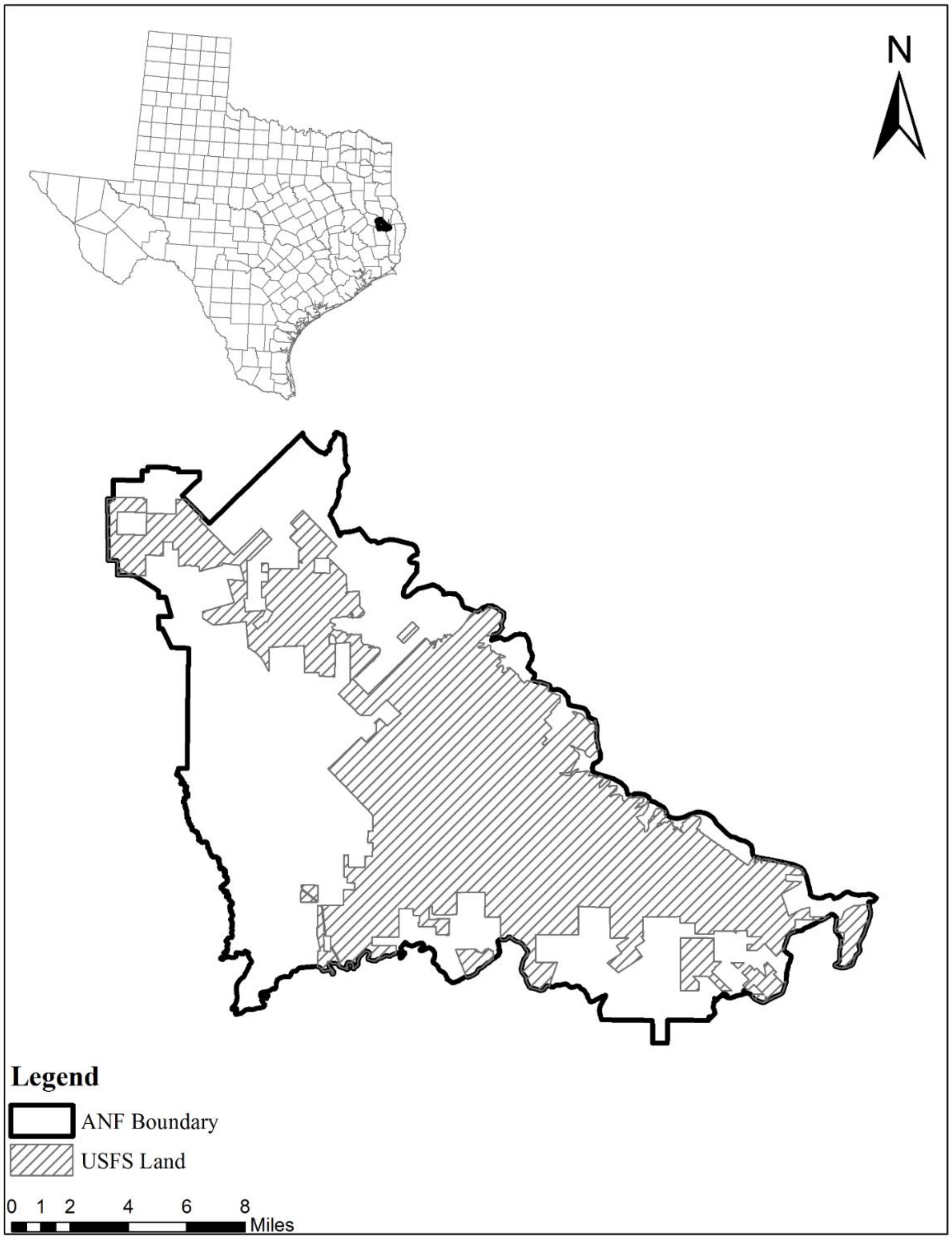

Figure 4.1. Administrative boundary of the southern management section of Angelina National Forest, Texas, USA. Horizontal lines represent publicly-owned land managed by the United States Department of Agriculture Forest Service.

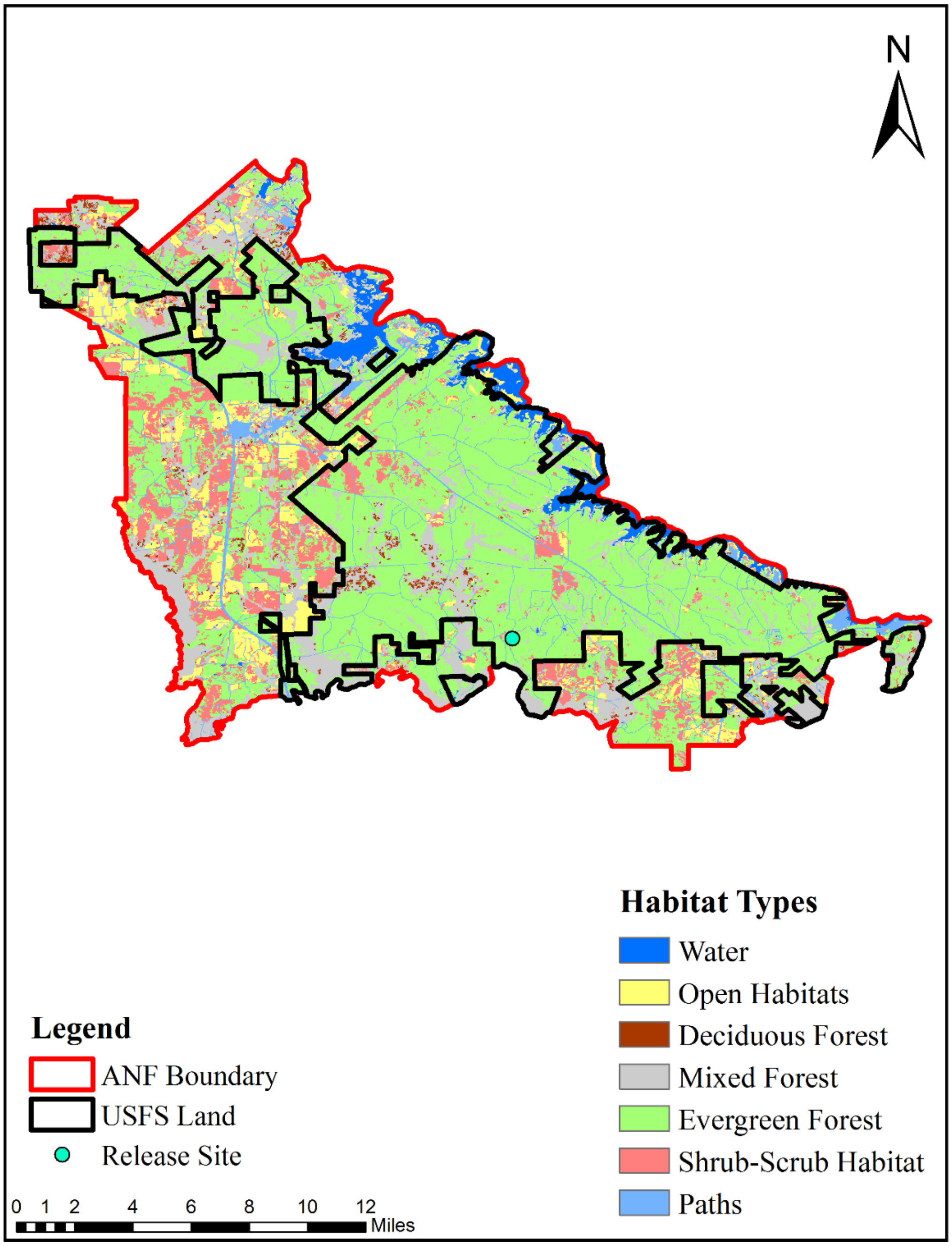

Figure 4.2. Land cover characteristics extracted from NLCD (2011) to represent habitat types within the administrative boundary of Angelina National Forest, Texas, USA. The blue circle represents the release site where turkeys were translocated during 2016-2017.

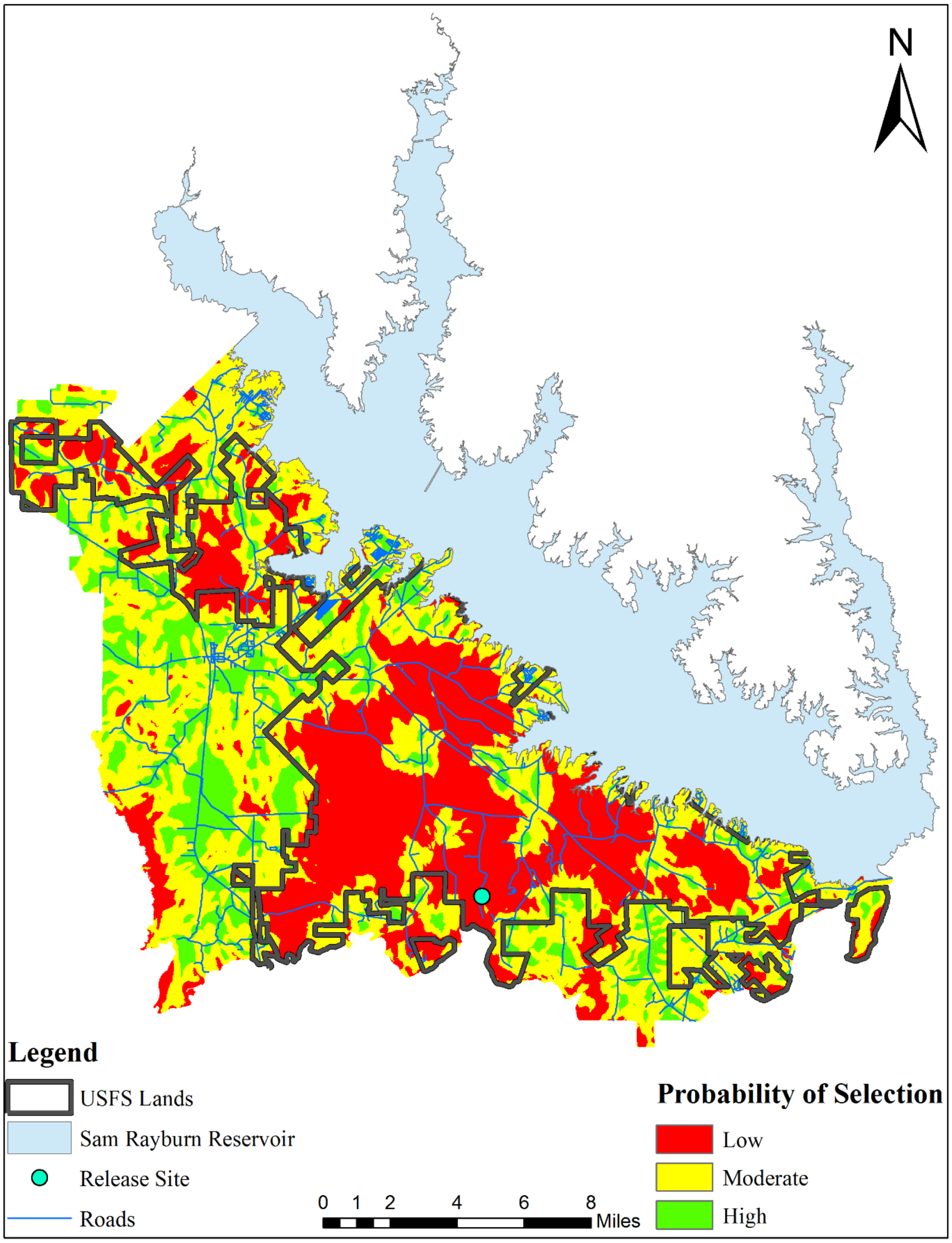

Figure 4.3. Predictive map representing probability of annual habitat selection (low, moderate, high) for translocated male turkeys in Angelina National Forest, Texas, USA. Predictive map was constructed using β coefficients resulting from GLMM with scaled habitat variables from annual habitat selection model.

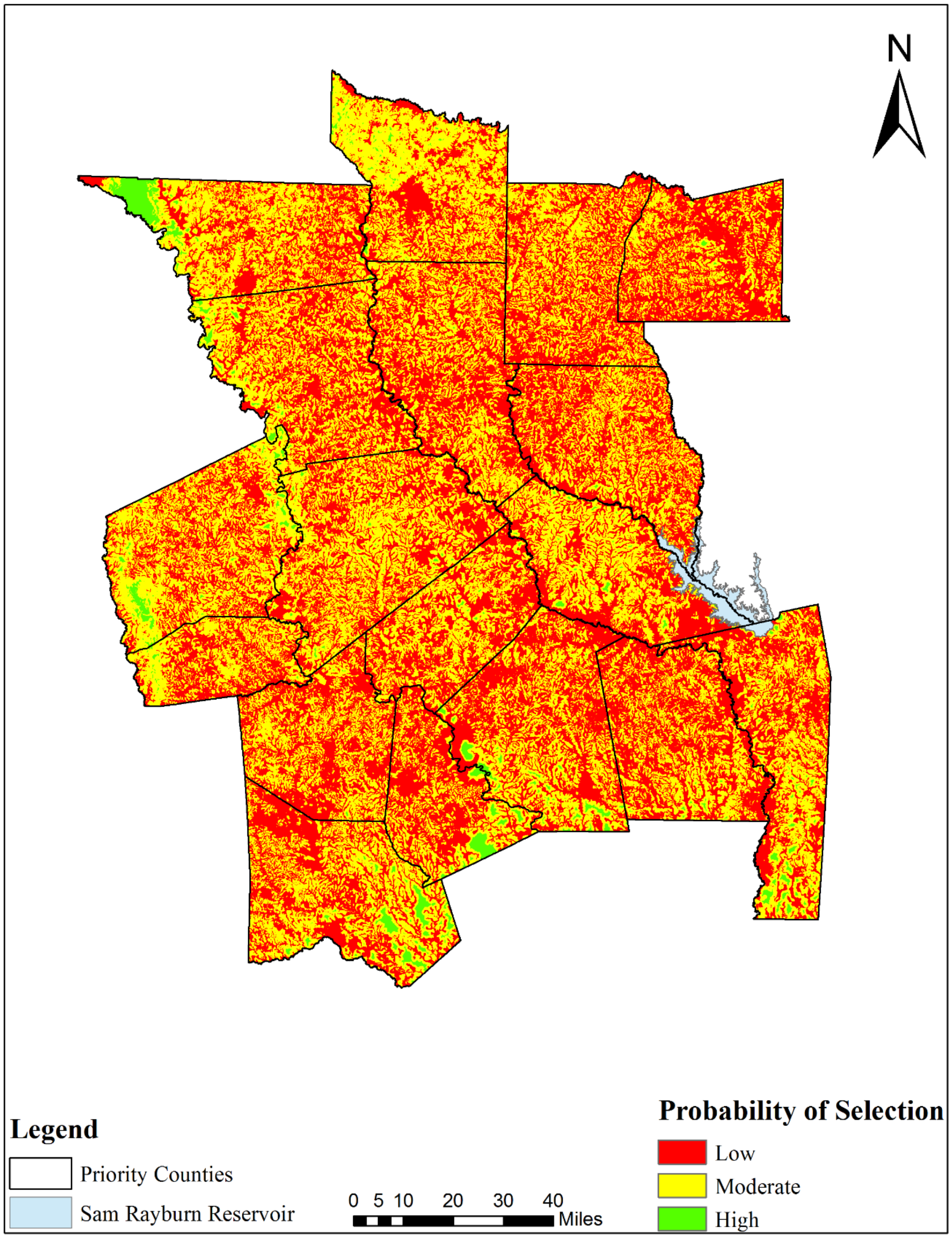

Figure 4.4. Predictive map representing probability of annual habitat selection (low, moderate, high) for translocated male turkeys within the 18-county priority region of east Texas, USA. Predictive map was constructed using β coefficients resulting from GLMM with scaled habitat variables from annual habitat selection model.

