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Wild Turkey Resource Use on Food-subsidized Landscapes and the Relationship between Nesting Chronology and Gobbling Activity

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I am submitting herewith a thesis written by Aaron David Griffith entitled "Wild Turkey Resource Use on Food-subsidized Landscapes and the Relationship between Nesting Chronology and Gobbling Activity." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

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Dedication

I dedicate this thesis to two influential people in my life that the Lord decided to call home before they could see its completion. My grandmother, Ann Webster, was an adventurous woman who loved me unconditionally and inspired me from a young age to chase my dreams. Denny Holland had a heavy hand in landing me my first job in the wildlife field. That first opportunity has led me to where I am today. I will see you both on the other side.

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Abstract

Across the Southeast, heightened concern exists that wild turkey (*Meleagris gallopavo*) productivity and populations are declining, but the underlying reasons are largely unknown. Further concern stems from declining turkey harvest in several southeastern states. I answered questions germane to formulating turkey harvest regulations, specifically related to supplemental feeding and the correlation of gobbling timing with nest incubation and the timing of the hunting season. I examined turkey resource use in the Red Hills region of northern Florida and southern Georgia, where supplemental feeding for northern bobwhite (*Colinus virginianus*) is common. This supplements food availability and may alter resource use of both target and non-target species. A potential shift in individual behavior on non-target species may have negative consequences and warrants exploration to understand potential impacts on population dynamics of turkeys. Using hierarchical conditional logistic regression in a Bayesian framework, I evaluated turkey resource use at two spatial scales: landscape and within home range. Fields had the greatest probability of use at both scales. Drains also were important at the landscape scale but less important within home ranges. Areas near feed lines, drains, and roads, exhibited greater probabilities of use. Turkeys selected specifically for large drains. Responsible management decisions must balance the desires of stakeholders while being biologically sound for the target species. To gain an understanding of the relationship between nesting and gobbling activity I used linear mixed effects modeling to evaluate this relationship on 3 sites across Florida. A weak relationship existed between gobbling activity and the proportion of hens incubating

nests. Additionally, I evaluated the correlation of the timing of Florida’s turkey hunting season with peaks of gobbling activity and proportion of hens incubating nests using incremental response modeling. Florida’s turkey hunting season may better correlate with the egg-laying stage if the hunting season was shifted one week later, especially for Tall Timbers and Dixie Plantation. Gobbling activity and incubation would be more closely correlated with the hunting season if the hunting season was shifted three weeks later. More regionally-based management zones would allow the hunting season to be timed more closely with turkey gobbling and nesting activity.

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CHAPTER ONE

INTRODUCTION

The wild turkey (*Meleagris gallopavo*; hereafter, turkey) is an important game species in Florida, with a long standing hunting tradition (Williams and Austin 1988). Turkey productivity has been in decline in recent years in various areas across the South which may be indicative of general large-scale population declines (Byrne et al. 2015). Declining turkey harvest in several southeastern states suggests productivity in some areas may have declined (SE Wild Turkey Working Group 2016). Byrne et al. (2015) reported declining productivity may be an artifact of density-dependent population regulation, such that as populations increase more hens are forced to nest in suboptimal habitat leading to a reduction of per capita recruitment. Beyond productivity, improperly timed turkey hunting seasons (Whitaker et al. 2005) have been suggested as cause for the observed population declines. Regardless of the cause, declining harvest has generated concern about the potential effects of spring turkey season timing on turkey demographics and population trajectories (SE Wild Turkey Working Group 2016). It is uncertain whether harvest is additive or compensatory in wild turkey (Caudill et al. *In Press*). In areas of low turkey density, improper timing of spring male harvest could negatively impact populations which may be worsened by hunter harvest and habitat fragmentation (Kurzejeski and Vangilder 1992, Vangilder 1992, Stafford et al. 1997, Chamberlain et al. 2012). Given that spring turkey hunting coincides with breeding and nesting, turkey reproductive chronology and harvest susceptibility must be taken into account when setting hunting regulations (Kurzejeski and Vangilder 1992).

Broadcast supplemental feeding is a common management practice for northern bobwhite (*Colinus virginianus*; hereafter, bobwhite[s]) plantations in northern Florida and southern Georgia (Landers and Mueller 1992). However, concern among ecologists exists regarding the application of supplemental feed given the potential (Boutin 1990, Doonan and Slade 1995) exists for concentrated prey species to concentrate predators, thus turning supplemental fed areas into ecological traps (Godbois et al. 2004, Turner et al. 2008). Generally, studies have investigated effects of supplemental feed distributed via feeders or bait stations. In these cases, supplemental feed has led to increased harvest rates of some species (Kilpatrick et al. 2010). Harvest susceptibility could be exacerbated if supplemental feed concentrates and alters turkeys' resource use, especially when associated with the concentration of non-target species such as predators such as raccoons (*Procyon lotor*), coyotes (*Canis latrans*), and bobcats (*Lynx rufus*; Davis 1959, Speake 1980, Ransom et al. 1987, Williams and Austin 1988). Supplemental feed also provides a potential conduit for the ingestion of aflatoxins which can have a detrimental effect on turkey health and population demographics (Quist et al. 2000). As such, feeding wildlife is a common concern which is potentially linked to increased mortality via disease outbreaks, predation, and harvest as a result of alteration of behavioral patterns.

Game management pioneers recognized the pitfalls of baiting and supplemental feeding (Leopold 1933, Allen 1954). More recent studies have demonstrated positive and negative impacts of feeding on both target and non-target wildlife species. In turkeys, increased disease transmission is particularly concerning when feeding, given their gregarious nature, foraging behavior, and flocking tendencies (Stoddard 1963). The risk for disease transmission increases among concentrated wildlife (Sorensen 2014). However, positive impacts of supplemental feeding have been documented in game birds including bobwhite (Sisson et al. 2000, Buckley et al. 2015), ring-necked pheasants (*Phasianus colchicus*) (Draycott et al. 1998), and wild turkey (Pattee and Beasom 1979). Taken collectively, scant empirical data coupled with mixed results can make sound management decisions difficult regarding use of supplemental feed for wild turkey. In particular, little information exists on the effects of broadcast supplemental feeding for bobwhite on wild turkey resource use.

I had a unique opportunity to work on both private and public lands under the support of Florida Fish and Wildlife Conservation Commission (FWC) and Tall Timbers Research Station and Land Conservancy (TTRS). These properties offered different management and harvest scenarios that allowed me to investigate common concerns, related to timing of spring hunting season and supplemental feeding. Specifically, my objectives were to:

1. Determine if supplemental feeding for bobwhite affects wild turkey resource use; and
2. Determine the relationship between gobbling activity and nesting chronology

Wild Turkey Resource use on Food-Subsidized Landscapes

Leopold (1933) stated that food, cover, water, and special factors are the collective resources needed by a species for its survival and reproductive success. Resources are selected when they are disproportionately used in relation to their availability (Johnson 1980). Applying supplemental feed to a landscape alters the availability of food resources and may impact resource-use decisions a species makes. If food is a limiting factor, provisioning additional food resources across the landscape could be beneficial to survival and/or reproduction and greatly alter the resource use decisions being made (Austin and Degraff 1975, Wunz and Hayden 1975, Oberlag et al. 1990). Williams (1992) postulated food is critical to turkey survival and reproduction, but vegetation structure and hunting pressure played much greater roles as limiting factors. Stoddard (1963) speculated it is possible to minimize the movements of turkeys by providing preferred food sources, thus resource use may differ even when food is not a limiting factor, depending on what supplemental food is provisioned.

Many studies have reported how supplemental feed impacted turkey survival (Ligon 1946, Wunz and Hayden 1975), but few have reported how supplemental feed impacted turkey resource use and landscape distribution. Studies have been conducted in Texas where there is a long tradition of supplemental feeding for wildlife (Brown and Cooper 2006), but the majority of this research centered on food provisioned via feeders or feeding stations. The effect of supplemental feed on reproduction often is a main focus of this arid region (Pattee and Beasom 1979). Thomas et al. (1966) reported some landowners used supplemental feed, in the form of milo and corn, during the hunting season to concentrate birds near blinds for hunters. Lambert and Demarais (2001) reported wild turkeys infrequently visited supplemental feeders in Texas. Stoddard (1963) reported feeders would concentrate turkeys on very small areas, but little information is available as to how broadcasting supplemental feed across a landscape affects wild turkey resource use.

Broadcasting supplemental feed for bobwhite is a common practice on intensively managed properties in the Southeast (Godbois et al. 2004, Buckley et al. 2015). Among bobwhites, the provision of year-round supplemental food increases demographic rates (e.g., survival, reproduction, lambda) and increases covey sightings during hunting (Sisson et al. 2000, Buckley et al. 2015). Supplemental feeding for one species, however, may have negative or positive consequences on another species (Godbois et al. 2004, Morris et al. 2010). There is little information available on the effects of supplemental feeding for bobwhite on wild turkeys. Information is also lacking as to how supplemental feed may impact turkey harvest rates. Studies have reported the use of supplemental feed as bait can increase hunter success rates (Winterstein 1992) fueling the debate on its utility as a wildlife management tool (Dunkley and Cattet 2003). Understanding how broadcasting supplemental feed influences wild turkeys is important to wild turkey management on plantations where supplemental feed is broadcast for bobwhite. Results of my study will help state agency biologists understand the influence of broadcasting supplemental feed for quail on turkey resource selection

To gain insight into turkey resource use on food-subsidized landscapes, I hypothesized that supplemental feed for bobwhite affects wild turkey resource use. For this hypothesis to be supported, food-subsidized areas will be used more by wild turkeys. To test my prediction I evaluated turkey resource use at two spatial scales: study area and within individual home ranges.

The Relationship between Gobbling Activity and Nesting Chronology

Researchers have recommended setting turkey season start dates based on peaks in gobbling activity (Healy and Powel 1999, Norman et al. 2001). Some studies have reported two peaks in gobbling activity whereby the first peak typically is associated with winter flock break-up and the onset of breeding activity, whereas the second peak is associated with peak dates of nest incubation by female turkeys (Bailey and Rinell 1967, Bevill 1975, Porter and Ludwig 1980, Hoffman 1990). The start of gobbling is triggered primarily by an increase in photoperiod, and the first peak marks gobblers attracting females for initial breeding (Healy 1992). The second peak is linked with nest incubation, whereby incubating hens spend the majority of the day sitting on their nest, and are not available to be bred (Bailey and Rinell 1967). During this time, increased gobbling is apparently in response to a decrease in availability of hens.

Hunting seasons that encompass the second peak in gobbling activity may be biologically conservative. Healy and Powell (1999) and Norman et al. (2001) recommended establishing turkey hunting seasons to encompass the second peak in gobbling activity because prohibiting hunting during the first peak would mitigate possible negative consequences associated with breeding. Harvesting too many gobblers early in the season could lead to insufficient gobbler availability for breeding. Insufficient gobbler availability may negatively impact localized population productivity (Exum et al. 1987, Isabelle et al. 2016). During times of peak nest incubation, when hens may only leave the nest to forage 1 to 2 hours a day (Green 1982, Williams and Austin 1988), the reduced number of available hens for breeding can cause an increase in gobbling activity (Bailey and Rinell 1967, Bevill 1975). The propensity of a gobbler to call and to respond to hunter's calls increases when absent from hens (Healy 1992).

Although the assumption of two peaks in gobbling activity is used for establishing spring wild turkey hunting seasons in some states, two peaks may not exist throughout the wild turkey's range or in hunted populations (Norman et al. 2001, Lehman et al.

2005). Bevill (1975) claimed inexplicable sporadic gobbling patterns among 5 separate sites wherein 2 peaks in gobbling activity were documented on the non-hunted sites. Kienzler et al. (1996) reported that gobbling activity in Iowa dropped with the onset of the hunting season throughout the duration of their study. In South Dakota, Lehman et al. (2005) reported gobbling activity was greater on the non-hunted site than the hunted site during the hunting season. Similarly, Norman et al. (2001) documented this same pattern in Virginia and West Virginia. However, Palmer et al. (1990) reported increased hunter density was positively correlated with increased gobbling activity. This relationship, however, could be an artifact of turkey hunters putting forth more effort when gobbling activity was high (Miller et al. 1997), because as gobbling activity decreased, so did hunter density. Miller et al. (1997) and Colbert (2013) reported only a single peak in gobbling activity which did not coincide with nest incubation during their studies in Mississippi and Georgia. Miller et al. (1997) and Colbert (2013) reported gobbling peaked with initiation of egg laying. Many researchers have highlighted the need for further investigation into how gobbling activity varies by region and its utility to establish the turkey hunting season (Williams and Austin 1988, Kienzler et al. 1996, Miller et al. 1997, Whitaker et al. 2005).

Hunters often suggest that turkey seasons should open earlier (Cartwright and Smith 1990, Taylor et al. 1996, Swanson et al. 2005, Casalena et al. 2010) to increase opportunity when gobbling activity is high (SE Wild Turkey Working Group 2016). Earlier start dates may afford hunting opportunity when gobblers are more vocal, thus perhaps increasing hunter success (Little et al. 2001, Swanson et al. 2005, Whitaker et al.

2005). The SE Wild Turkey Working Group (2016) recommended that hunting season start dates should commence during the peak of egg-laying, defined as the mean date of initial nest initiation. Following this method of establishing wild turkey hunting seasons may reduce illegal and inadvertent female harvest because hens are no longer flocking with gobblers (Norman et al. 2001). Ideally, wild turkey hunting seasons should offer a balance between the biological needs of the species and opportunity for hunters (SE Wild Turkey Working Group 2016).

Hunting seasons based on peak egg-laying require accurate knowledge of local nesting and gobbling chronology (SE Wild Turkey Working Group 2016). Prior studies of nesting and gobbling chronology in Florida were conducted in the southern and central regions on two study sites (Williams and Austin 1988). No studies have been conducted in the panhandle region. My study provides explicit information needed to set biologically informed hunting season start dates in Florida. Given the disparity across studies as to which part of the nesting cycle gobbling peaks occur, my research helps identify correlations between the nesting cycle and peak gobbling in north and north-central Florida. I hypothesized gobbling activity is influenced by the number of hens available to breed given that hens are not available to breed when they are incubating a nest. For my hypothesis to be supported, an increase in hens incubating nests will lead to an increase in gobbling activity. A peak in gobbling activity will accompany the time of peak nest incubation. I compared daily gobbling activity and the number of hens incubating nests to test my hypothesis and evaluate my predictions.

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CHAPTER TWO

WILD TURKEY RESOURCE USE ON FOOD-SUBSIDIZED LANDSCAPES

Abstract

Resource use decisions by wildlife often require that individuals balance risk in foraging with concealment from predators. These decisions are further influenced by the availability, abundance and juxtaposition of different resources requisite for daily requirements and improved fitness. In the Red Hills region of northern Florida and southern Georgia, supplemental feeding for northern bobwhite (*Colinus virginianus*) is common, which supplements food availability and may alter resource use of both target and non-target species. Potential shifts in individual behavior of non-target species may have negative consequences. As such, I evaluated wild turkey (*Meleagris gallopavo*) resource use on a food-subsidized landscape. Wild turkeys were equipped with a combination of GPS and VHF units and monitored on Tall Timbers Research Station and Dixie Plantation, Florida between 2014 and 2016. Using hierarchical conditional logistic regression in a Bayesian framework I evaluated wild turkey resource use at 2 spatial scales: landscape (2^{nd} Order) and within home range (3^{rd} Order). Fields were strongly selected for by wild turkeys at both spatial scales. However, use of hardwood drains varied in degree among scales such that at the landscape scale drains were very important, but their use diminished in importance at smaller spatial scales (i.e., within home ranges). Larger drains ostensibly fulfilled a resource need whereby turkeys used them curvilinearly relative to drain size with the greatest probability of use occurred when drains were 375 ha. Areas with supplemental food did not appear to drive resource use as feed lines were not disproportionately used at either spatial scale compared to other resources. These results provide useful habitat management with respect to the importance of fields and drains and can help guide state agencies when establishing

harvest regulations on private lands that practice supplemental feeding for northern bobwhite

Introduction

Individual habitat use decisions are governed by resource quality and availability which may influence survival and reproductive success (Leopold 1933). As a result, resource selection may vary based on an animal's perception of cost-benefit constraints imposed during foraging and/or previous experience with predation pressure (McGrath et al. 2017). For example, a trade-off often exists between time spent foraging in areas with ample food resources but poor protective cover, and time spent loafing in areas with good protective cover but poor food resources (Arnold and Hill 1972). Animals must balance food consumption based on nutritional requirements (Robbins 1983) while mitigating risk of mortality. Similarly, the ability for an animal to maintain body condition (Loesch and Kaminski 1989), especially during reproduction (Thorne et al. 1976), is interrelated with food resource availability and consumption. Food availability also has been demonstrated to influence animal behavior as foods can dictate an individual's home range size (Tufto et al. 1996), resource use, and movements (Isbell et. al. 1998).

Game management pioneers recognized pitfalls associated with baiting and supplemental feeding (Leopold 1933, Allen 1954). More recent studies have demonstrated positive and negative impacts of feeding on both target and non-target wildlife species (Reese and Kadlec 1984, Brittingham and Temple 1988, Lewis and Rongstad 1998, Godbois et al. 2004, Turner et al. 2008). The risk for disease transmission increases among concentrated wildlife (Sorensen 2014). However, positive impacts of supplemental feeding have been documented in upland game birds including northern bobwhite (*Colinus virginianus*; hereafter, bobwhite[s]) (Sisson et al. 2000, Buckley et al. 2015), ring-necked pheasants (*Phasianus colchicus*) (Draycott et al. 1998), and wild turkey (*Meleagris gallopavo*; hereafter, turkey[s]) (Pattee and Beasom 1979). Taken collectively, limited empirical data coupled with mixed results can make it difficult to make sound management decisions on the use of food supplementation. In particular, little information exists on the effects of broadcast supplemental feeding for bobwhites on wild turkey resource use.

Broadcasting supplemental feed for bobwhite is a common practice on intensively managed properties in the Southeast (Landers and Mueller 1992, Godbois et al. 2004, Buckley et al. 2015,). However, wild turkey may be more susceptible to predation or hunter harvest on a food-subsidized landscape because supplemental feed may concentrate turkeys or alter their resource use, especially if meso-predators are attracted to the feeding area (e.g., raccoons [*Procyon lotor*], coyotes [*Canis latrans*], bobcats [*Lynx rufus*]; Davis 1959, Speake 1980, Ransom et al. 1987, Williams and Austin 1988). Increased disease transmission among turkeys is particularly concerning given their gregarious nature when feeding, foraging behavior, and flocking tendencies (Stoddard 1935, Williams 1981, Davidson and Wentworth 1992, Sanderson and Schultz 1993). Supplemental feed also provides a potential conduit for the ingestion of aflatoxins, which can have detrimental effects on turkey health and population demographics (Quist et al. 2000). As such, feeding wildlife is commonly met with fear and resistance, which is supposedly linked to the potential of disease outbreaks and alteration of behavioral patterns.

The provisioning of additional food resources may have different effects on turkey resource use in the Southeast. A few studies have reported how supplemental feed impacts turkey survival (Ligon 1946, Wunz and Hayden 1975), but few have reported the impact on turkey resource use. Other studies, conducted in Texas documented a long tradition of supplemental feeding for wildlife (Brown and Cooper 2006), but the majority of this research centered on supplemental feeding via feeders. The effect of supplemental feed on reproduction is often a main focus of this arid region (Pattee and Beasom 1979). Thomas et al. (1966) reported some landowners supplementally fed grain sorghum and corn during the hunting season to concentrate birds near blinds for hunters. Hurst (1992) reported feeders would concentrate turkeys on very small areas, but no information is available as to how broadcasting supplemental feed affects wild turkey resource use.

Williams (1992) postulated food is critical to turkey survival and reproduction, but vegetation structure and hunting pressure played much greater roles as limiting factors. Turkeys are highly mobile, covering large areas in their daily foraging movements (Hurst 1992). This mobility allows turkeys to take advantage of seasonally and spatially limited food resources over wide areas. However, Stoddard (1963) stated it is possible to minimize the movements of turkeys by providing preferred food sources, thus resource use may differ even when food is not a limiting factor for turkey occurrence. Limited information exists on how food supplementation may impact turkey harvest rates. Winterstein (1992) reported the use of supplemental feed as bait can increase hunter success rates fueling the debate on its utility as a wildlife management tool (Dunkley and Cattet 2003). To inform state harvest regulations regarding baiting of wild turkey germane to the application of supplemental food for bobwhite, a better understanding of the potential influence(s) on wild turkeys is imperative.

As such, to gain insight on turkey resource use on food-subsidized landscapes, I hypothesized supplemental feed for bobwhite affects wild turkey resource use. For this hypothesis to be supported, food-subsidized areas will be used more frequently by wild turkeys than use in areas without supplemental feeding. The objectives of this study were to 1) describe the patterns of turkey resource use on a food-subsidized landscape; 2) determine how the patterns of resource use change as related to the distance to feed lines; 3) determine if these relationships change depending upon the scale of evaluation. I defined resource use as the way in which turkeys used space to forage, breed, raise young, and meet other seasonal and daily life requirements. To quantify resource use, I examined known turkey locations from GPS and VHF backpack transmitters compared to random locations at 2 spatial scales: study area and within individual home ranges.

Study Area

During 2014-2016, I conducted research on 2 sites (Figure 2.1). Tall Timbers Research Station (TTRS; 1,568 ha) and Dixie Plantation (Dixie; 3,682) which are located in Leon and Jefferson Counties, Florida, respectively. However, because turkey movements were outside the bounds of my original study sites, I gained access to surrounding properties as needed to monitor turkeys. This expanded my research study area to a larger area of interest incorporating multiple private properties (14,224 ha; see Figure 2.1).

TTRS (1,568 ha) is part of the greater Red Hills region of northern Florida and southern Georgia (Rush et al. 2014). Dixie (3,682 ha) lies on the eastern edge of the Red Hills region and is bordered along the western boundary by the headwaters of the Aucilla River. Both sites are dominated by upland loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus echinata*), and longleaf pine (*Pinus palustris*) forests (52% of TTRS, 36% of Dixie). Upland pine forests are interspersed with bottomland hardwoods (25% of TTRS, 28% of Dixie), including oaks (*Quercus spp.*), hickories (*Carya spp.*), sweet gum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), and bald cypress (*Taxodium distichum*). Small fallow fields (< 1.3 ha) comprised approximately 13% of TTRS, whereas Dixie contained a mixture of fallow and agricultural fields (7%). Fallow fields were disked annually in January to produce annual forbs such as ragweed (*Ambrosia artemisiifolia*), partridge pea (*Chamaecrista fasciculata*), and camphorweed (*Heterotheca subaxillaris*). On Dixie, agricultural fields were planted in cotton during the spring and planted in wheat during the winter. Other private properties consisted of similar land cover types, but different cover type proportions. Private properties surrounding TTRS totaled 7,190 ha and were primarily comprised of upland pine stands (31%), drains (25%), and planted pines (21%). Other private properties surrounding Dixie totaled 1,759 ha and were dominated by fields (34%), drains (32%), and upland pine stand (14%). Private properties in the Red Hills region are typically burned (45-70% annually) at a relatively small scale (average burn block size = 31.5 ha). Supplemental feed, usually grain sorghum (*Sorghum sp*.) (or a mixture of corn [*Zea mays*] and grain sorghum), was broadcast for bobwhite using a tractor and spreader on a continuous feed line. Supplemental feed was broadcast an average distance of 7.3 m from the center of the line once every 2-3 weeks at an annual rate of 1-2 bushels per acre per year. Feed lines were distributed evenly across properties. Feed lines were not mowed like roads, but vegetation remained of shorter height than surrounding areas as a result of tractors driving over the same routes at two-week intervals. In some locations bare ground was present in the tire paths.

Methods

Trapping

We captured turkeys on TTRS March-April of 2014, January of 2015 and January-February 2016 and on Dixie Plantation January-February of 2016. We used rocket nets based on recommendations of Bailey et al. (1980). Once captured, I placed turkeys in individual cardboard holding boxes until they were processed. Age and sex were determined through methods described by Williams and Austin (1988). Weight was recorded for all turkeys and for males, beard length and spur length were measured. Uniquely numbered rivet style leg bands were placed on each turkey's right tarsi. I equipped a subset of turkeys with rechargeable Quantum 4000E Mini Bird backpack style global positioning system (GPS) units (Telemetry Solutions. Concord, CA) in 2014 and 2015. Transmitter dimensions were 10.5 x 5 x 1.9 cm and weighed 110 g. In 2016, hens were equipped with a combination of non-rechargeable Quantum 4000 Mini Bird Backpack GPS units (Telemetry Solutions. Concord, CA) and Minitrack backpack style

GPS units (Lotek Wireless, Inc. Newmarket, Ontario, Canada). Non-rechargeable Quantum 4000 Mini Bird Backpack dimensions were 7 x 4 x 4 cm and weighed 107 g. Minitrack unit dimensions were 9.6 x 3 x 3.5 cm and weighed 97 g. I equipped a subset of gobblers with AWE-turkey very high frequency (VHF) backpack style transmitters (American Wildlife Enterprises. Monticello, FL). Transmitter dimensions were 6.5 x 1.9 x 2.3 cm and weighed 90 g. Turkeys were released immediately after processing at the site of capture. All GPS units were also equipped with VHF monitoring capabilities. All VHF and GPS units were equipped with an 8 hour mortality switch. Across all years, 33 hens and 6 gobblers were captured at TTRS whereas 15 hens and 13 gobblers were captured at Dixie Plantation.

