BREEDING SEASON GOBBLING CHRONOLOGY IN HUNTED AND NON-HUNTED POPULATIONS OF EASTERN WILD TURKEY (*MELEAGRIS GALLOPAVO SILVESTRIS*) IN SOUTHWESTERN GEORGIA

by

DEREK STEPHEN COLBERT

(Under the Direction of Robert J. Warren and Michael J. Chamberlain)

ABSTRACT

Using autonomous recording units (ARUs), we recorded gobbling activity of wild turkeys to determine what influence weather, nesting, and hunting have on gobbling on 2 similar study sites in southwestern Georgia—the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area. Sites experienced a single peak of gobbling activity annually, and 3 out of 4 times this coincided with peak nest initiation. Most (78%) of gobbling occurred within 2 hours of sunrise. The best model of gobbling activity was the global model (w_i = 0.88). Gobbling activity was greatest when mean daily temperature was 15 °C, when wind speed increased, and when barometric pressure decreased. No relationship between gobbling activity and hunting or peak nesting was detected, but 32-44% greater gobbling activity occurred on the Jones Center versus Silver Lake WMA when the general hunt opened on Silver Lake WMA through the end of the breeding seasons.

INDEX WORDS: eastern wild turkey, *Meleagris gallopavo silvestris*, gobbling, weather, hunting, nesting, ARU, ACR, habitat, avian

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DEDICATION

I would like to dedicate this thesis to my fiancé, Michelle, my parents, Tony and Wendy, my sister, Tabitha, and my grandparents, Larry and Sue Colbert and Mona Wolfe. Thank you for your loving support and patience throughout the pursuit of my M.S. Degree—I could not have done this without you all.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

The spring hunting season for male eastern wild turkeys (*Meleagris gallopavo silvestris*, hereafter, wild turkey) has typically been set based on tradition, with the intent to maximize hunter success while minimizing vulnerability to females, but is rarely backed by biological evidence (Bevill 1975, Miller 1984, Kennamer 1986, Hoffman 1990, Vangilder 1992). More recently, management strategies for establishing spring hunting seasons have involved knowing when peaks in gobbling and onset of nest initiation occur, with the intent of targeting the presumed second peak of gobbling activity for spring hunting opportunities, a time typically associated with peak nesting (Bailey and Rinell 1967, Bevill 1975, Hoffman 1990, Kurzejeski and Vangilder 1992, Kienzler et al. 1996). A better understanding of gobbling chronology is critical to setting more biologically-sound spring hunting seasons that also afford sufficient harvest opportunity for hunters (Bailey and Rinell 1967, Bevill 1975, Miller 1984, Hoffman 1990, Kienzler et al. 1996). To better understand gobbling chronology, regional patterns of gobbling activity need to be characterized (Williams and Austin 1988, Kienzler et al. 1996, Miller et al. 1997a, Miller et al. 1997b, Whitaker et al. 2005).

It has been postulated that improperly timed spring turkey hunting seasons could result in decreased reproductive success and recruitment of wild turkeys due to disturbance of breeding activity, resulting in long term population declines (Kimmel and

Kurzejeski 1985, Vangilder and Kurzejeski 1995, Healy and Powell 1999, Norman et al. 2001, Whitaker et al. 2005). Concern for the potential negative effects that improperly timed spring turkey hunting seasons may be having has been compounded by the observed declines in hunter harvest rates of wild turkeys during the past 5-10 years in Georgia (K. Lowrey, Georgia Department of Natural Resources, unpublished data), Alabama (S. Barnett, Alabama Department of Conservation and Natural Resources, unpublished data), and South Carolina (C. Ruth, South Carolina Department of Natural Resources, unpublished data).

Wild Turkey Life History and Vocalizations in Males

The wild turkey, a non-migratory game bird indigenous to North America, has a historical range that includes the continental United States, southeastern Canada, and northern Mexico (Mock et al. 2002). The eastern wild turkey is the most widely distributed, abundant, and hunted turkey subspecies (Tapley et al. 2001, Kennamer 2009). It is found throughout the eastern half of the United States, including the Cumberland and Appalachian plateaus, Ozarks, and Gulf States (Eaton 1992). The wild turkey is an important recreational resource within their range (Tapley et al. 2001) that uses a variety of habitats throughout the Southeast, including older-aged forests (Porter 1992), large timberlands having little human disturbance (Shaw 1959), forest openings, farms, plantations (Shaffer and Gwynn 1967), and managed pine landscapes (Kennamer et al. 1980, Holbrook et al. 1985, Exum et al. 1987, Miller et al. 1995, Miller and Conner 2007).

Male turkeys respond to increasing photoperiod during spring with a rise in the secretion of testosterone (Margolf et al. 1947, Lewis 1967, Schleidt 1968, Hale et al.

1969, Schleidt 1970). The rise in testosterone brings about physiological, physical, and behavioral changes characteristic of males during spring, all of which are associated with courtship behavior (Schleidt 1968, Hale et al. 1969, Schleidt 1970, Lisano and Kennamer 1977, Blankenship 1992). The most characteristic courtship behavior of males is gobbling, which attracts females for breeding, but is also known to attract other males (Bailey and Rinell 1967, Healy 1992). Courtship behaviors, including gobbling, consist of behaviors called fixed-action patterns (Hale and Schein 1962), meaning that gobbling is elicited by a stimulus, performed at a fixed intensity, and is either completely performed or not performed at all.

Gobbling is one of the few activities that can be elicited by multiple stimuli while also occurring spontaneously, without the presence of a stimulus (Schleidt 1968). At times, almost any sound will trigger a gobble when males are predisposed to gobbling, whereas at other times, a call cannot be stimulated. Of all stimuli, the best-known stimulus to release a gobble is the yelping call of a female (Scott and Boeker 1972).

Gobbling begins well before mating and can be heard as early as the first warm late-winter day, beginning as early as February in Texas (Healy 1992). In domestic males, Schledit (1968) found that gobbling peaked in the spring, was absent in summer, and was infrequent during the fall and winter. The general consensus among turkey managers is that 2 peaks of gobbling activity occur during the breeding season, with the first being associated with the beginning of breeding and the second occurring later, when most females are incubating (Bailey and Rinell 1967, Bevill 1975, Porter and Ludwig 1980, Hoffman 1990). In the South Carolina Piedmont, gobbling peaked between late-March and early-April with a secondary peak occurring from late-April to early-May (Bevill

1975). In contrast, Miller et al. (1997a) concluded that gobbling peaked earlier in Mississippi, from mid- to late-March.

Turkeys have acute hearing, and observations suggest that turkeys are capable of hearing lower-frequency, and more distant sounds than humans (Healy 1992). According to Healy (1992), "the frequency and pitch of a gobbling call ensures that it can be heard over long distances in most natural acoustical environments." Sound transmission can also be maximized by calling from an elevated area, such as a perch, which is why males often gobble most while on the roost (Dooling 1982, Healy 1992).

Gobbling and Environmental Factors

Effects of weather condition on gobbling activity are poorly understood. Some suggest that no particular weather condition stimulates gobbling activity (Scott and Boeker 1972). Others argued the best mornings to hear gobbling occurred when skies were clear, there was a light breeze, and a heavy dew, whereas little gobbling was heard on rainy and windy mornings (Bevill 1975, Healy 1992). Other studies have also found that although photoperiod controls the onset of gobbling in turkeys, weather affects the daily variation of gobbling activity (Bevill 1973, Porter and Ludwig 1980, Vangilder et al. 1987, Hoffman 1990, Kienzler et al. 1996). Kienzler et al. (1996) noted that temperature and light intensity were positively related to gobbling activity and that precipitation during the previous 12 hours as well as wind velocity were inversely related to counts. Hoffman (1990) noted gobbling to be more pronounced during morning as opposed to evening and that more gobbling occurred on than off the roost.

Gobbling and Nest Initiation

Many studies have concluded that 2 peaks in gobbling activity occur throughout a breeding season and that the second peak coincides with peak nest initiation (Bailey and Rinell 1967, Bevill 1975, Porter and Ludwig 1980, Hoffman 1990, Healy 1992). Hoffman (1990) concluded that males gobbled more in the absence of females than in their presence; this may explain the second peak of gobbling associated with peak nest initiation. Some studies observed only 1 peak of gobbling activity during breeding seasons and these studies found that this single peak did not coincide with peak nest initiation (Kienzler et al. 1996, Miller et al. 1997a).

Gobbling and Hunting

Sportsmen often support the idea that an earlier spring hunting season would allow hunters to better capitalize on peak gobbling activities (Little et al. 2001, Swanson et al. 2005, Whitaker et al. 2005). However, earlier seasons may increase the likelihood of accidental female harvest, decrease adult male densities, and reduce gobbling activity, all of which could decrease reproductive success and recruitment (Bevill 1975, Miller 1984, Kimmel and Kurzejeski 1985, Hoffman 1990, Vangilder and Kurzejeski 1995).

Kienzler et al. (1996) concluded that gobbling was negatively affected by intensity of hunting. They found that a drop in gobbling activity occurred in association with the onset of the hunting season during all 4 years of their study. Kienzler et al. (1996) also suggested that hunting had an impact on gobbling in Bevill's (1975) study. Bevill (1975) conducted a study on the influence of nesting on gobbling activity in which 7 gobble count stations were used. Only 2 of his 7 stations were used to study peaks in gobbling, and these 2 stations were located on non-hunted sites. The other 5 stations were located on hunted sites and produced “inexplicable sporadic gobbling patterns.” Bevill (1975) concluded that the data from those 5 sites could not be used to determine peaks in gobbling activity.

Lehman et al. (2005) observed that gobbling occurred more in a non-hunted population during the hunting season than in a hunted population. They concluded that gobbling activity was reduced during the hunting season because hunters disturbed the birds. Lehman et al. (2005) also noted that 57% of the harvest occurred during the pre-laying period. Norman et al. (2001) noted a difference in gobbling patterns among hunted and non-hunted populations and concluded that this could be due to reduction in gobbling in response to the presence of hunters.

Other studies have found different results. Palmer et al. (1990) noted a positive relationship between hunter numbers and gobbling activity. Miller et al. (1997a) hypothesized that the positive relationship may be a result of high gobbling activity resulting in more hunters pursing males, because as gobbling decreased, so did hunter numbers. They also hypothesized that there may be a threshold density of hunters that must be reached before gobbling activity is depressed but reported that, as measured by the number of hunters, hunting pressure did not have a negative influence on gobbling activity. Miller et al. (1997b) reported that hunting effort declined as gobbling declined on Tallahala Wildlife Management Area, Mississippi, which they attributed to hunters harvesting the more vocal birds. They speculated that this harvest might lead to observers and hunters being less likely to hear gobbling birds, resulting in less hunting effort. However, they recommended that the relationships among these factors should be investigated in future research.

In this thesis, I present data on the impact of weather, nest initiation, and hunting on gobbling activity on 2 similar study sites in southwestern Georgia—The Joseph W. Jones Ecological Research Center (Jones Center; a non-hunted site) and the Georgia Department of Natural Resources' Silver Lake Wildlife Management Area (Silver Lake WMA; a hunted site). Chapter 2 describes the methods involved in using autonomous recording units and computer software to collect these data. Chapter 3 describes the effects of weather, nest initiation, and hunting on gobbling activity. The final chapter provides guidelines for providing biologically sound hunting seasons that maximize hunter opportunity while minimizing female vulnerability to harvest. I also include suggestions for future research directions.

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CHAPTER 2

APPLICATION OF AUTONOMOUS RECORDING UNITS TO MONITOR EASTERN WILD TURKEY (*MELEAGRIS GALLOPAVO SILVESTRIS*) GOBBLING ACTIVITY IN SOUTHWESTERN GEORGIA[1]

[1]Colbert, D. S. To be submitted to the Wildlife Society Bulletin.

Abstract

Long-term changes in avian community behavior due to human activity and habitat modification can be effectively and efficiently monitored using autonomous recording units (ARUs). ARUs can be deployed by a single researcher, allow simultaneous sampling at multiple locations, provide archival recordings, and save surveying time. Our objective was to determine if ARUs are an effective tool to monitor eastern wild turkey (*Meleagris gallopavo silvestris*) gobbling activity and to determine if hunting pressure during spring altered gobbling activity. This research occurred on 2 similar study sites in southwestern Georgia—the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area. We deployed 14 Song Meter SM2 ARUs across the 2 study sites during 2011 and 2012. The ARUs were effective and efficient at recording gobbling activity and produced approximately 19,880 hours of recordings during 2 breeding seasons across both study sites. The ARUs were capable of recording a gobble from a bird on the roost, with no vegetative obstruction, up to 210 meters away; gobbles could be visually and acoustically identified by using the autonomous call recognition (ACR) software program Song Scope. Within Song Scope, we developed a recognizer file to autonomously search recordings and provide a list of candidate vocalizations the software identified as gobbles. The recognizer file detected between 74-78% of all wild turkey gobbling activity recorded across both study sites for both years, but also had false positive rates of 99% for both sites and both years. A false positive rate of 99% means that for every 1 turkey gobble the software identified correctly, there were 99 sounds identified that were not turkey gobbles. The data processing was a lengthy process due to the large number of false positives that had to be

evaluated individually. While ARUs are effective at recording gobbling activity, the ACR software was not efficient at distinguishing wild turkey gobbles from false positives.

Introduction

The advent of using sound recordings as a survey method of avian communities is a fairly recent development, with few researchers having used the technology prior to 2000 (but see Parker and Bailey 1991, Foster et al. 1994). Sound recordings have advantages when compared to traditional point counts. Specifically, sound recordings provide a permanent archival record of the survey period, do not require the presence of skilled observers in the field, and are capable of being replayed for identification verification (Telfer and Farr 1993, Haselmayer and Quinn 2000, Hobson et al. 2002, Rempel et al. 2005, Brandes 2008). Autonomous recording units (ARUs) are programmable recording units that can be left in the field, can be deployed by a single researcher, can monitor animals in the absence of an observer, and have the potential to save survey time while making more extensive and intensive surveys possible (Telfer and Farr 1993, Hobson et al. 2002, Rempel et al. 2005, Hutto and Stutzman 2009, Mennill et al. 2012).

For animals that produce sound, ARUs provide a route of data collection at multiple points over biologically significant time periods such as breeding, migration, and foraging (Blumstein et al. 2011, Mennill 2011). ARUs are an efficient way to sample populations and communities to produce estimates of species occurrence, richness, and possibly estimate abundance (Parker 1991, Blumstein et al. 2011). Acoustic monitoring also offers an efficient and effective method to examine long-term changes in behavior and biodiversity in response to seasonal variation, human activity, and habitat modification (Riede 1993, Riede 1998, Blumstein et al. 2011).

ARUs have been used to measure species richness and composition of birds (Haselmayer and Quinn 2000), bats (MacSwiney et al. 2008, Obrist et al. 2008), anurans (Courch and Paton 2002), and insects (Brandes 2005), while additional research has identified migratory bird species and described patterns in nocturnal migration activity (Hüppop et al. 2006, Farnsworth and Russell 2007). Researchers have also deployed ARUs in Arkansas and Florida to investigate the possibility that ivory-billed woodpeckers (*Campephilus principalis*) persist in these areas (Fitzpatrick et al. 2005, Hill et al. 2006, Swiston and Mennill 2009) and in Africa to study the behavior of the threatened African elephant (*Loxodonta africana*; Payne et al. 2003).

Previous studies of wild turkey (*Meleagris gallopavo* sp.) gobbling activity have used daily point count survey stations established along a predetermined route (Scott and Boeker 1972, Bevill 1973, Bevill 1975, Porter and Ludwig 1980, Hoffman 1990). Researchers traveled these routes every morning that weather permitted for a predetermined amount of time, stopping at stations for 4-10 minutes, and listening for gobbling activity (Kienzler et al. 1996, Miller et al. 1997a, Miller et al. 1997b, Healy and Powell 1999). Conducting these studies required skilled observers, proficient at identifying wild turkey gobbles, to commit time to daily sampling. Dahlquist et al. (1990) conducted a study in which individual male Gould's wild turkeys (*M. g. mexicana*) were identified by their vocalizations. Until now, this was the only research conducted on wild turkeys using audio recording equipment.

ARUs provide the ability to explore the effects of weather, nesting activity, and hunting pressure on many avian species, including eastern wild turkeys (*M. g. silvestris*). Considering that past studies made use of point count surveys, and that ARUs afford the opportunity to conduct more intensive and extensive point count surveys, there exists a need to explore these research questions through the use of ARUs. ARUs provide the opportunity to more thoroughly investigate the effects of multiple variables on gobbling activity of wild turkeys, given that they can be placed in the field for the entirety of the breeding season, sampling consistently on a daily basis, without the need for researchers to be present.

To further facilitate acoustic monitoring, automatic call recognition (ACR) software exists to also automate the data searching process (Brandes 2008). Bird songs are a complex and varied group of sounds and as such, many different ACR software packages exist, each taking their own approach to automate sound analysis. One such approach is to use Hidden Markov Models (HMMs), a technique commonly used for human speech recognition (Brandes 2008). HMMs have been used successfully to classify bird songs, but they can be susceptible to background noise, and can lead to poor classification of sounds that overlap in time but do not overlap in frequency. To facilitate data analysis, development of an ACR for use with wild turkey gobbling acoustic monitoring would be valuable.

To expedite development and adoption of ARUs, Blumstein et al. (2011) recommended that researchers adopting this technology write papers that document experiences and explain pitfalls and lessons learned about bioacoustics deployments and platforms. Herein we summarize work that involved deployment of ARUs to record eastern wild turkey gobbling activity. Our objectives were to evaluate performance of ARUs in monitoring gobbling activity, develop a recognizer file in the ACR software Song Scope (Wildlife Acoustics, Inc., Concord, MA) to allow successful detection of gobbles, evaluate the performance of this software and the associated recognizer file, and provide future recommendations for use of ARUs to monitor gobbling activity in wild turkeys.

Methods

Study Areas

This study was conducted on 2 similar study sites in southwestern Georgia—the Joseph W. Jones Ecological Research Center (Jones Center) and the Georgia Department of Natural Resources' Silver Lake Wildlife Management Area (Silver Lake WMA; Figure 2-1).

The Joseph W. Jones Ecological Research Center at Ichauway (Figure 2-2) was located in Baker County, Georgia, USA, approximately 16 km south of Newton. The property was the former hunting plantation of Robert W. Woodruff. The property was approximately 11,735-ha, but this study only used 4,046-ha located south of Highway 91. The site was characterized by hot, humid summers and short, mild winters, with an average daily temperature of 11^{o}C during winter and 27^{o}C during summer, and a rainfall average of 131 cm/year (Lynch et al. 1986, Goebel et al. 1997, Boring 2001).

The Jones Center was bordered by center-pivot agriculture on all sides, except for the southeastern portion of the property that bordered the Flint River. The Ichawaynochaway Creek bisected the property and the site consisted of a variety of forest types, including longleaf pine (*Pinus palustris*), loblolly pine (*P. taeda*), slash pine (*P.*

elliottii), mixed pine and hardwood forests, oak barrens, lowland hardwood hammocks, and cypress-gum (*Taxodium ascendens-Nyssa biflora*) limesink ponds (Boring 2001). Wiregrass dominated approximately 25% of the understory. Prescribed fire was the primary tool for conserving native ground cover with approximately 50% of the site being burned each year while never burning more than a few hundred adjacent hectares at a time (Atkinson et al. 1996).