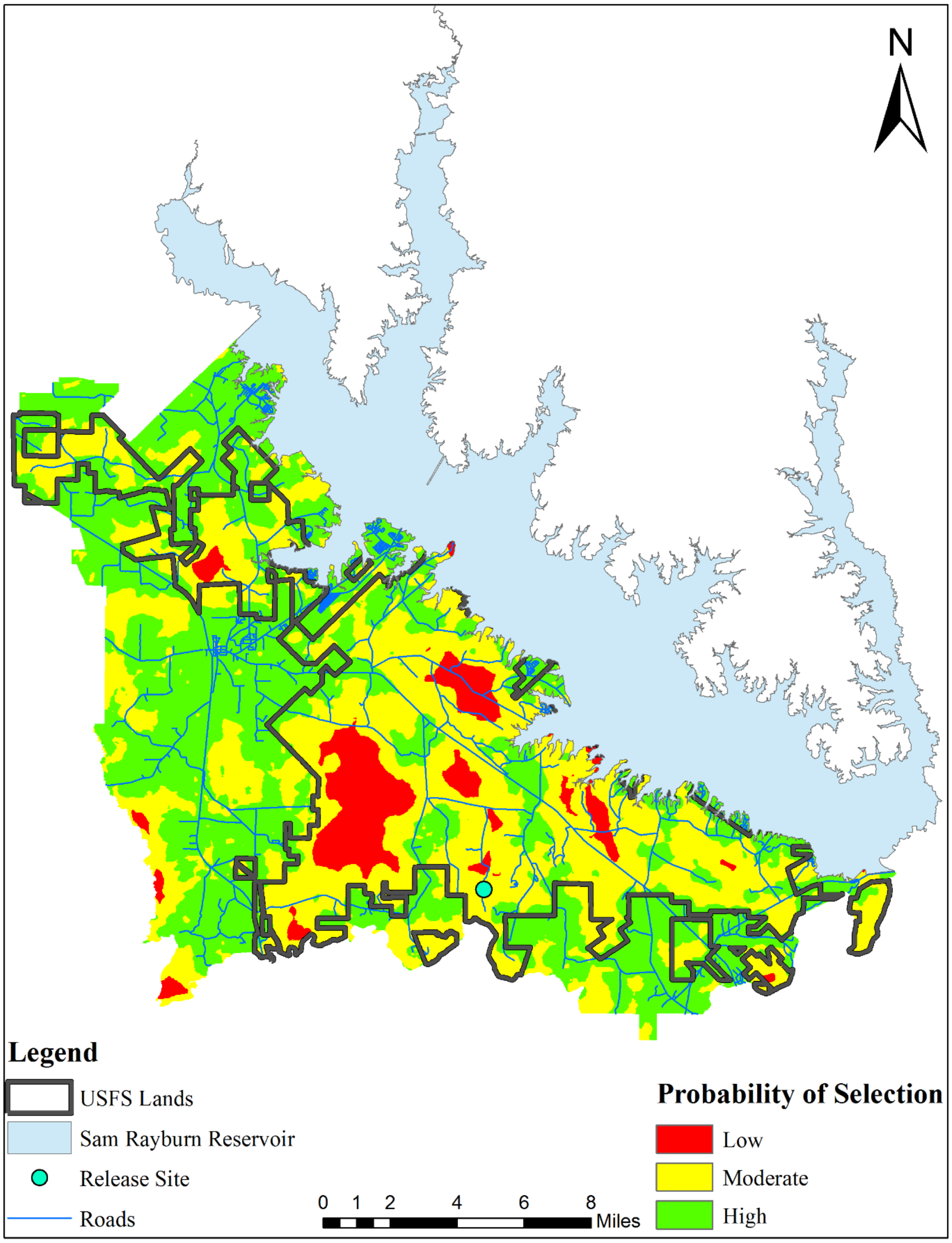

Figure 4.5. Predictive map representing probability of habitat selection (low, moderate, high) for translocated female turkeys in Angelina National Forest, Texas, USA. Predictive map was constructed using β coefficients resulting from GLMM with scaled habitat variables from annual habitat selection model.

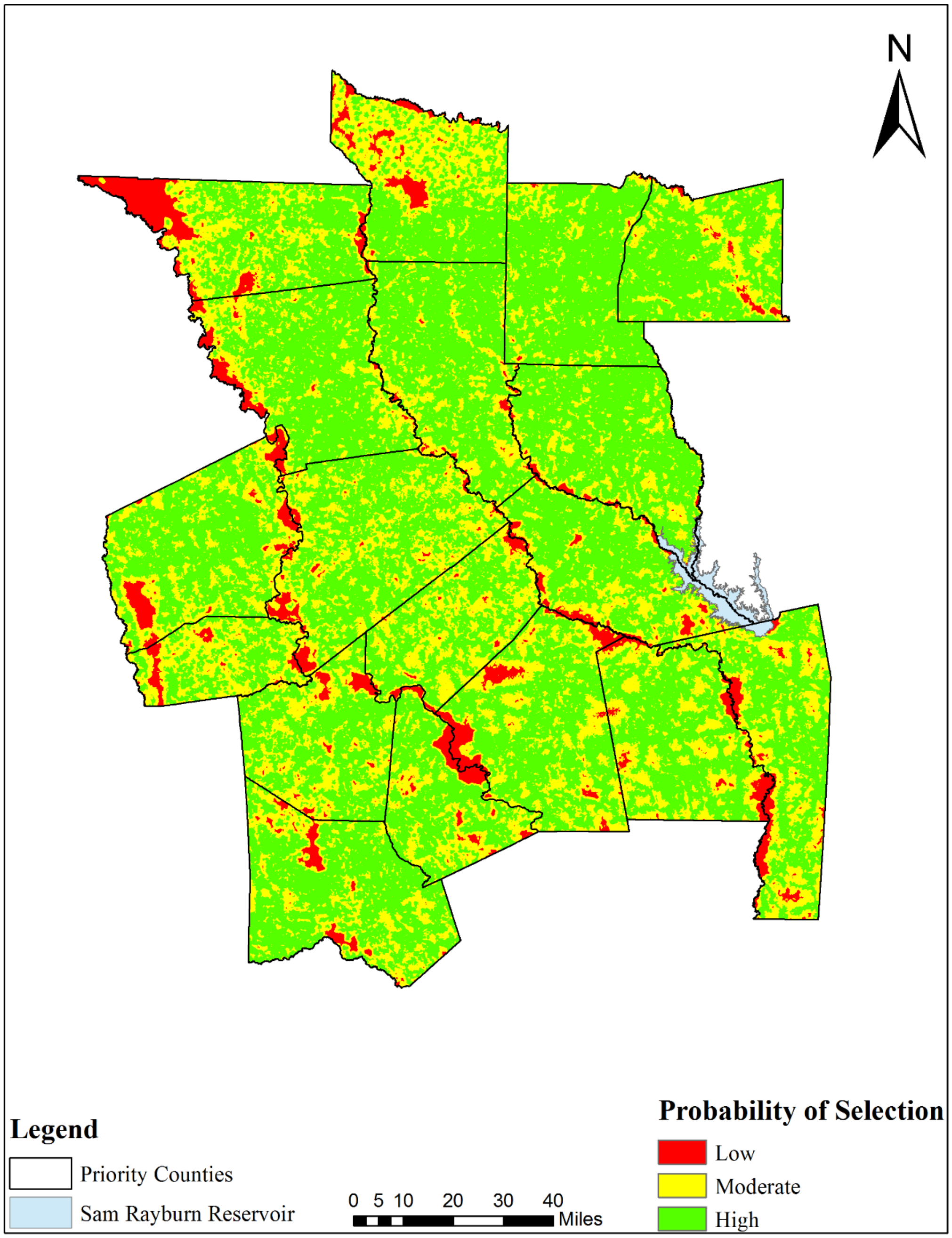

Figure 4.6. Predictive map representing probability of habitat selection (low, moderate, high) for translocated female turkeys within the 18-county priority region of east Texas, USA. Predictive map was constructed using β coefficients resulting from GLMM with scaled habitat variables from annual habitat selection model.

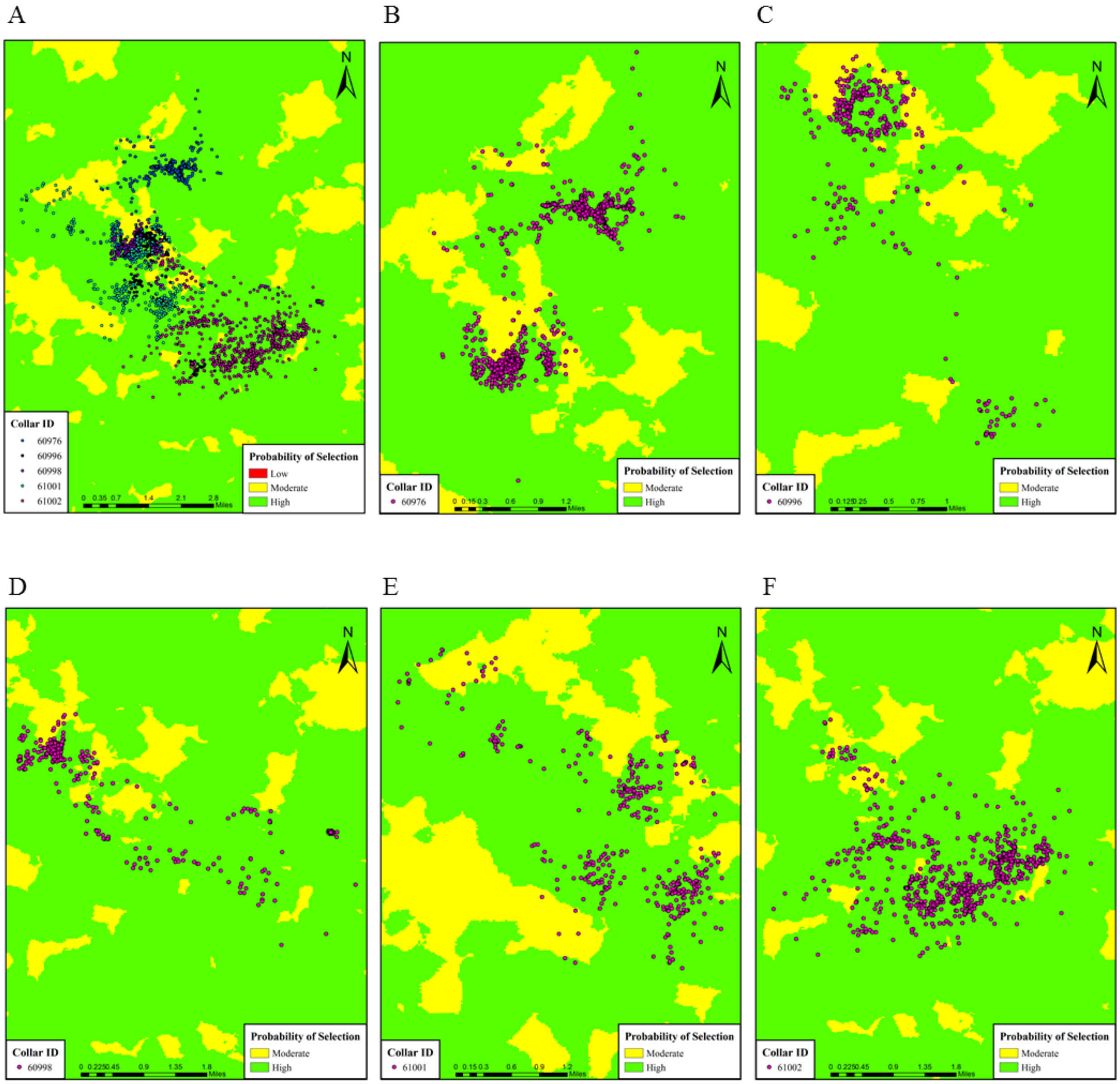

Figure 4.7. Predictive map representing probability of habitat selection (low, moderate, high) for translocated female turkeys near the Brushy Creek stocking site in east Texas, USA. Point locations from 5 translocated female wild turkeys were overlaid for model performance and visualization. Panel A shows locations of all 5 females, whereas the remaining panels show point locations for each female separately referenced by Collar ID numbers.

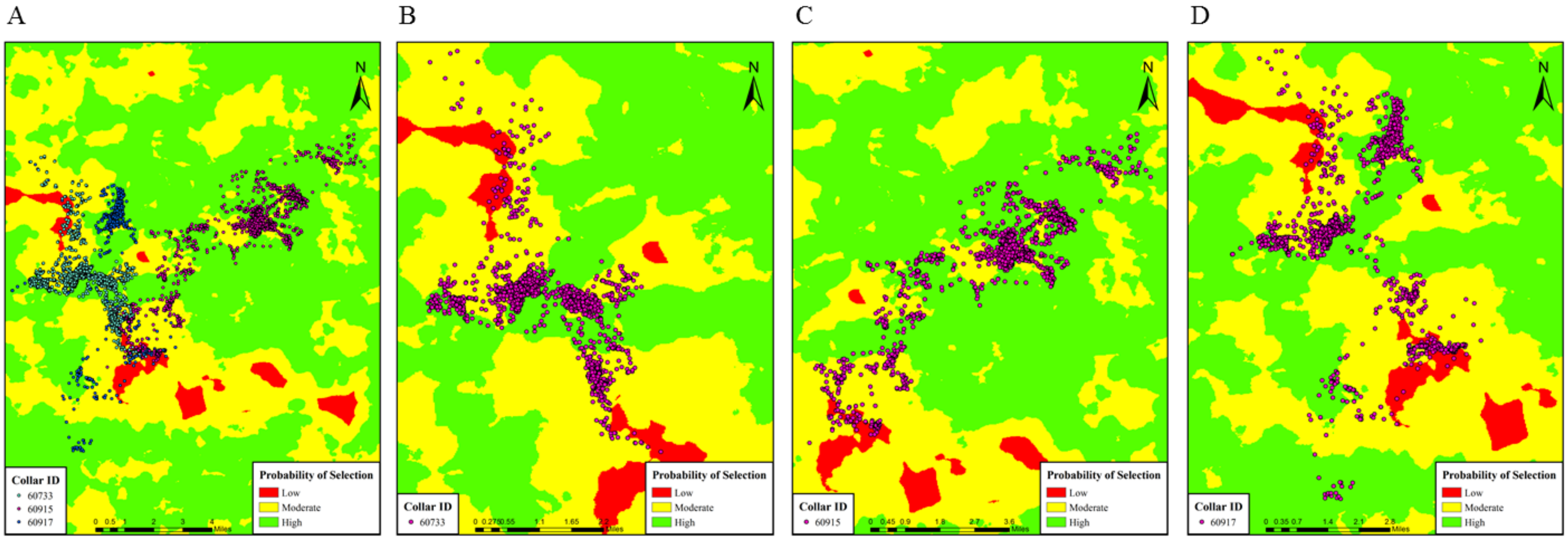

Figure 4.8. Predictive map representing probability of habitat selection (low, moderate, high) for translocated female turkeys near the privately-owned Coon Pond stocking site in east Texas, USA. Point locations from 3 translocated female wild turkeys were overlaid for model performance and visualization. Panel A shows locations of all 3 translocated females, whereas the remaining panels show point locations for each female separately referenced by Collar ID numbers.