Monitoring

I programmed GPS units using software to balance battery life of the GPS units with adequate sampling of daily movements and roost locations. In 2014 and 2015, GPS transmitters were programed to acquire 9 fixes a day for 4 days/week and 1 fix a day for the remaining 3 days/week. On days transmitters acquired 9 fixes, the schedule was to obtain a fix at midnight, 0730, 0800, 0830, 0930, 1430, 1530, 1630, and 1730 h. On the remaining days, I scheduled GPS units to acquire 1 fix per day at midnight. In 2016, I scheduled Telemetry Solutions GPS units to acquire locations every 30 min from 0730-1800 h excluding 0900 from March 27-June 11. I programmed Lotek GPS units to acquire locations at 0730, 0830, 0930, 1430, 1530, & 1630 h from time of capture to March 26. From March 27 - June 11 or until a hen’s brood failed locations were taken every 30 min from 0700 to 2000 h. All units turned off by July 20. I downloaded

Telemetry Solutions GPS in the field using ultra high frequency (UHF) transmissions, a 3-element mini-yagi antenna and laptop computer. Lotek GPS units were downloaded in the field with a 3-element yagi antenna and handheld command unit via VHF signal. I estimated error rates for Telemetry Solutions units by conducting static testing through a balanced sampling design in 3 cover types (field, upland pine, drain). I generated random locations in ArcMap and placed 6 GPS units on wooden stakes at the locations (Guthrie et al. 2011). I then used a Trimble GPS to mark the locations and applied differential correction. GPS units collected data at each location for 6 days. The units attempted a fix every 10 min on the first day, every 30 min on the second day, every 1 h on the third day, every 6 h on the fourth day, every 12 h on the fifth day, and after 24 h on the sixth day. I examined Lotek error rate by comparing differentially corrected nest locations marked with a Trimble GPS unit and recorded locations from Lotek units attached to incubating hens.

I located VHF radio-tagged turkeys 3-5 times per week from March until August of each year and 1-2 times per week the rest of the year via triangulation (White and Garrott 1990). In 2016, intensive VHF monitoring occurred on gobblers between March 17 and June 16. In 2015, VHF component failure occurred on a majority of the GPS units, preventing tracking of these turkeys. Project budgets precluded the purchase of as many replacement GPS units as needed during 2016, so intensive VHF monitoring was conducted to obtain a large sample of locations. I created a randomized schedule in which 2 gobblers were selected for 2 consecutive days of intensive monitoring each week. For each day of intensive monitoring, 15 locations were collected per gobbler. Each gobbler was intensively monitored during two different weeks during this time period. Locations were obtained by listening for transmitter signals from listening stations (n = 419 stations) with a 3-element yagi antenna and a TR-5 telemetry receiver (Telonics, Inc., Mesa, AZ) or a Biotracker telemetry receiver (Lotek, Newmarket, Ontario, Canada). Listening station locations were recorded using a Trimble GPS unit and applying differential correction to obtain sub-meter accuracy. Some locations were predetermined by marking the center of road intersections across the study area. Others were added as needed, marked on an Ipad Mini (Apple. Cupertino, CA) using the app PDFMaps (Avenza Systems Inc. Toronto, Ontario, Canada) and recorded with a Trimble GPS unit at a later date. A compass bearing was taken from a listening station in the direction in which the signal strength was the strongest. Three bearings were recorded within a 10-min interval. Bearings were uploaded into the software Location of a Signal (Ecological Software Solutions LLC. Hegymagas, Hungary) to determine location coordinates. Error testing was conducted with all project personnel by placing 3 GPS units and 2 VHF test units across each study site and recording 3 bearings as if a live bird was being tracked. Locations of test units were recorded with a Trimble GPS unit and differential correction was applied. Bearings were uploaded into the software Location of a Signal (Ecological Software Solutions LLC. Hegymagas, Hungary) to determine location coordinates from project personnel's bearings. These were compared to the differentially corrected locations to determine observer error.

Data Analysis

I conducted hierarchical conditional logistic regression (HCLR; Duchesne et al. 2010) in a Bayesian framework to determine turkey resource use at two spatial scales: landscape scale (2nd order) and within individual home ranges (3rd order). Locations used for the analysis were collected through mid-February and mid-July and generally spanned from late winter flock break-up to courtship, nesting, and brood rearing periods. The resource use documented in this study applies to those periods. I examined resource use at these scales to better inform management decisions. Evaluation at the landscape scale can provide insight into what land cover components are necessary to sustain a turkey population, whereas within home range evaluation can explain daily movements of turkeys and better inform finer scale management recommendations at the property level. I defined the landscape scale as the contiguous area around TTRS and Dixie, respectively, in which any turkey was located during the course of the study. Within home range analysis was conducted by comparing individual use locations to the availability of cover types within that individual's home range. Individual turkeys were my sampling unit and the predicted probability of use for the population is independent of the sampling intensity for individuals (Gillies et al. 2006). I used ArcMap 10.3 (Esri, Redlands, CA) to digitize TTRS, Dixie, and other private plantations and classified 8 land cover types using a interpretation of a combination of color infrared aerial imagery and ground-truthing: drain; field; water; planted pine; upland pine; road; feed line; and other. Feed lines were converted to cover types by buffering linear feed line shapefiles by 7.2 m on each side, the average broadcast range of supplemental feed. The difference in probability of use between land cover types was evaluated for biological significance by examining if the 95% credible intervals overlapped. I censored low-quality, 2D GPS locations to increase location accuracy (Lewis et al. 2007). Telemetry locations were censored when location error plumes were greater than 0.4 ha or the observer failed to collect 3 bearings within a 10-min time period. I created 95% fixed kernel density estimator (KDE) home ranges, following Worton (1989) using ArcMET 10.3.1v1 (Wall 2016) for gobblers equipped with VHF transmitters. I created Brownian Bridge home ranges, following Horne et al. (2007) using ArcMET 10.3.1v1 (Wall 2016) for gobblers and hens equipped with GPS units. Brownian Bridge home ranges are ideal for auto-correlated GPS data because the Brownian Bridge method assumes locations are not independent (Horne et al. 2007). These home ranges were used to evaluate 3rd order resource use. I incorporated both VHF and GPS data in my analysis to include all data that withstood my data screening requirements as a best case, conservative approach to understanding turkey resource use. Though VHF data are subject to larger error rates, error polygons were relatively small compared to land cover type patch size; therefore VHF data were pooled with GPS data for the analysis. Individuals tracked via VHF accounted for approximately 25% of my sample. Because only gobblers received VHF transmitters, error rates differed by transmitter type and by sex. Because of this situation, I couldn’t distinguish between differences in resource use by transmitter type from differences in resource use by sex.

I followed a similar approach as McGrath et al. (2017) to set up my HCLR analysis. I generated 5 random points (McFadden 1978) for each turkey location at the landscape and within home range scale using ArcMap 10.3 to represent availability. Five random locations gave a more accurate representation of land cover type availability as opposed to only using 1 random location, particularly for land cover types that made up a small percentage of the landscape or home range. I calculated distances in ArcMap 10.3 from both use and random locations to the nearest drain, feedline, and road. I conducted HCLR in a Bayesian framework using the R2Jags package in R (Plummer 2003). I used Pearson correlation tests to determine collinearity ($|r| > 0.7$) prior to modeling. Fixed effect predictor variables included distance to feed lines, distance to drains, size of closest drain, distance to roads, land cover type, site and sex. Individual was incorporated into the model as a random effect predictor variable. Incorporating individual as a random effect accounted for unequal sample size at the individual level (Gillies et al. 2006). Random points were coded as 0's and turkey locations were recorded as 1's to incorporate use as the response variable. Variables were standardized to have a mean of 0 and a standard deviation of 0.001. Posterior distributions of each model parameter were estimated using Markov chain Monte Carlo (MCMC) methods. I ran 3 chains using non-informative priors for 25,000 iterations after a 5,000 iteration burn-in and also using a thinning of 10. The results of HCLR afforded a metric for quantitatively describing turkey resource use on a food-subsidized landscape.

Results

Based on static GPS accuracy testing, average location error ranged from 17-42 m for the 6 tested units. Location error ranged from 10-15 m for Lotek units. The average triangulation location error for project personnel was 110 m. I used 14,303 locations representative of 13 hens and 11 gobblers to analyze resource use at Dixie and 44,362 locations representative of 25 hens and 6 gobblers at TTRS. None of the variables used were highly correlated(|r| > 0.7; Table 2.3), therefore collinearity did not appear to be a problem.

Turkey home range sizes did not differ by study sites or between sexes. Hens at TTRS had an average home range size of 652 ha (95% CI = 447 – 858). Gobblers at TTRS had an average home range size of 701 ha (95% CI = 192 – 1209). Hens at Dixie had an average home range size of 536 ha (95% CI = 316 – 756). Gobblers at Dixie had an average home range size of 697 ha (95% CI = 348 – 1045; Figure 2.12, Table 2.2)

At the 2nd order scale (i.e. landscape scale), availability of the 8 cover types based on the generated random points were: drain (27.32%), feed line (3.76%), field (7.1%), other (4.04%), planted pine (9.62%), road (1.56%), upland pine (32.8%), and water (13.78%). Fields had the greatest probability of use (0.1951), followed by drains (0.1843), feed lines (0.1669), roads (0.1614), planted pine (0.1592), and upland pine (0.1466). Water (0.0269) and other (0.0211) had very minimal probability of use (Figure 2.1). The probability of use did not differ between fields, drains, feed lines and roads. There were no differences in probability of use between upland pine, roads, planted pine, and feed lines. The probability of use decreased with increased distance to feed lines out to approximately 2,245 m (95% CrI = (-0.12) – (-0.07); Figure 2.2). The probability of use decreased with increased distance from drains to approximately 852 m (CrI = 0.06 – 0.08; Figure 2.3). The probability of use decreased as distance to road increased to approximately 1,107 m (CrI = (-0.15) – (-0.1); Figure 2.4). The probability of use increased as the size of the nearest drain increased to approximately 625 ha (CrI = (-0.28) – (-0.25); Figure 2.5). When the nearest drain was larger than 625 ha, probability of use began to decrease. Male and female resource use did not differ (SD = 0.1; CrI = (-0.37) – 0.03) and resource use also did not differ among study sites (SD = 31.77, CrI = (-61.26) – 61.82). The SD for the random effect of individuals was 0.04 (CrI = 0.26 - 0.4).

At the 3rd order scale (i.e. individual home range), availability of the 8 cover types based on the generated random points were as follows: drain (38.01%), feed line (4.9%), field (4.8%), other (0.81%), planted pine (11.2%), road (1.95%), upland pine (33.5%), and water(4.82%). Fields had the greatest cover-type probability of use (.0406), followed by feed lines (0.1264), and upland pine (0.1076). Upland pine did not differ in probability of use from roads (0.0893) or planted pine (0.0924), but feed lines had greater probability of use than planted pines and roads. Drains (0.0406), other (0.0401), and water (0.0238) generally had <5% probabilities of use (Figure 2.6). The probability of use decreased with increasing distance to feed lines to approximately 1,670 m (CrI = 0.06 – 0.07; Figure 2.7). The probability of use decreased with increasing distance to drain to approximately 351 m (CrI = 0.57 – 0.59; Figure 2.8). The probability of use decreased with increasing distance to a road to approximately 1,234 m (CrI = (-0.04) – (-0.03); Figure 2.9). The relationship between probability of use and nearest drain size displayed a parabolic relationship; probability of use increased as nearest drain size increased to approximately 373 ha and then probability of use decreased as nearest drain size increased above 497 ha (CrI = (-0.07) – (-0.03); Figure 2.10). Males and female resource use did not differ (SD = 0.1, CrI = -0.07 – 0.03) and resource use did not differ among study sites (SD = 31.55, CrI = (-61.5) – 62.13). The SD for the random effect of individuals was 0.03 (CrI = 0.27- 0.4).

Discussion

Wild turkey resource use was positively related to supplemental feeding for northern bobwhites at 2 spatial scales, but the probability of use varied among spatial scales. My findings demonstrate that broadcasting supplemental food for one species impacts resource use of wild turkey. Similarly, the presence of fields influenced resource use during the breeding season at 2 spatial scales. Drains, however, were used differentially among spatial scales such that proximity to drain and size of drain determined selection. The parabolic selection of drains relative to size underscores the value of drain size, especially at the landscape scale, to wild turkey resource use.

Compared to other cover types, fields were the most influential on turkey resource use at both spatial scales. The greatest difference between probabilities of use relative to other cover types was seen with fields at the home range (3^{rd} order) scale, suggesting that fields fulfill important ecological requirements required by turkeys, especially at fine spatial scales. Fields offer a wide variety of resources to turkeys during important reproductive periods of their annual cycle. Fields provide food in the form of forbs, soft mast, and insects for both adults and poults during the period we monitored their use (late February – July). Vegetative structure in fallow fields provides protective cover and easy mobility at the ground level for poults increasing their survival and overall fitness (Porter 1992). Anecdotally, I observed that adult hens moved poults to fields immediately following hatch and remained in the fields until poults fledged and were better equipped to fly to roost. Miller and Conner (2007) corroborate my results wherein they found open areas were important for hens rearing broods. Some hens even selected fields as nesting sites in my study, which has been documented in previous works (see Speake et al. 1975). Gobblers also use fields as strutting areas for attracting mates (Wunz and Pack 1992).

Drains, or hardwood hammocks, were particularly important to turkeys at the landscape scale (2^{nd} order), whereas drains were much less important to turkey resource use at the home range scale. At the landscape level, a positive correlation existed between proximity to drain and increased probability of use, suggesting that turkeys were more likely to use an area if a drain was nearby. Drains exhibited the greatest disparity between landscape scale (2^{nd} Order) and within home range (3^{rd} order) selection. This indicates drains are a requisite to holding turkeys at the landscape scale, but have much less influence on turkey daily movements. Burk et al. (1990) postulated turkeys use drains for traveling, roosting, feeding, loafing, and thermoregulation during the summer. Other studies showed that drains were used for roosting (Bailey and Rinell 1968, Flake et al. 1995, Chamberlain et al. 2000). The literature provides scores of examples of turkeys choosing roosting sites near water (Schorger 1966, Boeker and Scott 1969, Williams and Austin 1988).

The value of large drains for turkeys has been documented (Dalke et al. 1946, Stoddard 1963), but explicit drain size in relation to resource use has never been examined. Stoddard (1963) suggested turkeys required drains of "considerable acreage," but did not indicate an explicit size. The width of drains is also known to influence turkeys; for example, Burk et al. (1990) suggested minimum drain widths of 84 m were effective for turkey use. Palmer and Hurst (1995) recommended at the landscape scale, creek drainage systems may be useful as minimum habitat management planning units for hens. During my study, turkeys exhibited a strong selection towards large drains at the landscape scale with the optimum drain size for turkeys being approximately 700 ha. Often, plantations with the primary objective of managing for bobwhites seek to minimize the size of small and intermediate drains to increase bobwhite habitat. The selection of large drains by turkeys on my study sites demonstrated the importance of protecting large drains, and allowing smaller drains to expand to original extents on plantation properties where turkey management is a priority. Future research should further investigate how distance to drains and nearest drain size interact and influence turkey resource use intra- and inter-seasonally. Future research should also investigate the role of roost site fidelity in the selection of drains.

Turkeys exhibited a greater selection for feed lines at the landscape scale than compared to the home range scale, and feed lines ranked 3rd among all cover types in predicting probability of use across the landscape. Although probability of use decreased at the home range scale, probability of feed line use was greater relative to other land cover types, with the exception of fields. Probability of use decreased as distance to feed line increased at both scales. Feed lines may be more likely to influence where a turkey establishes a home range, but may be less influential in the daily travel patterns within the home range. The home ranges (from late winter-flock break up through brood rearing) of turkeys on my study areas were larger than or similar to many of those reported in the literature on sites without supplemental feed. Ellis and Lewis (1967) reported annual home ranges of gobblers to be 553 ha in Missouri, whereas the home ranges of hens were 448 ha. Speake et al. (1975) reported spring and summer home ranges of gobblers were 350 ha and 425 ha for hens in Alabama. In a review of wild turkey home range studies, Brown (1980) reported the average home range for turkeys in 10 different studies across 6 states was 286 ha. Given turkey home range size on my study sites were larger than those reported on sites without supplemental feed, broadcasting grain sorghum apparently was not significantly changing overall food resources.

Miller et al. (1999) conducted research on a highly forested landscape and found that turkeys did not select open areas, because they lacked appropriate structure or were not prevalent enough. The niche of open areas was filled by hardwood saw-timber and recently burned pine saw-timber stands. In the context of my study, there were few large drains at the landscape scale, which dictated turkey resource use and selection of a home range. Since upland sites and intermediate drains were managed for bobwhite through the frequent application of fire (Martin et al. 2012), vegetation in the uplands and along drain edges apparently was of high-quality, providing ample cover and food resources for wild turkeys. Miller et al. (1999) and Martin et al. (2012) reported that well-managed upland pine can provide high-quality turkey habitat. However, in spite of intensive management and frequent application of fire on upland pine on my study site, turkeys exhibited a strong selection for fields, especially for brood rearing. Fallow fields with annual forbs provided good structure and food resources for turkeys, and use of fields was more likely when they were in close proximity to drains, which were likely selected for roosting.

Turkeys likely used fields over pines because of the greater amount of forbs contained within annually disked fallow fields.

While my results demonstrate turkeys had an apparent affinity for feed lines, I cannot definitively say what was primarily driving their use. Increased food in the form of grain sorghum and/or an increased abundance of insects (Miller 2011) may have been attracting turkeys. Other explanations for the selection of feed lines include their use for travel, brood rearing, and nesting. Feed lines are linear features with low vegetation providing less inhibited travel and increased predator vigilance. Feed lines and roads were used very similarly on my study. Previous studies demonstrated that roads serve as a surrogate for fields or wildlife openings (Miller and Conner 2007) and are often used by turkeys for travel, feeding, and brood rearing in intensively managed pine landscapes (Smith et al. 1990, Hurst and Dickson 1992). During my study, turkeys often nested nearby feed lines or roads, and used feedlines during incubation recesses to access foraging areas in upland pines or fields. Similarly, Thogmartin (1999) reported increased nesting activity in close proximity to roads. Pollentier et al. (2017) reported turkeys selected nest sites with high edge densities and speculated that forest-field edges can function as travel corridors which may explain why feed lines and roads were used in my study. Feedlines on my study site were largely within upland pine stands and created similar edge conditions as reported by Pollentier et al. (2017). The use of feed lines could be driven by one or any combination of these reasons. Further research will be required to definitively identify the main reason for feed line use.

Concern among ecologists exists regarding the application of supplemental feed, given the potential concentration of prey species (Boutin 1990, Doonan and Slade 1995). An abundance of prey may concentrate predators, creating ecological traps (Godbois et al. 2004, Turner et al. 2008). However, broadcast supplemental feed via feed lines mitigate concentration of wildlife at a specific location through even distribution of food resources across the landscape. As such, broadcast feeding has been shown to neutrally impact survival yet positively impact reproduction for northern bobwhite (Buckley et al. 2015). Evenly distributing supplemental feed across a property minimizes site fidelity to any one given area. Evaluation of fidelity to specific locations along the feed line for individual turkeys did not reveal concentrated patterns of use. Thus, though there is clear use of feed lines by turkeys, their predictability of use at a particular location toward increased harvest or creation of an ecological trap does not appear to inflate mortality.

Management decisions for one species have consequences (positive or negative) on resource use of other species, as is evidenced by supplemental feeding of bobwhite and its effects on turkeys in this study. Resource use decisions impact how a species uses its habitat, which in turn can have implications on the fitness of both target and non-target wildlife. Feed lines do not concentrate turkeys any more than fields and large drains at the landscape level. Future research should examine nest-site selection, nest survival and poult survival on a food-subsidized landscape to better understand how food provisioning impacts demographic attributes beyond resource use. My results indicated significant individual variation of turkey resource use. Future research should aim to further disentangle breeding season resource use among hens, hens with broods, and gobblers.

Management Implications

Based on my results, wild turkey habitat can be improved by incorporating fallow fields or wildlife openings in settings in northern Florida with similar conditions to TTRS and Dixie Plantation. These fields could provide cover beneficial to mate selection, brood rearing, and nesting. Intensive bobwhite management often focuses on reducing drains in both scope and size, with aims of increasing habitat for bobwhites and reducing predation. However, this practice may have negative consequences for wild turkeys such that proximity to drains and drain size proved important determinants of resource use. Plantation properties where turkey management is a goal should protect large drains (>375 ha) and reconsider the practice of reducing or eliminating small drains.