Prior to the 1960's, the Jones Center maintained a sizeable population of wild turkeys but for unknown reasons populations declined during the mid-1960's (Sanders and Mueller 1988, DeVos and Sisson 1989). During the late-1980's, wild turkeys were reintroduced as part of a cooperative effort by the Jones Center, Tall Timbers Research Station, and Georgia Department of Natural Resources (GA DNR; Smith et al. 2006). From 1988-1990, 28 turkeys were released on the property (Sanders and Mueller 1988, DeVos and Sisson 1989, Sisson 1990). Wild turkey populations increased after the restocking efforts, in particular, during the decade prior to our research and turkey hunting was not been permitted on the Jones Center after birds were reintroduced.

Silver Lake WMA (Figure 2-3) was located in Decatur County, Georgia, USA, approximately 11 km southwest of Bainbridge and 56 km southwest of the Jones Center. Silver Lake WMA was a property owned and managed by the GA DNR. The property was 3,723 ha and bordered by center-pivot agriculture to the north, Lake Seminole to the south, the Flint River to the east, and Spring Creek to the west. The WMA was purchased during 2008-2009, primarily because of its importance to many threatened and endangered wildlife species, such as the gopher tortoise (*Gopherus polyphemus*) and red-cockaded woodpecker (*Picoides borealis*), which depended on the large tracts of mature longleaf pine forest. The property was formerly owned and managed as part of International Paper Company's Southland Experimental Forest. The WMA also provided hunting and recreational opportunities for the general public.

Silver Lake WMA was similar to the Jones Center in habitat type, consisting of a variety of forest types, including longleaf pine, loblolly pine, slash pine, mixed pine and hardwood forests, hardwood forests, lowland hardwood hammocks, as well as depressional wetlands, ponds, and the 150-ha Silver Lake (Silver Lake WMA 50-Year Plan 2009, GA DNR 2009). Also like the Jones Center, the primary management tool used on Silver Lake WMA was prescribed fire, on an approximately 2-year burn rotation.

Being a WMA, this site also had a yearly spring turkey hunting season. The turkey season on Silver Lake WMA for 2011 occurred during 26 March – 3 April (quota hunt with a maximum of 35 participants), 9 April – 17 April (child hunt quota of 35), and 23 April – 15 May (hunt open to the public). During 2012, the turkey season on Silver Lake WMA occurred during 24 March – 1 April (quota of 35), 7 April – 15 April (child hunt quota of 35), and 21 April – 15 May (hunt open to the public). During both 2011 and 2012, the bag limit for wild turkeys in Georgia was 3 males per hunter.

Whitehall Forest, used for a distance sampling analysis of the ARUs recording capabilities, was located in Athens-Clarke County, Georgia, USA. The property was an experimental forest owned and managed by the University of Georgia's Warnell School of Forestry and Natural Resources and was approximately 324 ha in size. The site was located in the Piedmont physiographic region and was bounded by the Middle Oconee and North Oconee Rivers. Forest types on the site included natural and planted pines, pine and hardwood forests, and hardwood forests. The site also contained roads, railroad tracks, power line openings, and interspersed grass openings. The ARU distance sampling was conducted in a power line opening.

Autonomous Recording Units

Recording equipment consisted of the Song Meter SM2 Digital Field Recorder and SMX-II Weatherproof Acoustic Microphone (Wildlife Acoustics, Inc., Concord, MA) (Figure 2-4). We placed 7 ARUs on each site and spaced them approximately 2 km apart to prevent overlap in recording areas. The ARUs were a forest green color, weatherproofed, had an external temperature sensor, had 2 external attachments for SMX-II omnidirectional microphones, and had a point of attachment for an external power source. For this project, the ARUs were powered by 2 AA batteries for the internal clock and 4 D-cell batteries that powered the recordings. Additionally, there were 4 memory card slots for storing recordings, 1 of which was occupied by a 16 GB memory card.

On the device hardware panel of the ARUs, we set gain stages 1 and 2 at +24 dB for a combined setting of +48 dB, as recommended for general use. All other settings on the device hardware panel were left on the factory settings. We also adjusted the sampling rate to 16 kHz, changed the channel to Mono-R (indicating that recordings were made using a single microphone located on the right side of the unit). At a sampling rate of 16 kHz, any sound below 8 kHz was recorded, which proved to be sufficient for this study.

Data Collection

To obtain an accurate representation of gobbling chronology throughout the day, we programmed the ARUs to record the first 10 minutes of every half hour for every hour of each day (i.e., 1200 hrs, 1230 hrs, 1300 hrs, 1330 hrs, etc.) using the software Song Meter Configuration Utility (Wildlife Acoustics, Inc., Concord, Massachusetts). At this sampling regime, the 4 D-cell batteries powering the ARUs were expected to last for a maximum of 24 days, whereas the single 16 GB memory card could record a maximum of 18 days of recordings. Given these parameters, we changed batteries and memory cards every 14 days. Also, conducting changes every 2 weeks minimized the risk of losing data in the event that ARUs malfunctioned. We placed ARUs in the field on both study sites on 7 February 2011, and with the exception of ARUs that needed to be removed for repair, left them deployed until 16 November 2012.

We placed ARUs approximately 6 m up in trees using a Swedish ladder and climbing harness in an attempt to discourage the general public from disturbing them, to elevate them above the understory vegetation layer, to increase recording distance, and to protect them from the prescribed burning that occurred on both properties. To strap the ARUs to trees, we attached a platform to the back of the units that allowed for a ratchet strap to be passed through (Figure 2-5). All ARUs were placed in living pines (*Pinus* spp.), with no branches on the bottom 6 m. All ARUs were placed on the north-facing side of trees to prevent overheating and ARUs were painted brown to provide camouflage.

Automatic Call Recognition Software

To autonomously search recordings for wild turkey gobbles, we used the ACR software Song Scope which displayed an audio recording in spectrogram form allowing researchers to visually identify sounds that were recorded. Wildlife Acoustics advertised that the ACR software program Song Scope provided the ability to develop what was termed a recognizer file, or rather a file containing the candidate vocalization a researcher is interested in, which the software could reference when autonomously searching through recordings, identifying potential candidate vocalizations of interest. To develop a recognizer file in Song Scope, field-recorded vocalizations of interest were identified in the software by a researcher and identified as annotations. These annotations were then transformed into a time-series of spectral feature vectors for analysis using HMMs (Agranat 2009). HMMs were then built to model the spectral and temporal features of individual syllables of a song as well as how the syllables are combined to form a complete song. Song Scope found candidate vocalizations by applying the Viterbi algorithm to determine statistical fit of candidate vocalizations to the HMMs (Agranat 2009).

To develop a recognizer file for eastern wild turkeys, we identified and annotated 20 gobbles recorded on the Jones Center during spring 2011. We imported these annotated gobbles into Song Scope and experimented with the parameters available for making a recognizer file until 20 variations of recognizer files were made. We then began to test these files against recordings with a known number of turkey gobbles to determine detection rates for the recognizer files. The file that performed the best (had the highest rate of detection) was used to autonomously search our recordings for gobbling activity. After autonomously searching recordings using the recognizer file, Song Scope provided a list of candidate vocalizations, which we confirmed as a gobble both acoustically and visually using the spectrogram.

We assessed performance of the recognizer file by calculating detection and false positive rates in Microsoft Excel. To determine detection rate, we used stratified random sampling of recordings. We sorted recordings into high and low activity days, with an equal number of days being chosen at random from each group. High days were determined to be days that contained >1% of the breeding season gobbling activity, while low days were days containing <1% of the breeding season gobbling activity. For each day that was chosen, we selected the recording that incorporated sunrise for that day. To further standardize this analysis, we used an afternoon recording 8.5 hours later for each randomly selected day. We tallied false positives while sorting through the candidate vocalizations list provided by the recognizer file in Song Scope.

Distance Sampling

To determine the maximum distance that we could record a gobble emitted by a bird on the roost, we made a recording of 2 wild turkeys gobbling at a known distance of 9-m facing directly at an ARU. We made this recording at Bear Hollow Zoo in Athens, GA using a Song Meter SM2. To determine the volume at which to play this recording through speakers to accurately simulate a wild turkey gobble, we placed an Insignia, model number NS-B2114, 9-m from a Song Meter SM2, with the speakers facing directly at the ARU, and played the sound clip at different volumes making a recording of each gobble at different volumes. We then compared the spectrograms of the test recordings to the original recording in Song Scope to determine the correct volume setting for evaluation (i.e., volume level of actual turkey gobble).

We conducted detection-distance sampling in Whitehall Forest located near Athens, GA. We elevated speakers above the level of the ARU, in this case approximately 6-m, to simulate a wild turkey gobble on the roost. For all recordings the speakers were facing the ARU and all recordings were made without any vegetative obstruction between the speakers and the ARU to demonstrate the maximum distance a Song Meter SM2 could record a wild turkey gobble emitted from a roost. The first recording was made at 9-m with all subsequent recording stops being made at additional distances of 9-m. The last recording was made with the ARU 228-m from the speakers. As the ARU was moved farther away from the speakers, it was accompanied by a researcher who started/stopped the recordings and also reported at each stop if they could hear gobbles.

Sampling Schedule Testing

To determine if the sampling schedule used for this research provided an accurate depiction of gobbling activity, a series of recordings were made from 10 -14 April 2012 on the Jones Center. It was important to determine whether or not we could observe glimpses of gobbling activity and still have an accurate understanding of gobbling chronology. The recordings began at 600 hours each morning and ended at 2130 hours every night to capture all gobbling activity throughout the day, with the exception of the first day when the recordings did not begin until 1200 hours and the last day when the recordings ended shortly after 1500 hours. These recordings represented 65 consecutive hours of daytime recordings. The recordings were too large to be opened in the Song Scope software, so we listened to all 65 hours, noting all gobbling activity and the time at which each gobble occurred. Total gobbling activity from the 65 hours of recordings was graphed along with sampling schedule results to provide a descriptive comparison.

Results

ARU Performance

On 2 occasions during the study, select ARUs did not make recordings during a 2-week sample period. We suspect that both failures resulted from faulty batteries because on both occasions the units worked correctly with new batteries. During the study, the ARUs performed well during the wild turkey breeding season but shortly thereafter ARUs had to be taken down for repairs because they leaked during storm events. After the first breeding season, 7 out of 14 (50%) ARUs had to be sent in for repair after being in the field for approximately 7 consecutive months. These ARUs experienced weatherproofing failures. Following the 2012 breeding season, 7 out of 14 (50%) ARUs needed repair. This time, 2 ARUs experienced screen failures, 4 leaked due to weatherproofing failures, and 1 ARU leaked due to ants destroying the weatherproofing. None of the ARUs sent in the second year were the same ARUs from the first year.

ACR Performance

We used the recognizer file within Song Scope to analyze approximately 19,880 hours of recordings covering the 2011 and 2012 wild turkey breeding seasons across both study sites. During both years on each site, the recognizer file detected between 72-78% of all gobbling activity that was recorded. For 2011, the detection rate for recordings at the Jones Center was 78.5%, resulting in a false negative rate of 21.5% (Table 2-1), whereas the false positive rate was 99.8% (Table 2-2). During 2012 the detection rate was 75.9 %, resulting in a false negative rate of 24.1% (Table 2-3), with a false positive rate of 99.8%. In 2011, the detection rate for recordings at Silver Lake WMA was 74.1%, resulting in a false negative rate of 25.9% (Table 2-4). During 2012 the detection rate was

74.1% resulting in a false negative rate of 25.9% (Table 2-5), with a false positive rate of 99.9%.

Distance Sampling

An eastern wild turkey gobble on the roost, unobstructed by understory/canopy vegetation, could be recorded on a Song Meter SM2 from a distance of approximately 210-m and was visually and acoustically identifiable as a gobble in Song Scope (Table 2-6). Additionally, the recognizer file was capable of finding and identifying gobbles recorded up to 210-m away. The researcher accompanying the ARU was capable of hearing the gobbling, and identifying it as such, up to the maximum distance we sampled too of 228-meters.

Sampling Schedule

The 65 consecutive hours of daylight recordings yielded 347 gobbles (Figure 2 6). Our sampling regime of the first 10 minutes of every half hour captured 87 of the 347 (25%) gobbles. When graphing the gobbling activity for both sampling regimes, similar trends were noted. Approximately 96% of gobbling activity occurred within 3 hours of sunrise and the abbreviated sampling regiment showed approximately 99% of gobbling activity occurring within 3 hours of sunrise.

Discussion

Blumstein et al. (2011) recommended that researchers adopting ARU technology document their experiences and explain pitfalls and lessons learned about bioacoustics deployments and platforms. Our findings suggest that ARUs are an effective tool to monitor and identify trends in eastern wild turkey gobbling activity. While we found that ARUs may not be able to detect gobbling activity at distances equal to that of a human observer, they allow for more thorough and consistent sampling of study areas during biologically significant time periods (Blumstein et al. 2011, Mennill 2011). With the ability to conduct point counts at multiple locations every half hour without the presence of a researcher, ARUs provided much data that could be archived and readily available for future research (Telfer and Farr 1993, Haselmayer and Quinn 2000, Hobson et al. 2002, Rempel et al. 2005, Brandes 2008). Such consistent sampling efforts increase opportunities to study the long-term changes in behavior and biodiversity of wild species in response to seasonal variation, human activity, and habitat modification (Riede 1993, Riede 1998, Blumstein et al. 2011).

Although the automated recording process provides the opportunity to save time and effort for researchers during data collection, the time required to process those recordings is significant. Effective and efficient ACR software could reduce greatly the time required for data processing. While we were able to develop a recognizer file in the proprietary ACR software, Song Scope, that had a high and consistent detection rate across both study sites annually, it also had a high false positive rate. Therefore, we had to devote months of time in analyzing false positives to ensure an accurate count of gobbles. While not ideal, this process required less time than would have been necessary to listen to all recordings, but just a slight improvement over visually analyzing spectrograms of recordings. The great percentage of false positives suggests that the recognizer file we created simply identified sounds within the frequency ranges of a gobble, rather than actual gobbles. For example, we noted throughout the analysis that the recognizer file was often calling crow calls a turkey gobble. When examining a crow call and turkey gobble in spectrogram form, both calls occur within the same frequency range and the crow call resembles the peak that occurs at the beginning of a turkey gobble.

The reason for the great prevalence of false positives is unclear. It is possible that the HMM approach used by Song Scope is not appropriate to identify wild turkey gobbles. Brandes (2008) reported that HMMs could be susceptible to background noise resulting in poor classification of sounds that overlap in time but not in frequency. With wild turkey gobbling occurring between 400-1800 Hz, the lower end of the spectrum where background noise tends to occur, an HMM approach is most likely not appropriate. Future research is needed to identify modeling approaches that reduce false positive rates.

When it comes to wild turkey research, the thorough dataset that ARUs provide present the opportunity to further our understanding of the effects of weather, nesting, and hunting of wild turkey breeding activity. Previous studies of this kind made use of point counts routes to gather gobbling data (Bevill 1975, Hoffman 1990, Kienzler et al. 1996, Norman et al. 2001, Lehman et al. 2005). Using ARUs, we collected approximately 19,800 hours worth of breeding season recordings for wild turkeys across 2 study sites in 2011 and 2012 for a total of 7,754 identified wild turkey gobbles. With the ability to conduct a point count survey in 14 spots every half hour, we have gained a more thorough dataset than previous studies of this kind, hopefully allowing for stronger conclusions concerning the response of gobbling activity in relation to weather, nesting, and hunting.

While ARUs are an effective tool, much thought needs to go into the scope of the project before they are deployed. They can be efficient tools for data collection (Telfer and Farr 1993, Haselmayer and Quinn 2000, Hobson et al. 2002, Rempel et al. 2005, Brandes 2008), but careful consideration needs to be taken regarding how data will be processed. Automatic call recognition software has the potential to streamline data processing aspect, but may not be as efficient as expected. Thus, any efficiency gains associated with data collection may be lost during data processing.

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Table 2-1. Results of random sampling of recordings to determine eastern wild turkey recognizer file detection rates on the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 2011.

Activity[1]			**Recognizer**[3]		
High	**Low**	**Time**[2]	**Total**	**Total**[4]	**Detection (%)**
3/15/2011		7:00	3	3	
4/3/2011		6:30	1	1	
4/14/2011		6:00	8	8	
4/20/2011		6:00	11	13	
4/25/2011		6:00	29	31	
5/3/2011		6:00	31	35	
5/4/2011		6:00	3	7	
			86	**98**	**87.8**
3/15/2011		15:30	0	0	
4/3/2011		15:00	0	0	
4/14/2011		14:30	0	0	
4/20/2011		14:30	0	0	
4/25/2011		14:30	2	3	
5/3/2011		14:30	0	0	
5/4/2011		14:30	0	0	
			2	**3**	**66.7**
	3/5/2011	7:00	0	0	
	3/18/2011	6:30	10	15	
	4/2/2011	6:30	0	0	
	4/4/2011	6:30	8	19	
	4/5/2011	6:30	0	0	
	6/9/2011	5:30	0	0	
	6/12/2011	5:30	0	0	
			18	**34**	**52.9**
	3/5/2011	15:30	0	0	
	3/18/2011	15:00	0	0	
	4/2/2011	15:00	0	0	
	4/4/2011	15:00	0	0	
	4/5/2011	15:00	0	0	
	6/9/2011	14:00	0	0	
	6/12/2011	14:00	0	0	
			0	**0**	**0**
	2011 Jones Center Totals		**106**	**135**	**78.5**
	False Negatives[5]		**29**	**135**	**21.5**

[1]High activity days were days containing >1% of the breeding season gobbling activity, low activity days were days containing <1% of the breeding season gobbling activity.
[2]Time at which the 10-minute recording started
[3]Total number of gobbles identified in the recording by the recognizer file
[4]Total number of gobbles in the recording, identified by a researcher visually and acoustically
[5]Turkey gobbles that were not identified by the recognizer file

Table 2-2. False positive rates from the scanning of recordings using the eastern wild turkey recognizer file in the automatic call recognition software Song Scope from the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area in southwestern Georgia, USA, 2011-2012.

Study Site	**Year**	**Total # of Gobbles**	**Total # of False Positives**	**Totals Summed**	**Gobbles (%)**	**False Positives (%)**
JC	2011	1484	813,590	815,074	0.2	99.8
SL	2011	1544	1,848,042	1,849,586	0.1	99.9
JC	2012	2409	962,621	965,030	0.2	99.8
SL	2012	2419	2,068,693	2,071,112	0.1	99.9

Table 2-3. Results of random sampling of recordings to determine eastern wild turkey recognizer file detection rates on the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 2012.