CHAPTER 5

SPATIAL SCALE AND SHAPE OF PRESCRIBED FIRES INFLUENCE USE BY WILD TURKEYS

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[1] Sullivan, D. J., K. D. McEntire, B. S. Cohen, B. A. Collier, and M. J. Chamberlain. To be submitted to Forest Ecology and Management.

ABSTRACT

In recent years, there have been increasing efforts to understand effects of prescribed fire on population dynamics of wild turkeys (*Meleagris gallopavo*) in frequently burned upland pine savannas. Although distribution of turkeys is not limited to upland-pine savannas, these forests constitute important reproductive habitat in the southeastern United States. Previous studies have typically investigated direct (e.g., nest loss to fire) and indirect (e.g., nest- and brood site selection) effects of prescribed fire, but little is known about how turkeys are influenced by the spatial scale and shape of prescribed fire. Individual-based models (IBM) are dynamic models used to assess how system-level properties emerge from individual behavior, while also assessing system-level effects on individuals. Population ecology of turkeys residing in upland-pine savannas is influenced by prescribed fire, therefore IBMs provide a suitable framework to assess how scale and shape of fires influence landscape use by wild turkeys. We constructed an IBM with landscapes of 2 burn unit shapes and 17 scales of fire. We used telemetry data obtained from GPS marked turkeys to inform and replicate movement behaviors of turkeys within the model. We hypothesized that use of units burned during the current year (< 1 year) would decrease as scale of fires increased, and that shape of burn units would influence use by turkeys. We found that spatial scale and shape of fires influenced turkey use, with greatest use of burned stands of approximately 23 ha in size, whereas least use was associated with burned stands exceeding 1269 ha. At a spatial scale of 23 ha, we observed a 7.13 % decrease in daily percent use between rectangular- (48.78 %) and square-shaped (45.30 %) burn units. Likewise, we observed a 34.72 % decrease in daily percent use between rectangular- (13.19 %) and square-shaped (8.61 %) burn units at a spatial scale of 1269 ha. When burn units were rectangular-shaped, we noted that daily percent use decreased by 48.78 % as the spatial extent of the fires increased from 23 ha to 203 ha. Likewise, when burn units were square-shaped, we noted that turkey use decreased by 49.43 % as spatial extent of fires increased from 23 ha to 203 ha. Our findings demonstrate the importance of managing forested landscapes with prescribed fires not exceeding ~ 200 ha if wild turkeys are a management concern. Likewise, our findings suggest shape of fire should be considered when conducting prescribed fires and illustrates the ecological importance of edge to perimeter ratios in promoting use by turkeys.

INTRODUCTION

Species abundance and distribution are limited by resources required to maintain life history strategies at varying spatial and temporal scales (Brown 1984, Rosenzweig 1985, Block and Brennan 1993). Resources necessary for species growth and survival are limited by the environment, and environmental changes result in unique arrangements of resources yielding variable habitats across the landscape (May 1974, Southwood 1997). Habitat or spatial heterogeneity is a central component of the structure and functionality of nature (Pickett and Rogers 1997) and has been shown to increase species richness and biodiversity (MacArthur and MacArthur 1961, Rosenzweig 1981). However, natural mechanisms of disturbance such as wildland fire and stochastic events have been anthropogenically limited, thereby reducing habitat complexity (Pickett and Rogers 1997, Culver and Buzas 1995). To prevent further loss in heterogeneity and resource availability for wildlife species, remaining habitat has been managed with disturbance to encourage successional vegetation communities and enhance growth and survival of wildlife populations (Andren 1995, Lashley et al. 2015).

Upland-pine savannas in the southeastern United States provide an excellent example of habitat managed by disturbance and demonstrate the role various forms of disturbances (e.g., distribution, frequency, size, severity; Pickett and White 1985) play in maintaining coevolutionary relationships between habitat and wildlife. The upland-pine savanna ecosystem in the southeastern United States is a fire-maintained ecosystem that evolved from lightning-induced fires (Komarek 1964, Pyne 1982, Rorig and Ferguson 1999, Block et al. 2016). Coadapted wildlife species inhabiting these savannas, such as red-cockaded woodpecker (*Picoides borealis*) and gopher tortoises (*Gopherus polyphemus*), are dependent on fire to maintain an open understory of early successional vegetation and prevent encroachment of shade-tolerant hardwood species (Komarek 1964, Pyne 1982). Therefore, resource managers use prescribed fire to maintain upland-pine savannas, thereby creating landscape heterogeneity (Alavalapti et al. 2002, Lashley et al. 2015).

Recently, there have been increasing efforts to understand effects of prescribed fire on population dynamics of wild turkeys (*Meleagris gallopavo*, hereafter; turkey) in fire-maintained pine savannas (Streich et al. 2015, Little et al. 2015, Yeldell et al. 2017*b, c*, Wood et al. 2018), as they provide important habitat to turkeys throughout the southeastern United States (Sisson et al. 1990). The relative influence of fire on turkey reproductive success can be affected by scale (size of fire), timing (dormant vs. growing season) and fire return interval (Martin et al. 2012, Kilburg et al. 2014, Yeldell et al. 2017*a*). Additionally, use of prescribed fire depends on funding and weather, which can subsequently alter fire prescriptions and cause an imbalance in spatial-temporal dynamics of fire-dependent habitat critical for wild turkey survival (Sisson and Speake 1994). Previous studies have investigated direct (e.g., nest loss to fire) and indirect (e.g., nest- and brood site selection) effects of prescribed fire (Sisson et al. 1990, Martin et al. 2012, Little et al. 2016, Wood et al. 2008), but little is known about how turkeys are influenced by the spatial scale and shape of prescribed fires.

The scale of prescribed fire management units (hereafter burn units) varies across lands managed by state and federal agencies. Contemporary literature has noted that average size of burn units on public lands can range from 26 ha (Wood et al. 2018) to approximately 1,587 ha (Yeldell et al. 2017*a,b,c*). Furthermore, scaling of burn units may continue to expand as management agencies increase reliance on aerial ignition due to limited time and resources, as federally-mandated fuel load reductions continue to increase nationally (Stephens et al. 2016). Therefore, expanding the scale of burn units may influence population dynamics of turkeys inhabiting public lands because habitat heterogeneity is influenced by scaling of burn units (Thaxton and Platt 2006, Knapp et al. 2009, Lashley et al. 2014). Although data are scant, it is plausible that increasing the spatial scale of burn units beyond some extent may decrease habitat heterogeneity across the landscape, as numerous smaller burn units are replaced by fewer larger ones (Beckage et al. 2005, Lashley et al. 2014, Holland et al. 2017).

Shape of a burn unit can affect an animal’s ability to traverse and occupy patches of forest (Lime and Dill 1990) because of the relationship between perimeter-area ratios and species core areas (Helzer and Jelinski 1999). Patches that have elongated or concaved perimeters provide greater perimeter-area ratios than patches of the same area that have unbroken perimeters (Helzer and Jelinski 1999). For edge species like turkeys, burn units with increased perimeter-area ratios provide a greater number of unburned areas juxtaposed to burned areas, thereby reducing movements necessary to reach escape cover during or after fires (Andersson et al. 2009, Lavoie et al. 2010) and during recolonization of burned areas immediately following fire (Yeldell et al. 2017*c*). For example, Yeldell et al. (2017*c*) noted that during fire, turkeys moved to unburned areas juxtaposed to burned areas but quickly recolonized burned areas after fire. Hence, altering burn unit shape to increase perimeter-area ratio may enhance the ability of turkeys to move to unburned patches juxtaposed to burned areas, increasing use of recently burned units (Lima and Dill 1990, Fischhoff et al. 2007).

No literature has detailed how scale and shape of burn units influence use of the landscape by turkeys. Previous studies on other species have used individual-based models (also known as agent-based models) to assess system-level mechanisms responsible for influencing population dynamics (DeAngelis and Gross 1992, Huse et al. 2002, Van Winkle et al. 1993). Individual-based models (hereafter; IBMs) are simulation models that can be used to assess how system-level properties emerge from individual behavior, while also assessing system-level effects on individuals (Grimm et al. 2006, Railsback and Grimm 2012). System-level mechanisms emerging from IBM simulations at the individual level are typically responsible for influencing population dynamics (*e.g.*, survival and growth) of a species, hence IBMs are important decision-making tools for population and community-level management. Because we know that turkeys residing in fire-maintained pine savannas are influenced by habitat heterogeneity linked to prescribed fire (Little et al. 2016, Yeldell et al. 2017*a,b,c*, Wood et al. 2018), IBMs provide a suitable framework to assess the influence of spatial scale and shape of prescribed fire on landscape use by turkeys.

Our objective was to assess and quantify the relationship between scale and shape of burn units and their effect on landscape use by turkeys using an IBM framework. We hypothesized that use of recently burned (< 1 year) units would decrease as spatial scale of prescribed fire increased. We also hypothesized that shape of burn units would influence turkey use, with shapes offering more area juxtaposed to unburned stands being used more.

METHODS

We developed an IBM to assess the influence of spatial scale and shape of prescribed fire on landscape use by turkeys. Turkey movement was the only process in the model, and the use of recently burned units by turkeys was an emergent property of the model. The model outcome recorded daily percent use of burned units for the length of each model run. We built the model using the program NetLogo (Wilensky 1999) and an Overview, Design Concepts, and Details (ODD) protocol (Grimm et al. 2006, 2010), and have included more detailed descriptions of model processes, along with a summary of the model and some of the naming conventions associated with NetLogo (see Appendix A).

We created artificial landscapes comprised of rectangular- or square-shaped burn units. The landscapes were comprised of 225 m^2 squares (patches), which were used to create a repetitive pattern of burn units ranging in scale from 23-1269 ha across the landscape (Figure 5.1). The square-shaped landscape consisted of 950 × 950, 225 m^2 patches that created an area of approximately 20,306 ha. The rectangular-shaped landscape consisted of 1,444 × 625, 225 m^2 patches that also created an area of approximately 20,306 ha. Each burn unit was equally distributed across the landscape creating a checkered pattern, with every fourth burn unit designated as a unit burned < 1 year prior (hereafter recently burned). The remaining 3 burn units represented > 1 but < 3 years post-burn. This helped establish spacing between burn units, assuming a fire return interval of 3 years, which is common across multiple study sites that use fire to manage forest conditions (Kilburg et al. 2014, Yeldell et al. 2017*a*,*b*,*c*, Wood et al. 2018). Since previous studies have already explored how timing of fire influences turkey response (Little et al. 2016, Yeldell et al. 2017*a*,*b*,*c*, Wood et al. 2018), we constructed our model to focus solely on issues relative to spatial scale and shape of prescribed fires. Thus, we programmed the model so that all recently burned units across the landscape were burned at a single time, so that we could evaluate how turkeys would respond to fire solely as a function of spatial scale and shape.

We programmed the model to randomly distribute 40 turkeys (mobile agents) to unburned units (units burned > 1 year prior) across the landscape when the model was initiated. We initiated turkeys in unburned units because burned units represented day 0 fire when the model initiated, and we assumed turkeys would not be present within burn units the day fires occurred. Recently published literature detailing movements of wild turkeys using GPS telemetry have typically described daily movements using 14 locations collected from sunrise to sunset (Yeldell et al. 2017*b*, Wood et al. 2018), hence we simulated turkeys in the model to move hourly for 14 hours per day, for 365 days. Turkeys could move in 2 ways, either through walking or foraging-loafing. We distinguished these 2 movements using distances moved per hour coupled with turning angles between consecutive movements (see below). Each turkey had an individual propensity for walking based on telemetry data that was dependent on when the burn unit was burned last (see Appendix A). This individual propensity for movement created stochasticity in the model. The turkeys also had a decreasing probability of movement to areas with increasing distance to the edge of the burned area (see Appendix A, Cohen et al 2019).

We calculated estimates of hourly distances moved and turning angles between consecutive locations for both walk and foraging-loafing movements using estimates for female wild turkeys reported in Cohen et al. (2019). For the walk movement, we set the distance a turkey walked to a numerical value drawn from a normal distribution with a mean of 241.72 m (SD = 41.11 m). Walking turn angle was randomly set to right or left, and drawn from a normal distribution with an average of 45.96° (SD = 6.98°). Similarly, we set the distance moved while foraging-loafing to a value drawn from a normal distribution with a mean of 76.02 m (SD = 11.37 m). Foraging-loafing turn angle was randomly set to right or left, and drawn from a normal distribution with an average 103.15° (SD = 9.84°; Cohen et al. 2019). Using these values, turkeys evaluated all patches at the given distance and turn angle, and used a probability for movement (based on distance to edge of a burned area) estimated for each patch, then compared to a random number between 0 and 1. If the patch probability was greater than the random value, the turkey moved to one of those patches. If all probabilities were less than the random value, the turkey rotated (based on turning angles as outlined above) and did not move that hour (Figure 5.2).

We described turkey use of landscapes relative to scale and shape of prescribed fires using the daily percent use of burn units, which we defined as the proportion of burned areas used at least once by a turkey within one day. We then ran the model for 10 simulations per burn unit size and shape (34 total landscapes) to capture variance in daily percent use and used an analysis of variance (ANOVAs) to compare daily percent use of recently burned units across different burned unit areas for both rectangular-shaped and square-shaped burn units. We used Tukey HSD post-hoc tests to determine significance levels among spatial scales at $\alpha = 0.05$.

We then binned daily percent use of recently burned units by spatial scales for each burn unit shape in increments of 10% difference starting with the spatial scale with greatest daily percent use. We delineated each bin as a category of high (50–40% use), moderate (40–30% use), minor (30–20% use), low (20–10% use), or very low (10–0%) levels of use for easier interpretation. We visualized our data and performed all analyses using program R (Wickham 2016, R Core Team 2013).

RESULTS

We observed that daily percent use of recently burned units was greatest at the smallest spatial scale of fire, regardless of shape, and declined as scale increased (Table 5.1). At a spatial scale of 23 ha, we observed a 7.13 % decrease in daily percent use between rectangular- (48.78 %) and square-shaped (45.30 %) burn units. Likewise, we observed a 34.72 % decrease in daily percent use between rectangular- (13.19 %) and square-shaped (8.61 %) burn units at a spatial scale of 1269 ha.