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Appendix

Table 2.1. Beta estimates and 95% credible intervals for covariates used in hierarchical conditional logistic regression of wild turkey resource use, Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

	2^{nd} Order			3^{rd} Order		
Covariate	β	LcrI	UcrI	β	LcrI	UcrI
DistDrain	0.068	0.06	0.0751	0.582	0.574	0.59
DistFeed	-0.095	-0.123	-0.07	0.063	0.055	0.072
DistRoad	-0.121	-0.145	-0.096	-0.034	-0.041	-0.027
DrainSize	-0.264	-0.275	-0.252	-0.049	-0.065	-0.034
Sex	-0.167	-0.369	0.028	0.13	-0.07	0.0337
Site	0.085	-61.26	61.82	0.943	-61.5	62.13
Deviance	2639e^2	2638e^2	2639e^2	2692e^2	2692e^2	2693e^2
Sd.Bird	0.324	0.264	0.4	0.327	0.266	0.403

Table 2.2. Wild turkey home range sizes, Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

UID	Sex	Site	Home Range Size (ha)
F1001	Female	TTRS	804.89
F1002	Female	TTRS	134.8
F1003	Female	TTRS	773.44
F1004	Female	TTRS	724.3
F1005	Female	TTRS	1410.44
F1006	Female	TTRS	88.07
F1007	Female	TTRS	821.57
F1008	Female	TTRS	1995.44
F1010	Female	TTRS	1694.88
F1072	Female	TTRS	200.39
F1073	Female	TTRS	687.67
F1075	Female	TTRS	214.07
F1077	Female	TTRS	337.84
F1078	Female	TTRS	913.19
F1079	Female	TTRS	835.85
F1080	Female	TTRS	254.14
F1081	Female	TTRS	271.6
F1082	Female	TTRS	489.13
F1083	Female	TTRS	404.44
F1084	Female	TTRS	351.36
F1085	Female	TTRS	361.1
F1086	Female	TTRS	325.82
F1087	Female	TTRS	264.44
F447448	Female	TTRS	1286.64
F449450	Female	TTRS	658.58
Mean	Female	TTRS	652.16
M1001	Male	TTRS	976.61
M1002	Male	TTRS	1220.65
M1160	Male	TTRS	43.18
M1161	Male	TTRS	241.99
M602603	Male	TTRS	603.9
M640641	Male	TTRS	1118
Mean	Male	TTRS	700.72

Table 2.2 (continued)

UID	Sex	Site	Home Range Size (ha)
F1088	Female	Dixie	242.12
F1089	Female	Dixie	146.25
F1090	Female	Dixie	446.47
F1091	Female	Dixie	1152.99
F1092	Female	Dixie	249.55
F1093	Female	Dixie	368.64
F1094	Female	Dixie	331.79
F1096	Female	Dixie	521.42
F1098	Female	Dixie	1118.84
F1099	Female	Dixie	288.32
F1100	Female	Dixie	881.6
F1101	Female	Dixie	683.8
F1102	Female	Dixie	317.04
Mean	Female	Dixie	519.14
M1162	Male	Dixie	343.31
M1163	Male	Dixie	246.52
M1164	Male	Dixie	378.11
M1166	Male	Dixie	486.69
M1167	Male	Dixie	1256.04
M1168	Male	Dixie	99.86
M1169	Male	Dixie	635.18
M1170	Male	Dixie	1106.52
M1171	Male	Dixie	216.76
M1173	Male	Dixie	1340.63
M1174	Male	Dixie	1552.69
Mean	Male	Dixie	696.57

Table 2.3. Pearson correlation coefficients (r) for variables used in evaluating wild turkey resource use, Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

Variable	Dist Feed	Dist Drain	Dist Road	Drain Size
Dist Feed	1	-0.32	0.42	0.07
Dist Drain	-0.32	1	-0.24	0.02
Dist Road	0.42	-0.24	1	0.18
Drain Size	0.07	0.02	0.18	1

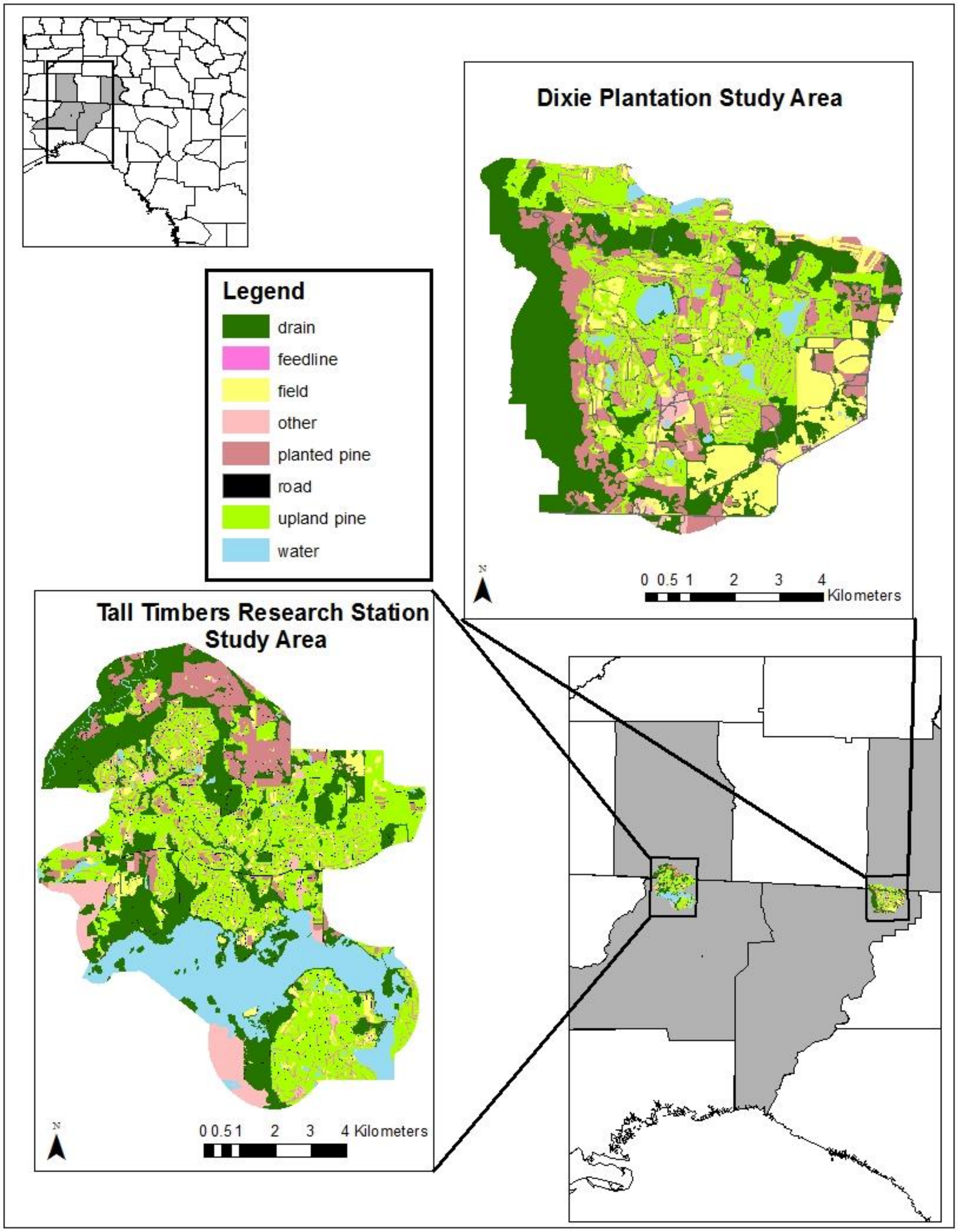

Figure 2.1. Maps of Tall Timbers Research Station and Dixie Plantation study areas.

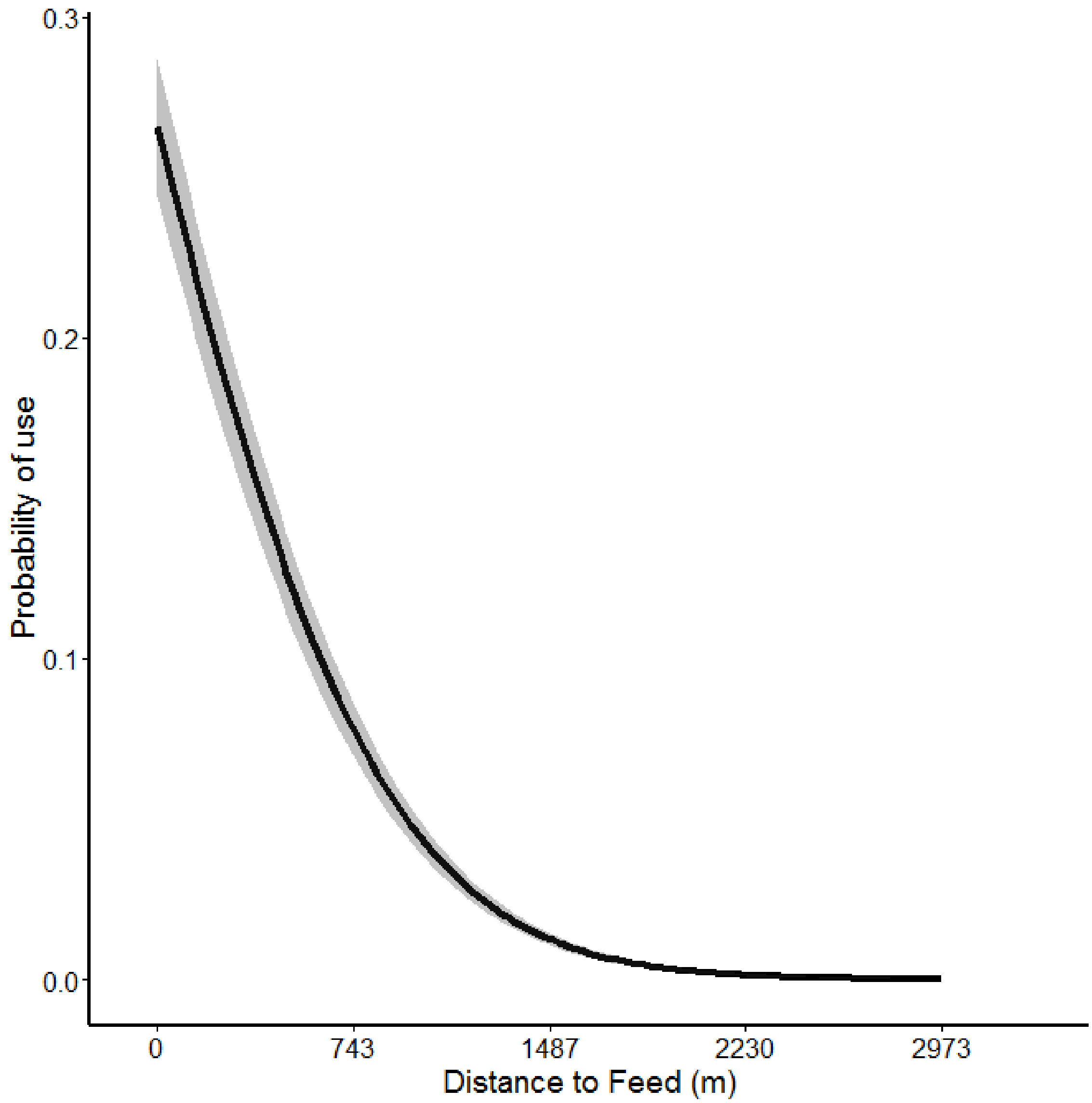

Figure 2.2. Probability of wild turkey use related to distance to supplemental feed lines at the landscape scale (2nd order), Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

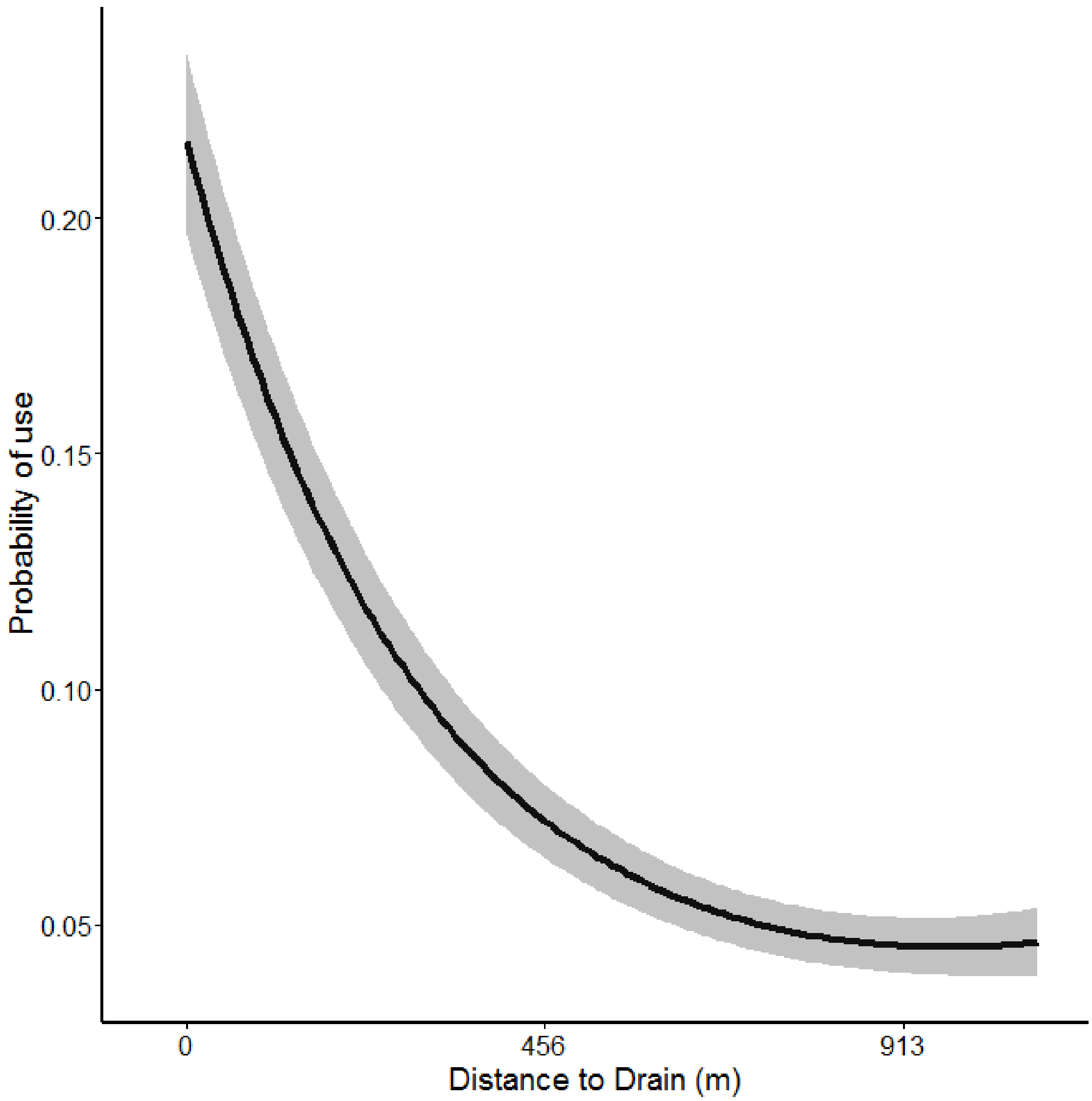

Figure 2.3. Probability of wild turkey use related to distance to hardwood drains at the landscape scale (2nd order), Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

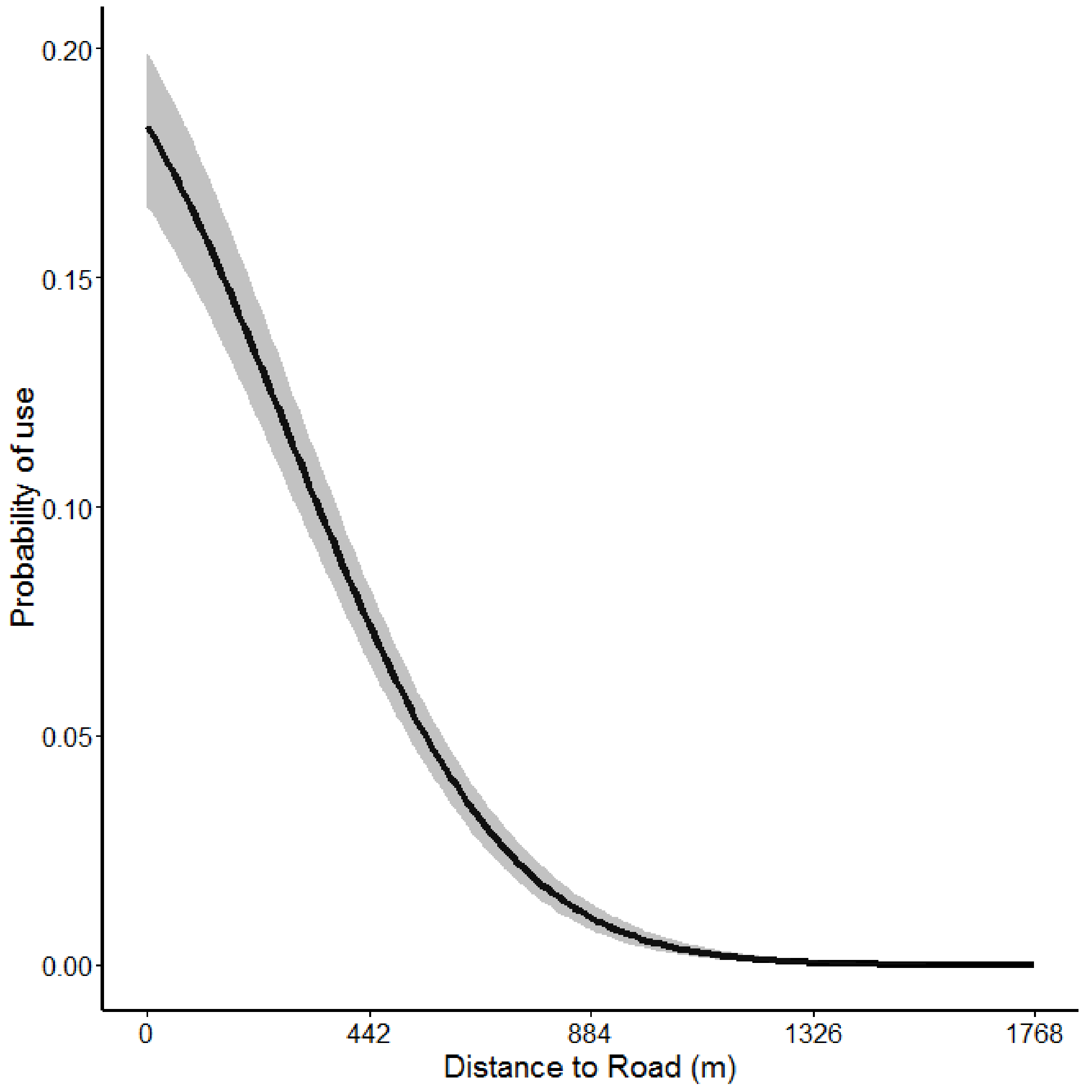

Figure 2.4. Probability of wild turkey use related to distance to roads at the landscape scale (2nd order), Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

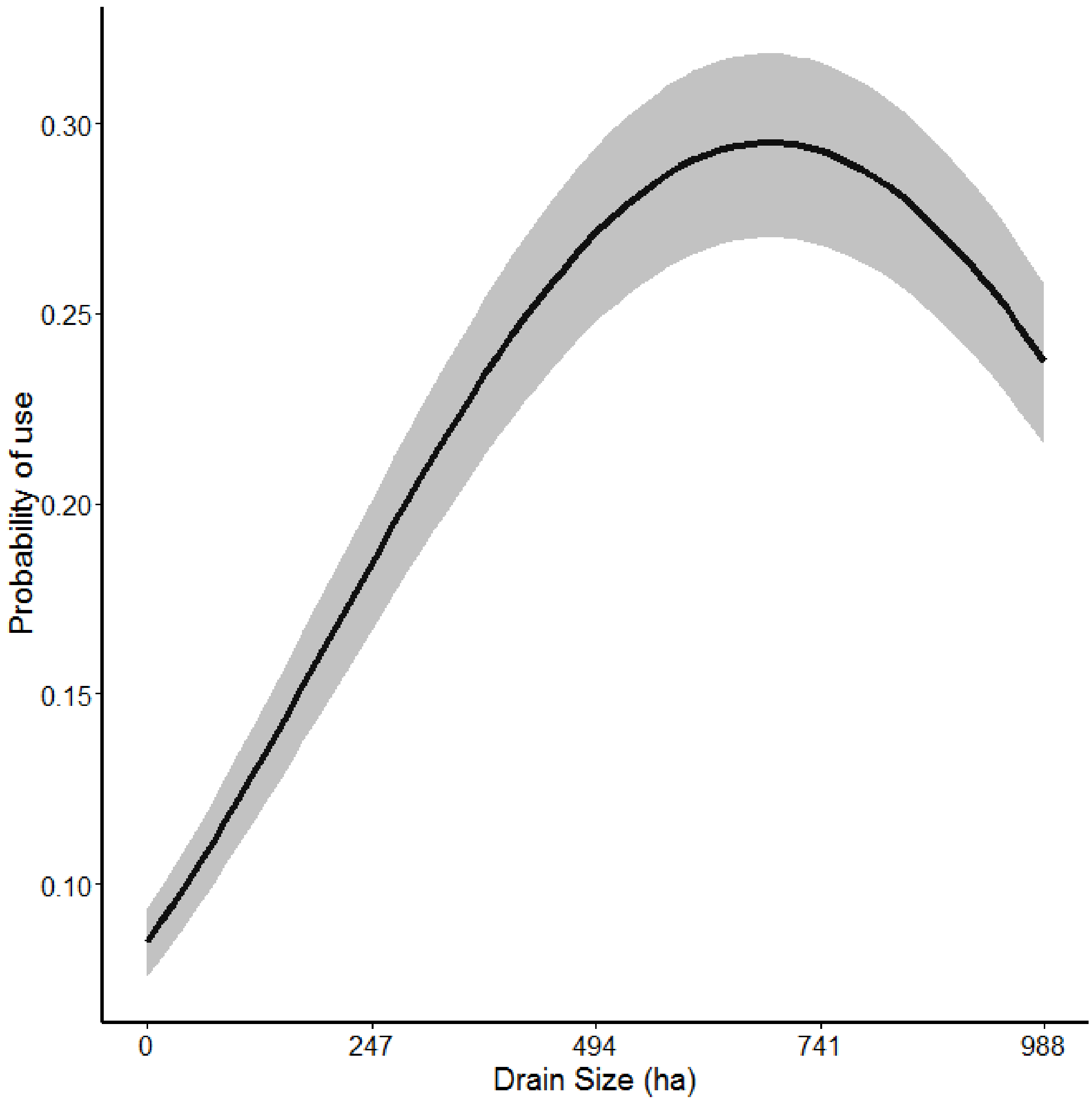

Figure 2.5. Probability of wild turkey use related to size of the nearest hardwood drain at the landscape scale (2nd order), Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

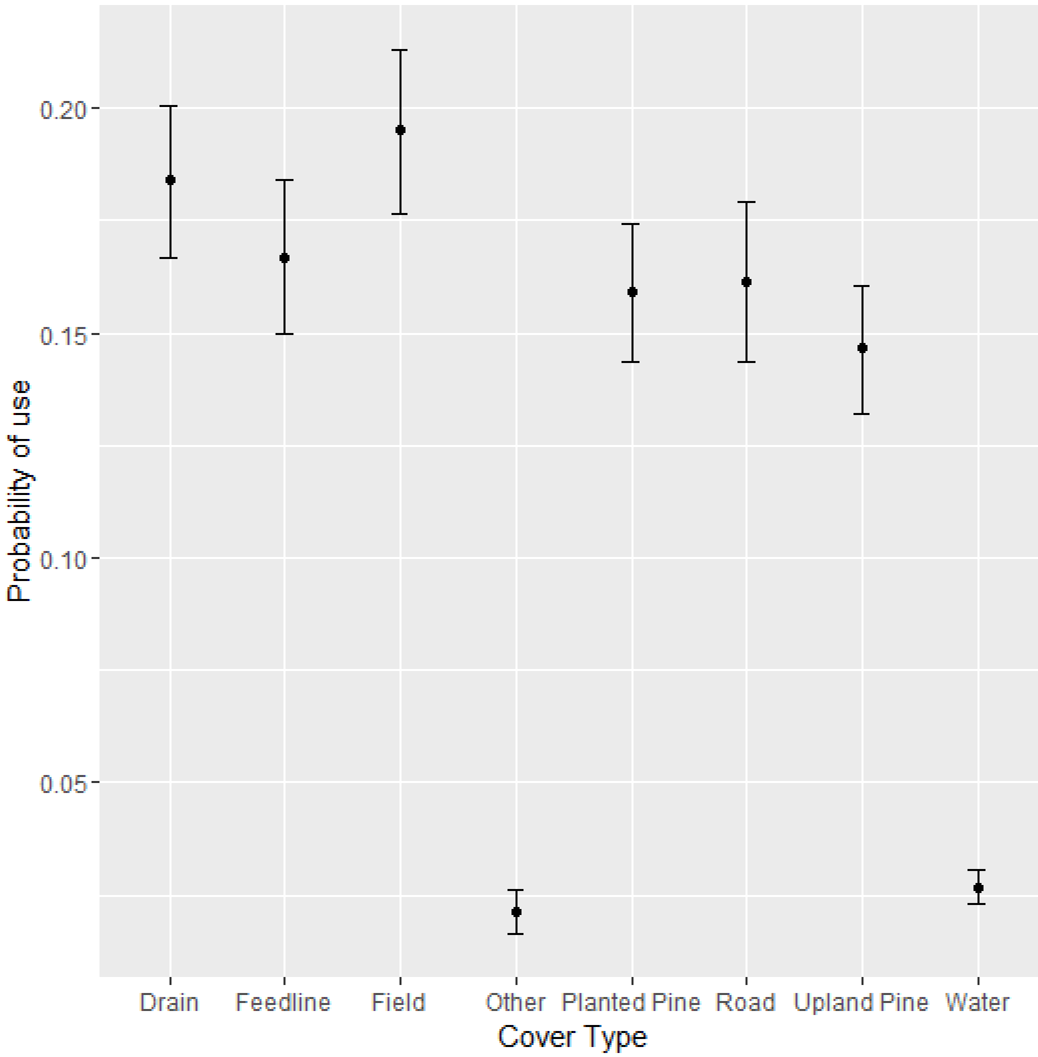

Figure 2.6. Probability of wild turkey use related to land cover type at the landscape scale (2nd order), Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