Activity[1]			**Recognizer**[3]		
High	**Low**	**Time**[2]	**Total**	**Total**[4]	**Detection (%)**
4/1/2012		6:30	8	13	
4/11/2012		6:00	12	17	
4/13/2012		6:00	4	8	
4/21/2012		6:00	24	26	
4/24/2012		6:00	0	0	
5/20/2012		5:30	32	34	
			80	**98**	**81.6**
4/1/2012		15:00	0	0	
4/11/2012		14:30	2	2	
4/13/2012		14:30	0	0	
4/21/2012		14:30	0	0	
4/24/2012		14:30	0	0	
5/20/2012		14:00	0	0	
			2	**2**	**100**
	2/25/2012	7:00	0	0	
	3/27/2012	6:30	0	1	
	5/1/2012	6:00	5	14	
	5/3/2012	6:00	0	0	
	5/17/2012	5:30	1	2	
	5/25/2012	5:30	13	16	
			19	**33**	**57.6**
	2/25/2012	15:30	0	0	
	3/27/2012	15:00	0	0	
	5/1/2012	14:30	0	0	
	5/3/2012	14:30	0	0	
	5/17/2012	14:00	0	0	
	5/25/2012	14:00	0	0	
			0	**0**	**0**
	2012 Jones Center Totals		**101**	**133**	**75.9**
	False Negatives (%)[5]		**32**	**133**	**24.1**

[1]High activity days were days containing >1% of the breeding season gobbling activity, low activity days were days containing <1% of the breeding season gobbling activity.
[2]Time at which the 10-minute recording started
[3]Total number of gobbles identified in the recording by the recognizer file
[4]Total number of gobbles in the recording, identified by a researcher visually and acoustically
[5]Turkey gobbles that were not identified by the recognizer file

Table 2-4. Results of random sampling of recordings to determine eastern wild turkey recognizer file detection rates on Silver Lake Wildlife Management Area in southwestern Georgia, USA, 2011.

Activity[1]			**Recognizer**[3]		
High	**Low**	**Time**[2]	**Total**	**Total**[4]	**Detection (%)**
3/23/2011		6:30	6	8	
3/26/2011		6:30	0	2	
3/28/2011		6:30	21	21	
4/3/2011		6:30	0	0	
4/14/2011		6:00	10	18	
4/29/2011		6:00	41	52	
5/13/2011		5:30	10	16	
			88	**117**	**75.2**
3/23/2011		15:00	0	0	
3/26/2011		15:00	0	0	
3/28/2011		15:00	0	0	
4/3/2011		15:00	1	1	
4/14/2011		14:30	0	0	
4/29/2011		14:30	0	0	
5/13/2011		14:00	0	0	
			1	**1**	**100**
	3/1/2011	7:00	1	2	
	3/2/2011	7:00	4	5	
	3/16/2011	7:00	5	9	
	3/22/2011	6:30	2	3	
	4/20/2011	6:00	0	0	
	4/25/2011	6:00	5	6	
	4/27/2011	6:00	0	0	
			17	**25**	**68**
	3/1/2011	15:30	0	0	
	3/2/2011	15:30	0	0	
	3/16/2011	15:30	0	0	
	3/22/2011	15:00	0	0	
	4/20/2011	14:30	0	0	
	4/25/2011	14:30	0	0	
	4/27/2011	14:30	0	0	
			0	**0**	**0**
	2011 Silver Lake Totals		**106**	**143**	**74.1**
	False Negatives (%)[5]		**37**	**143**	**25.9**

[1]High activity days were days containing >1% of the breeding season gobbling activity, low activity days were days containing <1% of the breeding season gobbling activity.
[2]Time at which the 10-minute recording started
[3]Total number of gobbles identified in the recording by the recognizer file
[4]Total number of gobbles in the recording, identified by a researcher visually and acoustically
[5]Turkey gobbles that were not identified by the recognizer file

Table 2-5. Results of random sampling of recordings to determine eastern wild turkey recognizer file detection rates on Silver Lake Wildlife Management Area in southwestern Georgia, USA, 2012.

Activity[1]			Recognizer[3]		
High	**Low**	**Time[2]**	**Total**	**Total[4]**	**Detection (%)**
3/20/2012		6:30	1	3	
3/29/2012		6:30	0	1	
3/30/2012		6:30	24	28	
4/10/2012		6:00	10	12	
4/18/2012		6:00	8	12	
4/24/2012		6:00	17	17	
5/11/2012		5:30	1	3	
			61	**76**	**80.3**
3/20/2012		15:00	0	0	
3/29/2012		15:00	18	18	
3/30/2012		15:00	0	6	
4/10/2012		14:30	0	0	
4/18/2012		14:30	0	0	
4/24/2012		14:30	0	0	
5/11/2012		14:00	0	0	
			18	**24**	**75**
	2/24/2012	7:00	0	0	
	2/29/2012	7:00	0	0	
	3/27/2012	6:30	7	9	
	4/17/2012	6:00	12	18	
	4/25/2012	6:00	5	12	
	5/6/2012	6:00	0	0	
	5/24/2012	5:30	0	0	
			24	**39**	**61.5**
	2/24/2012	15:30	0	0	
	2/29/2012	15:30	0	0	
	3/27/2012	15:00	0	0	
	4/17/2012	14:30	0	0	
	4/25/2012	14:30	0	0	
	5/6/2012	14:30	0	0	
	5/24/2012	14:00	0	0	
			0	**0**	**0**
	2012 Silver Lake Totals		**103**	**139**	**74.1**
	False Negatives (%)[5]		**36**	**139**	**25.9**

[1]High activity days were days containing >1% of the breeding season gobbling activity, low activity days were days containing <1% of the breeding season gobbling activity.
[2]Time at which the 10-minute recording started
[3]Total number of gobbles identified in the recording by the recognizer file
[4]Total number of gobbles in the recording, identified by a researcher visually and acoustically
[5]Turkey gobbles that were not identified by the recognizer file

Table 2-6. Results of distance sampling performed on Song Meter SM2 using recordings of eastern wild turkey gobbles on the roost, unobstructed by vegetation, Whitehall Forest, Athens, Georgia, USA, 2012.

Distance from Song Meter (m)	**Researcher could hear (Yes/No)**	**Visually/acoustically ID in Song Scope**	**Recognizer file found in Song Scope**
9	Yes	Yes	Yes
18	Yes	Yes	Yes
27	Yes	Yes	Yes
36	Yes	Yes	Yes
45	Yes	Yes	Yes
54	Yes	Yes	Yes
63	Yes	Yes	Yes
72	Yes	Yes	Yes
82	Yes	Yes	Yes
91	Yes	Yes	Yes
100	Yes	Yes	Yes
109	Yes	Yes	Yes
118	Yes	Yes	**No**
127	Yes	Yes	Yes
136	Yes	Yes	Yes
145	Yes	Yes	Yes
155	Yes	Yes	Yes
164	Yes	Yes	Yes
173	Yes	Yes	Yes
182	Yes	Yes	Yes
191	Yes	Yes	Yes
200	Yes	Yes	Yes
209	Yes	Yes	Yes
218	Yes	**No**	**No**
228	Yes	**No**	**No**

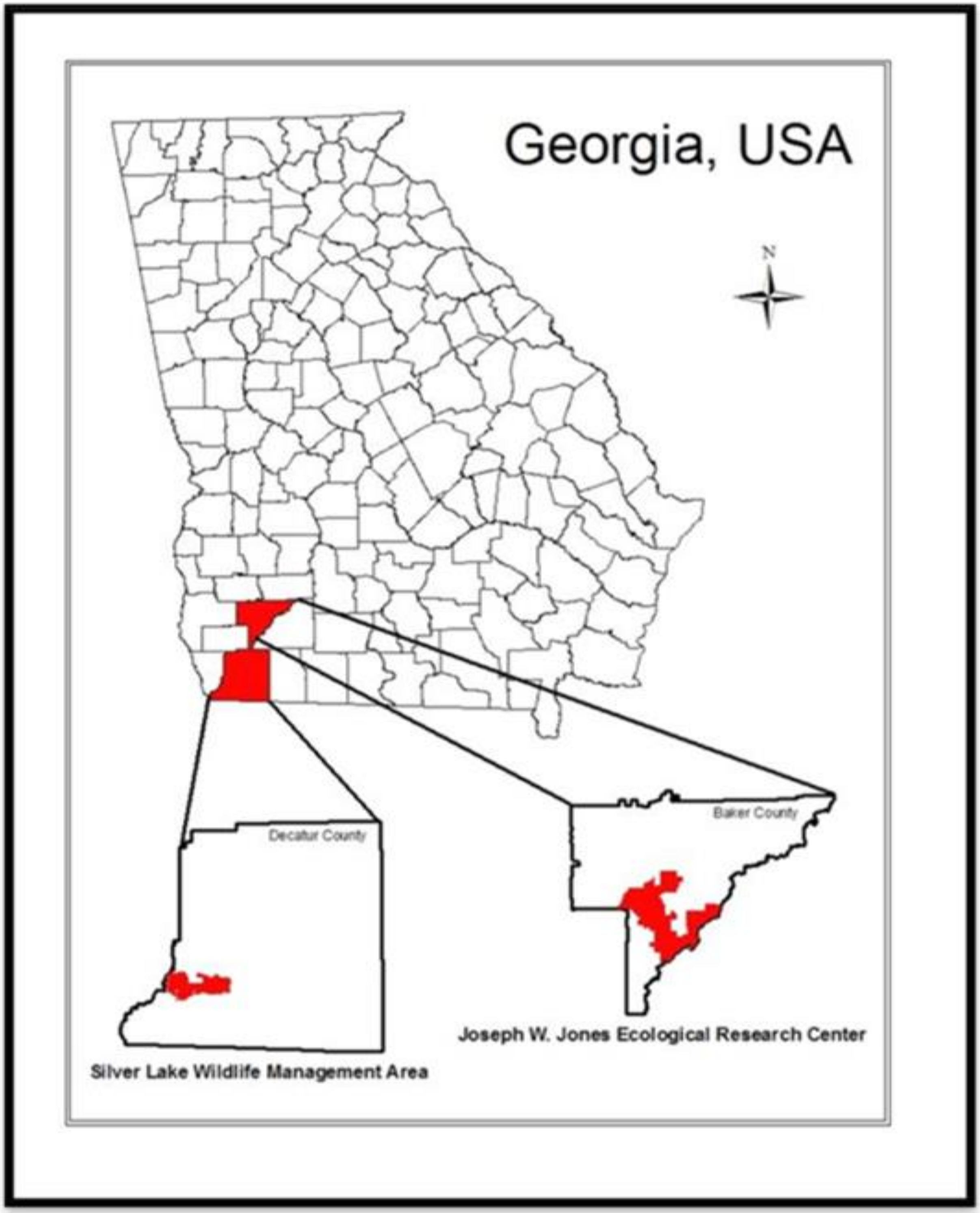

Figure 2-1. The Joseph W. Jones Ecological Research Center at Ichauway and the Georgia Department of Natural Resources' Silver Lake Wildlife Management Area in southwestern Georgia, USA, 2011-2012.

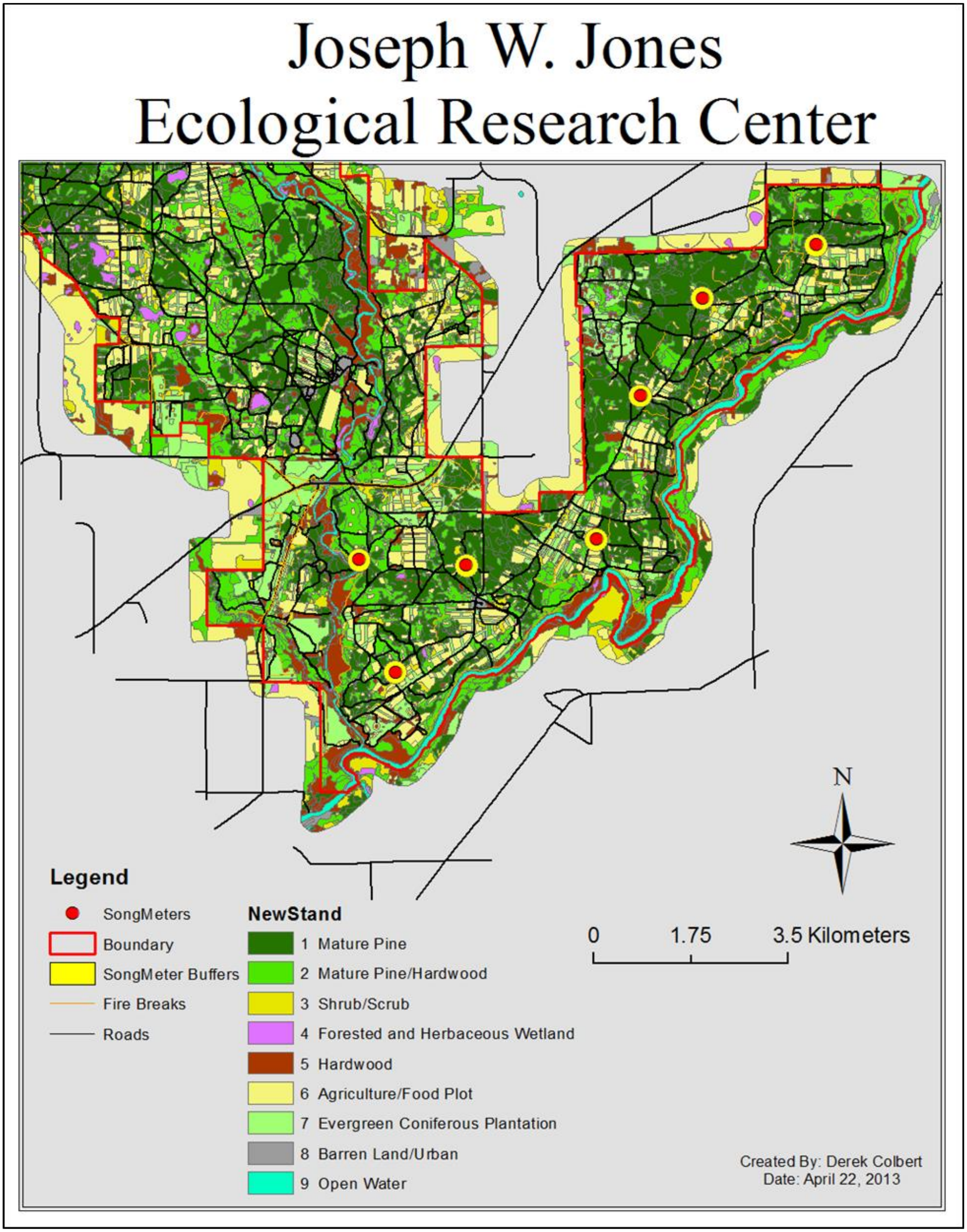

Figure 2-2. Locations of Song Meter SM2 autonomous recording units on the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 2011-2012.

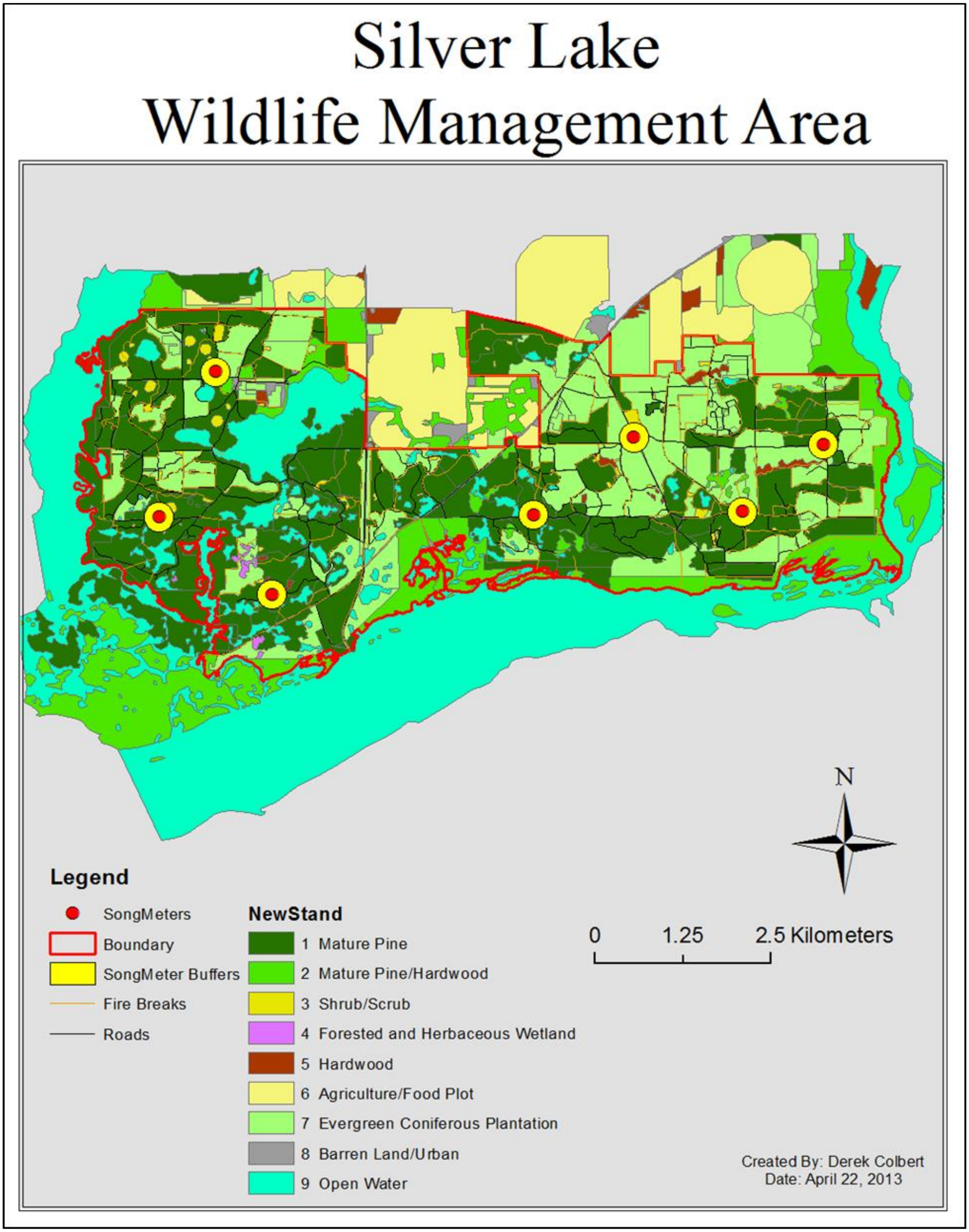

Figure 2-3. Locations of Song Meter SM2 autonomous recording units on Silver Lake Wildlife Management Area in southwestern Georgia, USA, 2011-2012.