For landscapes with rectangular-shaped burn units, we observed a 48.78 % decrease in daily percent use as the spatial scale increased from 23 ha to the median of 203 ha (Table 5.1, Figure 5.3). Similarly, for landscapes with square-shaped burn units, we observed a 49.43 % decrease in daily percent use as the spatial scale increased from 23 ha to 203 ha (Table 5.1, Figure 5.3). At 203 ha, daily percent use fell below 25%, irrespective of burn unit shape (Tables 5.1 and 5.3). Hence, at 203 ha, daily percent use of recently burned units was similar to use of other available habitats, and as scale increased thereafter, daily percent use of recently burned units decreased relative to other available habitats.

Results of ANOVAs and post-hoc tests indicated daily percent use significantly differed across all spatial scales within rectangular- ($F_{16,62033} = 13626$, $P < 0.001$) and square-shaped burn unit landscapes ($F_{16,62033} = 11326$, $P < 0.001$). Since all spatial scales differed and post-hoc tests did not reveal natural breaks in data, we binned daily percent use data in increments of 10% difference starting with the spatial scale with greatest daily percent use (23 ha; Figure 5.4). For rectangular-shaped burn units, we found that burns not exceeding 40 ha fell within high levels of daily percent use, whereas burns exceeding 507 ha fell within the low levels of daily percent use. No rectangular-shaped burn units produced levels of daily percent use that fell into the lowest category (very low). For square-shaped burn units, we found that burn units not exceeding 27 ha fell within highest levels of daily percent use, whereas burns 317–1015 ha fell within low levels and burns of 1269 ha fell within the lowest level (very low).

DISCUSSION

Prescribed fire plays an important role in the maintenance of patch-level heterogeneity by altering vegetation composition (Andren 1995, Picketts and Rogers 1997, Lashley et al. 2015), which is known to influence use by turkeys (Killburg et al. 2014, Yeldell et al. 2017*a,b,c*, Little et al. 2016, Wood et al. 2018). Our findings supported our hypothesis that use of recently burned units would decrease as spatial scale of fires increased. We observed a marked and consistent decline in turkey use of recently burned stands with each increase in spatial scale of fire. Indeed, turkeys selected recently burned units relative to the other 3 habitats available to them until reaching the median scale of 203 ha. At 203 ha, use of rectangular-shaped and square-shaped burn units fell below 25%, suggesting that at that scale, recently burned areas were used similar to or less than the other 3 habitats available to them.

Upland-pine savanna habitat is commonly managed with disturbance to promote successional vegetation important for maintaining life-history strategies of fire-dependent species (Andren 1995, Conner et al. 2011). Patterns of space use within a species are constrained by body size and metabolic rate (McNab 1963, Harestad and Bunnell 1979), so when the scale of disturbance exceeds the scale at which species use space, habitat conditions (e.g., lack of diversity, structural complexity) within the species’ home range can become exceedingly homogenous and unfavorable (Holling 1992, Lashley et al. 2015). Turkey space use is allometrically scaled (Gray 1986, Gray and Prince 1988, Coup and Pekins 1999) and published estimates of space use by wild turkeys in fire-managed landscapes lend support to our finding that prescribed fires at smaller spatial scales are more commensurate with the species ecology. For example, Yeldell et al. (2017*b*) reported that average core area size of female turkeys was ~71 ha during pre-nesting, and Wood et al. (2018) reported pre-nesting home range sizes to be ~390 ha. We offer that once fires exceeded the median scale (~200 ha) in our model, such fires would conceivably confront turkeys with habitat and vegetation conditions not congruent with their scaling and space use patterns, particularly during spring reproductive seasons (Martin et al. 2012, Yeldell et al. 2017*b*, Kilburg et al. 2014, Wood et al. 2018, Cohen et al. 2019).

Previous research has shown that species maintaining home ranges rarely leave them during disturbance events (Vernes and Pope 2001, Bechtoldt and Stouffer 2005, Thompson et al. 2008). Indeed, turkeys do not abandon their home ranges even during catastrophic disturbances such as flooding or wildfires (Chamberlain et al. 2013, Oetgen et al. 2015), instead shifting their use to areas not affected during the disturbance if possible, or remaining within the affected ranges. Yeldell et al. (2017*c*) reported that turkeys did not shift their home range in response to prescribed fires, and resumed using burned units almost immediately after fire events. Furthermore, turkeys are gregarious animals that maintain social groups, and their space use is influenced by hierarchical-dominance relationships developed through pecking orders (Healy 1992). Collectively, findings detailed in earlier literature and our model results suggest that turkeys reasonably respond to prescribed fires by using areas available within their ranges, even when the scale of fires are disproportionate to their ecology.

We note that our modeling efforts provide a simplified representation of how turkeys would be expected to respond to prescribed fires, and our inferences were constrained relative to how we constructed the model. For instance, our model did not allow adjacent stands to be burned, even at different temporal scales (i.e., during same year but not on same day), as fires were applied in a single day in our model. Clearly, this scenario is not how fires are applied to the landscape, although we note that in many situations, fires are applied in a narrow temporal window when fire conditions allow, and resource agencies often burn adjacent stands during the same year. Nonetheless, previous studies have already shown how timing of fire influences turkey behavior (see Little et al. 2016, Yeldell et al. 2017*a*,*b*,*c*, Wood et al. 2018) and our modelling efforts were solely focused on elucidating how spatial scale and shape of prescribed fire influences turkey use. Likewise, we recognize our model used landscapes represented by burn units with different fire-return intervals arranged systematically in a checkerboard fashion, rather than randomly distributing fires or otherwise distributing units with different fire-return intervals across the landscape. We did this for simplicity and consistency, as attempting to arrange fires more haphazardly across the landscape would inevitably introduce our own biases into the model.

Small-scale fires applied in a patch mosaic increase spatial heterogeneity (Martin and Sapsis 1992, Parr and Andersen 2006), thereby promoting diverse vegetation communities in upland pine-savannas (Brockett 2001, Beckage et al. 2005, Fuhlendorf et al. 2006). Likewise, shape of prescribed fire (e.g. elongated burn units) can produce discrete patches with different perimeter-area ratios (Helzer and Jelinski 1999) and edge characteristics, (Bradstock et al. 2005, Magrach et al. 2011, Parkins et al. 2018) that are known to influence turkey movements (Thogmartin 1999, Byrne and Chamberlain 2013, Kilburg et al. 2015). Small-scale and elongated burn units can reduce the distance a turkey must traverse within their home range to unburned areas after fires, thereby lessening energetic demands, reducing predation risks, and increasing the likelihood of survival (Thogmartin and Schaeffer 2000, Little et al. 2016). For example, insects are an important food source for turkeys during spring and summer (Healy and Nenno

1983, Miller et al. 1999), but are often limited in the distance they can traverse to recolonize burned areas (Swengel 2001). By creating a patch network of small-scale or elongated burn units, insects residing in adjacent unburned areas can rapidly recolonize burned areas, thereby increasing available forage to turkeys (Swengel 2001, Kiss and Magnin 2003, Kim and Holt 2012). Previous research also has shown that turkeys rarely use the interiors of larger burn units following fire (Yeldell et al. 2017*c*, Cohen et al. 2019). Hence, small-scale and elongated burn units decrease the total distance across each burn unit, thereby reducing the distance a turkey must traverse to find different habitat conditions and promoting greater use of the burned area. Therefore, we suggest that resource agencies managing upland pine savannas with prescribed fire conduct burns at smaller scales to increase spatial heterogeneity and promote diverse habitat conditions necessary to maintain turkey life history strategies. Likewise, resource agencies should consider implementing fires in a way that increases perimeter-area ratios, regardless of scale, to promote use of burned units by wild turkeys.

ACKNOWLEDGEMENTS

We appreciate funding and support provided by Texas Parks and Wildlife Department (TPWD), the Warnell School of Forestry and Natural Resources at the University of Georgia, and the Texas Chapter of the National Wild Turkey Federation (NWTF). Funding for this research was provided in part by TPWD and U.S. Fish and Wildlife Service through the Federal Aid in Wildlife Restoration Act (Pittman-Robertson) program, Grant number TX-W-164-R-1. We thank G. Miller and A. Farrell of NWTF, and J. Hardin of TPWD, and C. White and members of the Texas Chapter of NWTF for their support.

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Table 5.1. Simulated daily percent use of recently (< 1 year) burned units by wild turkeys across 17 spatial scales and 2 shapes (rectangular- and square-shaped).

Spatial Scale of Recent Burned Unit (ha)	Rectangular-Shaped Burn Unit					Square-Shaped Burn Unit				
	Mean	SD	SE	CI	% Decrease	Mean	SD	SE	CI	% Decrease
23	48.78	7.64	0.13	0.26	0.00	45.30	7.67	0.13	0.25	0.00
27	46.48	7.96	0.13	0.26	-4.72	43.80	7.83	0.13	0.25	-3.31
32	42.24	7.97	0.13	0.26	-13.41	39.49	7.73	0.13	0.25	-12.83
40	41.81	7.67	0.13	0.25	-14.29	38.91	7.75	0.13	0.25	-14.11
51	38.16	7.81	0.13	0.25	-21.77	35.84	7.77	0.13	0.25	-20.88
65	35.80	7.51	0.12	0.24	-26.61	33.51	7.24	0.12	0.24	-26.03
90	31.57	7.34	0.12	0.24	-35.28	30.63	7.30	0.12	0.24	-32.38
125	27.43	7.07	0.12	0.23	-43.77	26.63	6.98	0.12	0.23	-41.21
203	24.92	7.00	0.12	0.23	-48.78	22.91	6.97	0.12	0.23	-49.43
248	23.30	6.92	0.11	0.22	-52.23	22.00	6.52	0.11	0.21	-51.43
317	21.42	6.48	0.11	0.21	-56.09	19.78	6.26	0.10	0.20	-56.34
391	20.73	6.73	0.11	0.22	-57.50	19.17	6.33	0.10	0.21	-57.68
507	18.36	5.85	0.10	0.19	-62.36	16.96	5.97	0.10	0.19	-62.56
635	16.17	5.62	0.09	0.18	-66.85	15.14	5.55	0.09	0.18	-66.58
812	13.11	5.51	0.09	0.18	-73.12	12.05	5.14	0.09	0.17	-73.40
1015	13.34	5.52	0.09	0.18	-72.65	11.31	4.99	0.08	0.16	-75.03
1269	13.19	4.87	0.08	0.16	-72.96	8.61	4.75	0.08	0.15	-80.99

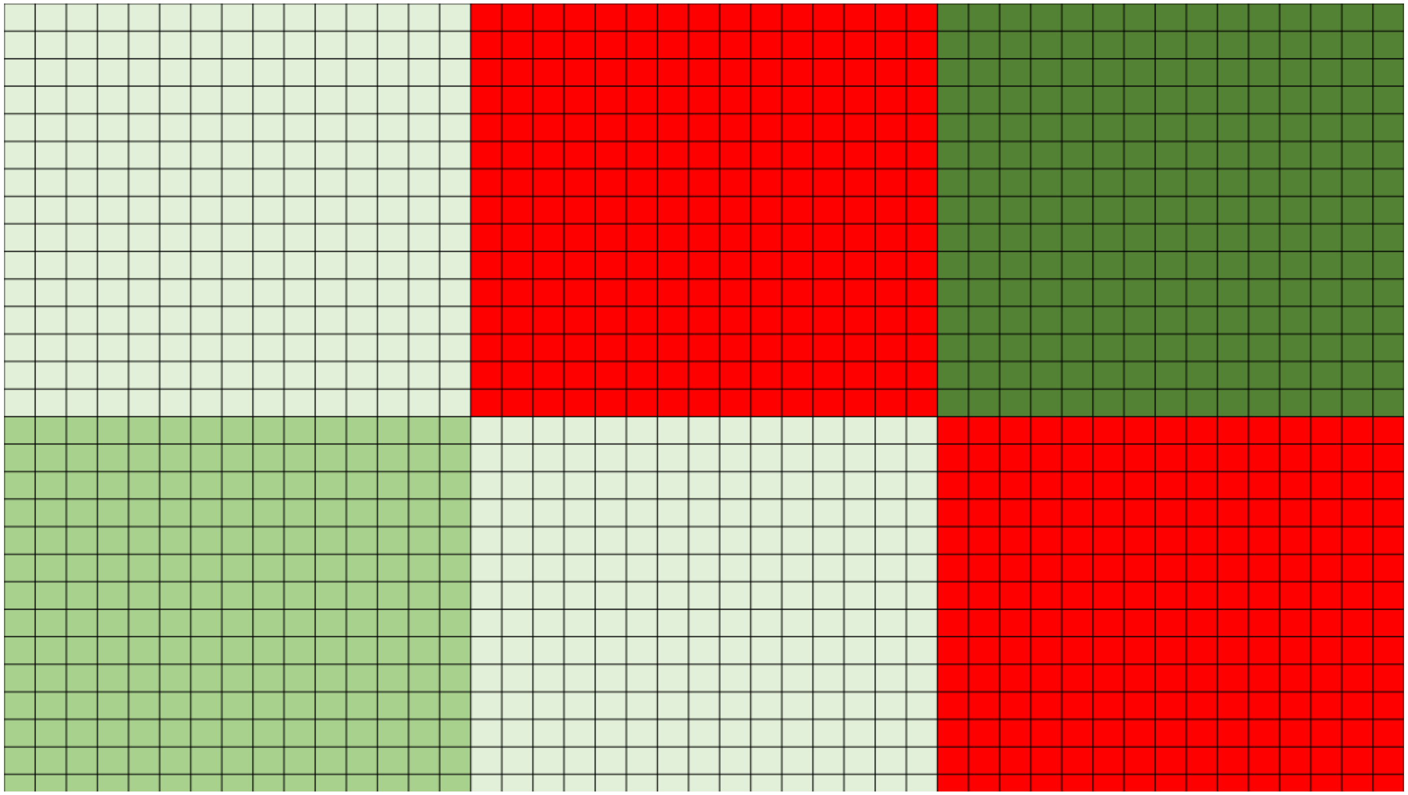

Figure 5.1. Example of simulated landscape comprised of 4 burn units created by 225 m^2 squares (patches). Repetitive patches were used to create landscapes with rectangular- and square-shaped burn units. Rectangular-shaped landscapes (1,444 × 625, 225 m^2 patches) and square-shaped landscapes (950 × 950, 225 m^2 patches) totaled 20,306 ha. Time since prescribed fire is represented by color of collective patches. Red indicates prescribed fire < 1 year, light green indicates fire > 1 < 2 years, green indicates fire > 2 < 3 years, dark green indicates fire ≥ 3 years.