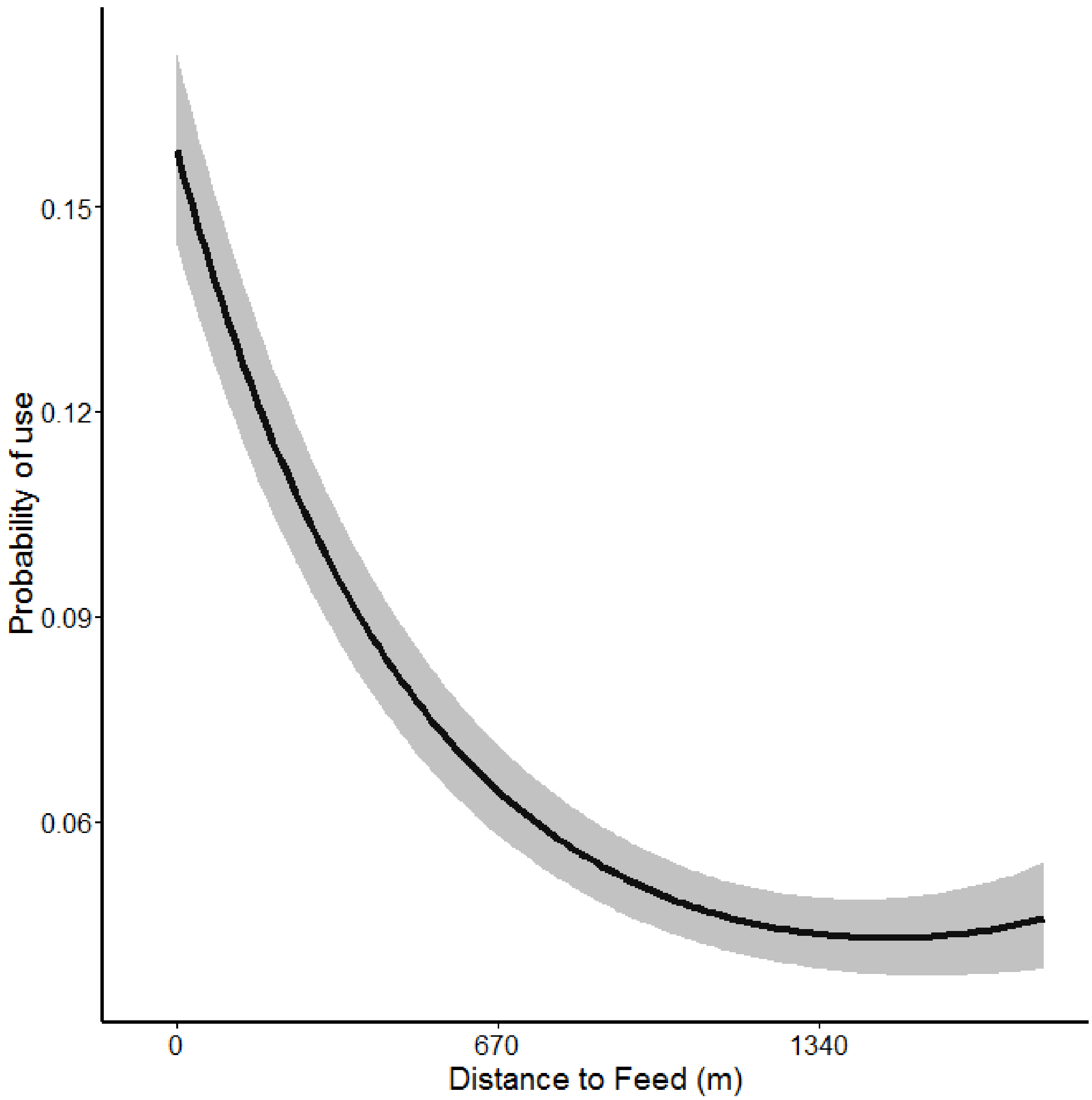

Figure 2.7. Probability of wild turkey use related to distance to supplemental feed lines at the individual home range scale (3rd order), Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

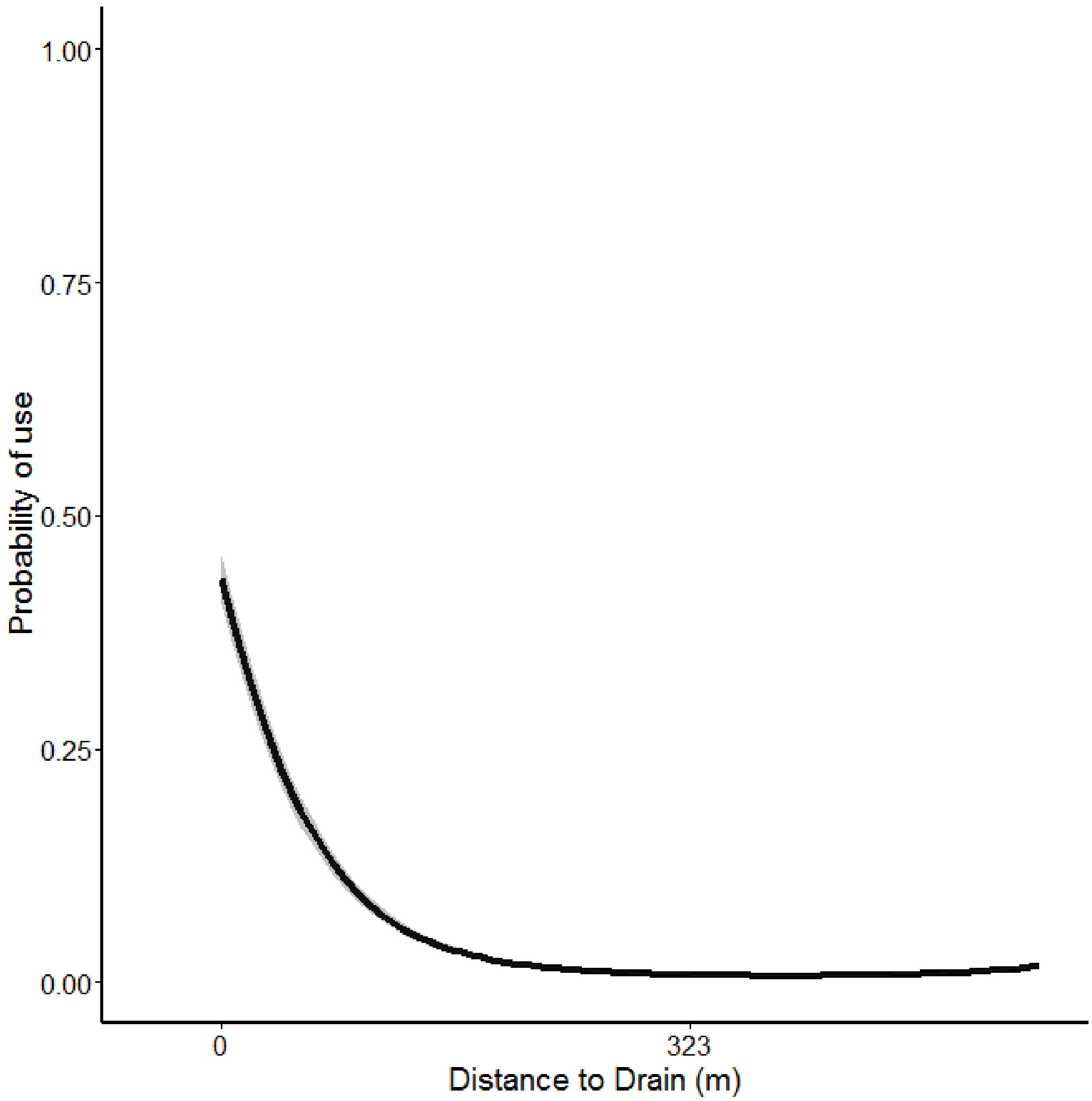

Figure 2.8 Probability of wild turkey use related to distance to hardwood drains at the individual home range scale (3rd order), Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

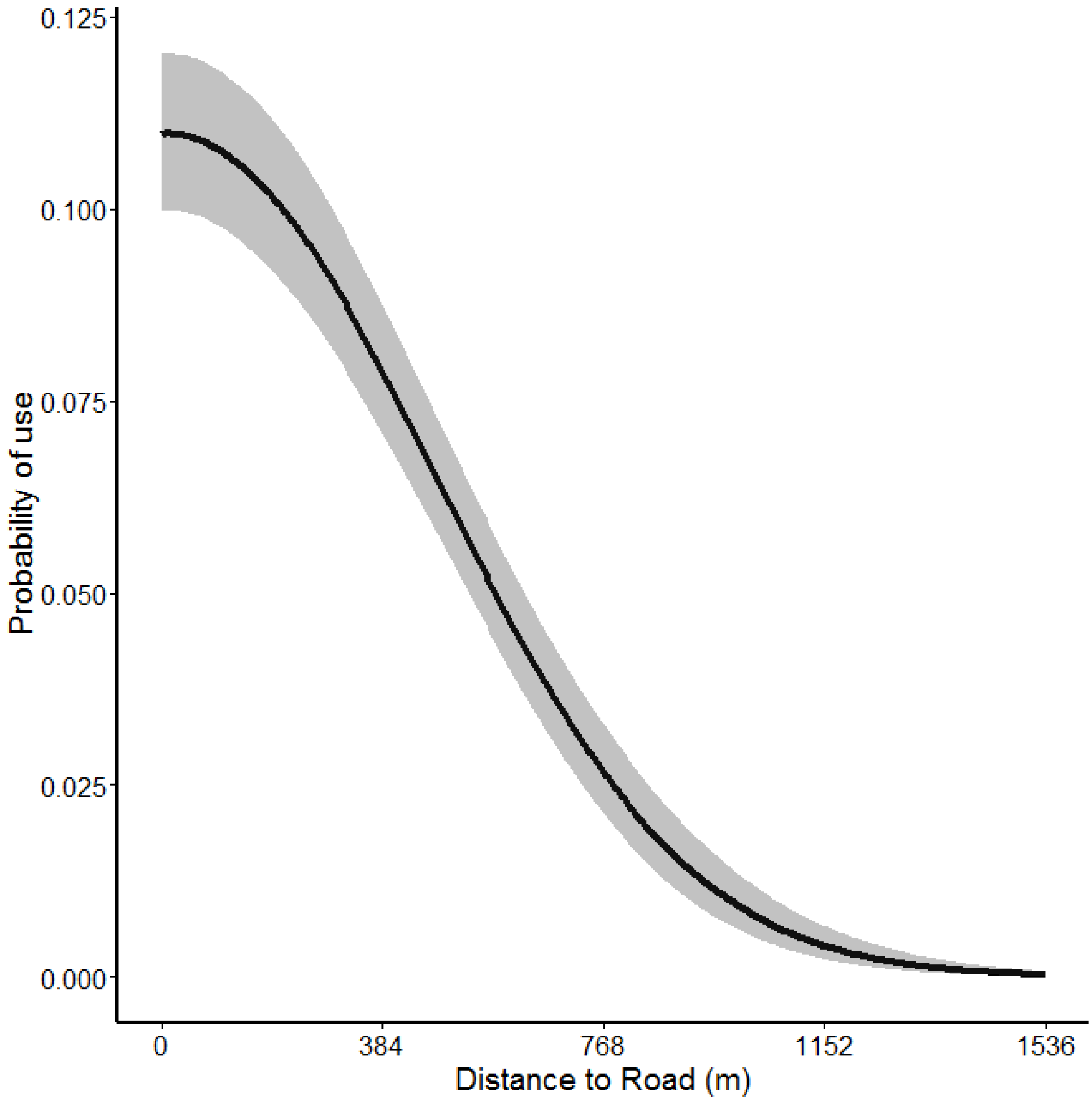

Figure 2.9 Probability of wild turkey use related to distance to roads at the individual home range scale (3rd order), Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

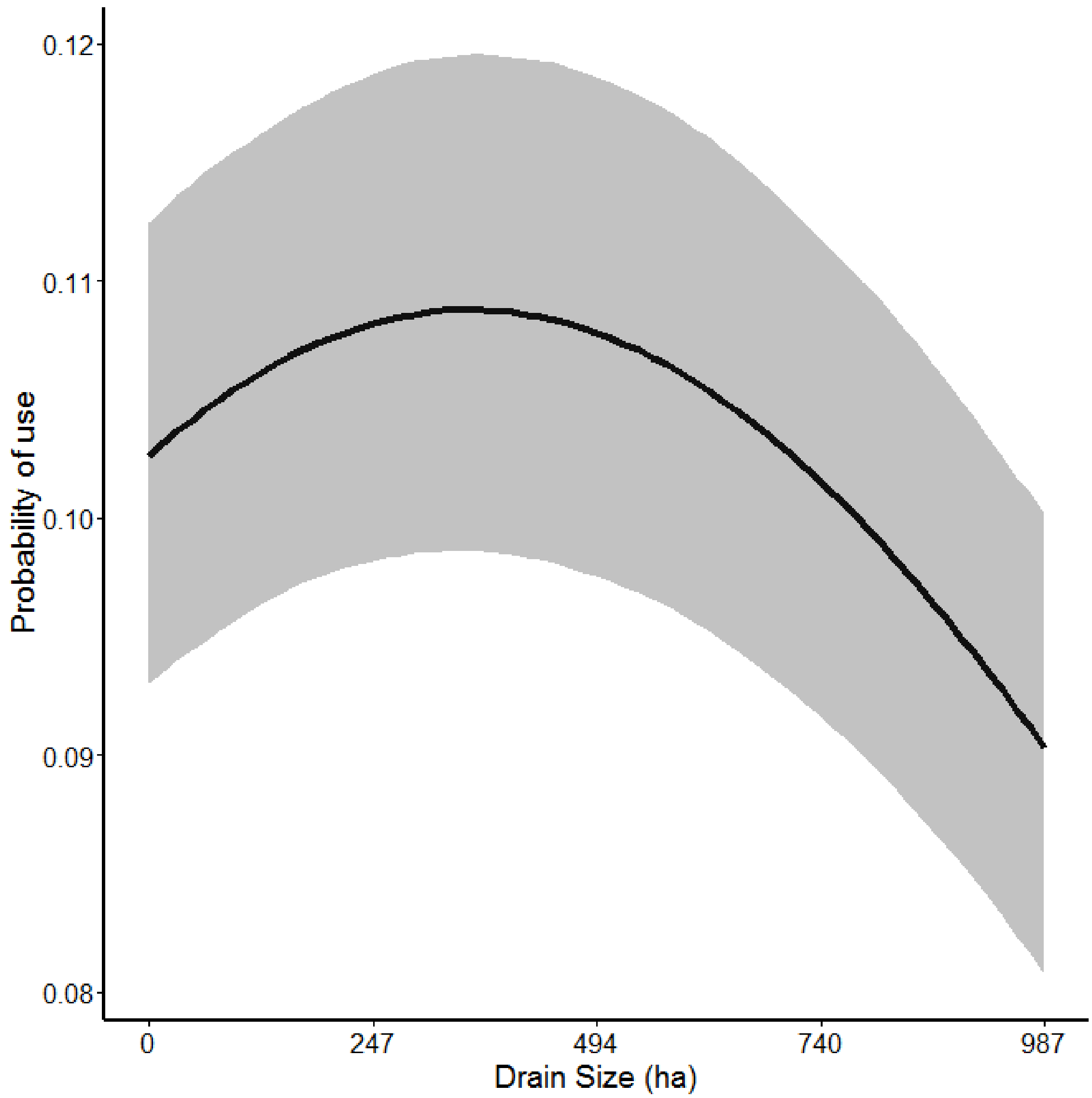

Figure 2.10. Probability of wild turkey use related to size of the nearest hardwood drain at the individual home range scale (3rd order), Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

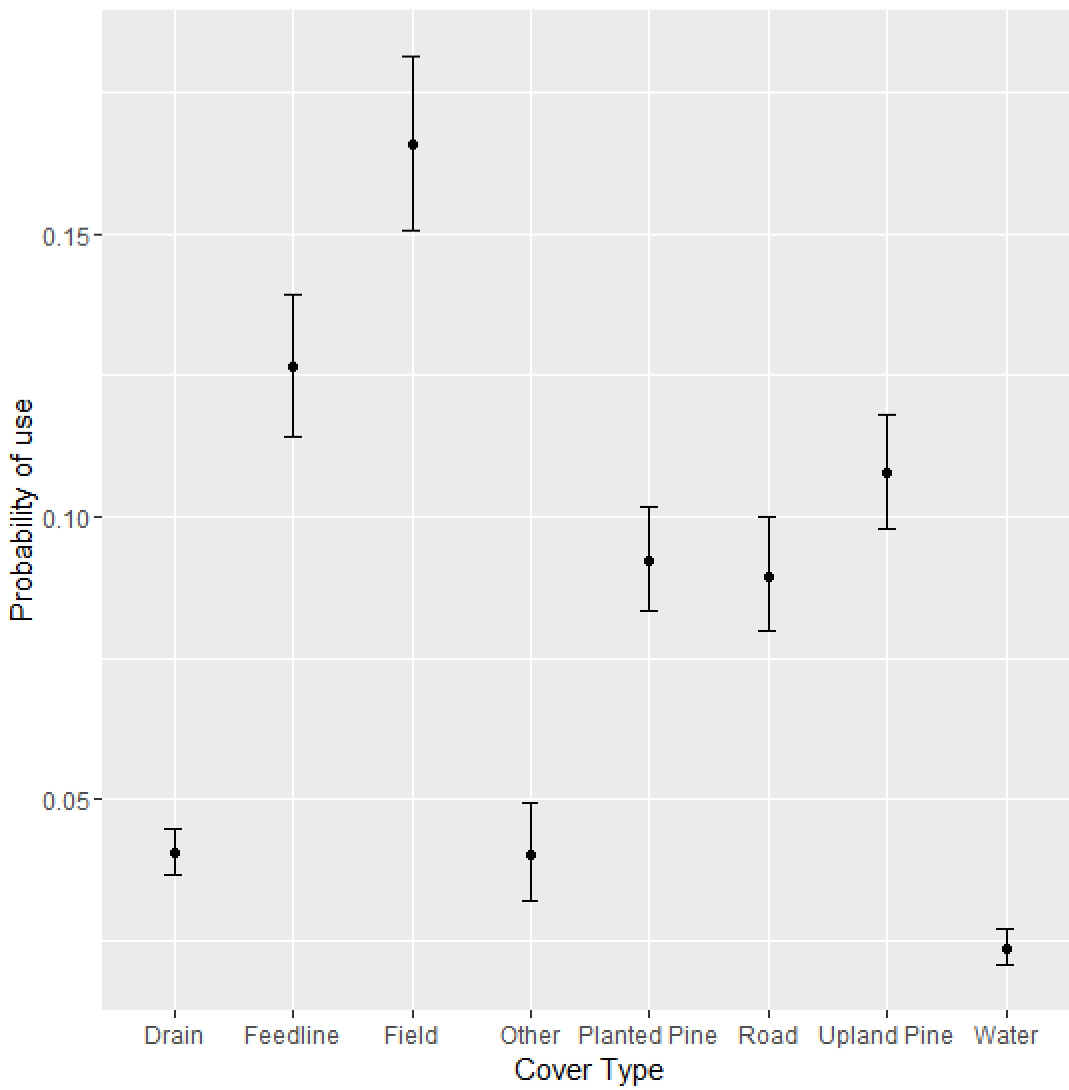

Figure 2.11. Probability of wild turkey use related to land cover type at the individual home range scale (3rd order), Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

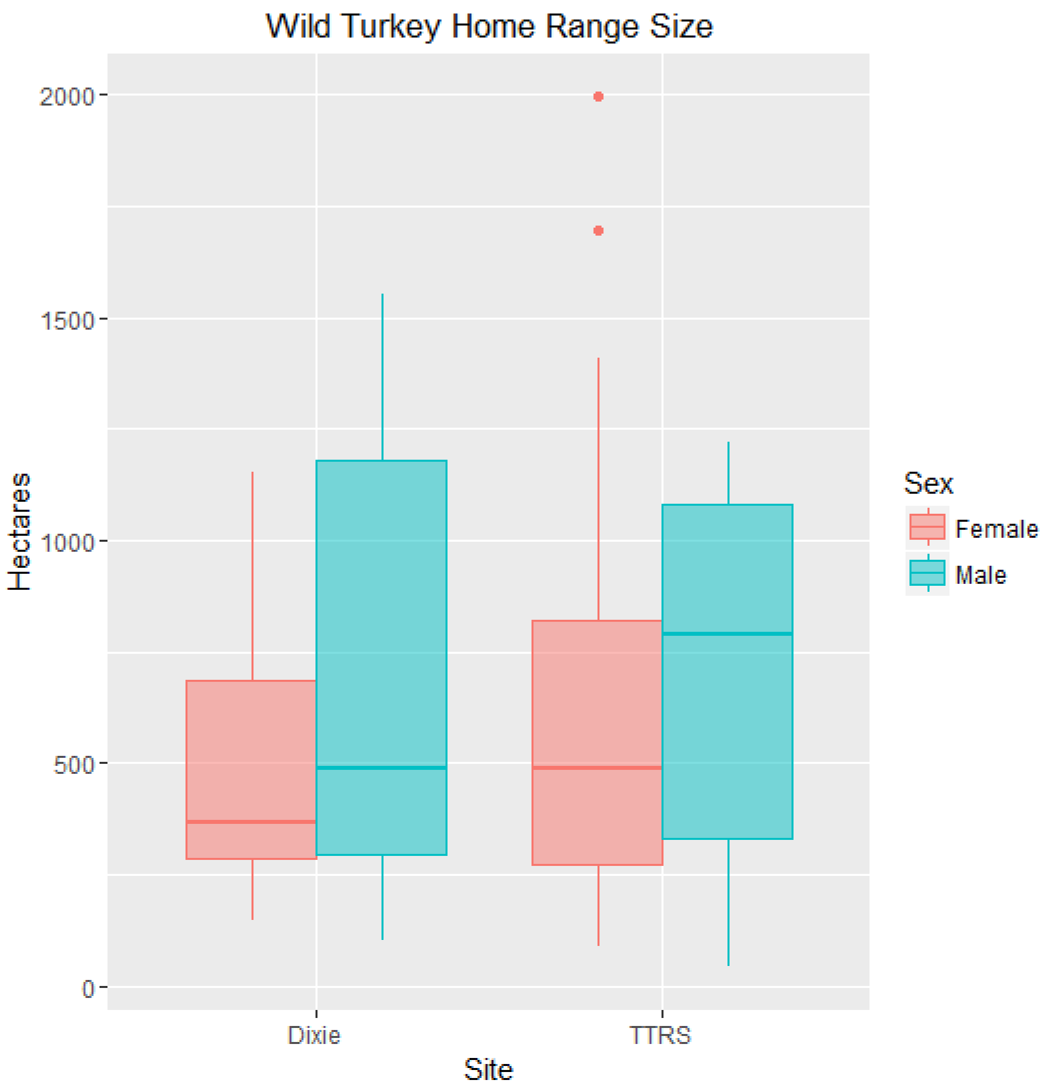

Figure 2.12. Wild turkey home range sizes at Tall Timber Research Station and Dixie Plantation, FL, 2014-2016.

CHAPTER THREE

THE RELATIONSHIP BETWEEN WILD TURKEY GOBBLING ACTIVITY AND NESTING CHRONOLOGY

Abstract

Setting harvest regulations for hunted species poses unique challenges not associated with the management of other species. I examined the relationship between wild turkey (*Meleagris gallopavo*), gobbling activity and nesting across two study sites in the panhandle and one study site in north-central Florida. I equipped hens with tracking devices (either VHF or GPS units) to determine onset of nesting activity and nest incubation. Autonomous recording units were deployed across sites to record daily gobbling activity. Using linear mixed effects modeling I evaluated the relationship of gobbling activity and nesting activity for multiple years and sites. Additionally, I evaluated the correlation of Florida's wild turkey hunting season dates to the peaks of gobbling activity and nesting using incremental response modeling. A weak relationship was detected between the proportion of hens incubating nests and gobbling activity, and gobbling activity varied widely temporally (within a season but not among seasons) and spatially. I also found that current hunting seasons do not correlate well with peak gobbling and nesting activity. Furthermore, optimization models indicated that shifting the hunting season later would better coincide with peaks in gobbling and nest incubation. If the goal of season setting is to coincide with the peak of egg-laying, then the hunting season in the Florida panhandle would need to start one week later. If the goal of season setting is to coincide with peak gobbling and nest incubation, then the season in the Florida panhandle would need to start three weeks later. Evaluating the utility of varying management strategies through structured decision making will aid wildlife policy makers in making responsible management decisions.

Introduction

The wild turkey (*Meleagris gallopavo*), presents a case where limited empirical data on abundance exists to inform harvest regulations proactively and/or adaptively (Williams 1996, Nichols et al. 2007). Limited data exists on gobbling and nesting chronology in Florida. This study provides gobbling and nesting chronology information in unexamined portions of the state and how they compare to the current turkey hunting season framework. To date, researchers have recommended establishing turkey season start dates based on peaks in gobbling activity (Healy and Powel 1999, Norman et al. 2001). But, more than one peak in gobbling activity can occur whereby the first peak is typically associated with winter flock break up and the onset of breeding activity and the second peak typically corresponds to nest incubation (Bailey and Rinell 1967, Bevill 1975, Porter and Ludwig 1980, Hoffman 1990). During nest incubation, increased gobbling activity may occur in response to a decrease in availability of hens to be bred which may increase hunter success (Healy 1992).

Targeting the second peak in gobbling activity instead of the first peak may be a biologically conservative approach because prohibiting hunting during the first peak may mitigate possible negative effects of hunting on breeding (Healy and Powell 1999, Norman et al. 2001). Harvesting too many gobblers early in the season may negatively impact population productivity (Exum et al. 1987, Isabelle et al. 2016). During times of peak nest incubation, when hens may only leave the nest to forage for 1 to 2 hours a day (Green 1982, Williams and Austin 1988), the reduction of available hens for breeding may elicit increased gobbling activity (Bailey and Rinell 1967, Bevill 1975). However, the relationship between gobbling activity and nesting chronology remains largely uncertain. Thus, the utility of establishing hunting season dates from gobbling activity data may be questionable.