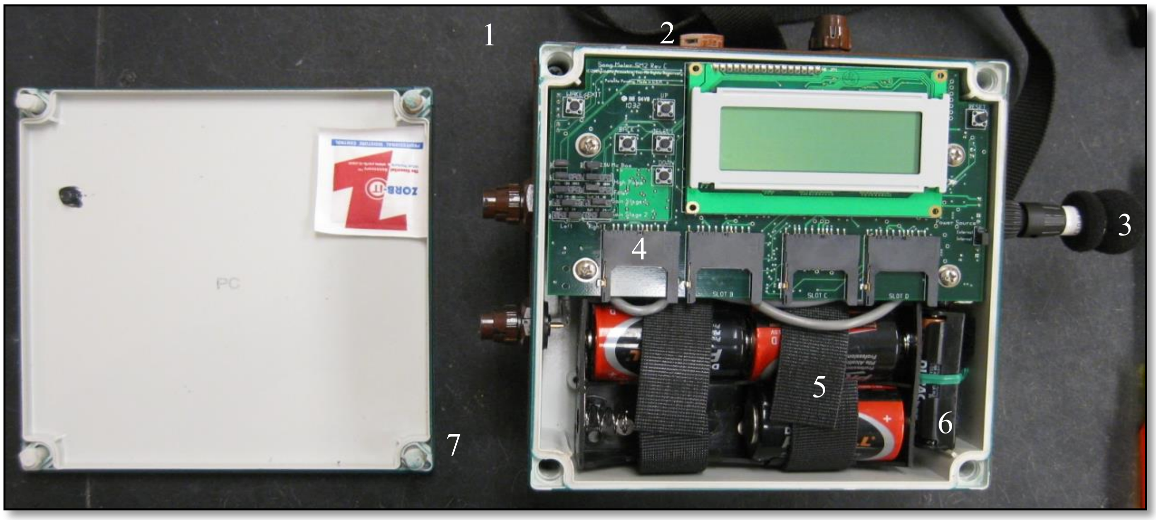

Figure 2-4. Diagram of Song Meter SM2 as deployed on the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 2011-2012.
[1]Song Meter SM2 which where a forest green color and 18x18x5 cm in size
[2]External temperature sensor
[3]SMX-II omnidirectional microphone
[4]Memory card slot
[5]Slot for D-Cell batteries to power the recordings
[6]Slot for AA batteries to power internal clock
[7]Lid for Song Meter SM2 that crates weatherproof sealing

Figure 2-5. Platform fitted to the back of the Song Meter SM2 to facilitate attachment of the unit to trees on the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 2011-2012.

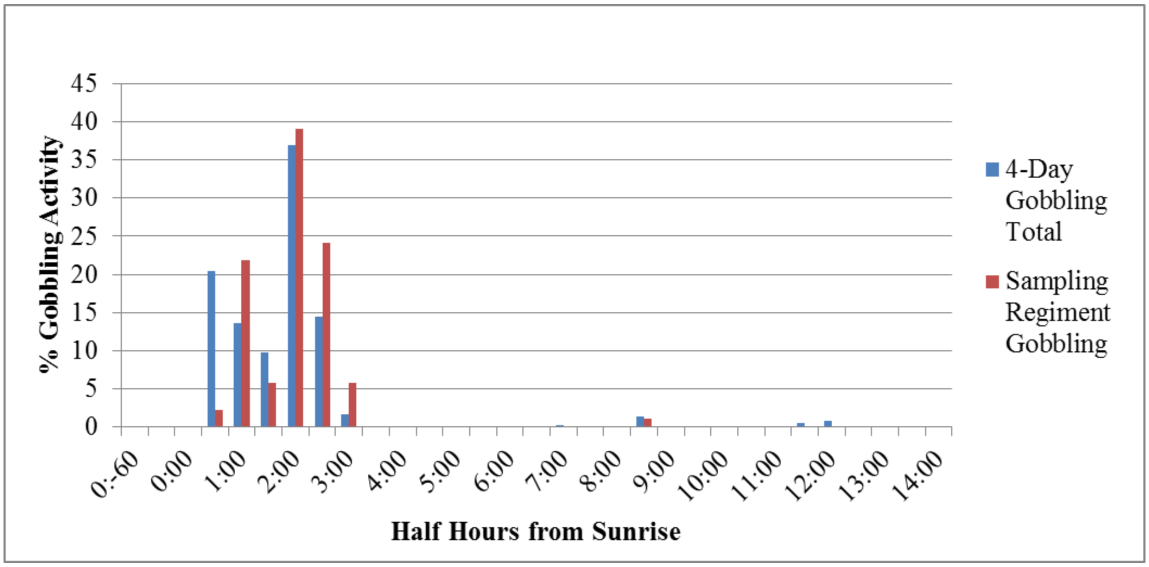

Figure 2-6. Total gobbling activity, depicted in half hours from sunrise, recorded over a 4-day period between the 10 April 2012-14 April 2012 graphed against gobbling activity from 4-day sampling period as seen using the sampling regiment of the first 10 minutes of every half hour, on the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 2012.

CHAPTER 3

EFFECTS OF HABITAT, WEATHER, FEMALE NESTING, AND HUNTING ON EASTERN WILD TURKEY (*MELEAGRIS GALLOPAVO SILVESTRIS*) GOBBLING ACTIVITY IN SOUTHWESTERN GEORGIA[1]

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[1]Colbert, D. S. To be submitted to the Journal of Wildlife Management.

Abstract

Concerns for the potential negative effects of improperly timed spring hunting seasons on wild turkey populations have been compounded by observed declines in hunter harvest rates of wild turkeys during the past 5-10 years in Georgia, Alabama, and South Carolina. We deployed autonomous recording devices (ARUs) to record breeding season gobbling activity of wild turkeys to determine what influence weather, nesting, and hunting have on gobbling activity. We also examined the influence of habitat variables on gobbling activity. Our research occurred on 2 study sites in southwestern Georgia—the Joseph W. Jones Ecological Research Center (Jones Center) and Silver Lake Wildlife Management Area (Silver Lake WMA). During 2011, we identified 1,478 and 1,510 gobbles on the Jones Center and Silver Lake WMA, respectively. During 2012, an approximately 60% increase in gobbling activity occurred on both study sites, resulting in 2,376 gobbles on the Jones Center and 2,390 gobbles on Silver Lake WMA. We experienced a single peak of gobbling activity on both sites for both years, and 3 out of 4 times this coincided with peak nest initiation. Seventy-eight percent of all gobbling occurred within 2 hours of sunrise. Fifty-six percent of gobbles recorded on the Jones Center came from a single ARU, whereas 66% of the activity recorded on Silver Lake WMA came from 2 ARUs, all of which were within 600-m of water. The best model of gobbling activity using weather, nesting, and hunting as predictors was the global model (w_i = 0.88). Gobbling activity was greatest when the mean daily temperature was 15 ˚C, gobbling activity increased as wind speed increased, and gobbling activity appeared to increase as barometric pressure decreased. We were unable to detect a relationship between gobbling activity and hunting or peak nesting activity but detected 32-44%

greater gobbling activity on the Jones Center versus Silver Lake WMA during the time frame incorporating the opening of the general turkey hunt on Silver Lake WMA through the end of the breeding season. Although the effect of nesting and hunting on gobbling was inconclusive, our results found that the Georgia spring turkey hunting season is structured to maximize hunting opportunity while minimizing hen vulnerability.

Introduction

Traditionally, timing of the spring hunting season for male eastern wild turkeys (*Meleagris gallopavo silvestris*, hereafter, wild turkey) was rarely backed by biological evidence (Bevill 1975, Miller 1984, Kennamer 1986, Hoffman 1990, Vangilder 1992). More recently, with the intent of maximizing hunter opportunity while minimizing vulnerability of females to harvest, timing of spring hunting seasons has considered when gobbling activity peaks and when nest initiation occurs. With this knowledge, it is possible to schedule spring hunting opportunities so they will target the presumed second peak of gobbling activity, a time typically associated with peak nesting (Bailey and Rinell 1967, Bevill 1975, Hoffman 1990, Kurzejeski and Vangilder 1992, Kienzler et al. 1996). A better understanding of gobbling chronology, including how weather, nest initiation, and hunting affect gobbling, is critical to setting biologically sound spring hunting seasons while offering sufficient hunting opportunities (Bailey and Rinell 1967, Bevill 1975, Miller 1984, Hoffman 1990, Kienzler et al. 1996).

The effects of weather on gobbling activity are poorly understood. Scott and Boeker (1972) reported that no particular weather condition was responsible for stimulating gobbling activity, whereas other studies have suggested that increasing photoperiod controls onset of gobbling and changes in weather can cause daily variation in gobbling activity (Bevill 1973, Porter and Ludwig 1980, Vangilder et al. 1987, Hoffman 1990, Kienzler et al. 1996). Bevill (1975) and Healy (1992) reported the most gobbling activity occurred when skies were clear, there was a light breeze, and a heavy dew, whereas little gobbling activity occurred on rainy and windy mornings. Kienzler et al. (1996) also noted that temperature and light intensity were positively related to gobbling activity. Hoffman (1990) observed more gobbling activity during mornings as opposed to evenings and that more gobbling occurred when turkeys were on than off the roost.

Many studies have concluded that 2 peaks in gobbling activity occur during a breeding season, and that the second peak coincides with peak nest initiation (Bailey and Rinell 1967, Bevill 1975, Porter and Ludwig 1980, Hoffman 1990, Healy 1992). Nest initiation may explain the second peak of gobbling as males may gobble more in the absence of females (Hoffman 1990). However, some studies observed only 1 peak of gobbling activity, and this single peak did not coincide with peak nest initiation (Kienzler et al. 1996, Miller et al. 1997a).

Sportsmen often support the idea of an earlier spring hunting season to capitalize on the first peak in gobbling activity (Little et al. 2001, Swanson et al. 2005, Whitaker et al. 2005). However, improperly timed seasons may increase the probability of accidental female harvest, decrease adult male densities, and reduce gobbling activity, all of which could decrease reproductive success and cause long-term population declines (Kimmel and Kurzejeski 1985, Hoffman 1990, Vangilder and Kurzejeski 1995, Norman et al. 2001, Whitaker et al. 2005). Compounding the concern for the potential negative effects of improperly timed spring turkey hunting seasons are the observed declines in hunter harvest rates of wild turkey during the past 5-10 years in Georgia, Alabama, and South Carolina (Stafford 2012).

Kienzler et al. (1996) concluded that gobbling was negatively affected by intensity of hunting, noting that gobbling declined with the onset of the hunting season. Kienzler et al. (1996) also suggested that hunting may have had an impact on gobbling in Bevill's (1975) study. Bevill (1975) conducted a study on the influence of nesting on gobbling activity in which 7 gobble count stations were used, but only data from 2 of his 7 stations were used to study peaks in gobbling activity. These 2 stations were located on non-hunted sites, whereas the other 5 stations were located on hunted sites. Bevill (1975) concluded that the data from those 5 sites could not be used to determine peaks in gobbling activity due to "inexplicable sporadic gobbling patterns."

Norman et al. (2001) and Lehman et al. (2005) concluded that gobbling activity was reduced during the hunting season due to hunter disturbance of birds. However, Palmer et al. (1990) noted a positive relationship between hunter numbers and gobbling activity, and Miller et al. (1997a) postulated that the positive relationship may be a result of greater gobbling activity resulting in more hunters pursuing males, because as gobbling decreased, so did hunter numbers. Miller et al. (1997a) also hypothesized existence of a threshold density of hunters that must be reached before affecting gobbling activity, but reported that observed number of hunters did not negatively impact gobbling activity. Additionally, Miller et al. (1997b) suggested that decline in gobbling activity may be attributed to hunters harvesting the more vocal birds. They speculated that harvest may lead to reduced gobbling and subsequent reduction in hunting effort.

To better understand gobbling chronology, and establish biologically sound hunting seasons that allow for undisturbed breeding activity to occur, regional patterns of gobbling activity need to be characterized (Williams and Austin 1988; Kienzler et al. 1996; Miller et al. 1997a, 1997b; Whitaker et al. 2005). Therefore, we recorded wild turkey gobbling activity in non-hunted and hunted populations in southwestern Georgia. We also investigated effects of weather, dates of nest initiation, and hunting on gobbling activity.

Methods

Study Sites

This study was conducted on 2 sites in southwestern Georgia—the Joseph W. Jones Ecological Research Center (Jones Center) and the Georgia Department of Natural Resources' Silver Lake Wildlife Management Area (Silver Lake WMA; Figure 3-1). The Jones Center (Figure 3-2) was located in Baker County, Georgia, USA, and was managed with the support of the Robert W. Woodruff Foundation. The property was approximately 11,735-ha, but our study only used 4,046 ha located south of Highway 91. With an average daily temperature of 27^{o}C during summer and 11^{o}C during winter, the site was characterized by hot, humid summers and short, mild winters, with an average rainfall amount of 131 cm/year (Lynch et al. 1986, Goebel et al. 1997, Boring 2001).

The Jones Center was bordered by center-pivot agriculture on all sides, except for the southeastern portion of the property that bordered the Flint River, and was bisected by the Ichawaynochaway Creek. Forest types on the property consisted of longleaf pine (*Pinus palustris*), loblolly pine (*P. taeda*), slash pine (*P. elliottii*), mixed pine and hardwood forests, oak barrens, lowland hardwood hammocks, and cypress-gum

(*Taxodium ascendens-Nyssa biflora*) limesink ponds (Boring 2001). Wiregrass (*Aristida stricta*) dominated approximately 25% of the entire understory with prescribed fire being the primary tool for conserving native ground cover. Approximately 50% of the site was burned each year with burned areas being well dispersed and averaging 40 ha (Atkinson et al. 1996).

Prior to the 1960's, the Jones Center maintained a sizeable population of wild turkeys, but for unknown reasons populations declined during the mid-1960's (Sanders and Mueller 1988, DeVos and Sisson 1989). During the late-1980's, wild turkeys were reintroduced as part of a cooperative effort by the Jones Center, Tall Timbers Research Station, and Georgia Department of Natural Resources (Smith et al. 2006). From 1988-1990, 28 turkeys were released on the property (Sanders and Mueller 1988, DeVos and Sisson 1989, Sisson 1990). Since then, wild turkey populations increased substantially. Turkey hunting was not been permitted on the Jones Center after restocking.

Silver Lake WMA (Figure 3-3) was located in Decatur County, Georgia, USA, and was owned and managed by the Georgia Department of Natural Resources (GA DNR). The 3,723-ha property was bordered by center-pivot agriculture to the north, Lake Seminole to the south, the Flint River to the east, and Spring Creek to the west. The WMA was purchased from 2008 – 2009 primarily because many threatened and endangered wildlife species, such as the gopher tortoise (*Gopherus polyphemus*) and red-cockaded woodpecker (*Picoides borealis*), were present on the property. The property was formerly owned and managed by International Paper Company. As a WMA, hunting and other recreational opportunities were provided for the general public. Forest types on Silver Lake WMA consisted of longleaf pine, loblolly pine, slash pine, mixed pine and hardwood forests, hardwood forests, lowland hardwood hammocks, as well as depressional wetlands, ponds, and the 150-ha Silver Lake (GA DNR 2009). The primary management tool used on Silver Lake WMA was prescribed fire, on an approximate 2-year burn rotation.

Unlike the Jones Center, Silver Lake WMA had an established spring turkey hunting season. The turkey season on Silver Lake WMA for 2011 occurred during 26 March – 3 April (quota hunt with a maximum of 35 participants), 9 April – 17 April (child hunt quota of 35), and 23 April – 15 May (hunt open to the public). During 2012, the turkey season on Silver Lake WMA occurred from 23 March – 31 March (quota of 35), 6 April – 14 April (child hunt quota of 35), and 20 April – 15 May (hunt open to the public). During both 2011 and 2012, the bag limit for wild turkeys in Georgia for 2012 was 3 males per hunter.

Data Collection

We collected gobbling data using autonomous recording units (ARU; Song Meter SM2 Digital Field Recorder equipped with SMX-II Weatherproof Acoustic Microphone, Wildlife Acoustics, Inc., Concord, MA). We deployed 7 ARUs on each study site. We programmed the ARUs to record the first 10 minutes of every half hour. We deployed ARUs during 7 February 2011 - 16 November 2012, which provided gobbler call counts for 2 breeding seasons. Gobbling activity was identified using the autonomous call recognition (ACR) software Song Scope (Wildlife Acoustics, Inc., Concord, MA). When gobbling was identified, date and time of the gobble was noted for data analysis.

Weather data for the Jones Center were collected from a weather station on the property. For Silver Lake WMA, weather data were obtained from a NOAA weather station located in Bainbridge, Georgia. We only used variables that could be compiled for both sites (i.e., average daily temperature, average daily wind speed, average daily wind direction, average daily relative humidity, rainfall, and average daily barometric pressure) in our analyses. For analysis, we considered daily rainfall as binomial variable (yes or no) and we categorized average daily wind direction into 8 classes: north, northeast, east, southeast, south, southwest, west, and northwest.

Mean initial nest initiation was reported by Williams (2012) and determined to be 13 April 2011 for the Jones Center, 22 April 2011 for Silver Lake WMA, 19 April 2012 for the Jones Center, and 21 April 2012 for Silver Lake WMA. For analysis, peak nesting was determined to be 28 days after mean date of nest initiation (Healy et al. 1975).

Data Analyses

We considered the end of the breeding season as the last recorded gobbling event on each site, annually. Gobbling activity was identified for each ARU and then pooled on each study site for each year to quantify gobbling activity for each population. Gobbling activity was also characterized on a daily basis for each site during both years to better understand peaks in daily gobbling activity.

Specific habitat selection for gobbling activity was not originally an aspect of our study but as the research progressed it became apparent that some of our ARUs recorded more gobbling activity than others. The literature is full of conclusions stating that abundant and well-dispersed water sources are necessary for wild turkey habitat (Wheeler 1948, Schorger 1966, Hurst 1981, Hurst and Dickson 1992, Porter 1992). The proximity to water and other habitat features, such as amount of openings or open habitat (both of which male and female wild turkeys select for during the breeding season) and distance from mature pines (which males have been found to select for roosting and from which most gobbling by males occurs) may influence where wild turkeys are gobbling (Barwick and Speake 1973, Speake et al. 1975, Hoffman 1990, Hurst and Dickson 1992, Ruttinger 2013). Therefore, to assess the influence of habitat on gobbling activity, we depicted the percent of habitat types contained within a 209-m buffer around each ARU (i.e., the maximum recording distance for the ARU; Chapter 2) and the distance from ARUs to permanent bodies of water as a basis for examining for patterns between habitat features and the ARUs that recorded a majority of the gobbling activity.

We modeled male gobbling counts using generalized linear modeling in the SAS GENMOD procedure (SAS Institute, Inc. 2000). Initial modeling efforts assumed a Poisson distribution (Link and Sauer 1997, 1999; McCulloch and Searle 2001) but the data did not fit this distribution according to a goodness-of-fit chi-squared test for the breeding season model ($\chi^2 = 9681.12$, $P \leq 0.001$). To address this problem, we log-transformed counts and fit the model assuming a normal distribution ($\chi^2 = 132.59$, $P = 1.00$).

We modeled log-transformed daily gobbling counts/study site as the response variable and the 6 weather variables (i.e., mean daily temperature, mean daily wind speed, mean daily wind direction, mean daily relative humidity, rainfall occurred [yes/no], mean daily barometric pressure), hunting season (i.e., yes/no), peak nesting variable (i.e., yes/no), study site (i.e., Jones Center or Silver Lake WMA), and the 2 temporal variables year and day, with day being a unique numerical value given to each date that matched similar dates to each other (i.e., 1 March 2011 = 1 and 1 March 2012 = 1), as predictor variables. We developed 26 a priori models (Table 3-5) to explore the effects of weather, hunting, nesting, individual variables, and combinations of these variables on gobbling activity.

To determine the weight of evidence in support of a priori models, we calculated the second-order Akaike's Information Criterion (AIC_C; Akaike 1973, Burnham and Anderson 2002). We considered the model with the lowest AIC*c* to be the best model; all models within 4.0 AIC_C units from the best model were considered as the best set of approximating models. We calculated Akaike weights for all models as an estimate of the probability of the model being the most predictive of examined models. Model-averaged parameters and their 90% confidence intervals were calculated. We considered parameter estimates with confidence intervals excluding zero to be important predictors (Miller and Conner 2007). To investigate important predictors, we plotted data and calculated means and standard errors (SE) for variable categories.