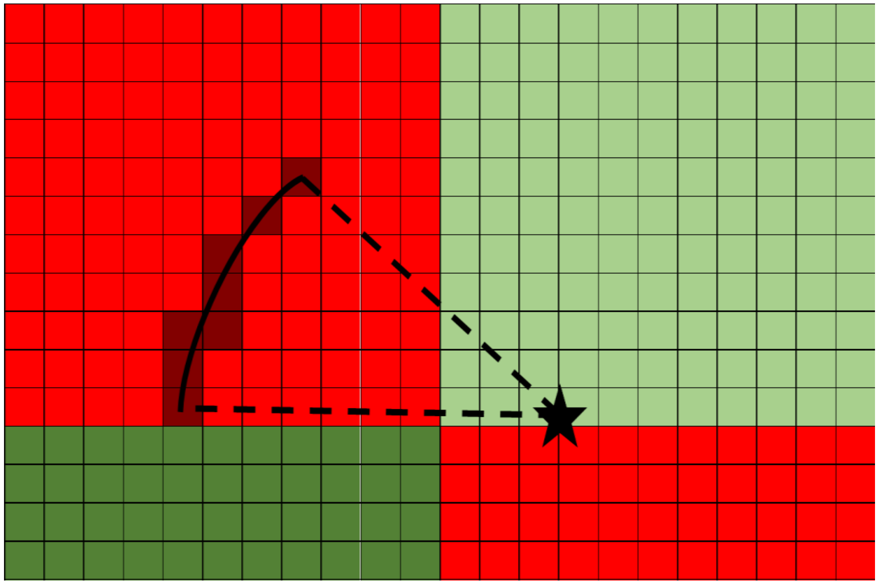

Figure 5.2. Graphical representation of how a wild turkey may potentially move within the individual-based model. The black-colored star represents the turkey. The dashed black lines represent the distance the turkey would move during that time step (depending on location and movement type). The solid black line represents the turn angle of the turkey, including both left and right turn directions. The red squares represent patches (225 m^2) within recently burned units. The dark red patches are those patches evaluated for potential movement. The probability of movement (based on distance to edge of a burned area) is estimated for each of these patches, then compared to a random number between 0 and 1. If the patch probability was greater than the random value, the turkey moved to one of those patches. If all probabilities were less than the random value, the turkey rotated (based on turn-angles as outlined above) and did not move that hour.

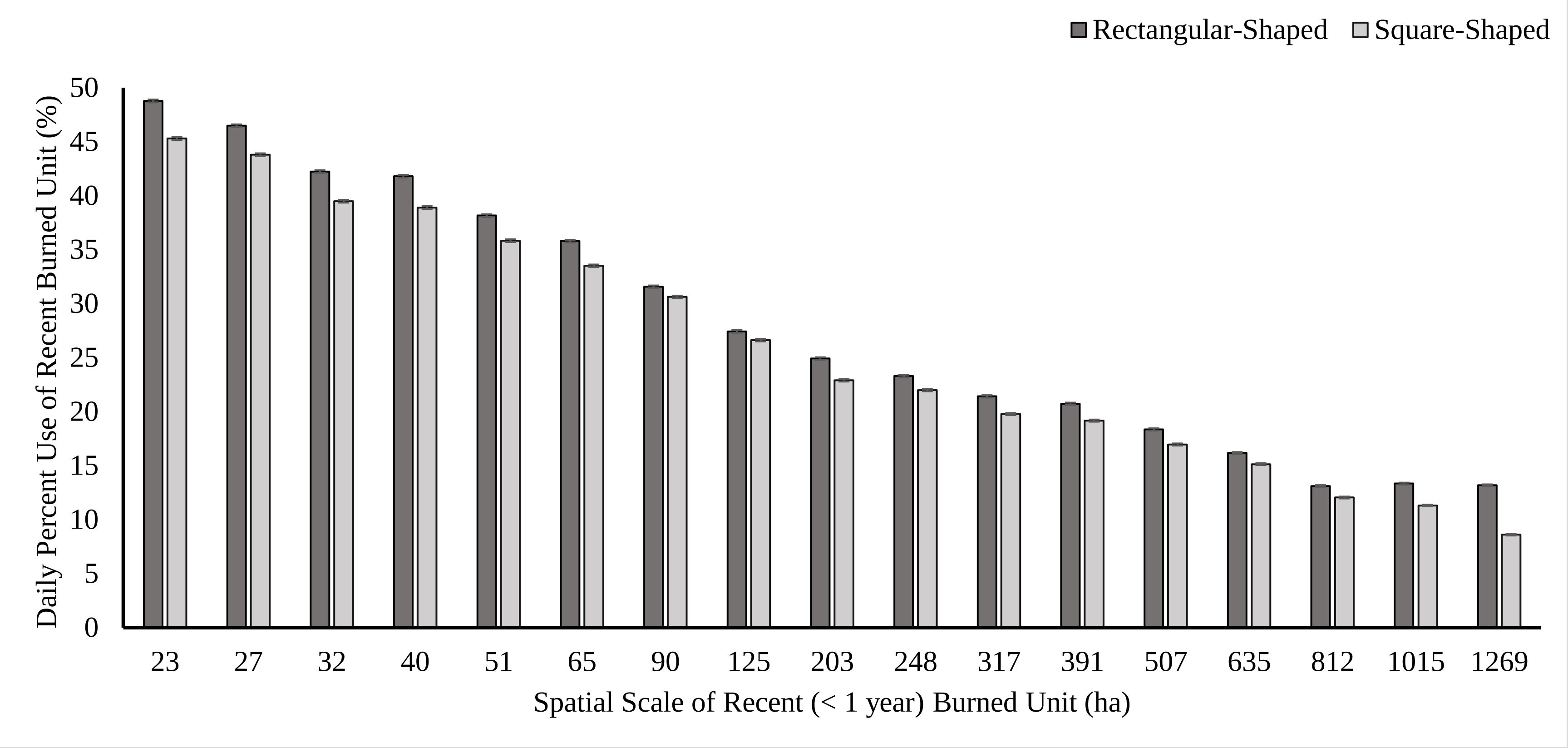

Figure 5.3. Daily percent use of recent burned units by wild turkeys for 17 spatial scales of recent burned units (ha) and 2 burn unit shapes (rectangular- and square-shaped). Mean ± 1 Standard error.

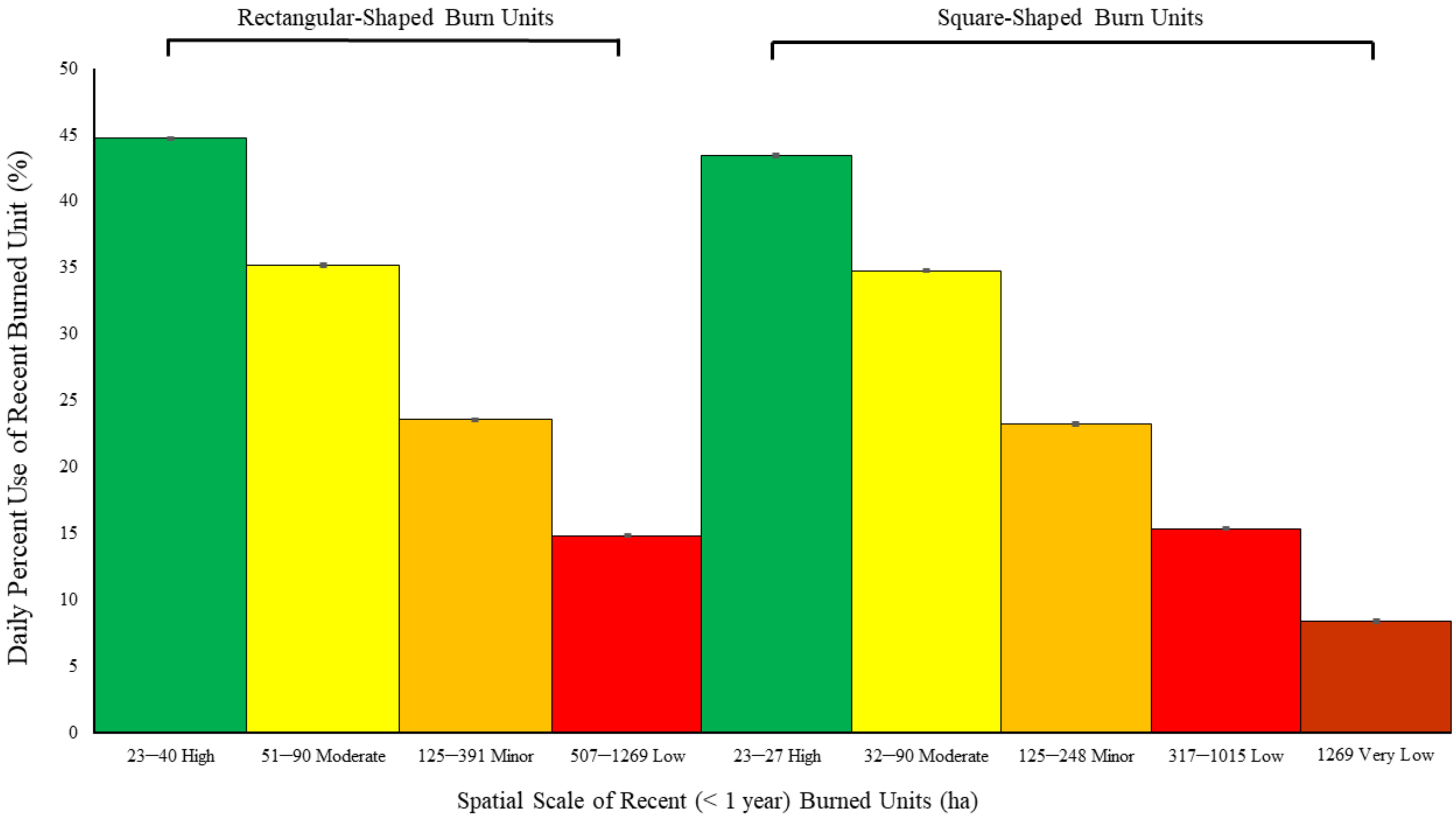

Figure 5.4. Binned daily percent use of recent (< 1 year) burned units by wild turkeys across 17 spatial scales and 2 shapes (rectangular- and square-shaped). Spatial scales of recent burned units were binned in increments of 10% difference starting with the spatial scale with highest daily use (23 ha), resulting in 4 bins (high, moderate, minor, low) for rectangular-shaped burn units and 5 bins (high, moderate, minor, low, very low) for square-shaped burn units.

CHAPTER 6

HOW PREVALENT IS BROOD PARASITISM IN WILD TURKEYS (*MELEAGRIS GALLOPAVO*)?[1]

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[1] Sullivan, D. J., P. H. Wightman, B. A. Collier, and M. J. Chamberlain. 2020. To be submitted to the National Wild Turkey Symposium.

ABSTRACT

Brood parasitism can play an important role in processes regulating fitness and population dynamics of both hosts and parasites. Interspecific and conspecific brood parasitism are 2 alternative reproductive strategies observed to occur in about 1% of all bird species. Recently, low reproductive productivity has been observed in wild turkey (*Meleagris gallopavo*) populations resulting in population declines across the southeastern United States. Reproductive productivity may be influenced by brood parasitism, but the extent of brood parasitism and how it may influence productivity of wild turkey populations is poorly understood. Herein, we illustrate multiple unreported examples of conspecific brood parasitism obtained using GPS telemetry data from female wild turkeys in Louisiana and Georgia. Further, we report the occurrence of conspecific brood parasitism by Rio Grande wild turkeys in Texas using photographic evidence. Lastly, we illustrate the potential extent of conspecific brood parasitism using data collected from research on reproduction and movement of female wild turkeys across the Southeast, and discuss potential impacts of brood parasitism on reproductive productivity.

INTRODUCTION

"Several hens sometimes associate together, I believe for their mutual safety, deposit their eggs in the same nest, and rear their broods together. I once found three sitting on 42 eggs. In such cases, the common nest is always watched by one of the females, so that no Crow, Raven, or perhaps even Pole-cat, dares approach it." [Audubon 1831]

It has been 187 years since Audubon first reported his observation of 3 female wild turkeys (*Meleagris gallopavo*) in care of a single nest with 42 eggs (Audubon 1831). Understanding why natural selection favored an alternative reproductive strategy would have been difficult for Audubon to explain absent the evolutionary knowledge available today.

However, embedded within Audubon’s observation there is a hypothesis that posits predation risk may influence selection of an alternative reproductive strategy requiring multiple maternal care of a single nest to ensure positive reproductive fitness. Similar types of alternative reproductive strategies are now commonly recognized as brood parasitism and occur in about 1% of all bird species (Payne 1977).

Brood parasitism can play an important role in processes regulating individual fitness and population dynamics of both hosts and parasites (Payne 1977, Payne 1998, Robinson et al. 1995, Sorenson 1997). Individuals exhibiting parasitic behavior reduce the reproductive fitness of hosts while increasing fitness of the parasitic species (Cichoń 1996, Croston and Hauber 2010). The effect of brood parasitism on host fitness can be estimated by the difference in success between parasitized and non-parasitized nests (Payne 1977). Brood parasitism is hypothesized to have originated when a non-parasitic female’s nest was destroyed, and she placed eggs in a nest of another female (Hamilton and Orians 1965, Lack 1968, Ducatez 2014). Furthermore, evolution of brood parasitism likely started with females parasitizing nests of conspecifics, and secondarily developing parasitism strategies of other species (Hamilton and Orians 1965, Krakauer and Kimball 2009).

Recently, management agencies have observed reduced productivity and concomitant population declines in wild turkeys across the southeastern United States (Byrne et al. 2015, Eriksen et al. 2015). Production, primarily manifested via nest success, is the driver of population sustainability in wild turkeys (Vangilder 1992). However, the potential for brood parasitism to serve as an alternative reproductive strategy by wild turkeys is poorly understood considering the extensive literature on reproductive ecology of the species. Instances of brood parasitism have been previously described for wild turkeys (Green 1982, Stoll 1992, Kennamer

1989, Pollentier et al. 2014, Brautigam et al. 2016), as has multiple maternity within clutches (Krakauer 2008). Although conspecific brood parasitism has been observed in wild turkeys, no studies have described the extent of brood parasitism or described how it may influence productivity of wild turkey populations. Hence, our objective was to describe multiple instances of brood parasitism using both GPS telemetry data and photographic evidence. We also sought to illustrate the potential extent of conspecific brood parasitism using an extensive dataset of GPS telemetry data on female wild turkeys across the southeastern United States and discuss potential impacts on reproductive output.

STUDY AREAS

We conducted our research on various sites throughout the southeastern United States during 2014–2018, including Kisatchie National Forest (KNF), and Peason Ridge/Fort Polk Wildlife Management Areas (PR) in Louisiana (see Yeldell et al. 2017), Silver Lake (SL, see Wood et al. 2018), B. F. Grant (BFG), and Cedar Creek (CC) Wildlife Management Areas in Georgia (see Wakefield 2019), and Webb Wildlife Management Area Complex (Webb) in South Carolina (see Wightman et al. 2018). The dominant habitat type across sites was pine forest along with stands of mixed forest, hardwood forest, and open vegetation communities. All pine-dominated study areas were managed to some degree with prescribed fire and forest thinning practices.

We also conducted research in the Edwards Plateau region of Texas during 2006─2007 (see Dreibelbis et al. 2008) and Texas Parks and Wildlife Oaks and Prairies Ecoregion of Texas during 2016─2017. The Edwards Plateau region was characterized by rolling hills with limestone bedrock forming steep outcrops with rocky soils, whereas the Oaks and Prairies

Ecoregion was characterized by post oak savannah and coastal prairie with interspersed bottomlands and open vegetation communities (Rideout 1994).