Hunters often state that turkey seasons should open earlier (Cartwright and Smith 1990, Taylor et al. 1996, Swanson et al. 2005, Casalena et al. 2010) to increase hunting opportunities when gobbling activity is greatest (SE Wild Turkey Working Group 2016). Southeastern state turkey biologists recommended that hunting season start dates should coincide with peak egg-laying to reduce illegal and inadvertent harvest of hens (SE Wild Turkey Working Group 2016). This approach may also minimize potential effects of gobbler harvest on productivity (SE Wild Turkey Working Group 2016). Ideally, wild turkey hunting seasons should offer a balance between the biological needs of the species and opportunity for hunters (SE Wild Turkey Working Group 2016).

Hunting season establishment based on peak egg-laying and incubation requires accurate knowledge of local nesting activity. Such data are based on expensive monitoring of individual hens that requires capture and use of radio transmitters and some form of tracking technology. Alternatively, if gobbling activity is linked to nesting activity, monitoring gobbling via automated recording units (ARUs) may be a more affordable option for establishing season start dates. Prior studies of nesting and gobbling chronology in Florida have been conducted in the southern and central regions (Williams and Austin 1988). However, no studies have been conducted in the panhandle region of Florida and it remains unclear to what extent the timing of gobbling activity and/or nesting activity varies geographically within the state. My study provides explicit information needed to set biologically-informed hunting season dates in northern Florida. I hypothesized that gobbling activity is affected by the number of available hens. I predicted that an increase in nest incubation will lead to an increase in gobbling activity such that peaks in gobbling activity will accompany peaks in nest incubation. The objectives of this chapter were to 1) determine if there is a relationship between the proportion of hens incubating nests and gobbling activity, and 2) determine how well Florida's turkey hunting season is correlated with gobbling and nesting.

Study Area

During 2014-2016, I conducted research on 6 sites. Tall Timbers Research Station and Land Conservancy (TTRS; 1,568 ha) and Dixie Plantation (Dixie; 3,682) are in Leon and Jefferson Counties, respectively, and are located in the northern panhandle of Florida. Because of turkey movements outside the bounds of my original study sites I gained access to surrounding properties as needed to monitor turkeys. This expanded my research study area for the panhandle region to a much larger area of interest incorporating multiple private properties (14,224 ha; see Figure 3.1). Four additional sites (Lochloosa Wildlife Management Area [LWMA; 4,184 ha], Newnans Lake Conservation Area [NLCA; 3,064 ha], Longleaf Flatwoods Reserve [LFR; 1,156 ha], and Grove Park Wildlife Management Area [GPWMA; 3,065 ha])) were located in Alachua County in north-central Florida, combining for a total of 11,469 ha (Figure 3.2).

TTRS is part of the greater Red Hills region of northern Florida and southern Georgia (Rush et al. 2014). Dixie lies on the eastern edge of the Red Hills region and is bordered along the western boundary by the headwaters of the Aucilla River. Both sites were dominated by upland loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus echinata*), and longleaf pine (*Pinus palustris*) forests (52% of TTRS, 36% of Dixie). Upland pine forests were interspersed with bottomland hardwoods (25% of TTRS, 28% of Dixie), including oaks (*Quercus spp.*), hickories (*Carya spp.*), sweet gum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), and bald cypress (*Taxodium distichum*). Small fallow fields (< 1.3 ha) comprised approximately 13% of TTRS, while Dixie contains a mixture of fallow and agricultural fields (7%). Fallow fields were disked annually in January to produce annual forbs such as ragweed (*Ambrosia artemisiifolia*), partridge pea (*Chamaecrista fasciculata*), and camphorweed (*Heterotheca subaxillaris*). On Dixie agricultural fields were planted in cotton during the spring and planted in wheat during the winter. Other private properties consisted of similar land cover types, but different cover type proportions. Private properties surrounding TTRS totaled 7,190 ha and were primarily comprised of upland pine stands (31%), drains (25%), and planted pines (21%). Other private properties surrounding Dixie totaled 1,759 ha and were dominated by fields (34%), drains (32%), and upland pine stand (14%). Private properties in the Red Hills region were typically burned (45-70% annually) at a relatively small scale (average burn block size = 31.5 ha). TTRS was hunted by approximately 7 staff and Dixie was hunted by approximately 10 lease hunters.

LWMA is managed for public hunting by the Florida Fish and Wildlife Conservation Commission (FWC). The majority of the property was covered in pine plantations primarily consisting of slash pine (*Pinus elliottii*), interspersed with other cover types (Williams and Austin 1988). The plant communities present on the property include pine flatwoods forests (wet flatwoods, mesic flatwoods, shrub flatwoods), sandhill, baygall, hammock (hydric hammock, mesic hammock, xeric hammock), cypress dome, basin marsh, depression marsh, floodplain swamp, basin swamp, and black water stream. Lochloosa Lake sits in the middle of LWMA and is Florida's 14th largest lake (St. Johns River Water Management District 2007). LWMA is managed as a general access wildlife management area (WMA) during turkey season for hunters with a wild turkey and WMA stamp. There was considerable hunting pressure on the property based on observations by project staff.

NLCA is a mixed use property that provides non-consumptive outdoor recreational opportunities along with limited hunting within 1,102 ha that is managed by FWC as Hatchet Creek WMA (HCWMA). The predominant land cover types were floodplain swamp and mesic flatwoods. The property also contained xeric hammock, sandhill, wet flatwoods, depression marsh, mesic hammock, and dome swamp land cover types (St Johns River Water Management District 2013). HCWMA is managed by FWC as a limited entry quota hunt area. Turkey hunters must apply and be selected to receive a quota hunt permit to hunt turkeys on the area. The property was limited to 5 hunters per hunt. Hunts lasted 3 days and occurred 4 times annually during turkey season, with 1 of the 4 hunts designated as a youth hunt. Hunting pressure on the area was considered low with a maximum of 60 hunter days occurring each season.

LFR is open to the public as a non-consumptive outdoor recreation area. Hunting was not allowed. The predominant land cover type was mesic flatwoods. Sandhills, and xeric hammocks in the uplands and floodplain and basin swamps at lower elevations were also present.

GPWMA was predominately comprised of pine plantations. Live oaks (*Quercus virginiana*) covered scattered ridges and areas of low elevation feature flood plain and basin swamps. GPWMA is managed as a as a limited entry recreation use area by FWC. Hunters must apply and be selected to receive a recreation use permit to hunt turkeys, or any other species, on the area. The property was limited to 200 recreational use permits. Hunting pressure on the area was considered moderate based on staff observations.

Methods

Trapping

We captured turkeys on TTRS during March-April of 2014, January 2015 and January-February 2016, on Dixie Plantation during January-February of 2016, and on Alachua County sites during February and November-December of 2015 and January-February 2016. We used rocket nets based on Bailey et al.'s (1980) recommendations. Once captured, we placed turkeys in individual cardboard holding boxes until they were processed. Age and sex were determined through methods described by Williams and Austin (1988). Weight was recorded for all turkeys. Uniquely numbered rivet style leg bands were placed on each turkey's right tarsi. I equipped a subset of hens with rechargeable Quantum 4000E Mini Bird backpack style global positioning system (GPS) units (Telemetry Solutions. Concord, CA) in 2014 and 2015. Transmitter dimensions were 10.5x5x1.9 cm and weighed 110 g. In 2016, hens were equipped with a combination of non-rechargeable Quantum 4000 Mini Bird Backpack GPS units (Telemetry Solutions.

Concord, CA) and Minitrack backpack style GPS units (Lotek Wireless, Inc. Newmarket, Ontario, Canada). Non-rechargeable Quantum 4000 Mini Bird Backpack dimensions were 7 x 4 x 4 cm and weighed 107 g. Minitrack unit dimensions were 9.6 x 3 x 3.5 cm and weighed 97 g. I equipped a subset hens with AWE-turkey very high frequency (VHF) backpack style transmitters (American Wildlife Enterprises. Monticello, FL). Transmitter dimensions were 6.5 x 1.9 x 2.3 cm and weighed 90 g. Turkeys were released immediately after processing at the site of capture. All GPS units were also equipped with VHF monitoring capabilities. All VHF and GPS units were equipped with an 8-h mortality switch. Across all years 33 hens were captured at TTRS, 15 hens were captured at Dixie Plantation, and 60 hens were captured at the Alachua County sites.

Monitoring

I programmed GPS units using software to balance battery life of the GPS units with adequate sampling of daily movements and roost locations. In 2014 and 2015, GPS transmitters were programed to acquire 9 fixes a day for 4 days/week and 1 fix a day for the remaining 3 days/week. On days when transmitters acquired 9 fixes, the schedule was to obtain a fix at midnight, 0730, 0800, 0830, 0930, 1430, 1530, 1630, and 1730 h. On the remaining days, GPS units acquired 1 fix per day at midnight. In 2016, I scheduled Telemetry Solutions GPS units to acquire locations every 30 min from 0730-1800 h excluding 0900 from March 27-June 11. I programmed Lotek GPS units to acquire locations at 0730, 0830, 0930, 1430, 1530, & 1630 h from time of capture to March 26. From March 27 - June 11 or until a hen’s brood failed locations were taken every 30 min from 0700 to 2000 h. All units turned off by July 20. I downloaded Telemetry Solutions

GPS in the field using ultra high frequency (UHF) transmissions, a 3-element mini-yagi antenna and laptop computer. Lotek GPS units were downloaded in the field with a 3-element yagi antenna and a handheld command unit via VHF signal. I estimated error rates for Telemetry Solutions units by conducting static testing through a balanced sampling design in 3 cover types (field, upland pine, drain).

I located VHF radio-tagged turkeys 3-5 times per week from March until July of each year via triangulation (White and Garrott 1990). Locations were obtained by listening for transmitter signals from permanent listening stations (n = 1009 stations) with a 3-element yagi antenna and a TR-5 telemetry receiver (Telonics, Inc., Mesa, AZ) or a Biotracker telemetry receiver (Lotek, Newmarket, Ontario, Canada). Listening station locations were recorded using a Trimble GPS unit and applying differential correction to obtain sub meter accuracy. Some locations were pre-determined by marking the center of road intersections across the study area. Others were added as needed, marked on an Ipad Mini (Apple. Cupertino, CA) using the app PDFMaps (Avenza Systems Inc. Toronto, Ontario, Canada) and recorded with a Trimble GPS unit at a later date. A compass bearing was taken from a listening station in the direction the signal strength was the strongest. Three bearings were recorded within a 10-min interval. Bearings were uploaded into the software Location of a Signal (Ecological Software Solutions LLC. Hegymagas, Hungary) to determine location coordinates. When a hen was located in the same specific location for 3 consecutive days, I assumed that hen was incubating a nest. Using the VHF receiver and 3- element yagi antennae, nests of VHF-equipped hens were approached within 50 m. Azimuths were taken from 4 locations surrounding the nest site in the direction of the nest. These locations were marked with flagging and the azimuths recorded to aid in finding the nest post-hatching. Initially the same procedures were conducted for hens with GPS units, but this procedure was soon abandoned because the recorded GPS locations were very accurate and nests could be found directly from those coordinates. After hatching, the number of hatched eggs was counted. A nest was considered successful if 1 or more eggs hatched.

Measuring Gobbling Activity

Gobbling activity was recorded using automatic recording units (ARUs, using SongMeter SM2+, Wildlife Acoustics, Inc., Concord, MA; Colbert 2015). ARUs were equipped with SMX-II weatherproof acoustic microphones (Wildlife Acoustics, Inc., Concord, MA). ARUs recorded acoustic data to a 16 GB SD card and ran on 4 D batteries and 2 AA batteries. Batteries and SD cards were changed monthly. ARUs were placed randomly on trees (approximately 4.5 m above the ground) across TTRS and Dixie, and were systematically placed across study sites in Alachua County. ARUs were placed in the same locations each year. Sites in Alachua County had extraordinarily thick understory growth in places that would have prevented hiking with a ladder. ARUs were placed in such a fashion that distribution was balanced across the sites, while ensuring ARU locations were accessible. ARUs were placed at least 450 m apart, as the effective gobble detection radius for SongMeter SM2 units has been reported as 209 m (Colbert 2013). Recorders were programmed to record at a sample rate of 8 kHz which recorded a bandwidth between 0 kHz and 4 kHz to a .wave file. Gobbles have a frequency <2 kHz (Colbert 2015). I also changed the recording channel from Stereo to Mono-R given the use of a single microphone (Colbert 2015). ARUs were programmed to record for 10-min intervals at the following times: 30 min before sunrise, sunrise, 30 minutes after sunrise, one hour after sunrise, one hour and 30 minutes after sunrise, and 2 hours after sunrise, for a total of 6 recordings with a duration of 1 h of recordings each day. In 2014 8 ARUs were placed in the field on March 18th and recorded until May 17th at TTRS. Additionally, in 2014 6 ARUs were placed in the field on March 26th and recorded until May 31st at LWMA. In 2015, 8 ARUs were deployed on Dixie from February 21st until May 31st. Additionally 8 ARUs were deployed on TTRS, 6 on LWMA, 5 on hunted portion of NLCA, 3 on LFR, and 2 on GPWMA from February 1st until May 31st. In 2016, 8 ARUs ran on TTRS, 8 on Dixie, 9 on NLCA (5 on hunted portion and 4 on non-hunted portion), 6 on LWMA, 3 on LFR, and 2 on GPWMA from February 1st until May 31st.

Data Analysis

I used Raven Pro software, Version 1.5 (Bioacoustics Research Program 2014) to create audio spectrograms of the recorded data. Spectrogram settings were left at the default Hann window function with 256 samples, time grid hop size of 128 with 50% overlap, and frequency grid spacing at 31.3 Hz. Color scheme was adjusted to cool and brightness was adjusted to 55. I used horizontal zoom until the x-axis was at a 2s interval. Given that automated detection protocols yielded numerous false positives and false negatives, I visually inspected all spectrograms for turkey gobbles. When a prospective gobble was visually identified, the sound was played for auditory confirmation of the presence of a gobble. The number of gobbles per recording was tallied to determine the number of gobbles per day on each site. Daily gobble count data were then divided by the number of functioning recorders across the respective site for each day. By employing this method, gobbling activity was standardized as the average number of gobbles per recorder and the effects of ARU mechanical failures were minimized. A peak in gobbling activity was defined as any time period gobbling activity exceeded 4 times the average amount of daily gobbling for the site and year. A peak in nesting activity was defines as any time period the proportion of hens incubating nests exceeded 0.3. Given the amount of files generated by our sampling scheme (n = 50,010 files), it was impractical to manually process every Song Meter recording. Therefore, I processed all of the data from 2014 (n = 4,540 files) and used the 2014 results to inform the minimum number of files needed to accurately depict gobbling activity on a given day. The first 3 recording periods were used in the analysis of TTRS and Dixie data, and the first 4 recording periods were used in the analysis of Alachua County data.

I obtained hourly weather data from the National Oceanic and Atmospheric Administration from the nearest airport for each study site, which included wind speed, precipitation, and cloud cover. Kienzler et al. (1996) suggested that increased wind speed, cloud cover, and precipitation negatively impacted gobbling activity. Therefore, to reduce the effects of weather on gobbling activity, I only used days in which wind speed did not exceed 6 kmph, the sky was clear, and there was no precipitation during the time of recordings. By truncating data to days with good weather, I isolated those factors most pertinent to my hypotheses and removed variability associated with weather.

The relationship between gobbling activity and nesting activity

I used linear mixed effects modeling in program R (R 2017, ver 3.2.3, package nlme) to estimate effects of year, proportion of incubating hens, site, and week on gobbling activity. Proportion of incubating hens was determined by dividing the total number of hens equipped with GPS or VHF units incubating a nest on a given day, by the number of hens that were being monitored for each respective site. My response variable was gobbling activity standardized for each site (average gobbles heard per recorder). Predictor variables included: year, site, proportion of incubating hens, and week. I treated year as a fixed effect whereas site and week were treated as random effects. Proportion of incubating hens was given an exponential variance structure to improve homogeneity (Zuur et al. 2009). I also added an auto-regressive moving average (ARMA) term to the residuals of week to account for temporal auto-regressive correlation (Zuur et al. 2009). Because initial examination of data indicated non-normality and heterogeneity, gobbling activity was log-transformed (Zuur et al. 2009). Proportion of incubating hens was included as a linear and polynomial term. To aid in the interpretation of regression coefficients, the continuous variable, proportion of incubating hens was standardized using unit normal scaling (Montgomery and Peck 1992).

I developed a set of 9 candidate models describing gobbling activity a priori, based on biological insight and hypotheses to be tested (Anderson et al. 2000, Burnham and Anderson 2002). I used model selection and an information-theoretic approach to determine the best approximating model(s) (Anderson et al. 2000, Burnham and Anderson 2002; Table 3.3). I used Akaike's Information Criteria (AIC), adjusted for small sample bias (AIC_c) and model weights to determine the best approximating model(s) given our data set and candidate set of models and to evaluate explicit hypotheses (Burnham and Anderson 2002). The AIC_c scores of all candidate models were compared and the model with the lowest AIC_c score was deemed to be the most strongly supported of the models evaluated. Akaike weight (w_i) was used to assess the probability each model was the best model of the 9 candidate models evaluated (Anderson et al. 2000, Burnham and Anderson 2002). Model fit was evaluated by visual examination of normality and residual plots as described in Zuur et al. (2009).

Hunting Season Dates

I used incremental response modeling to optimize gobbling activity and nesting activity based on hunting season date. An incremental response modelling approach uses one or alternate-response models to evaluate competing or alternative models compared to a control (Radcliffe and Surry 1999, Lo 2002, Hansotia and Rukstales 2002, Larsen 2010). For the control model, I used the regular Florida hunting season for each year and site combination (approximately mid-March to end of April) as the binomial response variable (0 = no hunting; 1 = hunting for each day) and I used the logit link function to build a model with proportion of nesting hens, standardized gobbling activity (number of gobbles recorded per ARU), site (treated as random effect) and year (treated as random effect) as predictor variables.

In addition, to the control model, I built 8 additional models where all predictor variables remained constant but the response variable shifted one week later (7d) for 6 incremental models and shifted one week earlier for 2 incremental models. For example, incremental (alternative) model 1, hunting season started and ended one week later than the control model. I kept the duration constant for each incremental model. Therefore, the only modification to incremental models was shifting of the hunting season on the response variable. To compare models, I measured the predicted values of the response variable from the incremental (alternative) model and compared them to the control model and calculated a difference score. Thus, each alternative (HS_A) model was built separately and compared to the control model (HS_C):

$$\widehat{Y_A} = X_A \hat{\beta}_A$$

$$\widehat{Y_C} = X_C \hat{\beta}_C$$

Then both models were used to calculate predicted values from the entire data set (D) as:

$$(D = D_A \cup D_C).$$

The difference scores were obtained from the predicted values as:

$$\widehat{DS}_i = \left(Y_A - \widehat{Y_C}\right)_i \; for \; i = 1, 2, \ldots, n$$

The model with the greatest positive value of $\widehat{DS}$ was considered the optimal model, and in this case the optimal hunting season that maximized gobbling activity and the proportion of hens incubating. I used generalized linear mixed modeling in program R (R 2017, ver 3.2.3, package lme4) to fit all models and perform model validation via examination of residual and normality plots.

Results

The relationship between gobbling activity and nesting activity

Ninety-one percent of gobbling activity occurred within the 10-minute recordings that started 30 min before sunrise, sunrise, and 30 min after sunrise at TTRS in 2014

(Figure 3.3) and 88% of gobbling activity occurred within the 10-minute recordings that started 30 min before sunrise, sunrise, 30 min after sunrise, and 1 h after sunrise at LWMA in 2014 (Figure 3.4). Between all study areas, 30,952, 10-min recordings were processed, totaling 5,158 h and 40 min of recording time (Table 3.1). In 2014, based on my definition of what constituted a peak in gobbling, there was a single peak in gobbling activity at TTRS during the last week of April (Figure 3.5) and a large peak in Alachua County the 2nd quarter of April and 2 smaller peaks during the beginning and end of April (Figure 3.10). In 2015, there was also a single peak in gobbling activity at TTRS spanning the last week of April and the first week of May (Figure 3.6), a double peak at Dixie the first week of May (Figure 3.8), and Alachua County exhibited many peaks with some occurring in March, April, and May (Figure 3.11). During 2016, there were 3 peaks of gobbling activity at TTRS with the first 2 spanning the last week of March and the first week of April. The third and largest peak in gobbling activity occurred during the first week of May (Figure 3.7). Additionally, there were 4 peaks in gobbling activity at Dixie in 2016, and the first occurred the last week of March, the second and third occurred the 2nd quarter of April, and the final peak occurred during the 2nd quarter of May (Figure 3.19). Gobbling activity in Alachua County peaked five times during 2016, the first occurred during the first week of March, the second occurred the first week in April, the third and fourth between the 3rd to 4th quarter of April and the final peak occurred the start of the 2nd quarter of May (Figure 3.12).

Through the course of the study 34 nests were located at TTRS, 16 at Dixie, and 27 in Alachua County (Table 3.2). Peak egg-laying, defined as the mean date of initial nest initiation (SE Wild Turkey Working Group), occurred at Dixie on 3/30/2016. Peak egg-laying occurred in Alachua County on 4/19/15 and 3/28/16. At TTRS, peak egg-laying occurred 3/20/14, 4/10/15, and 3/23/16.

At TTRS in 2014, 2 peaks in nest incubation occurred through the first 2 quarters April and again from the last quarter of May through the 1st quarter of June. The following year a single peak in incubating hens occurred from the 3rd quarter of April through the 3rd quarter of May. In 2016, 3 peaks occurred during approximately the same time periods as the previous 2 years (Figure 3.13). At Dixie, there was a single peak in nest incubation during the 1st half of May (Figure 3.14). In Alachua County, no peaks occurred in 2015. In 2016, 2 peaks occurred during the 3rd quarter of April and again through the 3rd quarter of May (Figure 3.15).

Among all candidate models the model containing the proportion of incubating hens, site, and week was best supported and most plausible (AIC_c = 372.91, AIC_c weight [w_i] = 0.88, Table 3.3). This model was 12.6 times more likely than the next best model. No other model had substantial support ($\Delta AIC_c \leq 2$, Table 3.3; Burnham and Anderson 2002). Models with polynomial poroportion of incubating hen terms ($ProportionNesting^2$ and $ProportionNesting^3$) had considerably less support ($\Delta AIC_c > 4$, w_i = 0.07 and w_i = 0.03 respectively, Table 3.3). The global model also had considerably less support (ΔAIC_c = 9.27, w_i = 0.01, Table 3.3) and was 88 times less likely than the top model. The last model having considerably less support contained year, proportion of incubating hens, site, and week (ΔAIC_c = 9.52, w_i = 0.01, Table 3.3). The model containing year, site, and week and both models lacking a site term were deemed implausible (w_i = 0.00,

Table 3.3). Model parameter averaging indicated proportion of incubating hens was not strongly related to gobbling activity in that the confidence interval for the coefficient overlapped 0 (model-averaged estimate: $\beta_{ProportionNesting}$ = 0.24[95% CI = -0.12 – 0.61], Table 3.4).

Hunting Season Dates

A shift in hunting season by 1 and 2 weeks earlier or later did not significantly improve optimization of capturing both gobbling activity and proportion of incubating hens; however, a 3-week shift in hunting season correlated better to nesting and gobbling activity (~20% greater; Figure 3.22). A shift in 4 weeks or greater resulted in significant reduction (-22% to -52%) in optimization of hunting during peak gobbling and peak nesting (Figure 3.22).

Discussion

Gobbling activity can be influenced by a multitude of factors, and can be highly variable across sites. State biologists often try framing turkey hunting seasons to encompass the peaks of nesting activities (i.e. nest initiation, or incubation) to mitigate potential negative effects on productivity associated with increased gobbler harvest. Additionally, hunting seasons that encompass the bulk of gobbling activity satisfy hunter mandates. I hypothesized that gobbling activity was affected by the number of hens that were available to breed given that hens are not available to breed when they are incubating a nest. There was a weak positive relationship between the proportion of hens incubating nests and gobbling activity. An objective of this study was to determine if Florida’s turkey hunting season is correlated with gobbling activity and nesting. Through the course of this evaluation a method was developed for biologists to evaluate whether current hunting season structures are meeting their objective criteria or would better meet their goals through timing or structural season changes. My results revealed that if the goal of season setting was to match the timing of the season with the bulk of gobbling activity and peak hen incubation, starting the hunting season 1-2 weeks earlier or delaying the hunting season 1-2 weeks would not improve the match with incubation or gobbling activity significantly. If the goal of season setting is meant to correlate with the peak of egg-laying, the match would be much closer for Alachua County but the season would still be one week too early in the Florida panhandle. This study answers the desire by state turkey biologists for empirical data on how gobbling activity and incubation varies by region and the utility for using these parameters for establishing the turkey hunting season (Williams and Austin 1988, Kienzler et al. 1996, Miller et al. 1997b, Whitaker et al. 2005).