Results

The earliest recorded gobbling activity during 2011 was on 15 February versus 7 February during 2012. The wild turkey breeding season for 2011 on the Jones Center was 8 March-15 June and on Silver Lake WMA was 8 March-3 June (Figure 3-4). For 2012, the breeding season on the Jones Center was 28 Februray-12 June and on Silver Lake WMA was 4 March-29 May (Figure 3-5). During both years, we detected a single peak in breeding activity on both sites. For 2011, gobbling activity peaked during April on both sites (Figure 3-6), compared to 2012 when it peaked during April on the Jones Center versus March on Silver Lake WMA (Figure 3-7).

We detected 1,478 – 2,390 gobbles depending upon study site and year. On the Jones Center, ARU 4 produced 56% of the detected gobbling activity for the site (Figure

3-8). On Silver Lake WMA, ARUs 9 and 11 produced 66% of the detected gobbling activity (Figure 3-9). Most (78%) gobbling occurred before or within 2 hours of sunrise with 21% of all gobbling occurring in the half hour prior to sunrise and < 1% of all gobbling occurring 1 hour prior to sunrise (Figures 3-10 and 3-11).

We found that ARU 4 on the Jones Center contained 40% mature pine and 30% agricultural field/food plot within its 209-m buffer (Figure 3-12). This was not the only ARU that had this combination of habitat types within its buffer, but it was the only one that had this combination of habitats and also was located within 600-m of a permanent water source (Figure 3-13). The only other ARU within 600-m of water was ARU 1, but it lacked openings within its buffer. All other ARUs on the Jones Center were > 1,000 m away from water.

In contrast, 5 out of the 7 ARUs on Silver Lake WMA were within 600-m of water and none of the ARUs on this site contained openings (Figures 3-14 and 3-15). The 2 ARUs that recorded the most gobbling activity had > 80% mature pine within their 209-m buffer. There was another ARU, ARU 10, that was similar in location to water and habitat type, but it did not perform as well with the only noticeable difference being that it contained mature hardwood within its buffer whereas ARUs 9 and 11 do not.

For the breeding season analysis of gobbling activity, the top-performing model was the global model (w_i = 0.88; Table 3-1), and no other models were within 4.0 AIC_C units. Parameter estimates and their CIs indicated that average daily temperature, average daily wind speed, average daily barometric pressure, and day were important variables (Table 3-2). Mean daily gobbling activity was highest when the mean daily temperatures were in the 15 °C range (Table 3-3). Gobbling activity increased as temperatures warmed from 10 ˚C through 15 ˚C until approximately 21 ˚C and then declined throughout 21 and 26 ˚C (Figure 3-16).

Mean daily gobbling activity changed significantly as mean daily wind speeds increased, with a general trend of increasing gobbling activity as wind speed increased (Table 3-4). While mean daily gobbling activity was at its highest on windier days, some of the most active days for gobbling activity appeared to occur when winds speeds were between 3-5 kph (Figure 3-17). Mean daily gobbling activity appeared to increase as barometric pressure decreased from 102 to 100 kPa, but differences were not significant (Table 3-5). Only 1 day out of all breeding seasons averaged 99 kPa and 2 days averaged 103 kPa, while all other days averaged between 100-102 kPa. Gobbling activity increased as barometric pressure increased from 100 kPa to approximately 101.5 kPa and then declined as barometric pressure approached 103 kPa (Figure 3-18). Mean daily barometric pressure ranged from 99.49-103.18 kPa and, on average, was significantly lower on rainy days (101.14 ± 0.04 kPa) versus days absent of rain (101.56 ± 0.03 kPa).

During both years and on both study sites, most gobbling activity occurred during the spring turkey hunting season. For 2011 on Silver Lake WMA, 18% of the total breeding season gobbling activity occurred during the first quota hunt, 10% occurred during the second quota hunt, and 37% occurred during the general hunt, with 79% of total breeding season gobbling activity occurring during the 2011 hunting season (26 March -15 May 2011). For 2012 on Silver Lake WMA, 25% of the total breeding season gobbling activity occurred during the first quota hunt, 15% occurred during the second quota hunt, and 21% occurred during the general hunt, with 76% of total breeding season gobbling activity occurring during the 2012 hunting season (23 March -15 May 2012).

Gobbling activity appeared to be slightly lower during some quotas hunts and both general hunts on Silver Lake WMA when compared to the Jones Center for both 2011 (Figures 3-19 and 3-20) and 2012 (Figures 3-21 and 3-22). Additionally, from the time when the general hunt opened on Silver Lake WMA to when the breeding season ended for 2011, we identified 630 gobbles on Silver Lake WMA versus 832 gobbles on the Jones Center during the same time frame, an approximately 32% difference. When we evaluated the same time periods for 2012, we identified 644 gobbles on Silver Lake WMA versus 924 gobbles on the Jones Center, an approximately 44% difference.

Discussion

Timing of the breeding season on our 2 study sites agreed with previous studies conducted in this region (Bevill 1973, 1975), but we did not detect 2 distinct peaks in gobbling activity as has been previously reported (Bevill 1975, Porter and Ludwig 1980, Hoffman 1990). We did detect a single distinct peak as has been reported by other studies (Kienzler et al. 1996, Miller et al. 1997a). These studies also found that the single peak in gobbling activity did not coincide with peak nesting activity. In our study, gobbling activity peaked in April 3 out of 4 times, which incorporated the second quota hunt and the first 2 weeks of the general hunt on Silver Lake WMA while incorporating peak nest initiation on both sites. For 2012, gobbling activity peaked in March on Silver Lake WMA which incorporated the first quota hunt on Silver Lake WMA, but preceded peak nest initiation. The spring wild turkey hunting season as structured in the state of Georgia incorporated all peaks in gobbling and nesting activity on both of our study sites during both years of this study. Daily peaks in gobbling activity, which mostly occurred within 2 hours of sunrise, agreed with previous studies that found more gobbling occurs in morning than evening (Hoffman 1990).

Gobbling counts were similar between sites, with both sites experiencing an approximately 60% increase in gobbling activity during the second year. The cause of the increase in gobbling activity between 2011 and 2012 is not clear, but the increase occurred on both sites suggesting that a regional climactic factor was responsible. Although it's been determined that increasing photoperiod is ultimately responsible for breeding behavior in wild turkeys (Margolf et al. 1947, Lewis 1967, Schleidt 1968), changes in weather can also affect gobbling activity (Bevill 1973, Porter and Ludwig 1980). Above-average temperatures occurred during the winter prior to the 2012 breeding season and may have stimulated more frequent gobbling activity that began approximately a week earlier on each site. Although males may have responded to the warmer temperatures, it seems females did not as the mean initial nesting dates for 2012 did not differ from 2011 (Williams 2012).

We were surprised that only a few ARUs recorded most of the gobbling activity. This prompted investigation of landscape variables that could explain this variation. Wild turkeys need well-dispersed water sources (Wheeler 1948, Schorger 1966, Hurst 1981, Hurst and Dickson 1992, Porter 1992). Because both sites have abundant water resources, we did not expect that proximity to water would be important when establishing our sample sites. However, the importance of availability of water appears to be evident on the Jones Center as 5 out of 7 ARUs appeared to have the necessary habitat types for wild turkey but were > 1,000-m from water and recorded < 10% of the gobbling during this study. Ruttinger (2013) found that 66 out of 72 male wild turkey roosts across both study sites were located within 600-m of water. Ruttinger (2013) also determined that gobblers on both of these study sites selected for stands of mature pine for roost sites; Hoffman (1990) found that most gobbling occurs on the roost, and we found that that 78% of all gobbling activity occurred within the first 2 hours of sunrise. On Silver Lake WMA, water did not seem to be the limiting factor, but rather presence of > 80% mature pine seemed to be the limiting factor, with the 2 ARUs that recorded the most gobbling activity meeting these requirements. In both cases, the ARUs that recorded the most gobbling activity on the Jones Center and Silver Lake WMA were within 600-m of water. Future studies of gobbling activity should consider distance to water in the sampling design.

Mean daily temperature, mean daily wind speed, and mean daily barometric pressure were important predictors of gobbling activity. Gobbling activity was greatest on days when temperatures averaged 15 ˚C, and activity appeared to increase as average temperatures approached 21 ˚C; activity decreased when temperatures averaged >21 ˚C. Mean daily gobbling activity changed significantly as mean daily wind speeds increased, with a general trend of gobbling activity increasing as wind speed increased. A wind speed of 16 kph may represent a critical point at which gobbling activity either begins to decrease or detection of gobbling activity begins to decrease due to increased background noise (Bevill 1975, Healy 1992, Kienzler et al. 1996). Alternatively, males may not gobble as much on windy days to avoid a potential increased predation risk due to the increased level of background noise. While mean daily gobbling activity was at its highest on windier days, some of the most active days for gobbling activity occurred when wind speeds were between 3-5 kph.

The finding that mean daily gobbling activity increased as wind speeds increased is supported by the finding that mean daily gobbling activity appeared to increase as mean daily barometric pressure decreased. Low pressure days are often associated with a turbulent atmosphere characterized by higher winds and rain as opposed to a stable atmosphere, with little to no wind and sunny skies, which is often associated with high pressure days. Additional support was lent by the finding that barometric pressure was significantly lower on rainy days versus days without rain in our dataset. This is in contrast to previous findings that state most gobbling occurs on clear, sunny days versus cloudy, rainy days (Bevill 1975, Healy 1992, Kienzler et al. 1996). Our finding may also suggest turkeys are cueing in on the lower barometric pressure and are gobbling more preceding the oncoming weather disturbance, rather than gobbling more during the rain events themselves. Finally, gobbling activity decreased as the breeding season progressed. When we consider that the Jones Center had 32-44% more gobbling activity than Silver Lake WMA after the general hunt opened on the WMA, gobbling activity decreasing as the breeding season progressed may reflect a harvest and/or hunting effect that is occurring on Silver Lake WMA but not on the Jones Center.

Even so, our findings were inconclusive regarding the effects of peak nesting and hunting pressure on gobbling activity. The lack of solid findings may suggest that hunting is not negatively affecting gobbling activity and thus, breeding activity. Previous studies suggested that peaks in gobbling activity were associated with nest initiation (Bailey and Rinell 1967, Bevill 1975, Porter and Ludwig 1980) and that gobbling activity was negatively associated with hunting pressure (Kienzler et al. 1996, Lehman et al. 2005). Other studies found no relationship between nest initiation and gobbling activity

(Kienzler et al. 1996, Miller et al. 1997a) and that hunting pressure was positively related to gobbling activity (Miller et al. 1997a). With respect to hunting, we do not have data regarding daily hunting pressure on the WMA and where it was occurring because hunters only had to sign in once at the beginning of the season. With that being said, we know that on Silver Lake WMA, a total of 182 hunters harvested 22 males during the 2 years of this study.

Continued research on the potential impacts of hunting and nesting on wild turkey gobbling activity should include a variety of different public and private lands, with variable hunting seasons that are open to the general public earlier in the year, with greater potential to impact breeding activity. Future studies should also quantify daily, spatially explicit hunting pressure. Hunting pressure may not be perceived by the entire turkey population but rather by isolated pockets where pressure is greater on a daily basis. What amount of hunting pressure is required to negatively affect gobbling activity and on what spatial scale is that effect perceived? To address these questions, specific locations should be targeted by ARUs and hunters to investigate the effect of hunting pressure on gobbling activity on smaller spatial scales. Future studies should continue to use ARUs as they allow more consistent sampling across study sites and throughout days providing a more complete picture of gobbling activity throughout the day and season.

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Table 3-1. A priori models, number of variables (*K*), distance from the second-order Akaike's Information Criterion (ΔAIC*c*), and model weights (*wi*) for models explaining the effects of weather variables (mean daily temperature, mean daily wind speed, mean daily wind direction, mean daily relative humidity, rainfall occurred [yes/no], mean daily barometric pressure), hunting seasons (yes/no), peak nesting activity (yes/no), site, year, and day on gobbling activity of eastern wild turkey on the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Model	*K*	ΔAIC_C	w_i
Global Model	11	0.00	0.88
Weather + Hunting + Nesting + Year + Site	10	5.46	0.06
Weather + Nesting + Year + Site	9	5.80	0.05
Weather +Hunting + Year + Site	9	9.38	0.01
Weather + Site + Year	8	13.12	0.00
Weather + Site	7	18.94	0.00
Weather + Year	7	21.31	0.00
Nesting + Site + Year	3	24.26	0.00
Hunting + Site	2	24.39	0.00
Hunting + Site + Year	3	26.07	0.00
Nesting + Site	2	27.17	0.00
Nesting + Year	2	27.75	0.00
Weather	1	27.80	0.00
Hunting	1	27.84	0.00
Hunting + Year	2	29.74	0.00
Nesting	1	29.88	0.00
Site + Year	2	32.10	0.00
Temperature	1	33.71	0.00
Year	1	36.81	0.00
Site	1	37.84	0.00
Rainfall	1	37.89	0.00
Null Model	0	41.58	0.00
Barometric Pressure	1	42.29	0.00
Relative Humidity	1	42.98	0.00
Wind Direction	1	43.24	0.00
Wind Speed	1	43.39	0.00

Table 3-2. Parameter estimates, standard errors, and 90% confidence intervals for parameters used to predict gobbling activity of eastern wild turkey in relation to weather, hunting, and nesting on the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Effect	Parameter Estimate	SE	Lower 90% CI	Upper 90% CI
Mean Daily Temperature[a]	-0.014	0.007	-0.002	-0.026
Mean Daily Wind Speed[a]	-0.041	0.018	-0.011	-0.070
Mean Daily Wind Direction	0.010	0.017	0.037	-0.018
Mean Daily Relative Humidity	0.004	0.004	0.010	-0.003
Rainfall Occurrence	-0.125	0.139	0.104	-0.353
Mean Daily Barometric Pressure[a]	-0.192	0.081	-0.060	-0.325
Hunting Season	-0.068	0.093	0.084	-0.220
Peak Nesting Activity	-0.130	0.139	0.099	-0.357
Site	-0.082	0.092	0.070	-0.233
Year	-0.066	0.094	0.087	-0.220
Day[a]	-0.004	0.002	-0.002	-0.007

[a] CI does not contain zero.

Table 3-3. Means and standard errors of eastern wild turkey gobbling activity by daily temperature ranges (˚C) for data used to model the effects of weather on breeding season gobbling activity on the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 2011-2012.

Daily Temperature Range (˚C)	Mean	SE
4.44	13.00	0.00
10.00	15.12	3.49
15.56	30.83	3.93
21.11	15.25	1.36
26.67	7.55	2.80

Table 3-4. Means and standard errors of eastern wild turkey gobbling activity by daily wind speed ranges (kph) for data used to model the effects of weather on breeding season gobbling activity on the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 2011-2012.

Daily Wind Speed Range (kph)	**Mean**	**SE**
1.61	11.20	4.98
3.22	21.14	2.90
4.83	15.46	2.74
6.44	26.52	4.56
8.05	18.33	3.72
9.66	21.13	5.27
11.27	29.75	9.19
12.87	11.75	4.06
14.48	33.71	14.92
16.09	3.80	2.33
17.70	15.80	6.47
19.31	3.00	1.00

Table 3-5. Means and standard errors of eastern wild turkey gobbling activity by daily barometric pressure ranges (kPa) for data used to model the effects of weather on breeding season gobbling activity on the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 2011-2012.

Daily Barometric Pressure Range (kPa)	**Mean**	**SE**
99	8.00	0.00
100	23.32	4.21
101	19.94	1.98
102	19.00	3.89
103	0.00	0.00

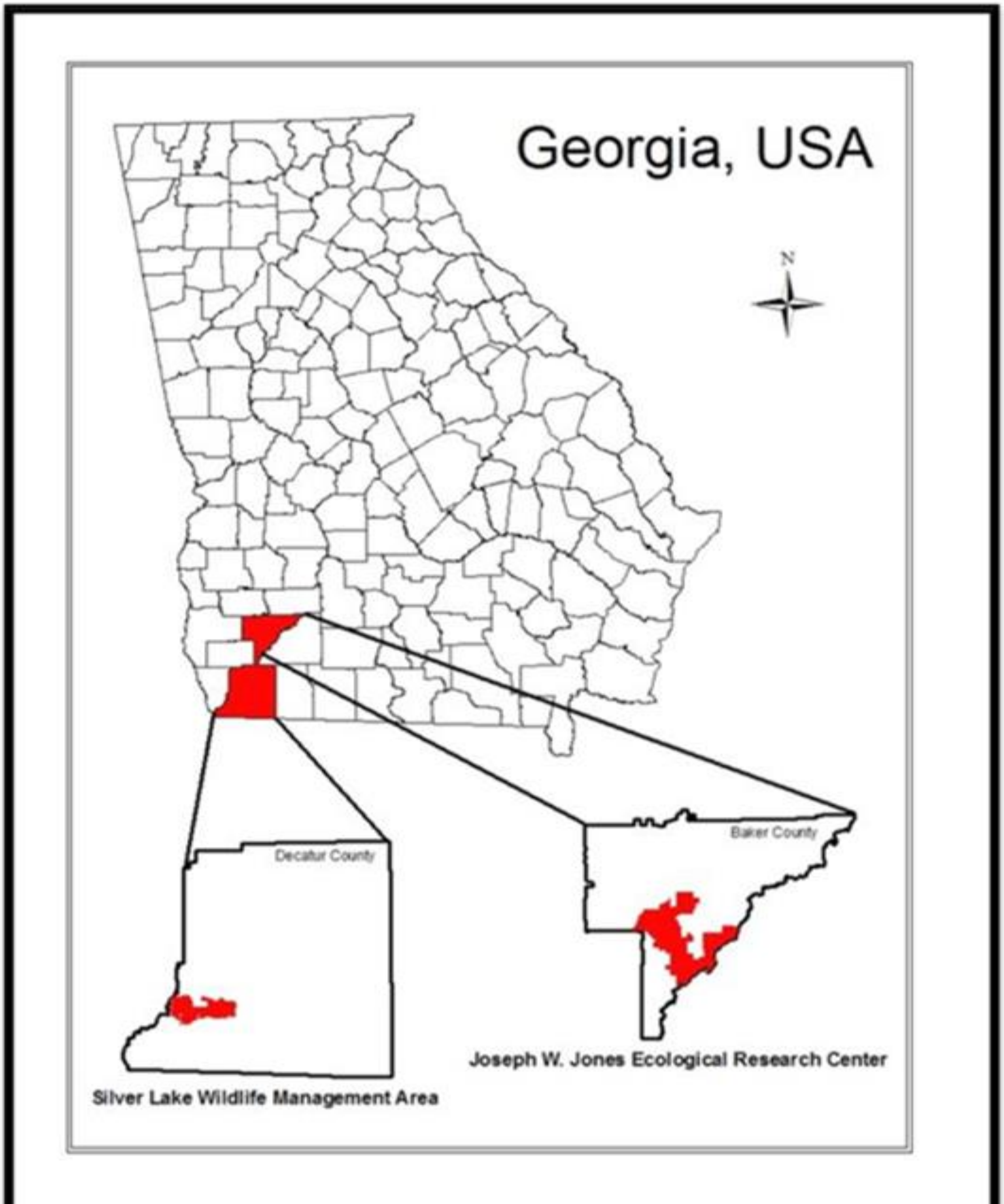

Figure 3-1. The Joseph W. Jones Ecological Research Center at Ichauway and the Georgia Department of Natural Resources' Silver Lake Wildlife Management Area in southwestern Georgia, USA, 2011-2012.