CAPTURE AND MARKING METHODS

We captured female wild turkeys using rocket nets, walk in traps and drop nets from January-March during 2006–2007 and 2014–2018. We classified each female as adult or subadult based on presence of barring on the ninth and tenth primaries (Pelham and Dickson 1992). During 2006–2007, females were affixed with VHF telemetry transmitters (Advanced Telemetry Systems, Isanti, MN, USA) weighing approximately 82-g. During 2014–2018, females were affixed with GPS telemetry transmitters (Lotek-Biotrack LTD: Wareham, Dorset, UK) weighing approximately 88-g with remote downloadable capabilities. We programmed GPS units to collect a location per hour from 0500 hrs to 2000 hrs with 1 nightly roost site location at midnight (Cohen et al. 2018). All birds were released on site immediately after processing.

We located and monitored status of GPS marked females ≥1 time per week. To monitor nesting activity, we downloaded and viewed GPS locations from each female ≥1 time per week. We considered a female to be incubating a nest when recorded locations were concentrated at a central location for several days (Yeldell et al. 2017, Wood et al. 2018). Once a female was determined to be laying or incubating a nest, we monitored its location until nest cessation. After nest cessation, we located nests using GPS locations to determine nest fate and clutch size (number of eggs incubated). We considered a nest successful if ≥ 1 poult hatched from the clutch. Females radio-tagged with VHF transmitters were monitored following methods outlined by Dreibelbis et al. (2008). Once females were confirmed to be incubating, we used motion-activated trail cameras to monitor a sample of nests (see Dreibelbis et al. 2008 for details of methodology).

OBSERVATIONS OF BROOD PARASITISM

On KNF, we observed a GPS marked female (Female 71) visit the nest for the first time on 22 April 2014. Female 71 repeatedly visited the nest from 22 April to 27 April daily, presumably while laying. On 28 April, Female 71 initiated incubation, and was detected by VHF near the nest site on 29 April (Figures 6.1). On 30 April we detected Female 71 approximately 1100-m west of the nest and assumed the nest had failed. When approaching the nest to identify the cause of the believed nest failure, we flushed an unmarked female from the nest (Figure 6.1). The nest was ultimately abandoned by Female 71, and a subsequent visit to the nest confirmed that it failed after not being incubated.

On SL, we observed a marked adult female visit the nest site of another marked adult female on several occasions while the nest was laid (Figure 6.2). Female 60857 initiated laying on approximately 21 March 2016 and began incubating on 02 April 2016. Female 60560, who was not incubating a nest, visited the nest of Female 60857 at least 3 times based on GPS locations; on 26 March at 1100 hours, 28 March at 1100 hrs, and 29 March at 1700 hrs (Figure 6.2). Female 60857 was eventually depredated while incubating the nest and Female 60560 was observed to incubate a different nest on 20 April 2016 before being depredated.

On BFG, we observed conspecific brood parasitism of 2 marked adult females while both were laying (Figure 6.3). Females 61089 and 61079 both initiated nests on 18 and 20 March, respectively, and both started incubation on 2 April. The nests were approximately 158-m apart. On 27 March while Female 61089 was absent from the nest, Female 61079 visited the nest of Female 61089 at 1700 hrs. The nests of both females failed.

Dump nesting behaviors were also observed at multiple study sites. We observed a dump nest in 2016 on SL at the nest of a GPS marked female 60852; the nest was observed on the hatch date (17 May 2016) with a clutch size of 18 eggs and 3 that were not viable. On CC, we observed a GPS marked female (Female 46239) begin laying on 10 March and incubation on 25 March. On 26 March, we found Female 46239 depredated approximately 200-m from the nest, and upon locating the nest noted 22 eggs present (Figure 6.4).

PHOTOGRAPHIC EVIDENCE OF BROOD PARASITISM

In 2007, we observed 2 cases of brood parasitism in Rio Grande wild turkeys. In April, we detected via VHF that Female 3016 was incubating. While Female 3016 was presumably on a recess approximately 500-m from the nest, we located the nest and discovered an unmarked female incubating it. The unmarked female continued to incubate the nest for several days until it failed. We also noted an instance of a dump nest with Female 2565 (Figure 6.5), who was observed to begin incubation on 6 April. At the time of hatching on 7 May, the observed clutch size was 26 eggs.

On 30 March 2016, we observed via GPS that Female 60606 began incubation (Figure 6.6). On 12 April we approached the nest at 0900 hrs to place a camera at the nest and observed 3 eggs (Figure 6.7). GPS data showed that Female 60606 returned to the nest on 13 April at 1300 hrs, and photographs on 15 April at 1330 hrs showed a marked female at the nest site. However, GPS data revealed that Female 60606 was on an incubation recess at 1400 hrs and returned at 1500 hrs. At 1800 hours on 15 April, Female 60606 abandoned the nest permanently. On 16 April and 25 April, we obtained photographs of an unmarked female at the nest site (Figure 6.6). We approached the nest again on 25 April at 1450 hrs and no female was present, but the nest contained 9 eggs (Figure 6.7). On 5 May, we returned to the nest and found that it had been predated.

ASSESSING POTENTIAL FOR BROOD PARASITISM

After documenting known examples of brood parasitism using GPS data and nest site photographs, we sought to investigate the potential extent of brood parasitism for females across all study sites where marking with GPS occurred. We visually inspected GPS data relative to known nest sites of GPS marked females using ArcGIS® 10.3.1 (Environmental Systems Research Institute Inc, Redlands, CA, USA). Previous authors noted that the 90th quantile of GPS locations around incubating females were within 27-m of the nest (Collier et al. 2019, Bakner 2019), the area of which also encompasses the extent of fix errors associated with the GPS units we used (Guthrie et al. 2011). Hence, we defined a potential parasitic female as either a non-nesting or nesting female that visited within a 30-m buffer surrounding a known nest site of another female during laying or incubation. We defined a host female as a nesting female with a nest that was potentially parasitized.

To determine potential parasites and host nests, we visually inspected all GPS locations within each buffered nest site when each respective nest was laid and incubated, and excluded locations of the host female. We excluded GPS data outside of the buffered nest site, but recorded if a GPS location of a potential parasitic female fell within the buffered nest site of a host female. We generated 2 metrics to describe potential instances of parasitism, which included numbers of females that appeared to parasitize host nests and numbers of nest buffers visited by females other than host females. To illustrate potential effects of brood parasitism on reproductive success (Payne 1977), we counted number of non-parasitized and parasitized nests based on GPS location data within buffered nest sites. We then compared the proportion of successful (≥ 1 hatched egg; Yeldell et al. 2017) non-parasitized and parasitized nests to the total number of non-parasitized and parasitized nests annually at each study site. We then estimated nest success for non-parasitized and parasitized nests.

Because conspecific brood parasitism has been linked to kinship and sociality in avian species (Andersson et al. 2019) and visual detection of other reproductively active females laying nests can stimulate egg laying by parasitic females (Petrie and Moller 1991, Kraak and Groothuis 1994), we visually inspected all GPS locations of potential parasites and host females during the laying period to quantify the percentage of potential parasitic females that interacted with host females. To quantify an interaction between potential parasite and host females during the laying period, we only considered GPS locations of potential parasite and host females that were within 30-m of each other on the same date and time ≥ 1 time during the laying period.

RESULTS

We visually inspected GPS location data of 384 (352 adults, 32 juveniles) female wild turkeys and 405 nest sites monitored during 2014-2018 across study sites (Table 6.1). We observed the potential occurrence of brood parasitism on all study sites (Table 6.1). We identified 27 (25 adults, 2 juveniles) of 384 females (7%) as potential parasites of 25 of 405 nests (6%; Table 1). Notably, 25 of 27 (93%) potential parasitic females were found to interact with host females during the laying period. Of these 27 females, 4 (2 adult, 2 juveniles; 15%) did not exhibit laying behavior or initiate incubation. Additionally, we noted that 3 adult females potentially served as both hosts and brood parasites. Furthermore, we noted several instances of multiple brood parasitism, when a host nest appeared to be parasitized by more than 1 female. Specifically, we noted multiple brood parasitism of 1 nest by 2 potential brood parasites at PR and 3 nests at Webb (2 host nests by 2 parasites each, 1 host nest by 3 parasites) in 2016 (Figure 6.8).

At KNF, we noted that 4 of 104 females (4%) were potential parasites of 4 nests (3%; Table 6.1). Similarly, on PR 2 of 67 (3%) females were identified as potential parasites of 1 nest. At SL, 6 of 49 females (12%) were potential parasites of 8 nests, whereas at BFG 6 females (15%) were potential parasites of 5 nests (13%). At CC, we only noted 1 potential parasite (2%) of 1 nest whereas at the Webb 8 of 77 females (10%) were potential parasites of 6 of 58 nests (10%). We observed similar nest success rates between potentially parasitized nests and non-parasitized nests, and nest success of both were highly variable across sites (Table 6.2).

DISCUSSION

We documented multiple examples of brood parasitism and provide a basis to improve our understanding of the extent that brood parasitism occurs in southeastern wild turkey populations. We provide previously unpublished examples of brood parasitism using both GPS data and photographic evidence in populations of both Rio Grande and Eastern subspecies. We recognize that GPS relocations within buffered nest sites of host females do not constitute known occurrences of brood parasitism. However, previous authors have noted that the visual detection of a host nest by other reproductively active females often stimulates egg laying by the parasitic female in turkeys and other species (W. M. Healy, personal communication, Petrie and Moller 1991, Kraak and Groothuis 1994). Therefore, we offer that confirmed presence of other females at host nests could logically be assumed to present parasitism opportunities to the non-host female. We note that hourly GPS locations may not fully describe the extent of potential brood parasitism. Therefore, we postulate that estimated numbers of females exhibiting parasitic behavior may have been greater if GPS units were programmed to collect more intensive numbers of relocations. Our inferences using GPS data, with 2 exceptions noted above, are primarily based on examples using data from marked females. Hence, we offer that the extent of brood parasitism may be greater than what we report, given our inability to detect parasitic behaviors by unmarked females.

Conspecific brood parasitism has been previously reported in 32 species in Galliformes, and tends to be more prevalent in environments where nesting females are patchily distributed and predation risk is significant (Yom-Tov 2001). We observed that 6% of nests were potentially parasitized, and note that previous authors have documented considerably higher rates of brood parasitism in other Galliform populations. For instance, Krakauer (2008) used genetic markers to document that ~22% of nests in a Rio Grande wild turkey population were parasitized by conspecifics. Likewise, Faircloth (2008) observed that ~24% of wild northern bobwhite nests and 50% of artificial nests over a 3-year period were parasitized by conspecifics. Furthermore, we observed examples of multiple brood parasitism, lending support to previous studies noting that multiple females may attend a single nest (Williams and Austin 1988, Krakauer 2008). However, our findings suggest that most parasitic females also laid and incubated nests, suggesting that parasites may derive a fitness advantage relative to females that lay no eggs parasitically (Payne 1977, Petrie and Moller 1991, Krakauer 2008). We found that nest success rates of potential parasitized nests were similar to non-parasitized nests, although we note that nests we delineated as non-parasitized could have been parasitized by unmarked females. Regardless, estimating fitness consequences of conspecific brood parasitism is confounded by various environmental factors (e.g., habitat and predation; Dugger and Blums 2001), particularly with datasets and coarse assessments like those reported herein. We encourage researchers to more thoroughly evaluate potential fitness consequences of parasitic strategies on both parasite and host females in wild turkey populations.

Improved fitness for parasitic females often relies on synchronizing the laying sequence with host females to ensure successful hatching (Feeney et al. 2012). We observed that females presumed to be parasitic associated with host females during the laying period, and speculate that these associations may be explained by 2 non-mutually exclusive phenomena. Brood parasitism is expected in species like wild turkeys that have large clutch sizes, and by default long laying sequences, with nests that are unguarded (Geffen and Yom-Tov 2001). Parasites often adopt tactics to monitor host behavior, including visits to territories before parasitism occurs and direct monitoring of host movements, presumably to ensure attempts to parasitize nests occurs when hosts are absent (Emlen and Wrege 1986, Petrie and Moller 1991). Likewise, kin selection and cooperative courtship display occurs in male wild turkeys (Krakauer 2005), providing indirect fitness benefits to subordinate males. Brood parasitism can enhance fitness of the host if the parasite is related to the host (Lopez-Sepulcre and Kokko 2002), and kinship is known to promote brood parasitism if the cost to the host is slight relative to potential fitness gains (Andersson 2001). It is plausible to assume that females associated with each other as laying begins are related, so we speculate that perhaps related females monitor movements of the eventual host female by associating with them during laying. Future research should evaluate relatedness of female associations prior to and throughout the reproductive season to assess potential influences of relatedness of reproductive behaviors.

The behavior Audubon (1831) observed of multiple females caring for a single nest, presumably in response to predation risk, has not been reported in contemporary literature on wild turkey reproductive ecology. However, contemporary literature on other species has noted selective advantages of brood parasitism under elevated predation risk, suggesting that nest predation may be a primary driver of brood parasitism (McRae 1997, Pőysä and Pesonen 2006).

Numerous authors have noted that elevated predation risk can promote brood parasitism, presumably as females exhibit risk spreading and distribute eggs across multiple nests to improve fitness (Petrie and Moller 1991, Geffen and Yom-Tov 2001). Logically, one would expect brood parasitism to become more common as a response to increasing predator densities under favorable habitat conditions (Rogers and Caro 1998, Lima 2009). Landscape changes, such as increased fragmentation and conversion of hardwood forests (Andren 1994, Carroll 2007, Baggio et al. 2011), within the past several decades have generally favored generalist mesocarnivores and not wild turkeys (Johnson et al. 2007, Eagan et al. 2011). Likewise, predation is the primary cause of nest failure in wild turkeys (Yeldell et al. 2017, Wood et al. 2008), and predation risk can be an important determinant of reproductive behaviors (Fontaine and Martin 2006, Lima 2009). Despite monitoring improvements such as GPS that allow more intensive monitoring of female laying and incubation behaviors, it is conceivable that brood parasitism may become more prevalent as predation risks further influence wild turkey populations. Research should continue assessing potential for brood parasitism in wild turkey populations, particularly in the context of predator abundance and activity.

ACKNOWLEDGEMENTS

We thank N. Yeldell, J. Wood, J. Dreibelbis, K. Melton, J. White, C. Wakefield, and A. Lohr for providing detailed accounts of field observations. We also thank N. Bakner, L. Schofield, and A. Gerrits for their efforts in collecting and providing additional data used in this study. We appreciate funding and support provided by Texas Parks and Wildlife Department, and the Warnell School of Forestry and Natural Resources at the University of Georgia. Funding for this research was provided in part by TPWD and U.S. Fish and Wildlife Service through the Federal Aid in Wildlife Restoration Act (Pittman-Robertson) program, Grant number TX-W-

164-R-1. This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, McIntire Stennis project under No. 1005302 (B. A. Collier).

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Table 6.1. Numbers of potential parasitic and host nests for female Eastern wild turkeys across 6 study sites in the southeastern United States, 2014-2018.