Temporal variation in gobbling activity existed among my study sites, similar to (Palumbo 2010). Although the assumption of two peaks in gobbling activity has been used for establishing spring wild turkey hunting seasons in some states (Bailey and Rinell 1967, Bevill 1975, Porter and Ludwig 1980, Hoffman 1990), two peaks may not exist throughout the wild turkey’s range or in hunted populations (Norman et al. 2001, Lehman et al. 2005). Miller et al. (1997b) and Colbert (2013) reported only a single peak in gobbling activity during their studies in Mississippi and Georgia. They also reported the single peak did not coincide with the peak of nest incubation by hens. Miller et al. (1997b) reported peak gobbling corresponded to the initiation of egg-laying and Colbert

(2013) reported peak gobbling coincided with peak nest initiation. Although not completely in agreement with Miller et al. (1997b) and Colbert (2013), a weak relationship between gobbling activity and the proportion of incubating hens did exist, hen incubation rates did not appear to be a primary driver of gobbling activity on my study sites (see Figures 3.16-21).There were some instances where peaks in gobbling activity coincided with peaks in the proportion of incubating hens in April and early May, but in March there were some peaks in gobbling activity prior to the onset of any nesting. These inconsistencies explain why proportion of incubating hens was not a strong predictor of gobbling activity during my study.

Spatial variation best explained uncertainty in gobbling activity in my study indicating that gobbling activity varied between my three sites. A commonality between the 2 lowest scoring candidate models was their lack of a site term indicating site is important in explaining variation in gobbling activity. Many factors may contribute to variation in gobbling activity across sites including weather, land cover types, hunting pressure, turkey abundance, hen density, forage availability, and availability of suitable cover. Land cover types varied considerably across my study areas. TTRS and Dixie were comprised primarily of open pine cover types, whereas Alachua County sites were characterized by swamps with thick vegetation and commercial pine plantations with considerably greater tree densities. Dense vegetation can affect the ability of sound to travel. The thick vegetation present on Alachua County sites could have resulted in the lower amount of gobbles recorded in Alachua County compared to TTRS and Dixie. Colbert (2013) demonstrated site parameters such as distance to water on the property level can influence gobbling activity. Whitaker et al. (2005) and Palumbo (2010) demonstrated latitude could predict gobbling activity at the regional level. Many studies have investigated the effects of weather and hunting pressure, but results have been conflicting as to their effects (Scott and Boeker 1972, Kienzler et al. 1996, Miller et al. 1997a, Miller et al. 1997b, Colbert 2013).

Further evidence of spatial variation in gobbling activity was exhibited whereby peaks in calling activity occurred earlier on Alachua County sites when compared to TTRS and Dixie. Florida's turkey hunting season is currently divided into 2 separate hunting zones (southern 1/3 of the state and northern 2/3 of the state). Given our results that gobbling activity varied spatially, splitting the northern management zone into two (Panhandle and north-central) may provide for a better match for hunting seasons with peak gobbling activity across the state. Future research should aim to disentangle the effects of site and regional influences on gobbling activity.

SE state turkey biologists stated that the initiation of the turkey hunting season should be timed with the peak in egg-laying (SEWTWG 2016), whereas others have suggested the season would best be timed to coincide with incubation (Bailey and Rinell 1967, Hoffman 1990, Kurzejeski and Vangilder 1992). Results from the incremental response modeling revealed that FWC could better correlate the bulk of gobbling activity and nest incubation with turkey hunting season by shifting the start and end of the season 3 weeks later. Later starting dates may be better than early if harvesting too many gobblers early in the season can negatively impact productivity (Exum et al. 1987, Isabelle et al. 2016). In our study, however, we saw no evidence that productivity was impaired by the removal of gobblers from the population during the early nesting season. The proportion of hens nesting and the hatchability of the eggs appeared to be within the range of values reported for other southeastern turkey populations.

Turkey researchers and biologists have also suggested that the season should coincide with the peak of gobbling to promote hunter satisfaction and to enable greater hunter success (Kurzejeski and Vangilder 1992). In one half of the sites/years monitored in this study (4 of 8 site-years), however, the peak in gobbling activity actually occurred after the conclusion of Florida's turkey hunting season. This result underscores the need for additional data collection in the process of setting turkey hunting seasons in Florida. Survival data, hunter satisfaction survey data, harvest data, and other information could additionally be collected and incorporated into incremental response models, structured decision models (Gregory et al. 2012) or Bayesian Belief Networks (BBNs; Marcot et al. 2001) to afford state agencies a robust, reliable means for guiding wild turkey harvest regulations. The updating of information from year to year would make these models much more flexible and adaptable among, and within states rendering a better conservation tool for managing wild turkeys and other exploited species.

Management Implications

If the goal in Florida is to allow hunting during the bulk of gobbling and nest incubation, FWC could shift the current season 3 weeks later. If the goal is to have the season start coincident with the egg-laying period, the current season appears to be reasonably timed for Alachua County but is still one week early for the panhandle of Florida. Furthermore, wild turkey harvest regulations may be better timed to coincide with gobbling and nesting if the northern zone was further divided into a north-central and panhandle regions. Additional research on gobbling activity and nesting could be conducted across central Florida to help further delineate turkey management zones. Formalizing decisions in a structured decision making format will facilitate future management considerations, conservation decisions and help to guide turkey hunting seasons and harvest regulations using an adaptive, responsible approach.

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Appendix

Table 3.1. Number of files and hours of Song Meter data processed to determine wild turkey gobbling activity at Tall Timbers, Dixie, and Alachua County, FL, 2014-2016.

Study Area	Number of 10-min Files	Duration of Recordings
TTRS	7,602	1,267 h
Dixie	4,336	722 h 40m
Alachua Co.	19,014	3,169 h

Table 3.2. Nesting information for wild turkey at Tall Timbers, Dixie, and Alachua County, FL, 2014-2016. Start of nesting season was defined as the first day continuous incubation began. End of nesting season was defined as the day the last nest hatched or failed.

Site	Year	Number of Hens Monitored	Percentage of Hens Nesting	Total Number of Nests	Number of Renests	Initial Nest Success	Overall Nest Success	Start of Nesting Season	End of Nesting Season
TTRS	2014	2	50%	2	1	0%	0%	03-Apr	06-Jun
TTRS	2015	9	77.78%	8	1	42.86%	37.50%	29-Mar	13-Jun
TTRS	2016	15	86.67%	24	11	15.38%	25%	01-Apr	25-Jun
Dixie	2016	13	69.23%	16	7	33.33%	18.75%	02-Apr	19-Jun
Alachua Co.	2015	16	18.75%	3	0	66.67%	66.67%	14-Apr	03-Jun
Alachua Co.	2016	24	87.50%	24	3	38.09%	33.33%	25-Mar	13-Jun

Table 3.3. Model selection statistics for candidate regression models used to test competing hypotheses of wild turkey gobbling activity at TTRS, Dixie, and Alachua County, FL 2014-2016

Model	*K*	AIC_c	ΔAIC_c	w_i	Log-likelihood	Percentage of maximum w_i
ProportionNesting+(1|Site)+(1|Week)	8	372.91	0.00	0.88	-177.97	100.00%
ProportionNesting+ProportionNesting²+(1|Site)+(1|Week)	9	377.94	5.04	0.07	-179.37	7.95%
ProportionNesting+ProportionNesting²+ProportionNesting³+(1|Site)+(1|Week)	10	379.83	6.92	0.03	-179.17	3.41%
Global Model	11	382.18	9.27	0.01	-179.19	1.14%
Year+ProportionNesting+(1|Site)+(1|Week)	10	382.42	9.52	0.01	-180.47	1.14%
Year+(1|Site)+(1|Week)	9	384.77	11.86	0.00	-182.78	0.00%
Year+ProportionNesting+ProportionNesting²+(1|Week)	8	405.65	32.74	0.00	-194.34	0.00%
ProportionNesting+(1|Week)	7	405.95	33.04	0.00	-195.6	0.00%

Table 3.4. Table of model coefficients for effects of proportion of incubating hens on gobbling activity at TTRS, Dixie, Alachua County, FL.

Model Parameter	Coefficient	SE	95% CI	
			Lower	Upper
Intercept	0.04	0.21	-0.38	0.46
ProportionNesting	0.24	0.19	-0.12	0.61
$\text{ProportionNesting}^2$	0.53	0.32	-0.09	1.16
$\text{ProportionNesting}^3$	-0.14	0.78	-1.66	1.39
Year (2015)	0.01	0.18	-0.34	0.35
Year (2016)	0.04	0.13	-0.21	0.28

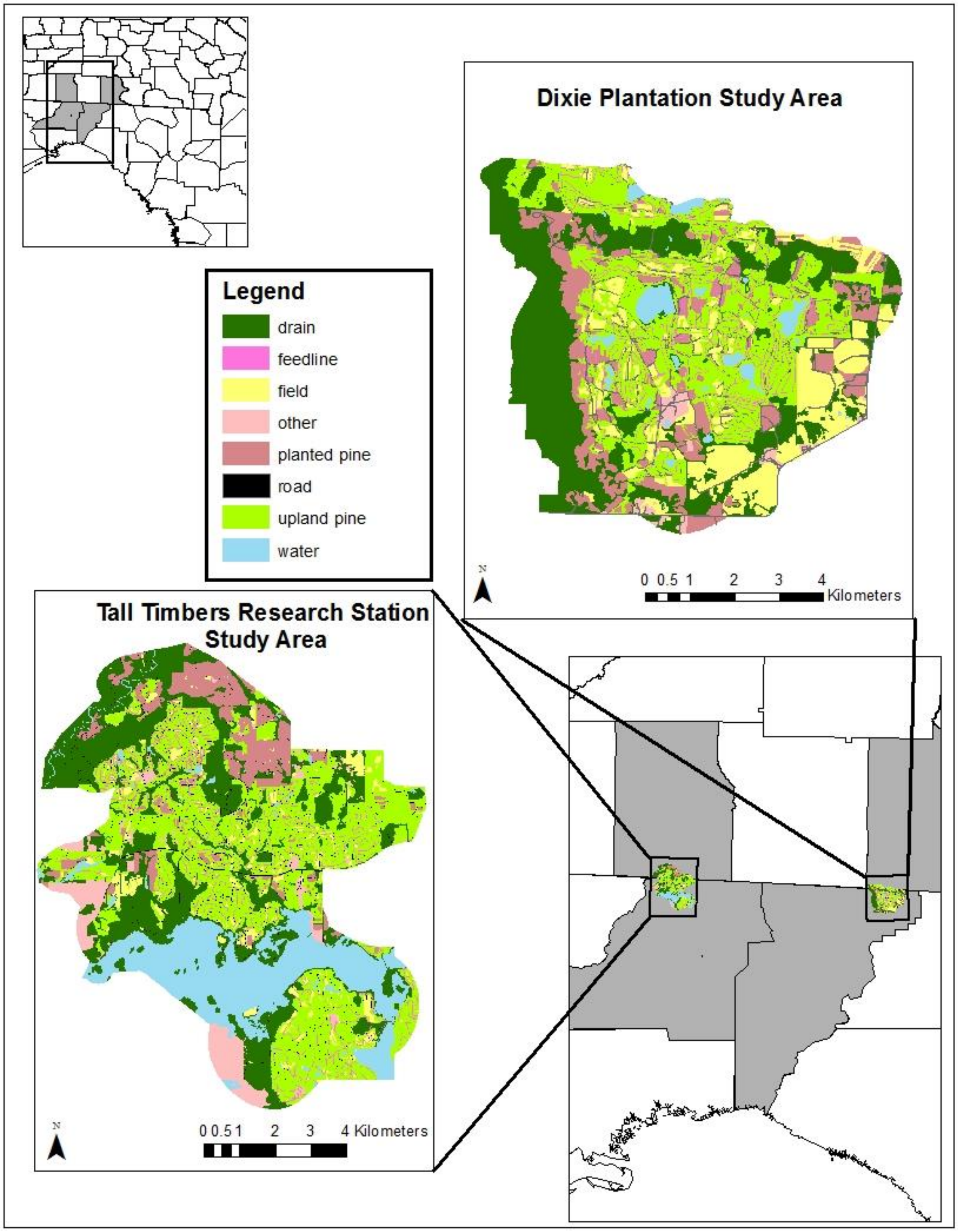

Figure 3.1. Maps of Tall Timbers Research Station and Dixie Plantation, FL study areas.

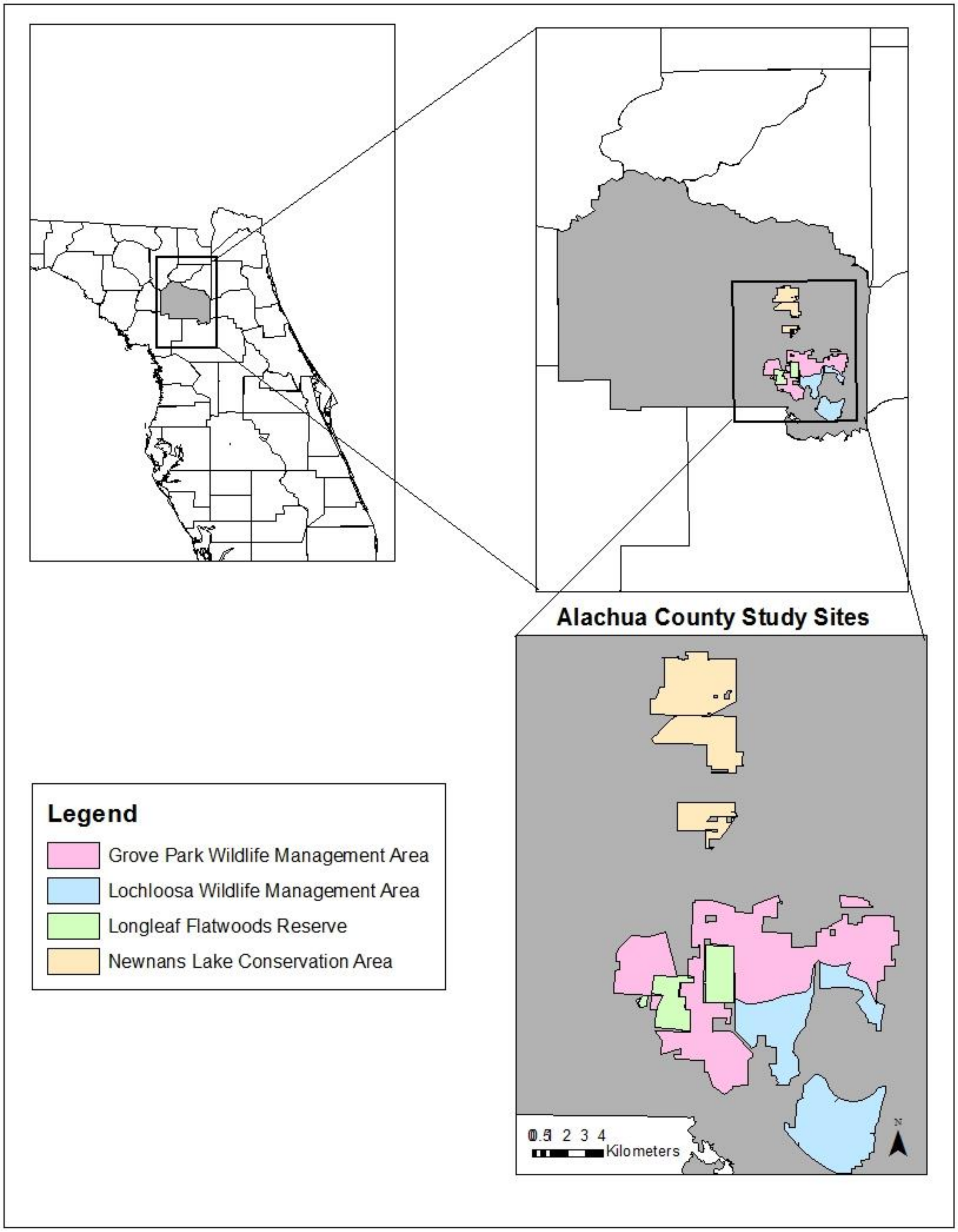

Figure 3.2. Maps of Alachua County, FL study areas.

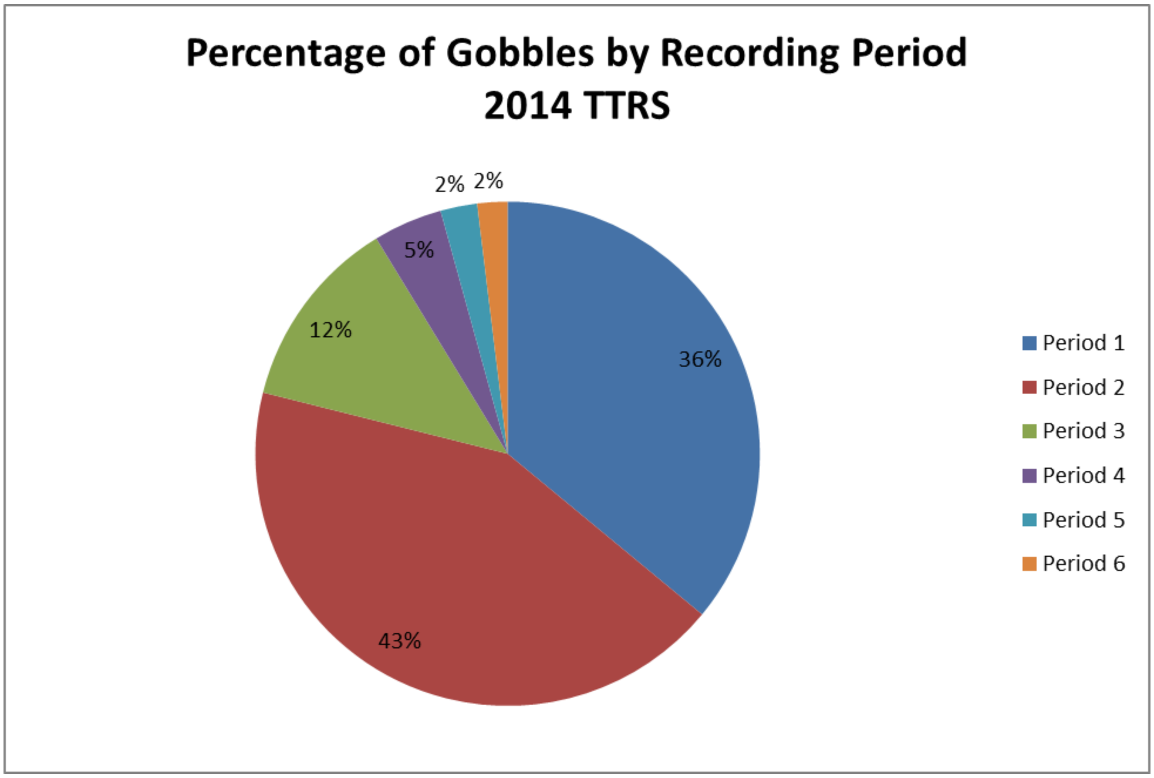

Figure 3.3. Percentage of gobbles based on order of daily Song Meter recordings at Tall Timber Research Station, FL, 2014. Period 1 began 30 min before sunrise and ended 20 min before sunrise. Period 2 began at sunrise and ended 10 min after sunrise. Period 3 began 30 min after sunrise and ended 40 min after sunrise. Period 4 began 1 h after sunrise and ended 1 h and 10 min after sunrise. Period 5 began 1 h and 30 min after sunrise and ended 1 h and 40 min after sunrise. Period 6 began 2 h after sunrise and ended 2 h and 10 min after sunrise.

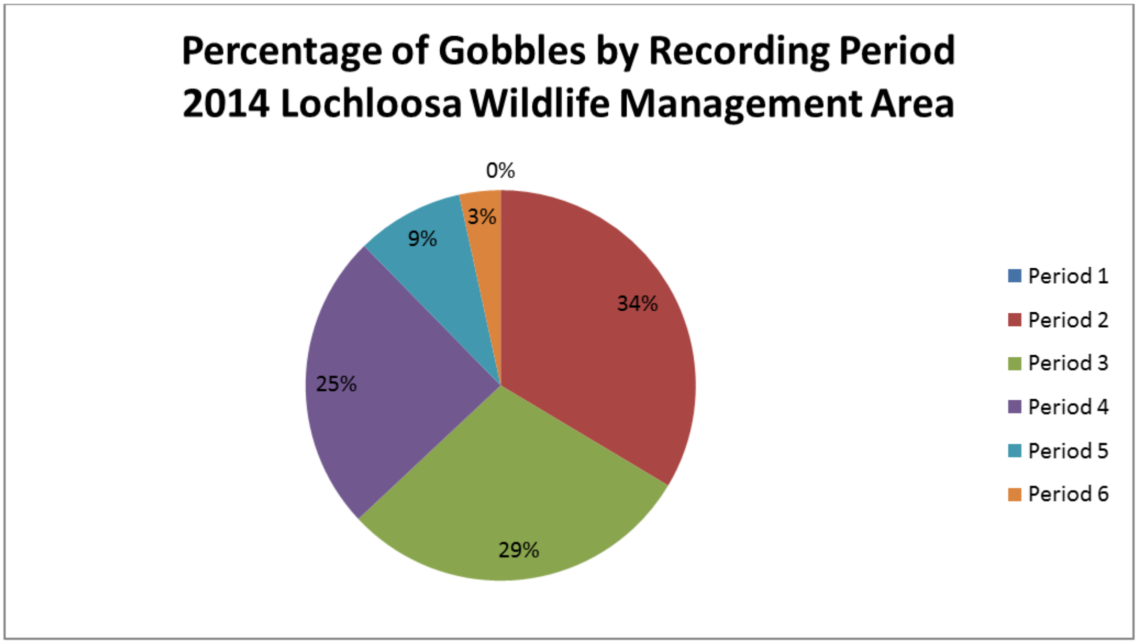

Figure 3.4. Percentage of gobbles based on order of daily Song Meter recordings at Lochloosa Wildlife Management Area, Alachua County, FL, 2014. Period 1 began 30 min before sunrise and ended 20 min before sunrise. Period 2 began at sunrise and ended 10 min after sunrise. Period 3 began 30 min after sunrise and ended 40 min after sunrise. Period 4 began 1 h after sunrise and ended 1 h and 10 min after sunrise. Period 5 began 1 h and 30 min after sunrise and ended 1 h and 40 min after sunrise. Period 6 began 2 h after sunrise and ended 2 h and 10 min after sunrise

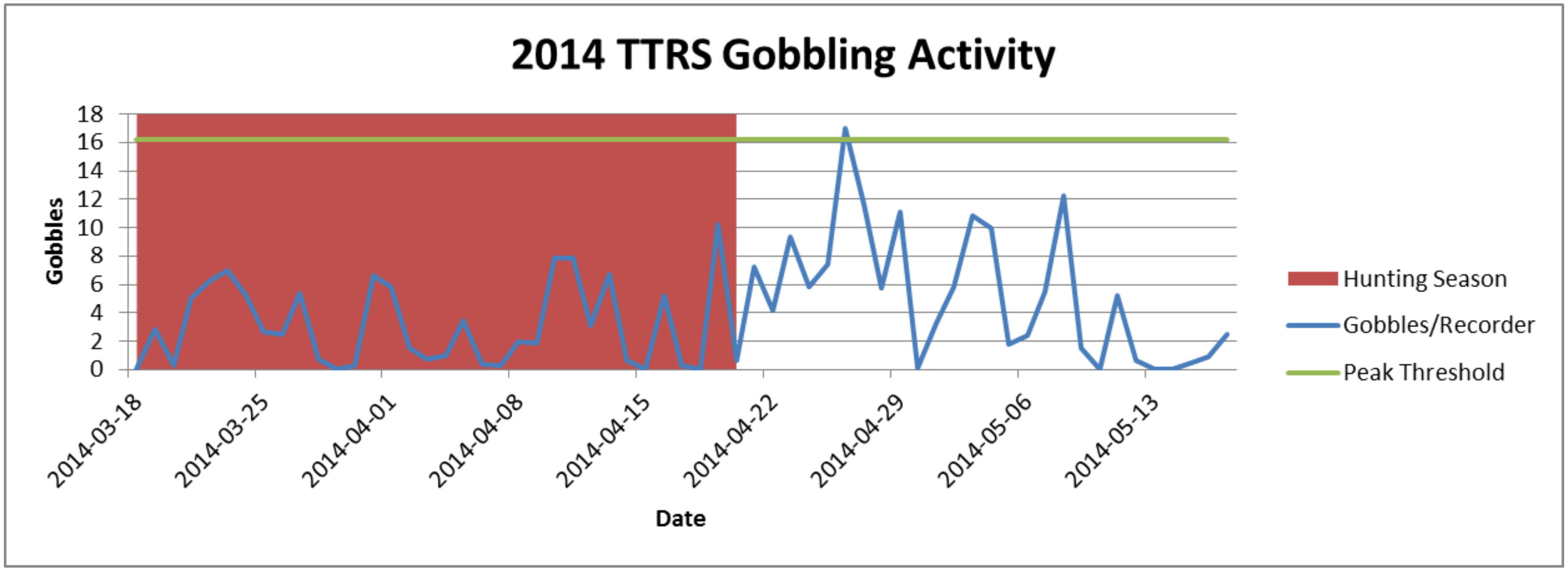

Figure 3.5. Wild turkey gobbling activity in relation to hunting season at Tall Timbers, FL, 2014