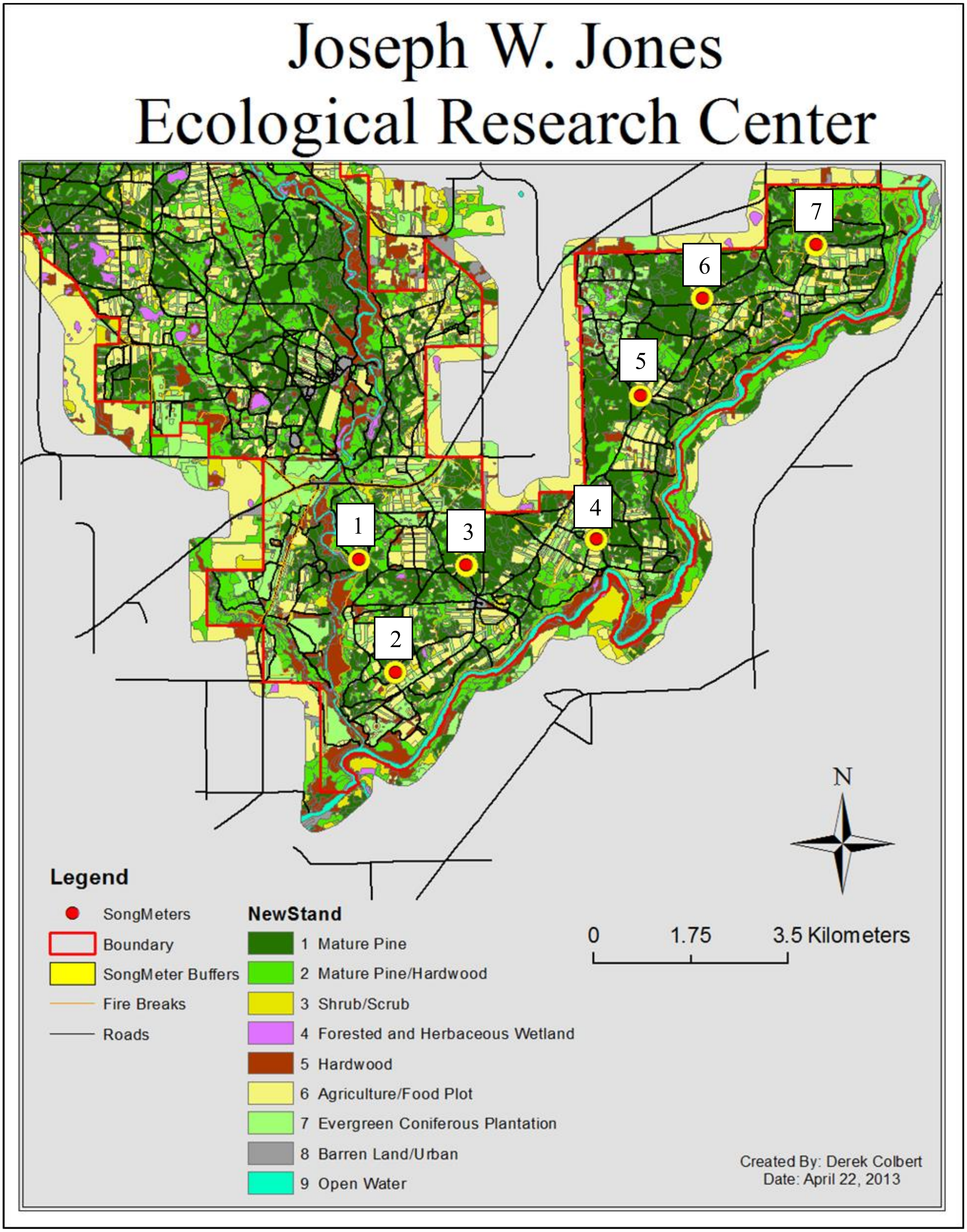

Figure 3-2. Locations of Song Meter SM2 autonomous recording units 1-7 on the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 2011-2012.

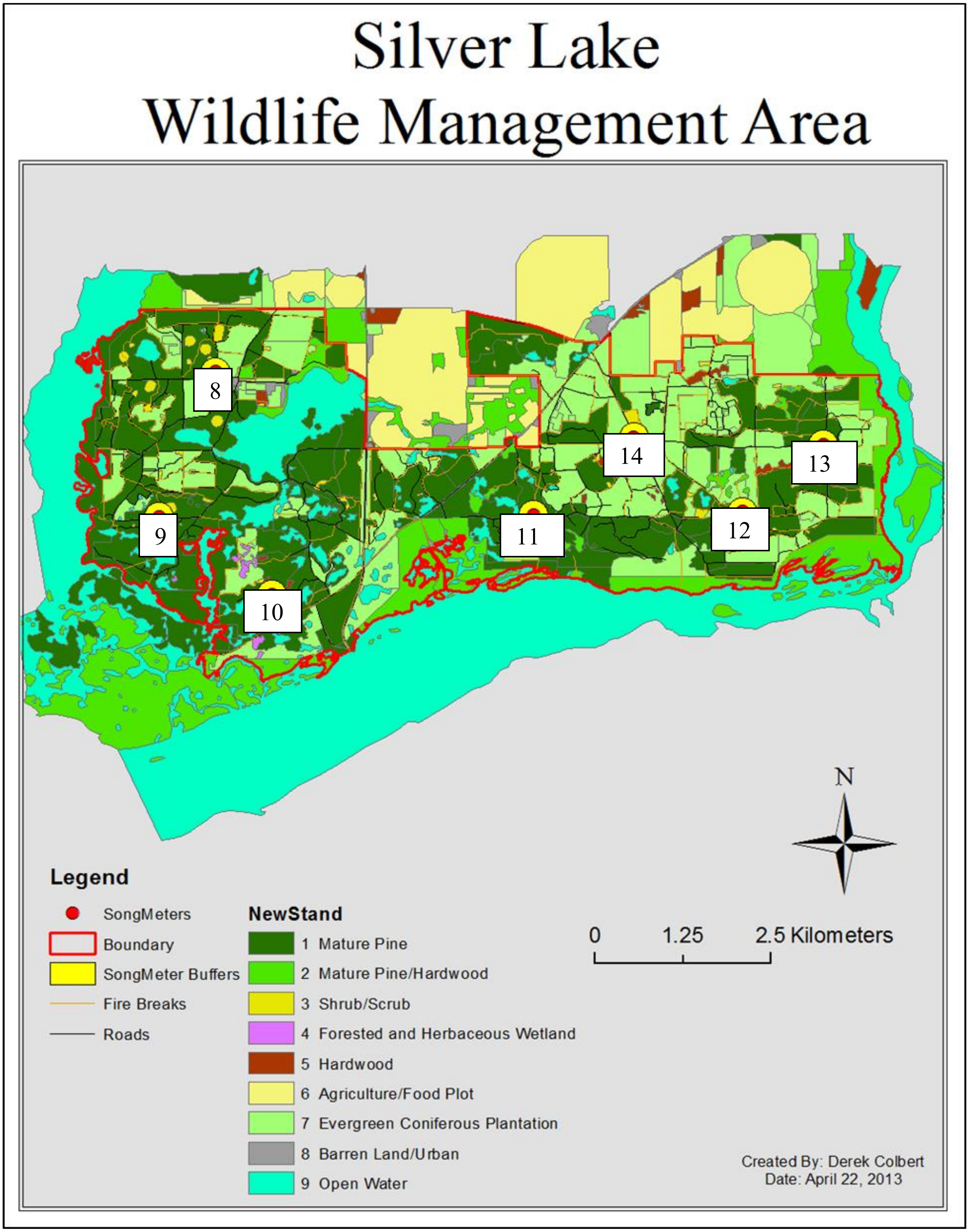

Figure 3-3. Locations of Song Meter SM2 autonomous recording units 8-14 on Silver Lake Wildlife Management Area in southwestern Georgia, USA, 2011-2012.

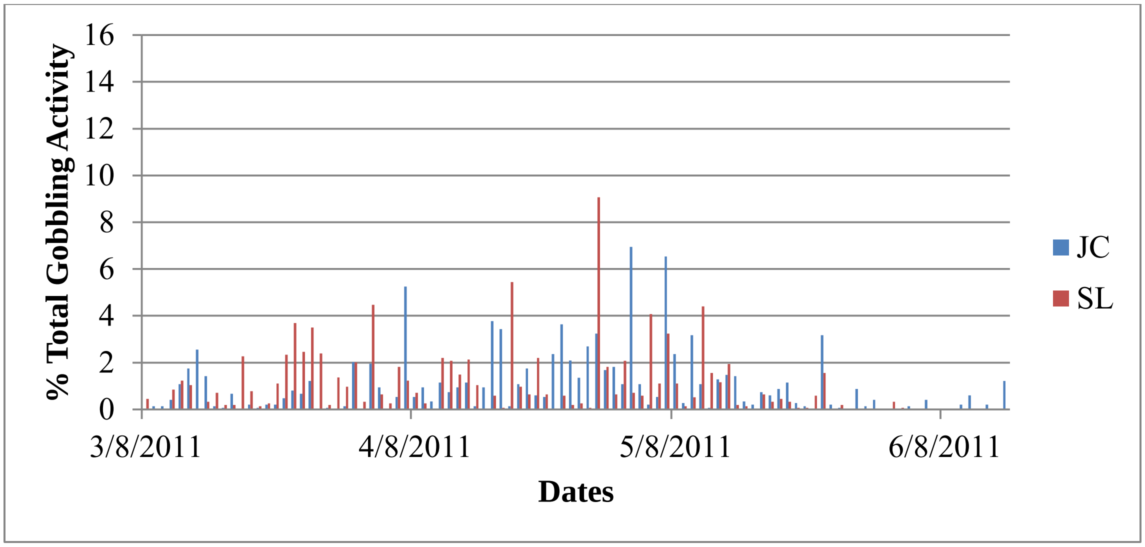

Figure 3-4. Comparison of daily gobbling activity in percentage of total breeding season gobbling activity of eastern wild turkey on the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 8 March 2011-15 June 2011.

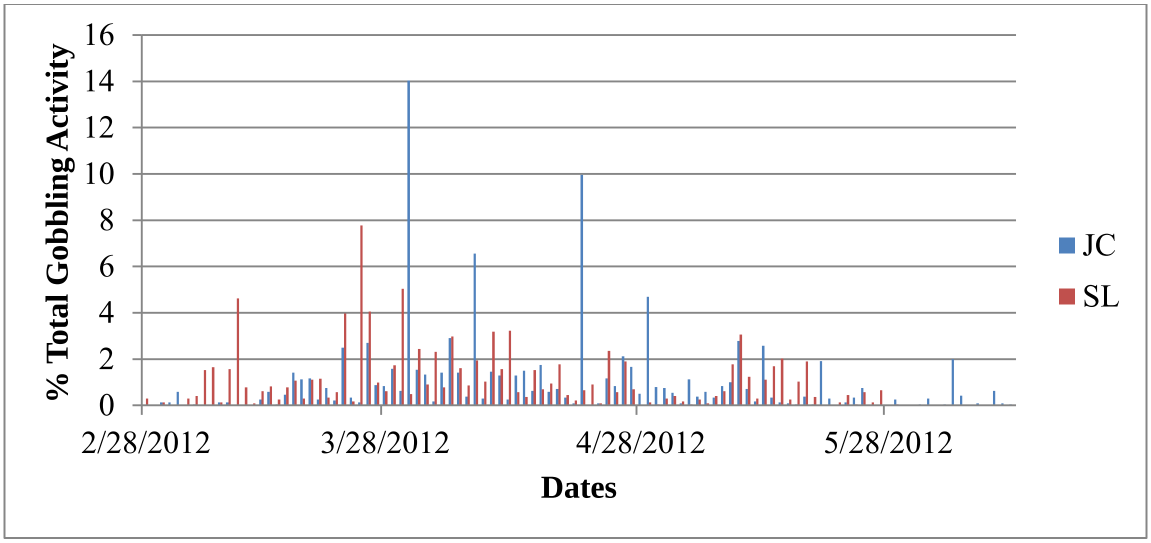

Figure 3-5. Comparison of daily gobbling activity in percentage of total breeding season gobbling activity of eastern wild turkey on the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 28 February 2012-12 June 2012.

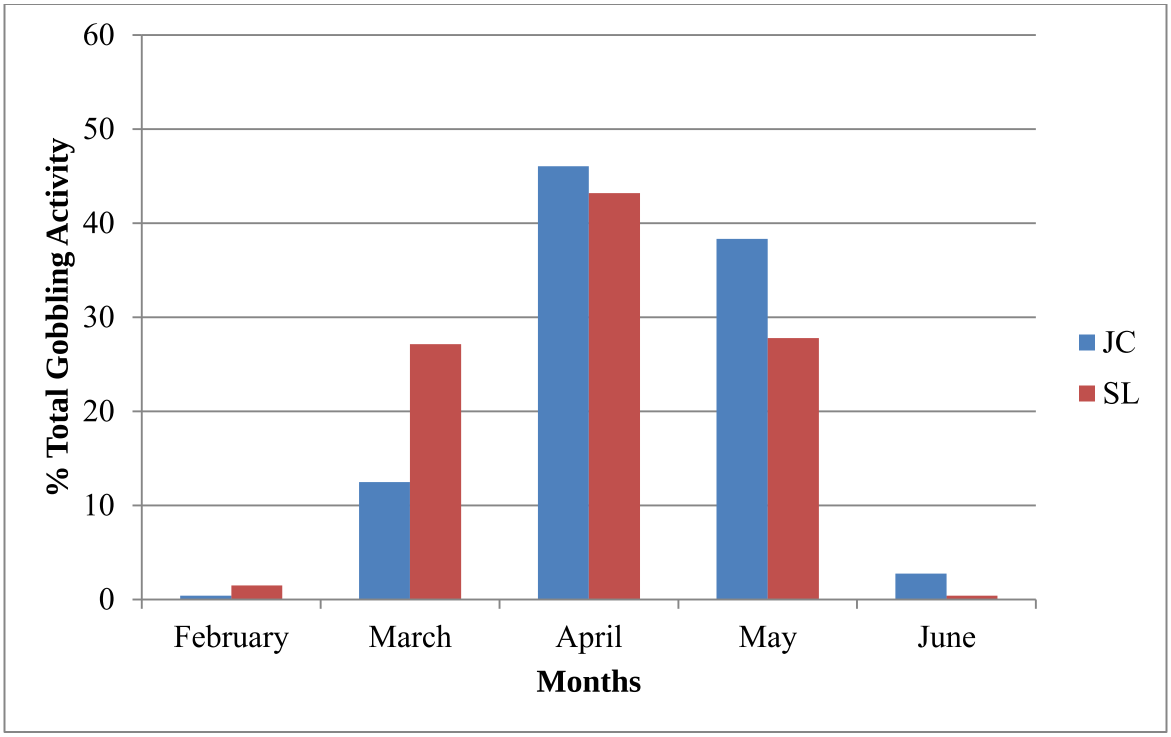

Figure 3-6. Percentage of eastern wild turkey gobbling activity graphed by months for the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 2011.

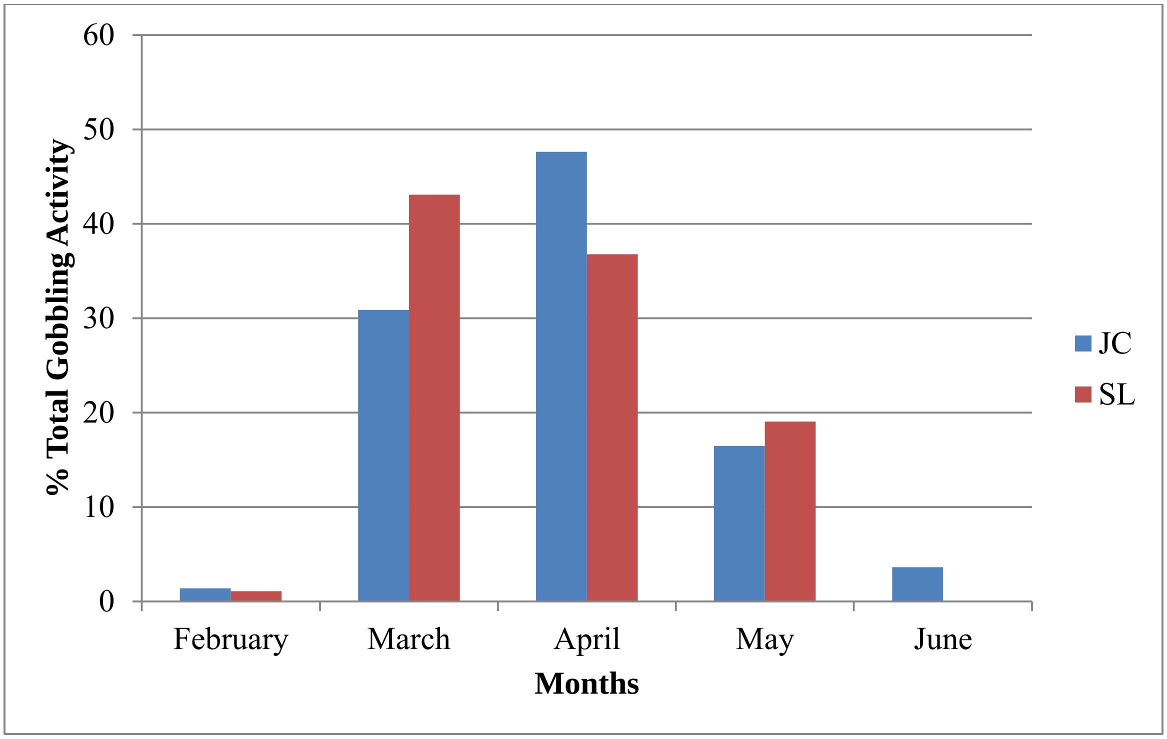

Figure 3-7. Percentage of eastern wild turkey gobbling activity graphed by months for the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 2012.