Site	**Year**	**Total Females (n)**	**Total Nests (n)**	**Potential parasitic females with locations within 30-m of host nest (n)**	**Host nests with parasitic female locations within 30-m (n)**
KNF	2014	31	36	3	3
	2015	20	26	0	0
	2017	30	36	0	0
	2018	23	22	1	1
	Total	104	120	4	4
	Percent	—	—	3.85	3.33
PR	2016	30	23	2	1
	2017	24	18	0	0
	2018	13	17	0	0
	Total	67	58	2	1
	Percent	—	—	2.99	1.72
SL	2015	28	36	3	5
	2016	21	27	3	3
	Total	49	63	6	8
	Percent	—	—	12.24	12.70
BFG	2017	11	15	2	2
	2018	30	32	4	4
	Total	41	47	6	5
	Percent	—	—	14.63	12.77
CC	2017	32	41	1	1
	2018	14	18	0	0
	Total	46	59	1	1
	Percent	—	—	2.17	1.69
Webb	2014	7	3	0	0
	2015	25	15	0	0
	2016	40	36	8	6
	2017	5	4	0	0
	Total	77	58	8	6
	Percent	—	—	10.39	10.34
All Sites & Years	Total	384	405	27	25
	Percent	—	—	7.03	6.17

Table 6.2. The nest success rates of non-parasitized and potential parasitized nests of female eastern wild turkeys based on GPS location data within 30-m of each nest site across 6 study sites in the southeastern United States from 2014 to 2018.

Site	**Year**	**Non-parasitized Nests (n)**	**Non-parasitized Success (%)**	**Potential Parasitized Nests (n)**	**Potential Parasitized Success (%)**
KNF	2014	33	6.06 (n = 2)	3	0
	2015	26	26.92 (n = 7)	0	0
	2017	36	19.44 (n = 7)	0	0
	2018	21	9.52 (n = 2)	1	0
	Total	116	15.51 (n = 18)	4	0
PR	2016	22	4.54 (n = 1)	1	0
	2017	18	5.56 (n = 1)	0	0
	2018	17	11.76 (n = 2)	0	0
	Total	57	7.02 (n = 4)	1	0
SL	2015	31	36.11 (n = 13)	5	20.00 (n = 1)
	2016	24	41.67 (n = 10)	3	0
	Total	55	41.82 (n = 23)	8	12.50 (n = 1)
BFG	2017	13	0	2	6.67 (n = 1)
	2018	28	35.71 (n = 10)	4	50.00 (n = 2)
	Total	41	24.39 (n = 10)	6	50.00 (n = 3)
CC	2017	40	15.00 (n = 6)	1	0
	2018	18	11.11 (n = 2)	0	0
	Total	58	13.79 (n = 8)	1	0
Webb	2014	3	100.00 (n = 3)	0	0
	2015	15	40.00 (n = 6)	0	0
	2016	30	40.00 (n = 12)	6	33.33 (n = 2)
	2017	4	50.00 (n = 2)	0	0
	Total	52	44.23 (n = 23)	6	33.33 (n = 2)
All Sites & Years	Total	379	22.69 (n = 86)	26	23.08 (n = 6)

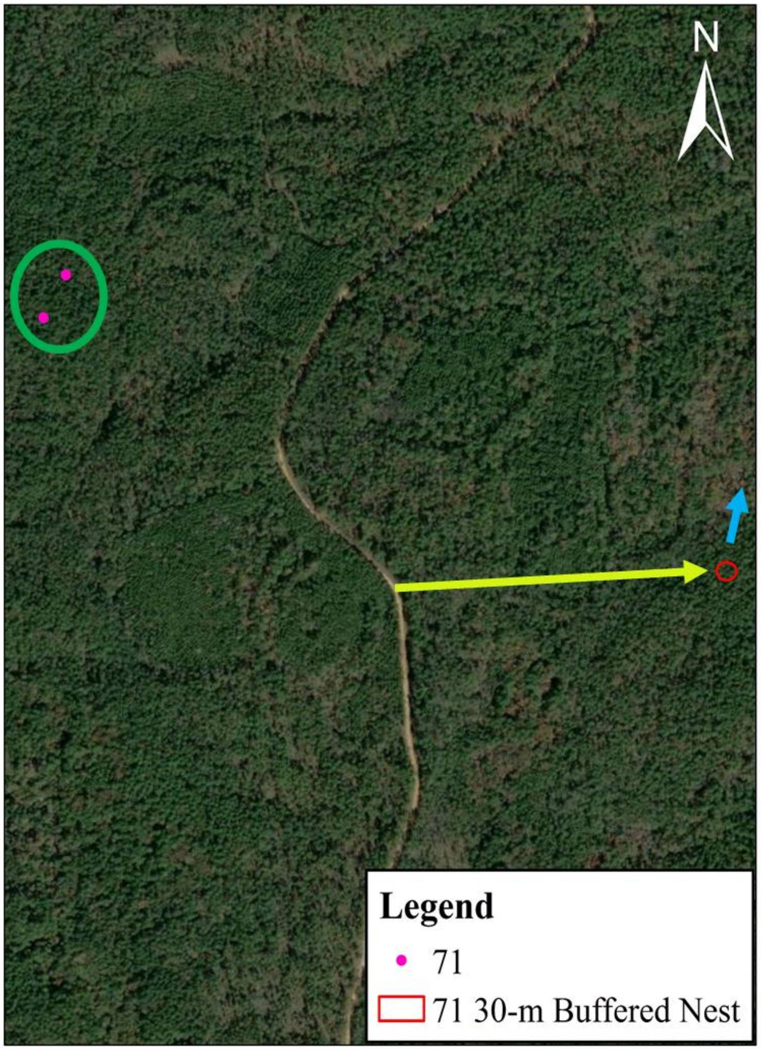

Figure 6.1. Order of events on 30 March 2014 when a GPS marked female (Female 71) abandoned nest in the Kisatchie District of Kisatchie National Forest, Louisiana, USA. On the morning of 30 March 2014 between 0800 hrs and 0900 hrs, Female 71 was detected approximately 1120-m from the nest site by VHF radio telemetry (green circle with two pink dots indicating GPS locations). The nest was approached from the United States Forest Service road west of the nest (yellow arrow). As the nest site was approached, an unmarked female flushed from the nest of Female 71 (blue arrow).

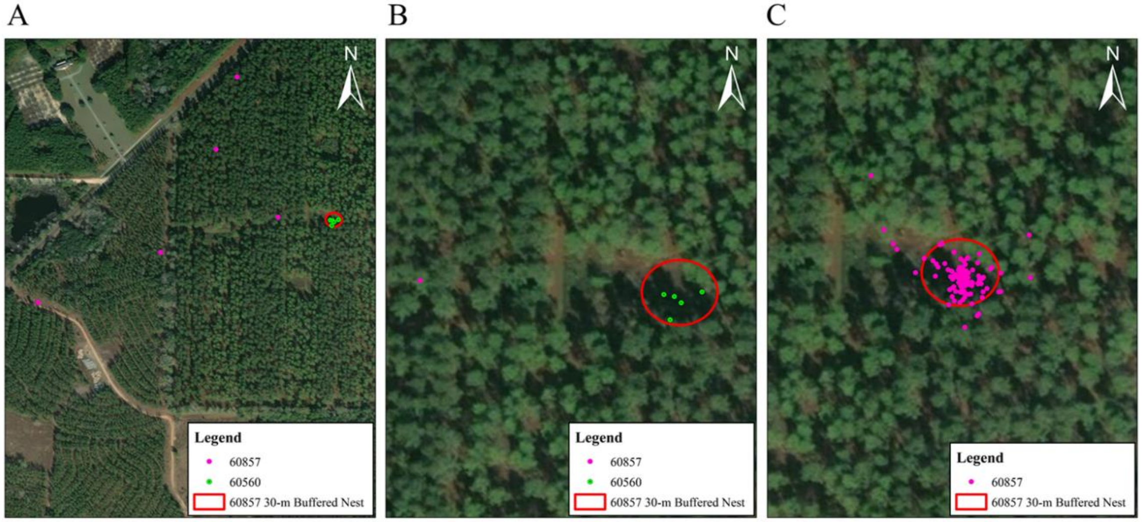

Figure 6.2. GPS data collected from two GPS marked adult female wild turkeys (Females 60560 and 60857) on Silver Lake WMA in South Georgia, USA. Female 60857 was in the process of laying eggs at the nest when Female 60560 visited the nest of Female 60857. **A)** Female 60560 present at the nest of Female 60857 during the laying period. Female 60560 visited the nest on 26 March 2016 at 1000 hrs, 28 March 2016 at 1100 hrs, 29 March 2016 at 1700 hrs, 31 March 2016 at 1000 hrs, with last visit occurring on 01 April 2016 at 1300 hrs. Female 60560 was present while Female 60857 was not located near the nest as indicated in the figure. **B)** Zoomed image of GPS data of Female 60560 visiting the nest site of Female 60857. **C)** Zoomed image of GPS data of Female 60857 incubating the nest starting 02 April 2016 after Female 60560 visited the nest in preceding days.

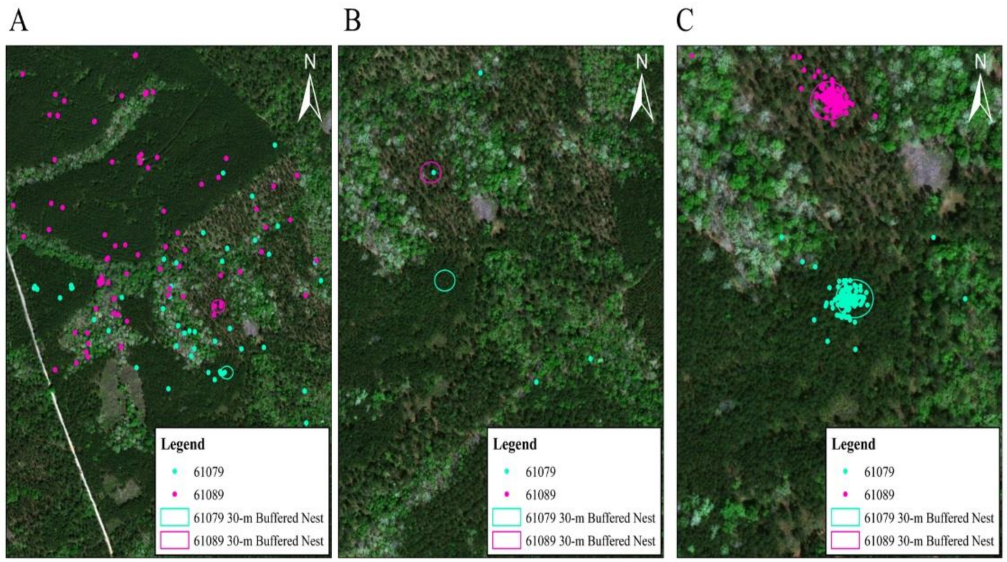

Figure 6.3. GPS data collected from two marked adult female wild turkeys (Females 61079 and 61089) on B. F. Grant WMA in the Piedmont region of Georgia, USA. Female 61079 and Female 61089 were in the process of laying at respective nest sites approximately 158-m from each other when Female 61079 visited the nest of Female 61089 on 27 March 2018 at 1700 hrs. **A)** GPS data showing the locations of Female 61079 and Female 61089 during the laying period prior to 27 March 2018. **B)** Female 61079 present at the nest of Female 61089 during the laying period. Female 61079 visited the nest on 27 March 2018 at 1700 hrs. Female 61079 was present at the nest while Female 61089 was located west of her nest. **C)** Zoomed image of GPS data collected from Female 61079 and Female 61089 incubating respective nests starting 02 April 2018 until failing on 01 and 02 May 2018.

Figure 6.4. Dump nest of a GPS marked female eastern wild turkey on Cedar Creek WMA, Georgia USA in March 2017. The nest belonged to Female 46239 and contained a clutch of 22 eggs. GPS data indicated the laying period was approximately 14 days starting 10 March 2017. Female 46239 initiated incubation on 25 March, failing on 26 March. Photograph provided by Ashley Lohr.

Figure 6.5. Dump nest of a VHF marked Rio Grande female wild turkey in Kerr county, Texas, USA. The nest belonged to Female 2565 and contained a clutch of 26 eggs. Photograph provided by Justin Dreibelbis and Kyle Melton.

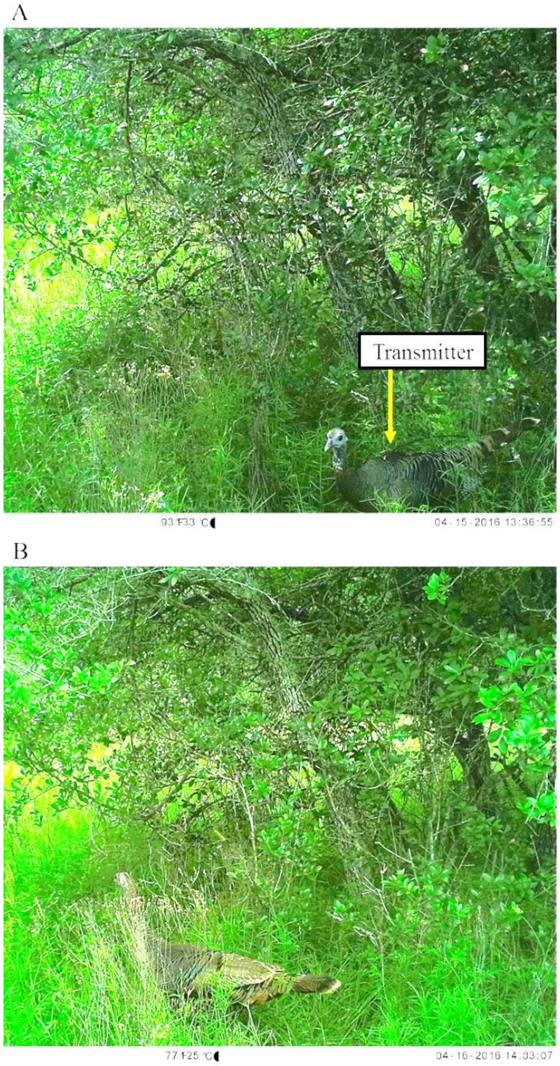

Figure 6.6. Photographs captured between 30 March 2016 and 25 April 2016 of marked and unmarked Rio Grande female wild turkeys exiting and entering a nest of GPS marked female (Female 60606) in Texas, USA. On 30 March 2016, Female 60606 initiated incubation of the nest. **A)** Female 60606 shown with transmitter present exits the nest at 1336 hrs on 15 April 2016. At 1800 hrs on 15 April 2016, Female 60606 abandoned the nest permanently. **B)** A photograph of an unmarked female at the abandoned nest is captured on 25 April 2016. Photographs provided by Jacob White and Bret Collier.

Figure 6.7. Photographs on 12 April and 25 April of a Rio Grande female wild turkey nest in Texas, USA. The incubating female was GPS marked (Female 60606). **A)** Clutch of 3 eggs found in the nest of Female 60606 on 12 April 2016 at 0900 hrs. GPS data indicated Female 60606 abandoned the nest permanently on 15 April 2016 at 1800 hours. **B)** On 16 and 25 April 2016, we obtained photographs of an unmarked female present at the nest. We visited the nest on 25 April at 1450 hours, and observed a clutch of 9 eggs. Photographs provided by Jacob White and Bret Collier.

Figure 6.8. Example of suspected multiple brood parasitism at a single nest inferred using GPS point data from female wild turkeys on the Webb WMA Complex, South Carolina, USA in 2016. Female 644 (yellow points and line segments) and Female 676 (pink points and line segments) visit the nest (turquoise point) buffered by 30-m (red circle) of Female 693. Both females visited the nest while Female 693 was laying, which was between 28 March and 14 April 2016.