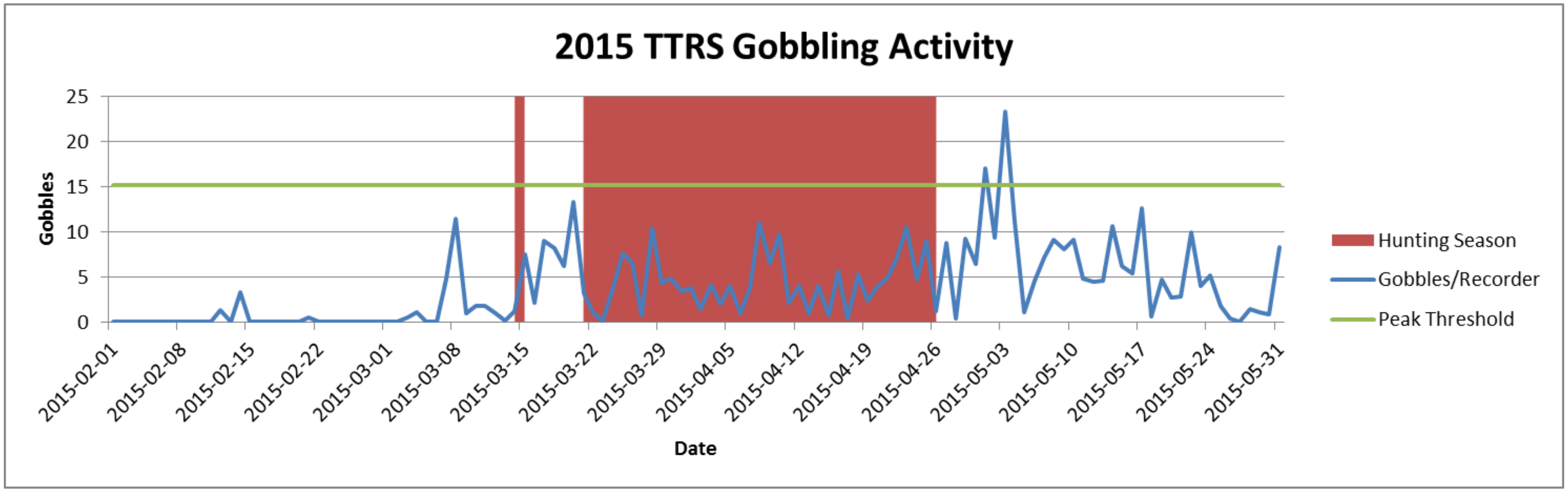

Figure 3.6. Wild turkey gobbling activity in relation to hunting season at Tall Timbers, FL, 2015

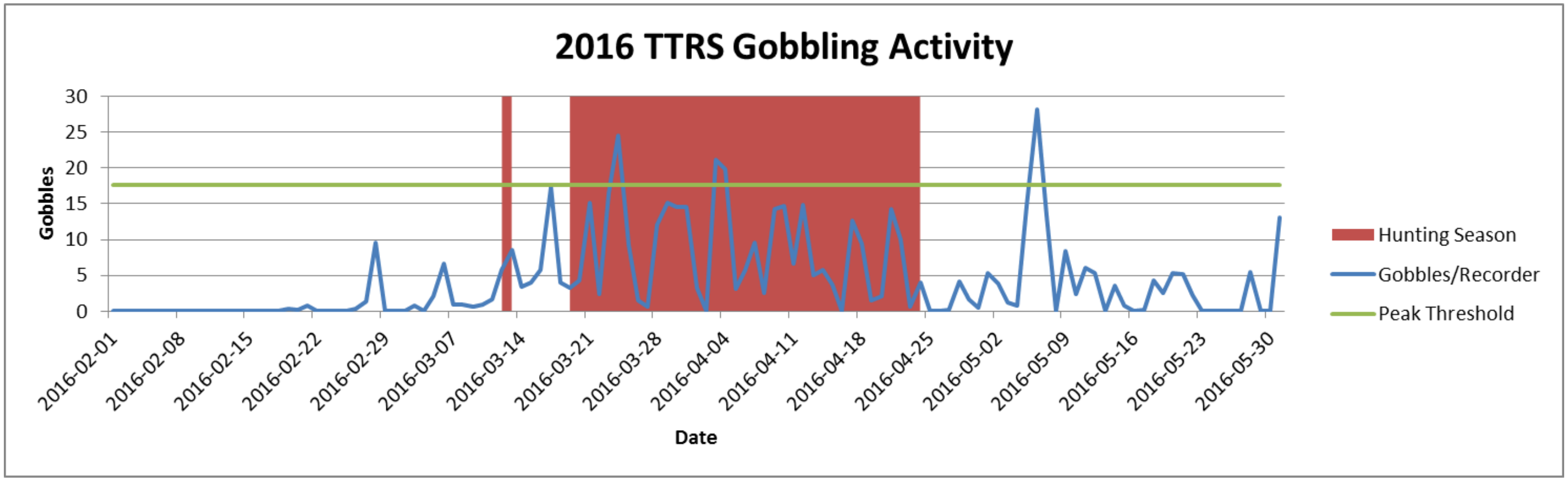

Figure 3.7. Wild turkey gobbling activity in relation to hunting season at Tall Timbers, FL, 2016.

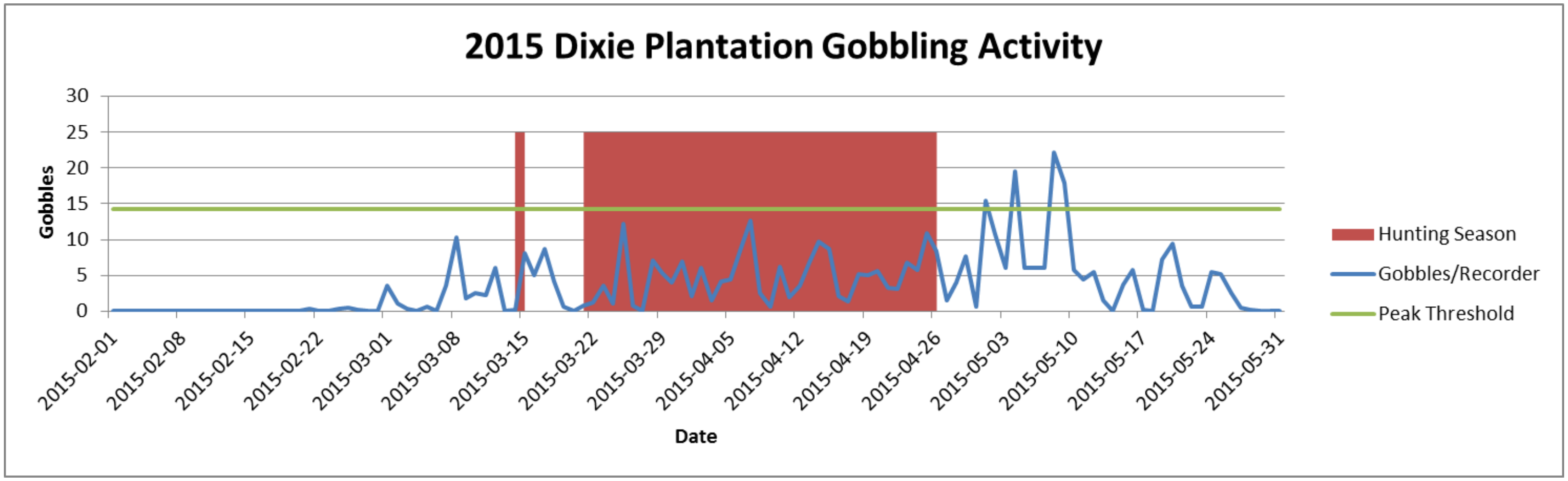

Figure 3.8. Wild turkey gobbling activity in relation to hunting season at Dixie Plantation, FL, 2015.

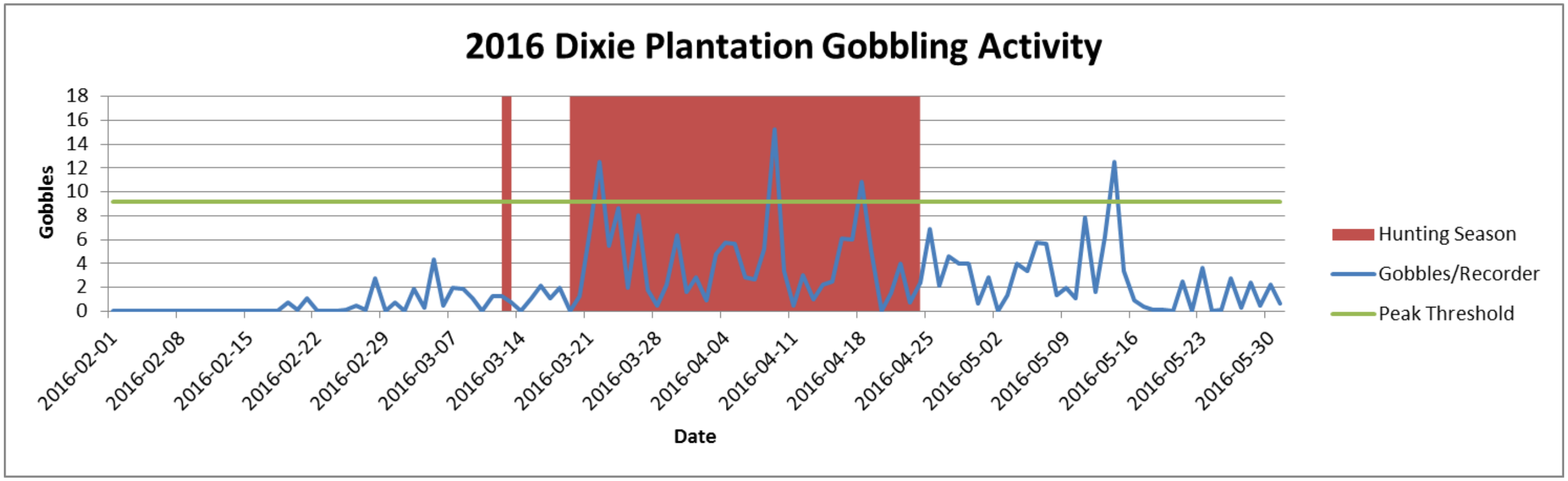

Figure 3.9. Wild turkey gobbling activity in relation to hunting season at Dixie Plantation, FL, 2016.

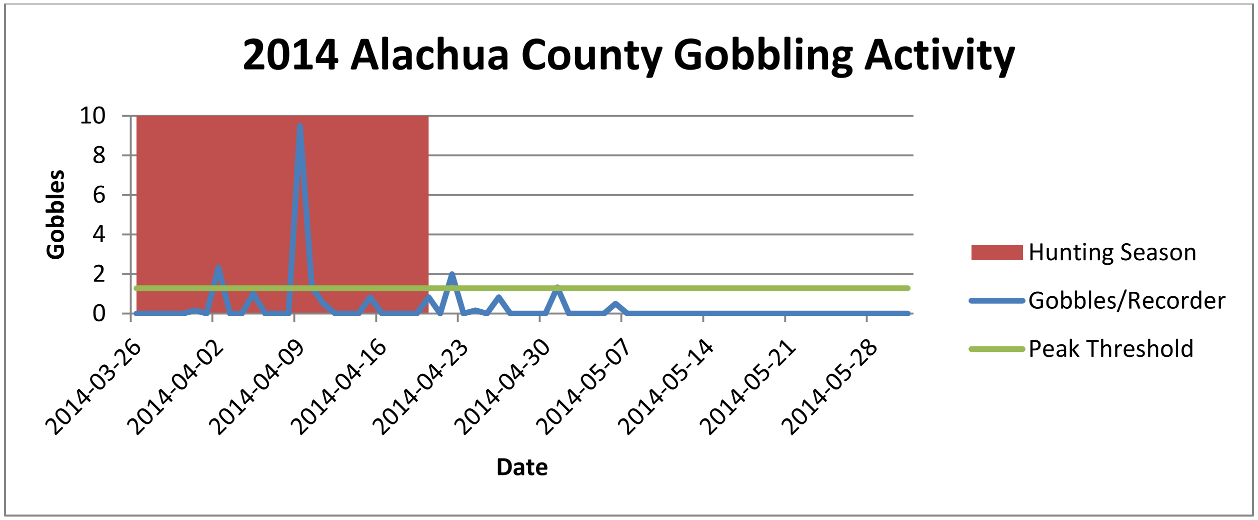

Figure 3.10. Wild turkey gobbling activity in relation to hunting season, Alachua County, FL, 2014.

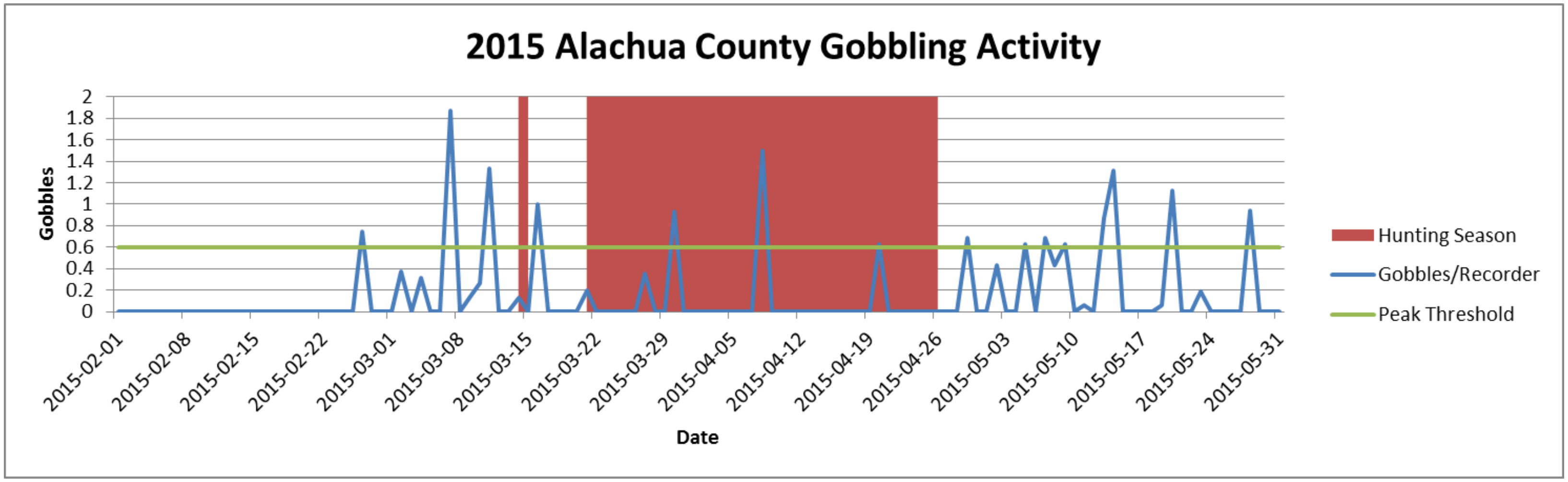

Figure 3.11. Wild turkey gobbling activity in relation to hunting season, Alachua County, FL, 2015.

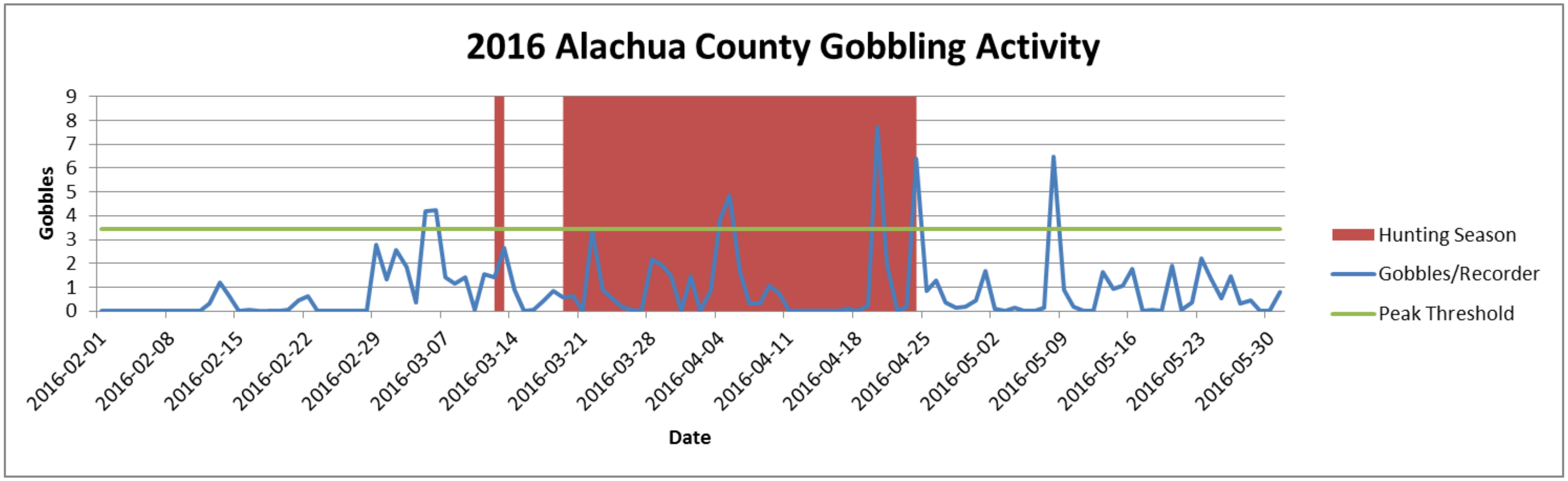

Figure 3.12. Wild turkey gobbling activity in relation to hunting season, Alachua County, FL, 2016.

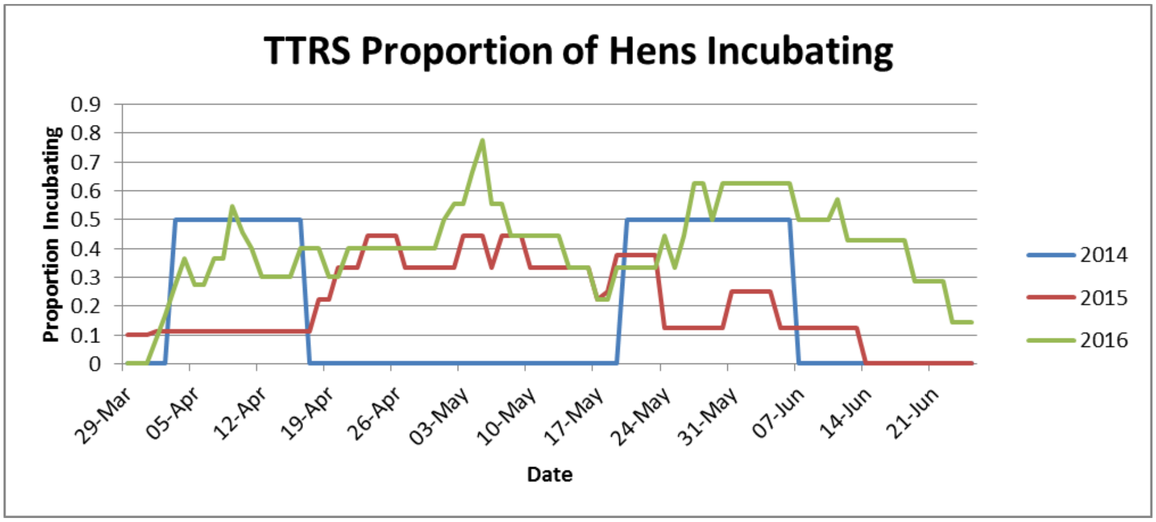

Figure 3.13. Proportion of wild turkey hens incubating, Tall Timbers, FL, 2014-2016.

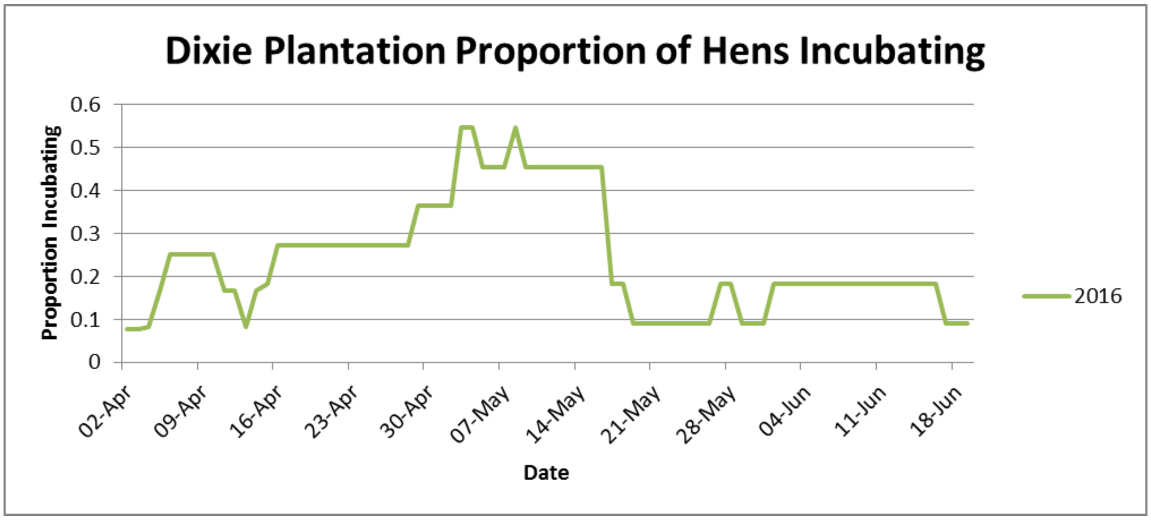

Figure 3.14. Proportion of wild turkey hens incubating, Dixie Plantation, FL, 2016.

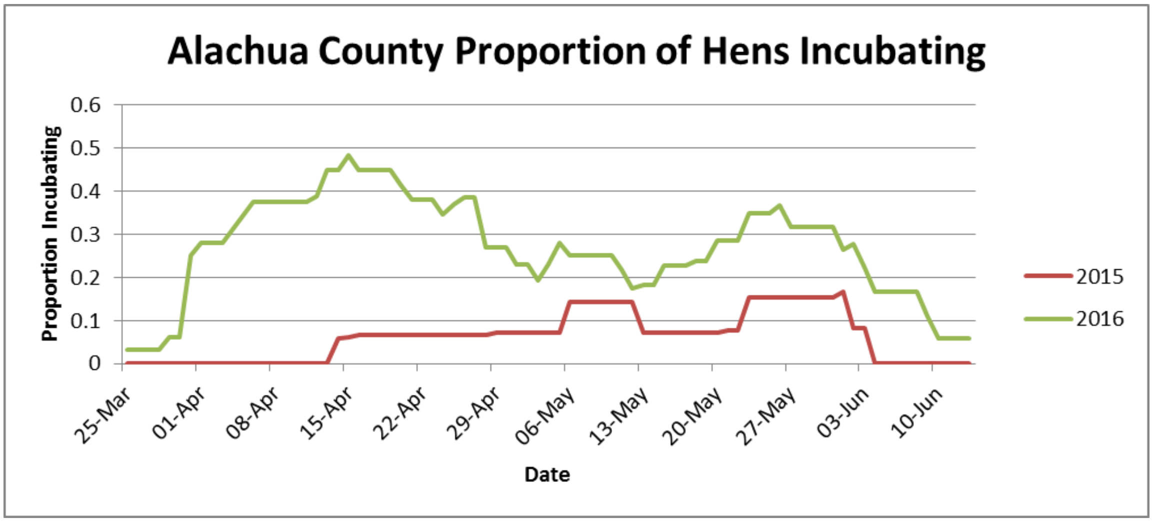

Figure 3.15. Proportion of wild turkey hens incubating, Alachua County, FL 2015- 2016.