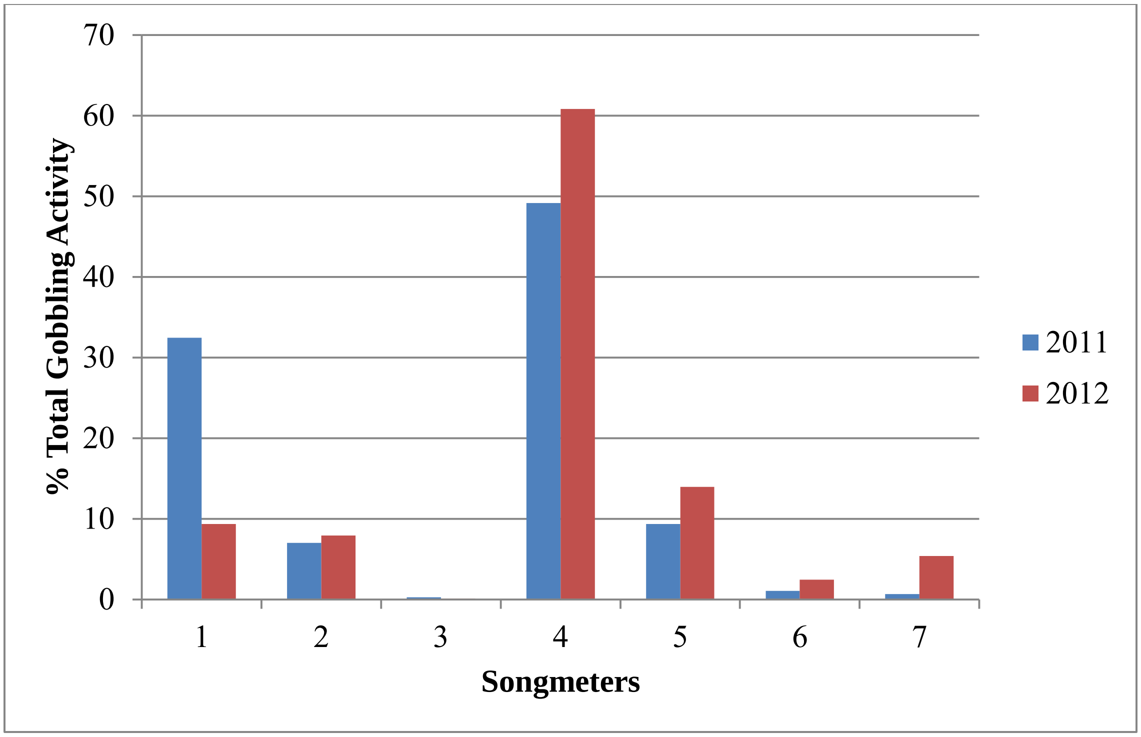

Figure 3-8. Percentage of eastern wild turkey gobbling activity recorded by autonomous recording units on the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 2011-2012.

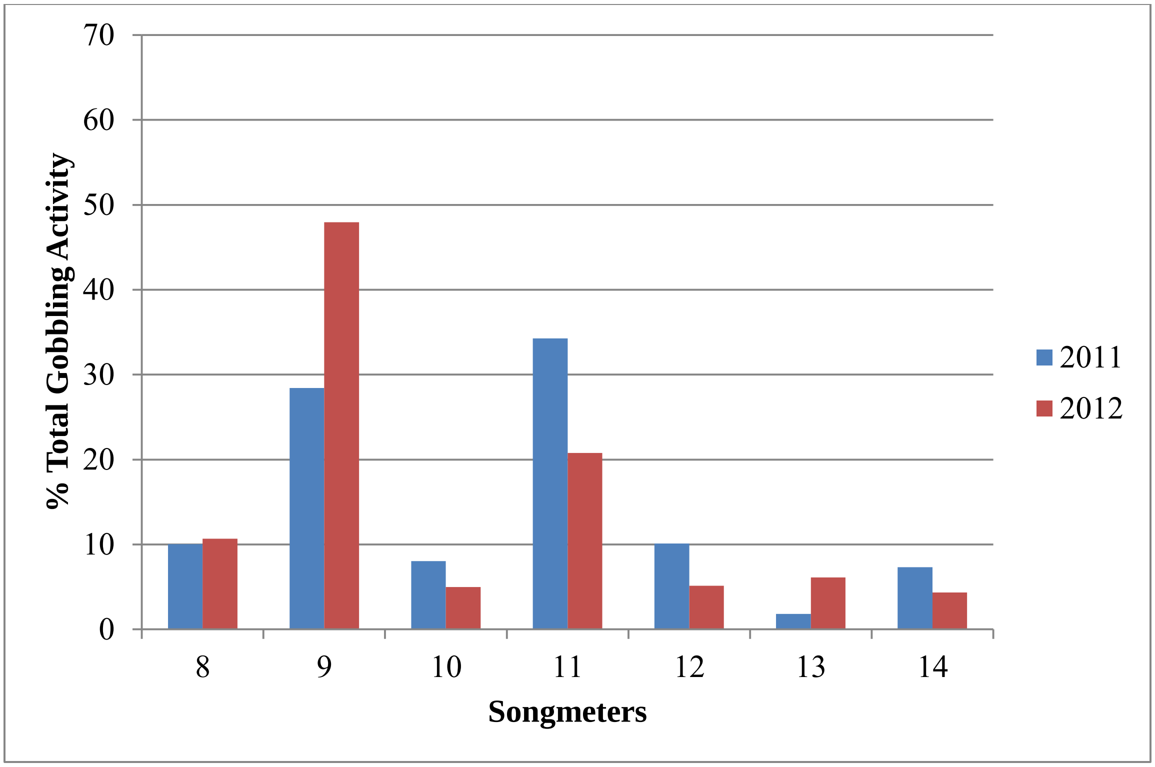

Figure 3-9. Percentage of eastern wild turkey activity recorded by autonomous recording units on Silver Lake WMA in southwestern Georgia, USA, 2011-2012.

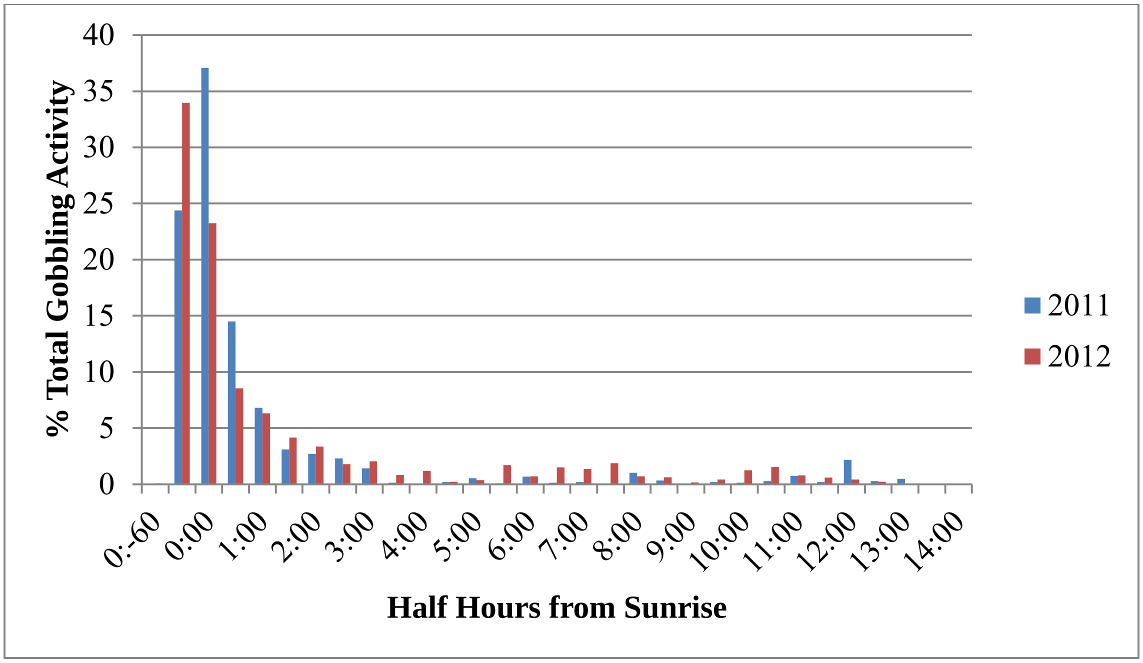

Figure 3-10. Percentage of eastern wild turkey gobbling activity in half-hour increments from sunrise for the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 2011-2012.

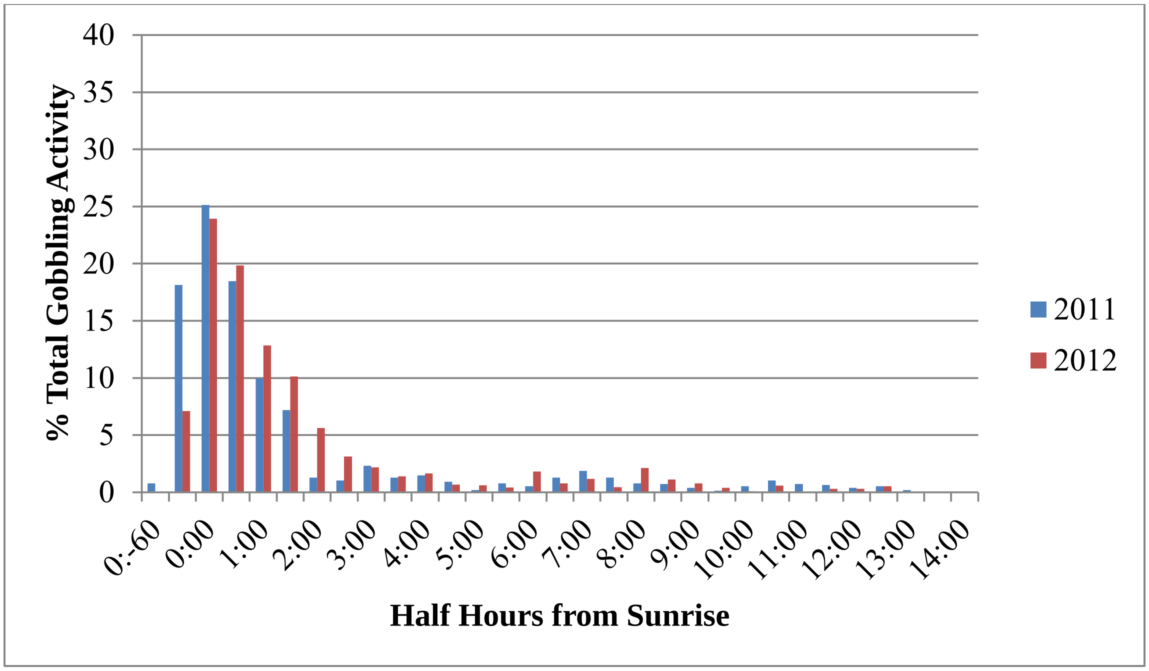

Figure 3-11. Percentage of eastern wild turkey gobbling activity in half-hour increments from sunrise for Silver Lake Wildlife Management Area in southwestern Georgia, USA, 2011-2012.

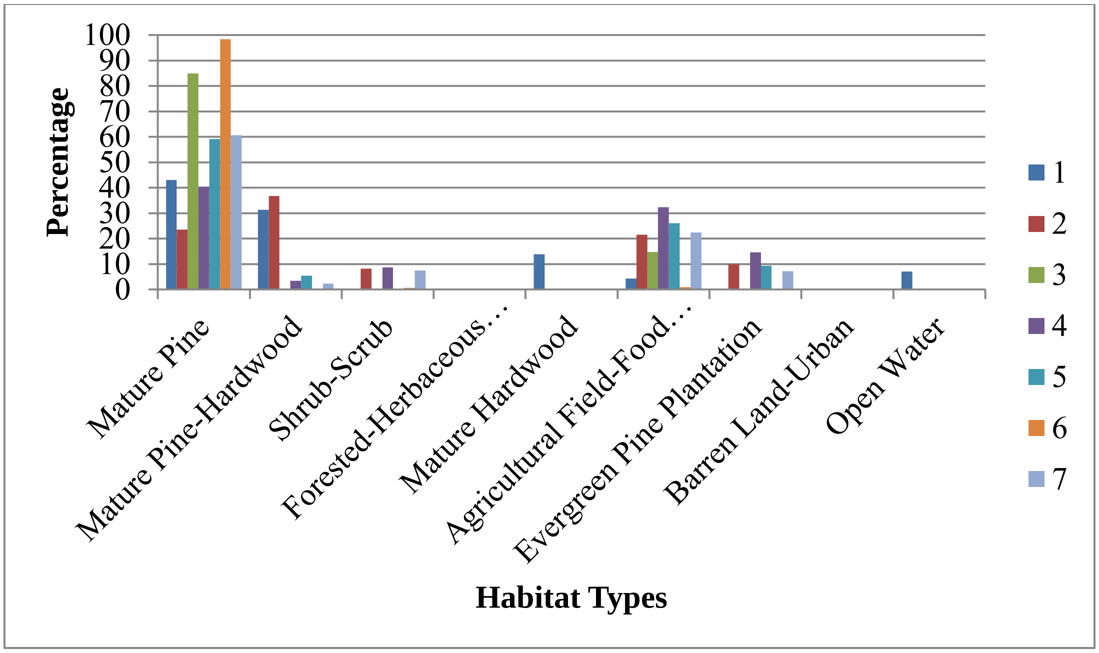

Figure 3-12. Habitat types by percentage within a 210-m buffer around autonomous recording units on the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 2011-2012.

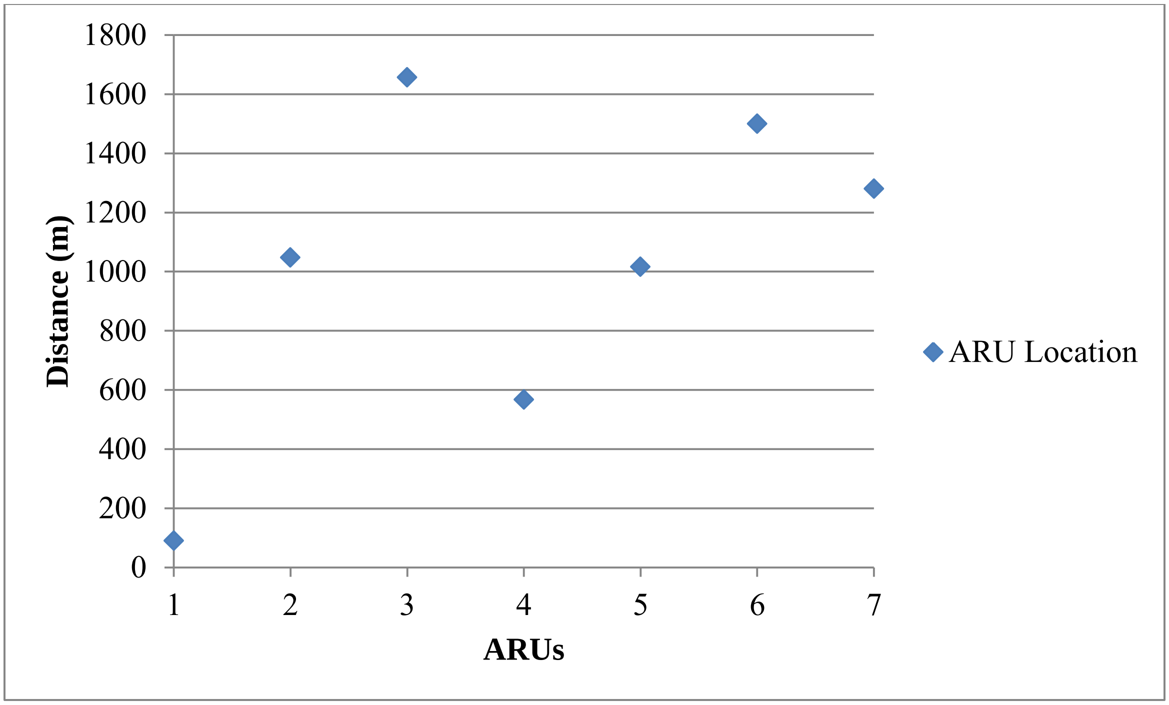

Figure 3-13. Distance of autonomous recording units from the nearest permanent body of water on the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 2011-2012.

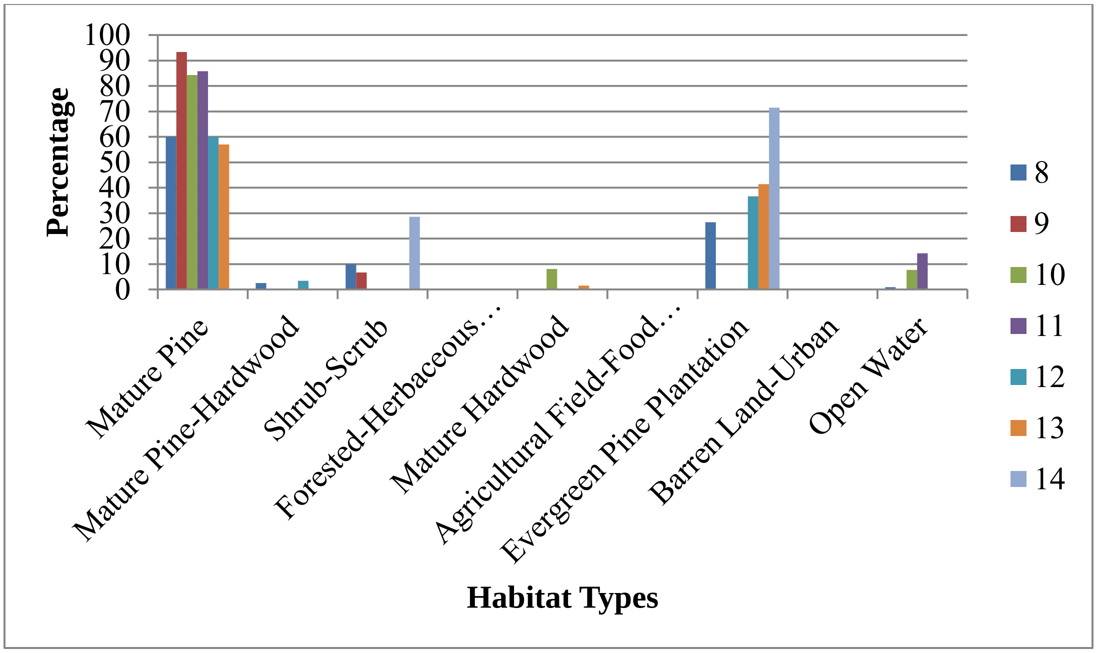

Figure 3-14. Habitat types by percentage within a 210–m buffer around autonomous recording units on Silver Lake WMA in southwestern Georgia, USA, 2011-2012.

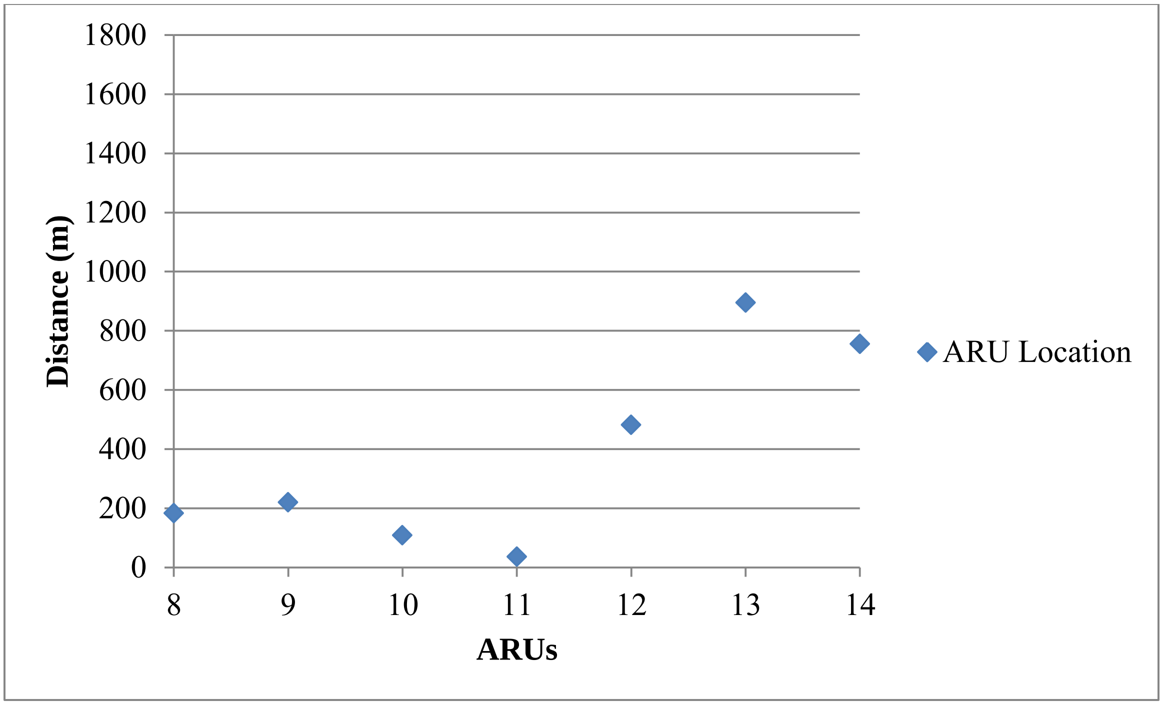

Figure 3-15. Distance of autonomous recording units from the nearest permanent body of water on Silver Lake WMA in southwestern Georgia, USA, 2011-2012.