CHAPTER 7

CONCLUSIONS

I found that translocated eastern wild turkeys (hereafter; wild turkey) in east Texas suffered substantive mortality following release and prior to nesting. I observed 15 of the 78 translocated females were lost to mortalities prior to first nest initiation during 2016-2017. Conversely, I observed greater initial nesting rates (2016: 74%, 2017: 67%) than those previously reported for translocated wild turkeys in east Texas. I offer that the use of GPS telemetry provides a more precise assessment of nest initiation rates through improved abilities to monitor reproductive behaviors and movements associated with nesting. Moreover, I observed rates of nest success well below those necessary to ensure sustainable populations based on extant literature, with only 2 successful nests during 2016-2017. I found that nest success for both translocated and resident birds on Angelina National Forest (ANF) was lower than that reported for any population of wild turkeys in the southeastern United States. Therefore, I suggest that multiple years of translocations will be necessary to establish a sustainable population of wild turkeys on ANF. Likewise, I recommend that when possible, translocated birds be taken from source populations with prominent habitat types similar to release sites to promote greater nest success.

My findings relative to space use and movements indicate that wild turkeys translocated in the absence of conspecifics exhibited exploratory behaviors up to day 20, at which point space use and movement declined as individuals settled in their new landscape. During the first 20 days post-release, I found that females maintained larger mean daily core areas and home ranges and moved greater distances from the release site and between roosts than days 21-80. Likewise, I found that males maintained larger mean daily core areas, moved greater distances from the release site with increasing mean daily distance travelled during days 1-20 than days 21-80. Conversely, I found that females translocated in 2017 in the presence of conspecifics maintained smaller mean daily core areas, moved less distances from the release site and between roosts, and travelled less daily during days 1-20 than days 21-80. Females translocated in 2017 also maintained similar mean daily home ranges during days 1-20 and 21-80. I found that females translocated in 2017 when conspecifics were present maintained smaller core areas and home ranges than females translocated in 2016 (conspecifics absent) during the exploratory phase (days 1-20). Likewise, I found that females translocated in 2017 moved less distances from the release site and between roosts, and travelled less daily than females translocated in 2016. During the exploitation phase (days 21-80), I observed that females translocated in 2017 maintained slightly larger core areas than females translocated in 2016, and these females moved less distances from the release site and between roosts. However, home range sizes and daily distance travelled were similar during days 21-80 for both females translocated in 2016 and 2017. My survival models indicate that increased core area size influenced survival, but the effect was weak. Conversely, I noted a strong negative relationship between mean daily distance travelled and survival for turkeys when translocated in absence of conspecifics. Notably, during 2017 when turkeys were translocated in the presence of conspecifics, I found the negative effect of daily distance travelled on survival did not occur. My findings suggest that conspecifics are an important driver of space use, movement, and survival of translocated wild turkeys. Hence, managers should consider conducting translocations where conspecifics exist on the landscape. If conspecifics are not initially present, managers should translocate individuals over multiple years as conspecifics appear to positively influence space use and movement. Multi-year translocations should be conducted to replace individuals lost to mortality the first year, and to bolster population numbers during subsequent years.

I observed that translocated wild turkeys exhibiting exploratory behavior post-release selected shrub-scrub and open habitats while females also selected linear paths. Conversely, when translocated wild turkeys transitioned from exploratory movements to settling and exploiting resources, they began exhibiting greater plasticity in habitat selection, while still exhibiting selection for early successional habitats. On an annual basis, wild turkeys exhibited plasticity in habitat selection, consistent with our understanding that wild turkeys exploit multiple habitat types during the annual cycle. Although my modeling efforts suggest that east Texas is generally comprised of suitable habitat for wild turkeys, poor reproductive success and loss of adults to predators following earlier translocations suggests that multiple year stocking events at sites where conspecifics are present is necessary to establish extant turkey populations in east Texas.

The results of my individual-based model (IBM) indicate that spatial scale and shape of fires influence turkey use. I found greatest use of burned stands approximately 23 ha in size, and least use of burned stands ≥ 1269 ha. I observed a 7.13% decrease in daily percent use between rectangular- (48.78 %) and square-shaped (45.30 %) burn units at a spatial scale of 23 ha, Likewise, I observed a 34.72 % decrease in daily percent use between rectangular- (13.19 %) and square-shaped (8.61 %) burn units at a spatial scale of 1269 ha. When burn units were rectangular-shaped, I found that daily percent use decreased by 48.78 % as the spatial scale of fire increased from 23 ha to median scale of 203 ha. Likewise, when burn units were square-shaped, I found that daily percent use decreased by 49.43 % as spatial scale of fire increased from 23 ha to the median scale of 203 ha. Notably at 203 ha, I found that use of rectangular-shaped and square-shaped burn units fell below 25%, suggesting that at that scale, recently burned areas were used similar to or less than the other 3 habitats available to them. My findings demonstrate the importance of managing forested landscapes with prescribed fires not exceeding ~ 200 ha if wild turkeys are a management concern. Likewise, my findings suggest shape of fire should be considered by managers when conducting prescribed fires and illustrates the ecological importance of edge to perimeter ratios in promoting use by wild turkeys. I suggest that managers charged with managing upland pine savannas with prescribed fire conduct burns at smaller scales to increase spatial heterogeneity and promote diverse habitat conditions necessary to maintain wild turkey life history strategies. Likewise, managers should consider implementing fires in a way that increases perimeter-area ratios, regardless of scale, to promote use of burned units by wild turkeys.

I documented multiple examples of brood parasitism and provided a basis to improve our understanding of the extent that brood parasitism occurs in southeastern wild turkey populations. I provided previously unpublished examples of brood parasitism using both GPS data and photographic evidence in populations of both Rio Grande and Eastern subspecies. I identified 27 of 384 females (7%) as potential parasites. I also found that 6% of 405 nests were potentially parasitized. I observed examples of multiple brood parasitism, lending support to previous studies noting that multiple females may attend a single nest. I found that most parasitic females also laid and incubated nests, therefore I suggest that parasites may derive a fitness advantage relative to females that lay no eggs parasitically. I also found that nest success rates of potential parasitized nests were similar to non-parasitized nests, although I noted that nests I delineated as non-parasitized could have been parasitized by unmarked females. Nonetheless, I encourage researchers to more thoroughly evaluate potential fitness consequences of parasitic strategies on both parasite and host females in wild turkey populations. Likewise, since kinship is known to promote brood parasitism if the cost to the host is slight relative to potential fitness gains, I offer it is plausible to assume that females associated with each other as laying begins are related, and speculate related females monitor movements of the eventual host female by associating with them during laying. I suggest future research should evaluate relatedness of female associations prior to and throughout the reproductive season to assess potential influences of relatedness on reproductive behaviors. Moreover, predation is the primary cause of nest failure in wild turkeys, hence I offer that it is conceivable that brood parasitism may become more prevalent as predation risks more influence wild turkey populations. I suggest future research should continue assessing potential for brood parasitism in translocated and resident wild turkey populations, particularly in the context of predator abundance and activity.

APPENDIX A

OVERVIEW, DESIGN CONCEPTS, AND DETAILS (ODD PROTOCOL)[1]

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[1] Sullivan, D. J., K. D. McEntire, B. S. Cohen, B. A. Collier, and M. J. Chamberlain. To be submitted as supplementary material with Chapter 5 to Forest Ecology and Management.

PURPOSE

Prescribed fires are a common management tool for wild turkeys in the southeastern United States. Across the region, the average scale of prescribed fire ranges from 26 ha in southern Georgia on a state-managed WMA (Wood et al. 2018) to approximately 485 ha in Louisiana on Kisatchie National Forest (Yeldell et al. 2017*c*). Previous research has shown that turkeys often use burned areas as habitat, but have a decreasing probability of use as distance to a non-burned edge increases (Cohen et al. 2019). The purpose of this model was to determine the scale and shape of burn unit that best promoted habitat use by turkeys.

ENTITIES, STATE VARIABLES, AND SCALES

The mobile agents represented turkeys. Each patch was equivalent to a 15 × 15 m square. These patches were used to construct burn units of varying size. There were 2 major landscape shapes, square (950 × 950 225 m^2 patches) and rectangular (1,444 × 625 225 m^2 patches), for a total landscape extent of approximately 20,306 ha. These landscapes were split into equal squares or rectangles of varying size (equivalent to relevant burn units). The world ‘wrapped’, meaning turkeys could move off the left side and reappear on the right and vice versa. We believe this was representative of a larger, continuous landscape. This also prevented any bias in the movement data of turkeys directly moving away from the edges of our virtual world.

The landscapes were spit into equal sections, and a subset of these sections were designated as burned patches. The largest burn patches split the landscape in half, whereas the smallest created 900 burn patches. For landscapes with total sections that were not perfect squares, some of the areas were smaller along the edges. This kept most patches in proportion to each other, rather than changing the shape of the patch along with the size. The sections alternated in “time since the last burn” with every fourth section designated as a recent burn (i.e., burn occurred this year). This created a theoretical checkerboard pattern of burn units on the landscape. The other patches were those burned 1, 2, or 3 years previously but these patches did not affect turkey movement. Hence, turkeys had 4 types of patches available to them relative to time since fire, but only patches burned recently influenced turkey movement. This reflects typical management strategies in the southeastern United States.

The mobile agents possessed individual tendencies to walk or forage/loaf in both burned and unburned areas. The agents were likely to walk 14.8 ± 4.3% of the time in non-burned areas and 22.7 ± 6.7% of the time in burned areas. These values were based on behavioral states as inferred from telemetry data reported by Cohen et al. (2019). The turkeys (agents) recorded the amount of time (in hours) they spent in a burned area and this value was reset every day. Each tick or time step in the model represented 1 day, with the turkeys making 14 hourly movements per day. The 14 hourly movements replicated the number of daily locations collected via GPS telemetry used to describe hourly movements and behavioral states of turkeys as detailed in Cohen et al. (2019). The model ran for one year or 365-time steps.

PROCESS OVERVIEW AND SCHEDULING

Turkey movement was the only process in the model. During each time step, turkeys moved 14 times, did not interact with each other, and each individual completed all 14 movements before the next individual moved. At the end of each movement, each turkey recorded if they were in a recently burned area. The output file was updated at the end of each time step (day). The output data included the number of locations recorded in burned areas for all turkeys collectively as a proportion of total number of movements (possible location records), the proportion of turkeys who used a burned area at least once throughout the day, the average number of times the turkeys were recorded in a burned area, and the cumulative number of records of turkeys in the center of the burned area.

DESIGN CONCEPTS

The *basic principle* addressed in this model was habitat use of turkeys in a landscape managed with prescribed fire. The use of burned areas by turkeys was *emergent* from the model by recording how much time they spent in a recently burned area, how much the center of the burned area was used, and visually by tracing each turkey’s movement paths over a year. The turkeys *adapted* to their environment by changing their propensity to walk or forage in a recently burned or previously burned area. In or at the edges of burned areas, turkeys *sensed* the distance to an unburned area ~200 m away (Cohen et al. 2019). This information was used to calculate their probability of moving to that spot (see submodels). *Stochasticity* was used to give turkeys individual variability in tendency of movement and actual distance moved per hour. These values were drawn from a normal distribution around a mean and variance inferred from telemetry data reported by Cohen et al. (2019). The probability of moving to a given patch in a burned area was based on a logistic equation derived from telemetry data reported by Cohen et al. (2019). The parameters of the logistic equation included a range of values. *Observation* of the model primarily occurred in the graphics interface while the model was running, where patterns of individual movement were traced and visible in comparison to the recently burned areas. The output data recorded at each time step (day) included the number of locations recorded in burned areas for all turkeys collectively as a proportion of total possible locations, the proportion of turkeys who used a burned area at least once throughout the day, the average number of times turkeys were recorded in a burned area, and the cumulative number of records of turkeys in the center of the burned area. These values evaluated how much the burned areas were being used by turkeys and if the most central part of the burned area was being used or only the edges. An increasing proportion of turkey movements in a burned area and increased proportion of turkeys using burned areas at least once suggests increased overall use of the recently burned areas. The visual observations of individual movement patterns also confirmed use of the entire burn unit or primarily the edges.

INITIALIZATION

The landscape was loaded from a saved file and included the locations and size of burned areas. Each burned area had a set value for distance to the nearest non-burned patch, this value was zero for all non-burned patches. In the model, 40 individual turkeys were randomly distributed on the landscape outside of recently burned areas to replicate occupancy of turkeys when fires are applied. Previous research has shown that turkeys disperse to adjacent unburned areas when fire is applied (Yeldell et al. 2017*c*).

INPUT DATA

There was no input data for this model.

SUBMODELS

Movement- First a number between 0 and 100 was randomly generated. This number was compared to the turkey's propensity for walking in the current habitat (recently burned or not). If the random number was less than the propensity for walking, then the turkey proceeded through the walk submodel, otherwise, the turkey proceeded through the forage submodel.

Walk- First the distance walked was set to a value drawn from a normal distribution with a mean of 241.72 m and a standard deviation of 41.11 m (values from GPS telemetry data collected from 121 female turkeys, Cohen et al. 2019). The turn angle was randomly set to right or left and drawn from a normal distribution with an average of 45.96° and a standard deviation of 6.98° (Cohen et al. 2019). Turkeys then evaluated all patches at the given distance and within the turn angle (see Figure 2). The distance to edge value for each patch was used to generate a probability of use. The probability of use formula was based on telemetry data reported by Cohen et al. (2019) and was as follows:

$$p = \frac{e^{\beta_0 + d\beta_1}}{1 + e^{\beta_0 + d\beta_1}}$$

Where β_0 was drawn from a normal distribution with an average of 0.067 and a standard deviation of 0.021; β_1 was drawn from a normal distribution with an average of -0.525 and a standard deviation of 0.227; and *d* was the distance to edge as a factor of 100 m.

Each of these probabilities was compared to a random value less than one. If the patch probability was greater than the random value, the turkey moved to one of those patches. If all probabilities were less than the random value, the turkey rotated (based on turn-angles outlined above) and did not move that hour.

Forage-loafing- First the distance moved while foraging was set to a value drawn from a normal distribution with a mean of 76.02 m and a standard deviation of 11.37 m (values from telemetry data). The turn angle was randomly set to right or left and drawn from a normal distribution with an average of 103.15° and a standard deviation of 9.84°(Cohen et al. 2019). Turkeys then evaluated all patches at the given distance and within the turn angle (see Figure 2). The distance to edge value for each patch was used to generate a probability of use. The probability of use formula was telemetry data reported by Cohen et al. (2019) and is as follows:

$$p = \frac{e^{\beta_0 + d\beta_1}}{1 + e^{\beta_0 + d\beta_1}}$$

Where β_0 was drawn from a normal distribution with an average of 0.067 and a standard deviation of 0.021; β_1 was drawn from a normal distribution with an average of -0.525 and a standard deviation of 0.227; and d was the distance to edge as a factor of 100 m.

Each of these probabilities was compared to a random value less than one. If the patch probability was greater than the random value, the turkey moved to one of those patches. If all probabilities were less than the random value, the turkey rotated (based on turn-angles outlined above) and did not move that hour, remaining within the occupied patch.

LITERATURE CITED

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