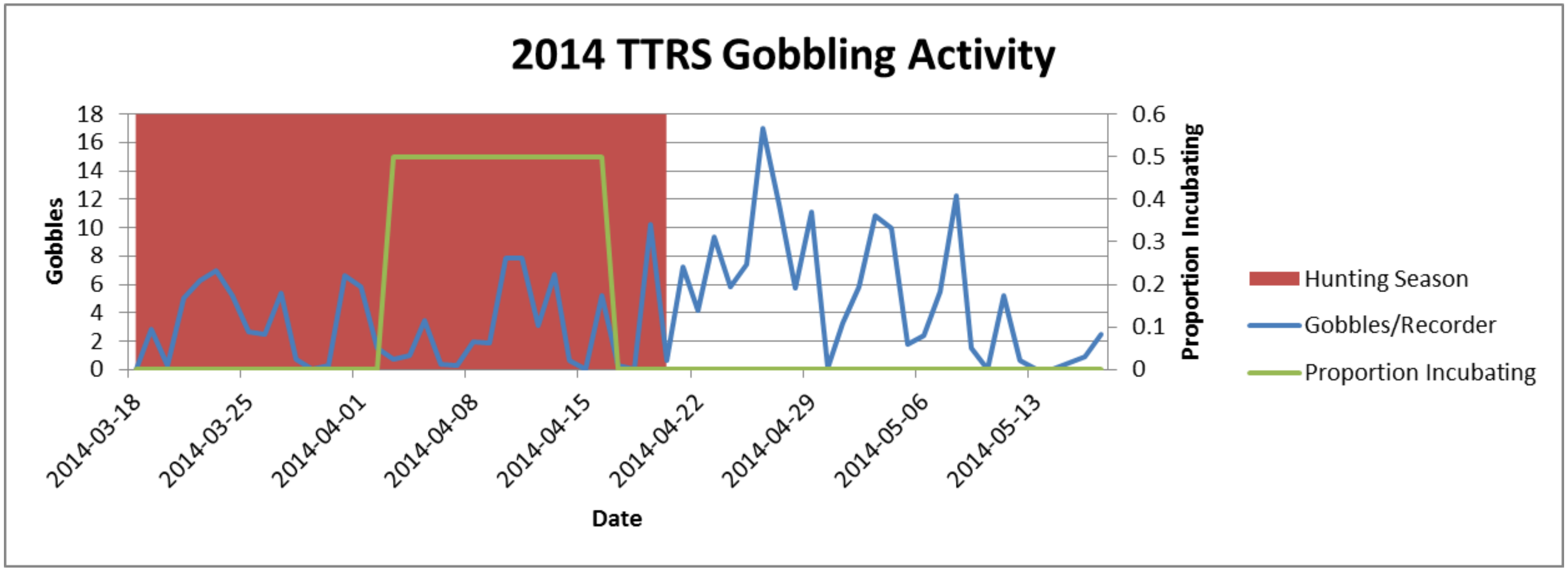

Figure 3.16. Gobbling activity in relation to the proportion of wild turkey hens incubating and hunting season, Tall Timbers, FL 2014.

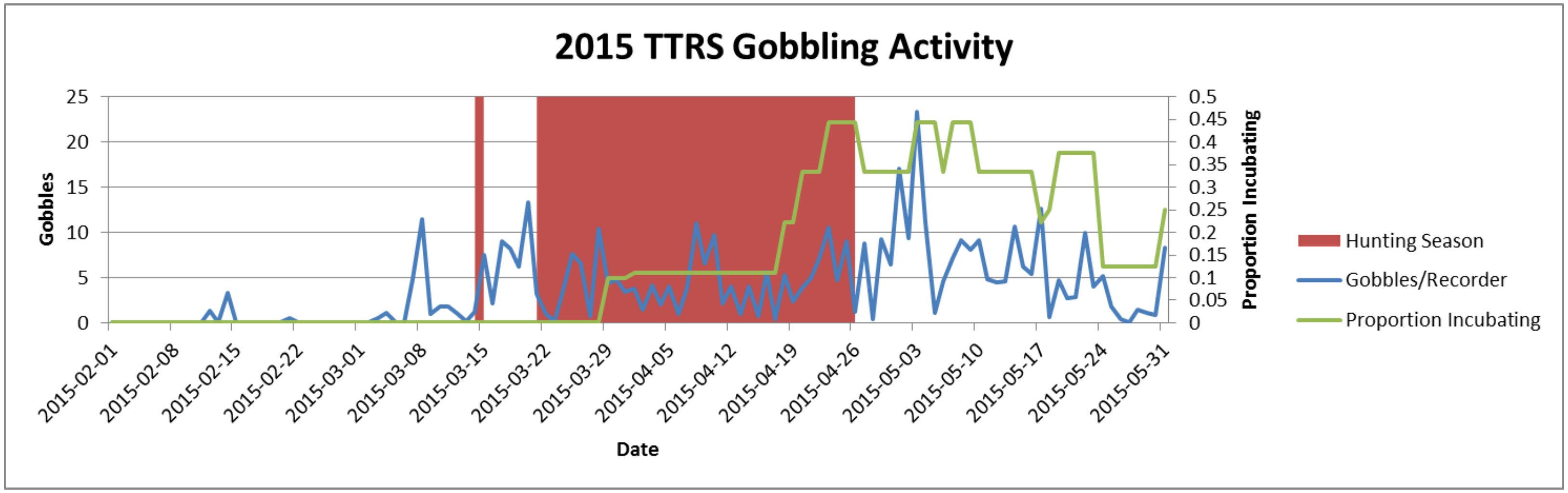

Figure 3.17. Gobbling activity in relation to the proportion of wild turkey hens incubating and hunting season, Tall Timbers, FL 2015.

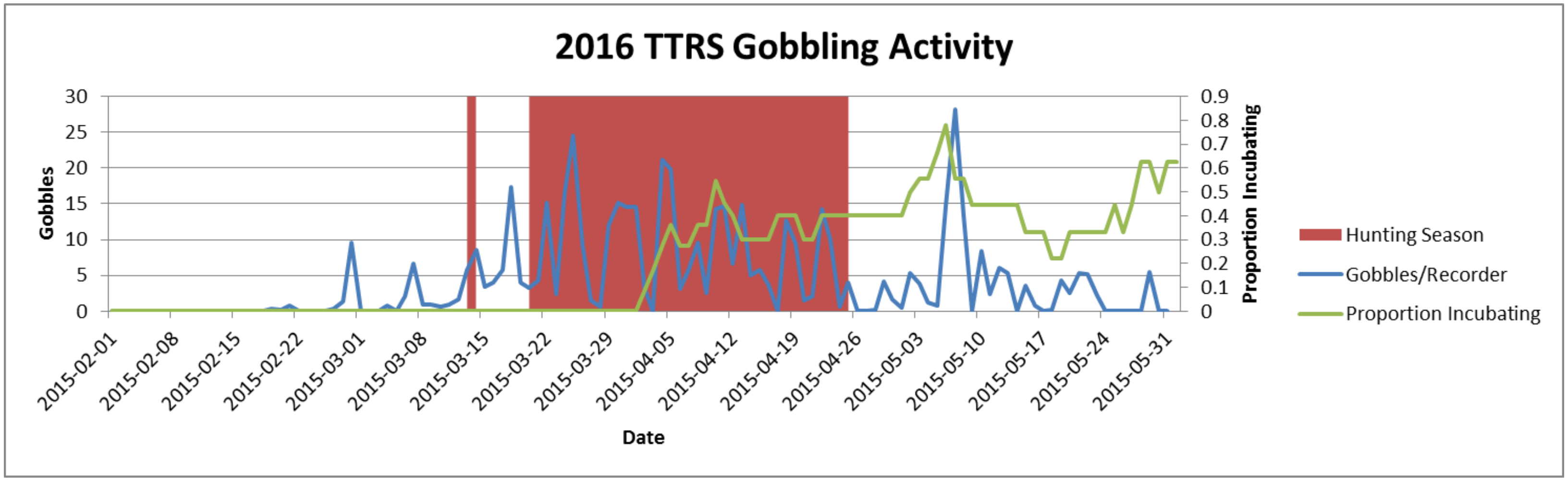

Figure 3.18. Gobbling activity in relation to the proportion of wild turkey hens incubating and hunting season, Tall Timbers, FL 2016.

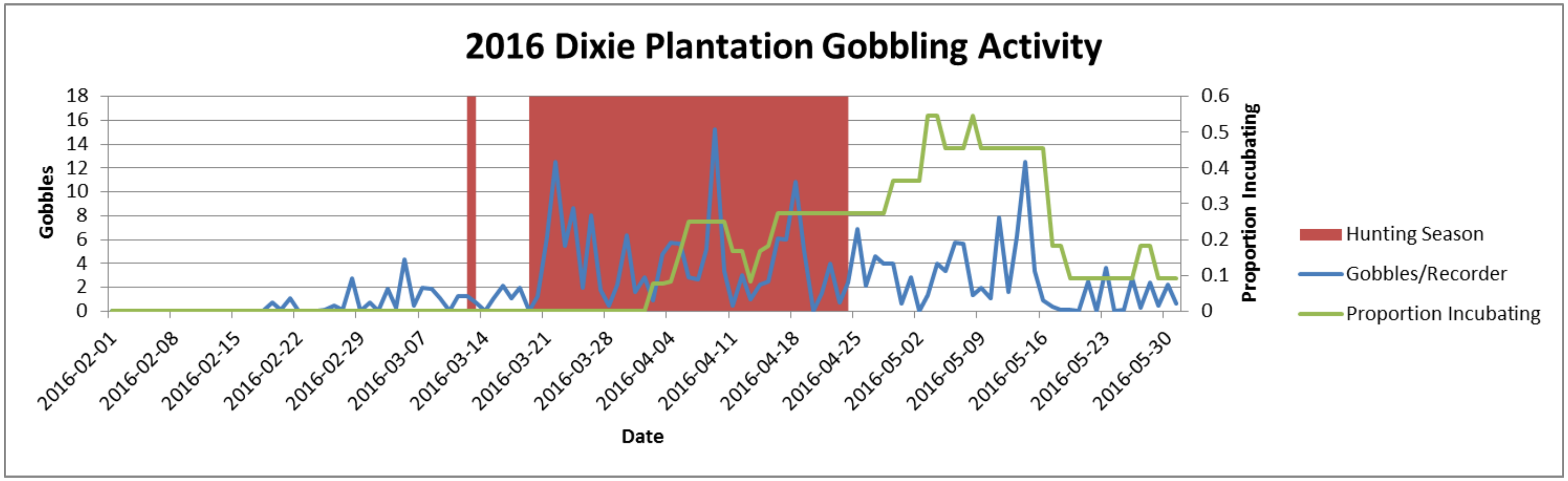

Figure 3.19. Gobbling activity in relation to the proportion of wild turkey hens incubating and hunting season, Dixie Plantation, FL 2014.

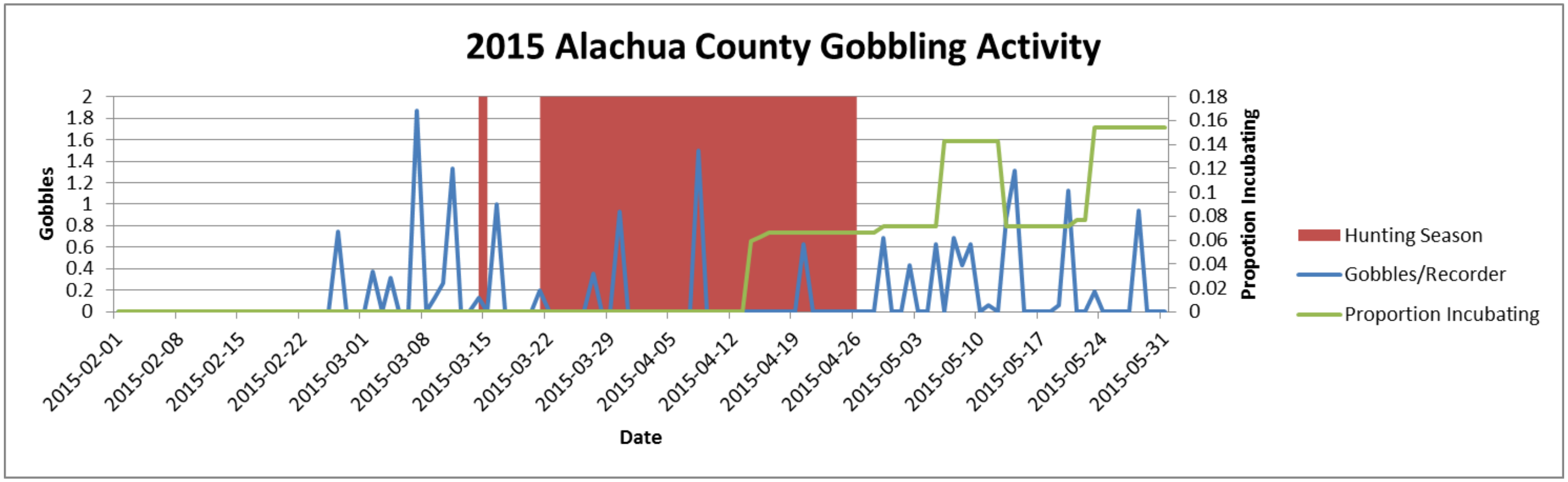

Figure 3.20. Gobbling activity in relation to the proportion of wild turkey hens incubating and hunting season, Alachua County, FL 2015.

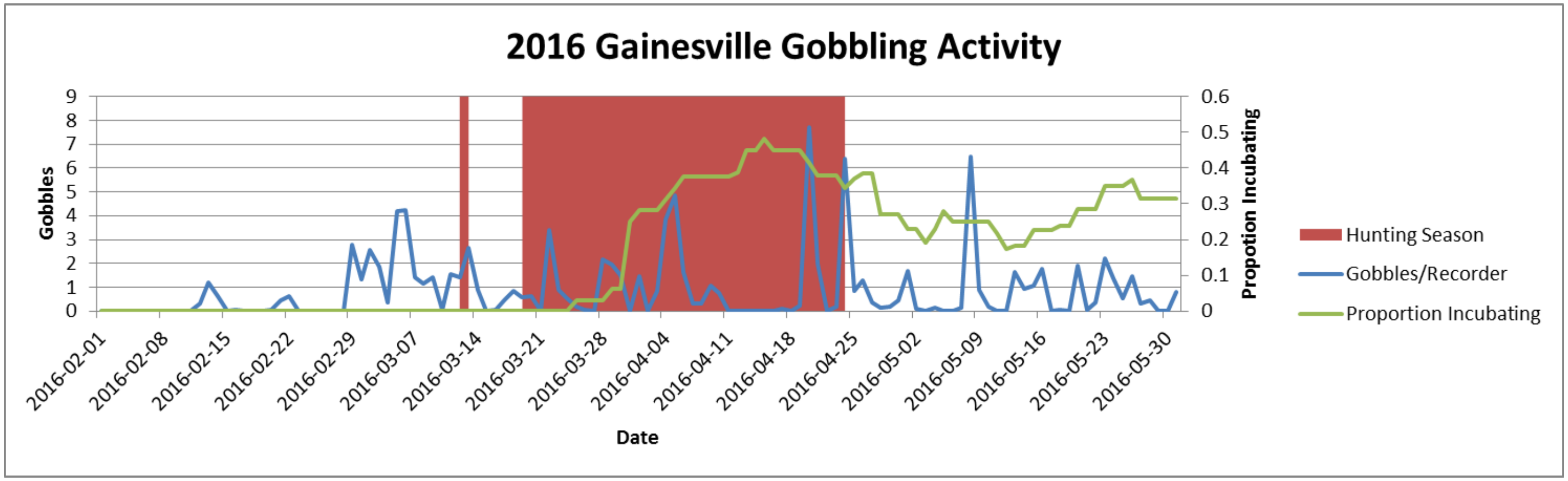

Figure 3.21. Gobbling activity in relation to the proportion of wild turkey hens incubating and hunting season, Alachua County, FL 2016.

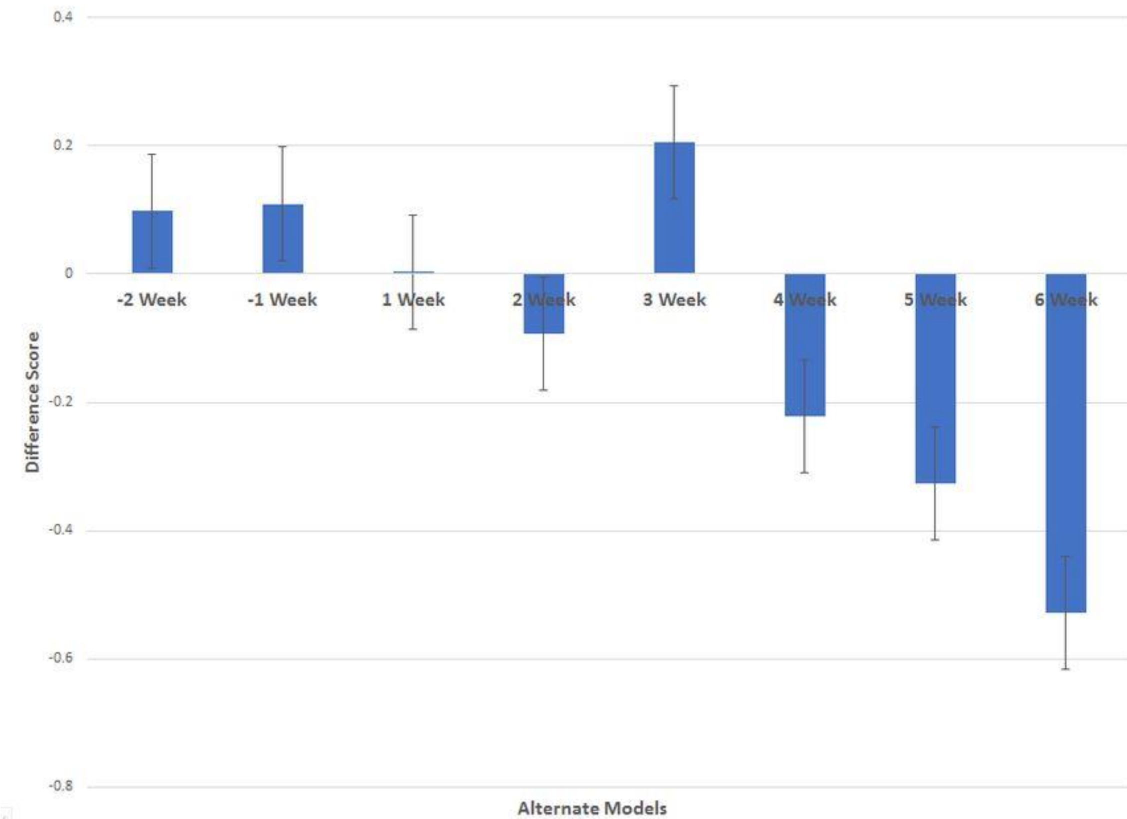

Figure 3.22. Model results for hunting season date comparison optimizing gobbling activity and nesting activity using, incremental response modeling with the baseline comparison (control) model using regular hunting season dates as compared to each incremental model (n = 8) shifting hunting season start and end dates by one week. Difference scores (+95% Cis) greater than zero indicate improvement over the control.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

The primary objectives of this thesis were to 1) describe the patterns of turkey resource use on a food-subsidized landscape; 2) determine how the patterns of resource use changed as related to the distance to feed lines; 3) determine if these relationships change depending upon the scale of evaluation; 4) determine if there is a relationship between the proportion of hens incubating nests and gobbling activity; and 5) determine if Florida's turkey hunting season is correlated with gobbling and nesting.

Fields were the most influential cover type on turkey resource use at both scales on a food-subsidized landscape. Large drains were also selected by turkeys. Feed lines had the 3rd greatest probability of use at the landscape level but did not differ from use of fields, drains, roads, and upland pine at the landscape scale. This pattern of resource use highlights the importance of creating fields or wildlife openings for turkeys and maintaining large contiguous drains. Additionally, on plantation properties where the reduction of small drains is a common practice, if turkey management is the goal, turkeys could benefit if small drains were allowed to revert back to their original extents. While turkeys used supplemental feed lines, there are still questions regarding what aspect of the feed lines motivate turkeys to use them. Future research should investigate the causal mechanisms associated with turkey use of feed lines, including foraging, traveling, brood rearing or nest-site selection.

There was a weak relationship between the proportion of hens incubating a nest and gobbling activity. Many studies have indicated gobbling activity is a variable behavior, and my study supports these findings. However, I found that variation among site played a large role in explaining differences in gobbling activity. Future research should aim to further disentangle what factors contribute to spatial variable within and among sites. Given the site variability among gobbling activity, wild turkey harvest regulations could better match local gobbling and nesting activity if Florida were broken into smaller management zones. Much of what we know regarding gobbling activity has come from only a handful of sites. The current timing of the turkey hunting season does not coincide with peak gobbling or peak incubation and these relationships vary by region. Shifting the start and end dates of the hunting season 3 weeks later, would better optimize the correlation between peak gobbling and incubation. However, given the weak relationship between the proportion of hens incubating a nest and gobbling activity, FWC may review the importance of the biological basis for setting the hunting seasons and consider how that balances with the desires of hunters. Formalizing decisions in a structured decision making format will facilitate future management considerations, conservation decisions and help to guide turkey hunting seasons and harvest regulations.

Across the Southeast, there is rising concern regarding apparent declines in wild turkey *(Meleagris gallopavo)* productivity among researchers, biologists, and turkey hunters alike. Biologists are concerned this is indicative of general large scale population declines. Further concern stems from declining turkey harvest in several southeastern states. An urgent need exists for scientifically-based management decisions and harvest regulations. The foundation of scientifically-based decisions is sound study designs that facilitate consistent and accurate collection and analysis of biological data. With modern technology, I was able to collect an enormous amount of data on turkey movements and gobbling activity. While large data sets provide for greater statistical certainty, these voluminous data come with their own set of unique challenges in terms of data processing time and data analysis challenges.

Researchers should be aware that while autonomous recorders may save much effort on field data collection, manual processing of data will require substantial allocation of staff resources. On average individuals working on this project could process 30 hours of recordings a day. It took 6 people about 11 months to process all of the recordings. Future research should develop an effective and accurate automated process for detecting and classifying gobbling activity.

GPS units present the opportunity to collect a multitude of data compared to traditional VHF counterparts. With this vast amount of data, unique challenges arise. Researchers wishing to use GPS units should understand that with more frequent location data, analysis problems can arise. My resource use models took approximately 12 days to complete on super computers. Sufficient computing resources should be available to handle large data sets. Additionally, GPS data are often autocorrelated which violates many of the assumptions of traditional analysis methods. Many analysis methods dealing with autocorrelation are computationally taxing, but they are preferred over censuring locations to extract the maximum value from using GPS units.

It is my hope this thesis can be used as a spring board for future studies that further refine the collective knowledge germane to turkey management. My study was a first step in understanding the variety of impacts broadcast supplemental feeding for bobwhite could have on turkeys. Is the selection of feed lines based on a reproductive advantage? Do feed lines provide good bugging areas for poults or minimize the impacts of scent when hens are beginning and ending their nest recess? Linking nesting data and survival data of poults and adults to resource use on food-subsidized landscapes could be even more informative for making management and regulation decisions. My gobbling activity models could have been further strengthened by incorporating hunting pressure data. Gobbling activity and resource use studies could be further improved by the development of a more reliable method for estimating turkey abundance and density. Future research should explore the potential impacts of vegetation density on ARU gobble detection distance and rates at which individual turkeys gobble, such that ARUs may serve as an estimator of turkey density.

VITA

Aaron Griffith is from Wentworth, North Carolina, where he developed his interest in wildlife management through his experiences hunting, fishing, and trapping. He attended North Carolina State University where he received a Bachelor of Science degree in Fisheries, Wildlife, and Conservation Biology in 2011 and served as chapter president for the State College Chapter of the National Wild Turkey Federation. Upon graduation, Aaron embarked on a journey of seasonal technician jobs with a variety of employers including the U.S. Fish & Wildlife Service, the National Park Service, the North Carolina Wildlife Resources Commission, and the University of Missouri. Aaron worked in areas that spanned from the Outer Banks of North Carolina to the prairie pothole region in North Dakota. In 2014, he began working towards his Master's Degree in Wildlife and Fisheries Science at the University of Tennessee, Knoxville while spending the majority of his time at his field site, Tall Timbers Research Station in Tallahassee, Florida.