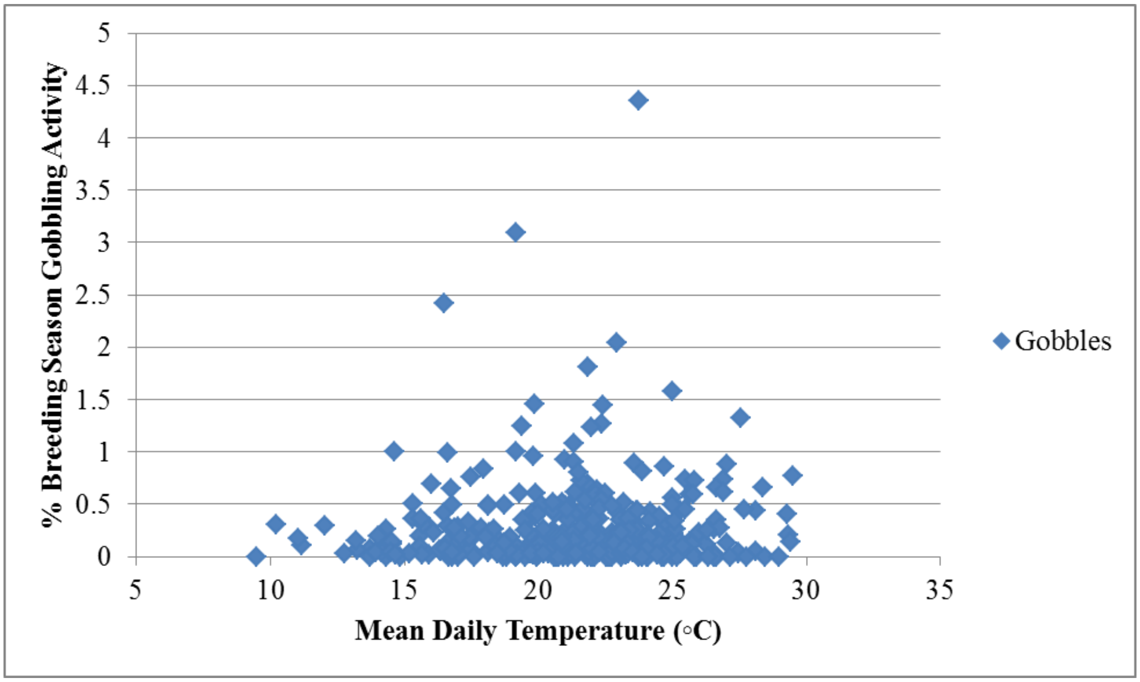

Figure 3-16. Scatter plot of percent daily gobbling activity associated with mean daily temperatures (˚C) for weather modeling of eastern wild turkey breeding season gobbling activity for the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 2011-2012.

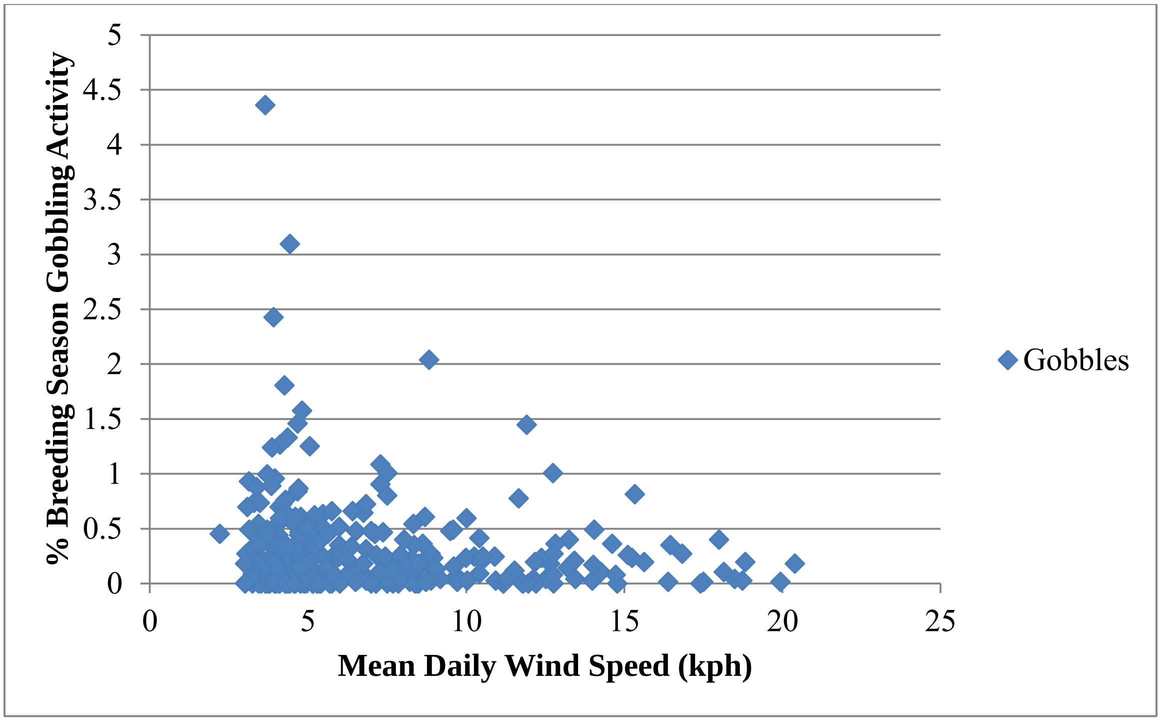

Figure 3-17. Scatter plot of percent daily gobbling activity associated with mean daily wind speed (kph) for weather modeling of eastern wild turkey breeding season gobbling activity for the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 2011-2012.

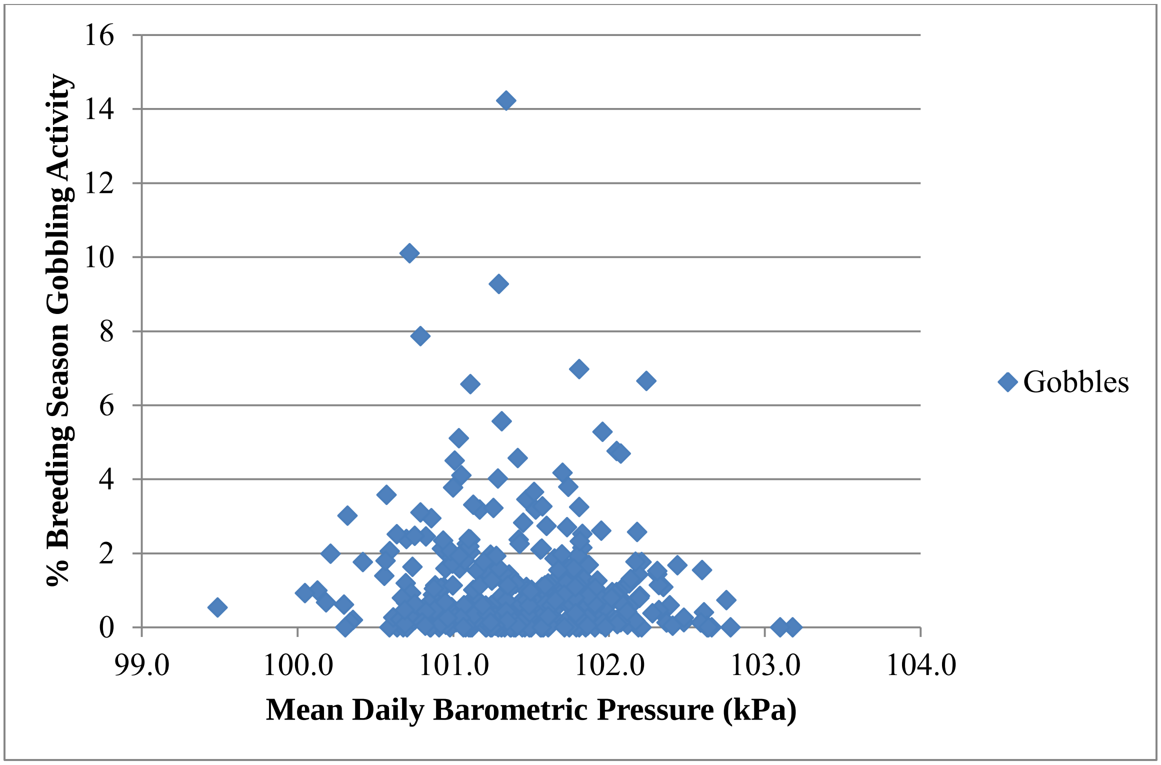

Figure 3-18. Scatter plot of percent daily gobbling activity associated with mean daily barometric pressure (kPa) for weather modeling of eastern wild turkey breeding season gobbling activity for the Joseph W. Jones Ecological Research Center and Silver Lake WMA in southwestern Georgia, USA, 2011-2012.

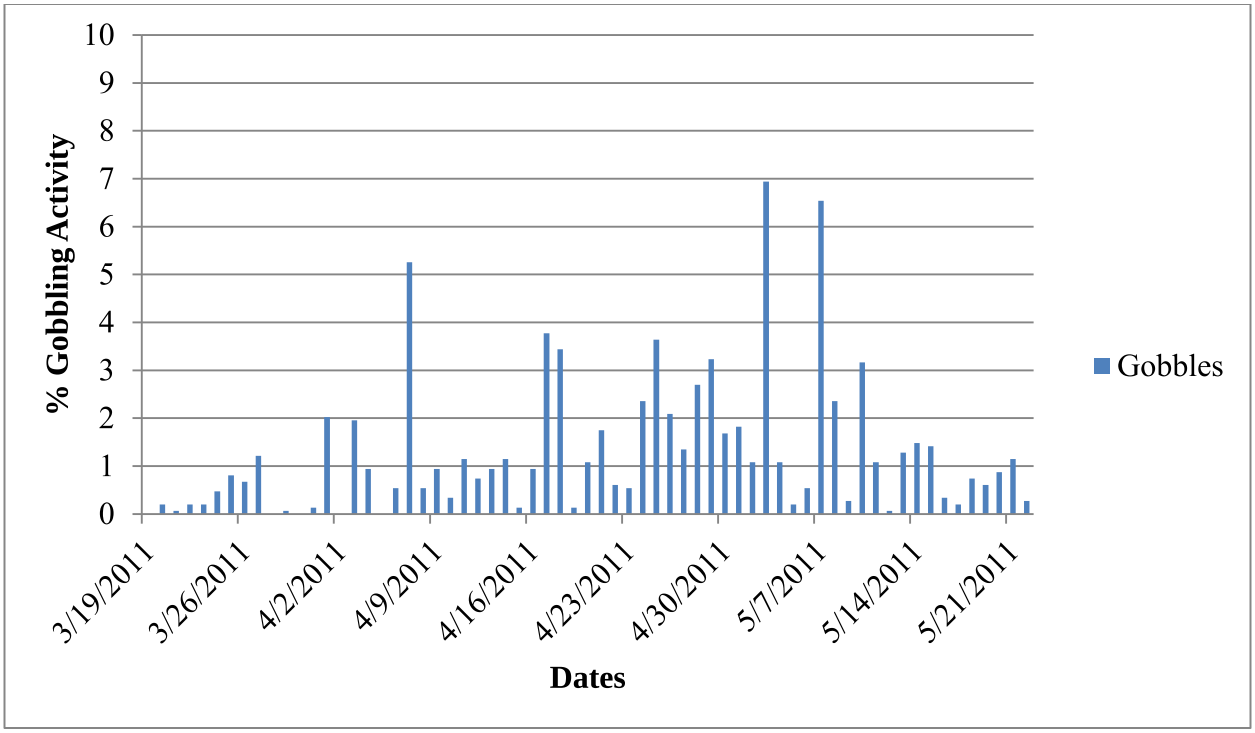

Figure 3-19. Percentage of gobbling activity by eastern wild turkeys, starting one week before the opening of the wild turkey season in Georgia and ending one week after the season closed, on the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 19 March 2011-22 May 2011.

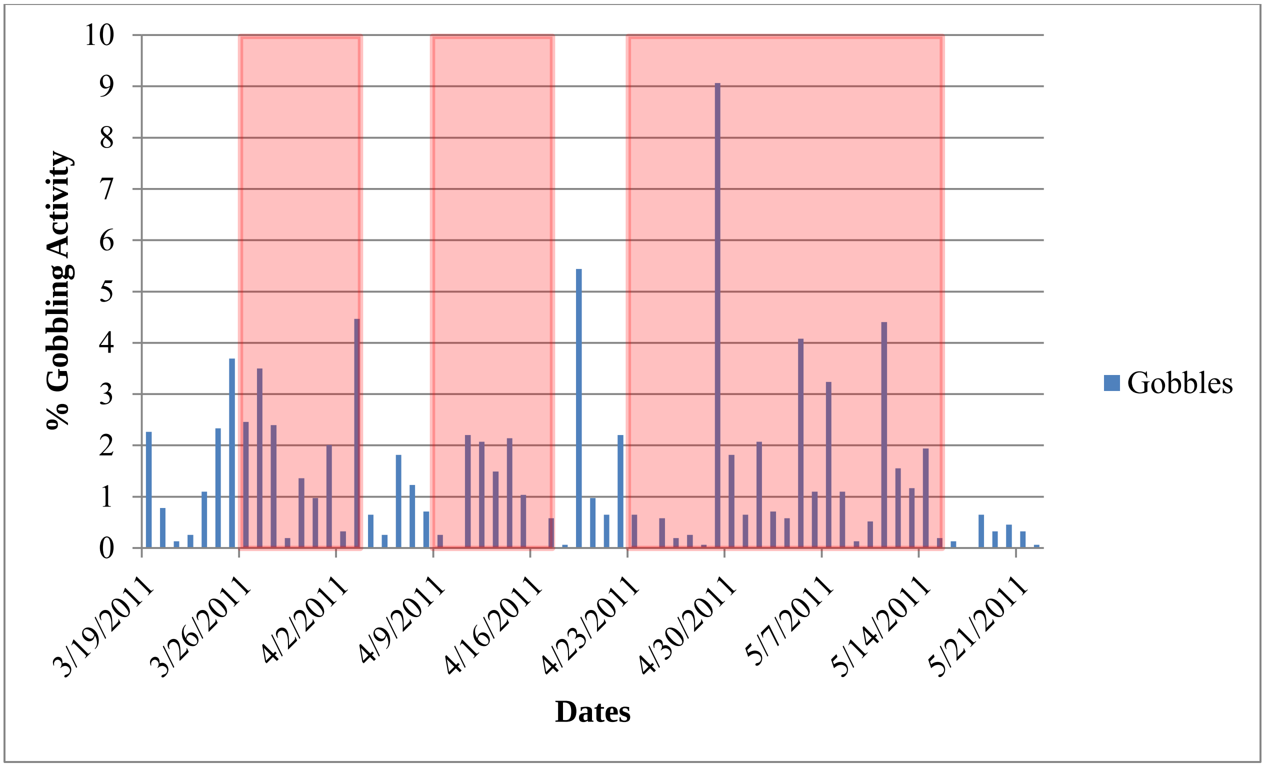

Figure 3-20. Percentage of gobbling activity by eastern wild turkeys, starting one week before the opening of the wild turkey season in Georgia and ending one week after the season closed, on Silver Lake WMA in southwestern Georgia, USA, 19 March 2011-22 May 2011. Highlighted dates outline the first quota hunt, the second quota hunt, and the general hunt on Silver Lake WMA.

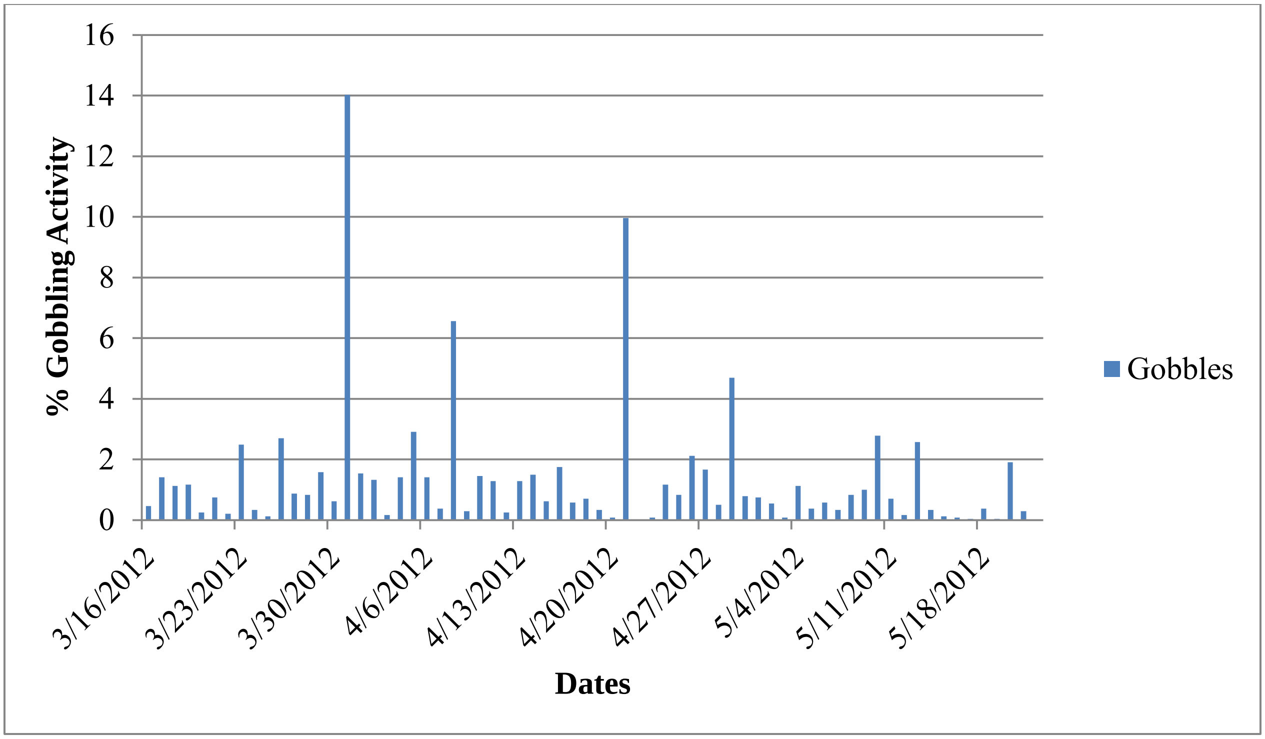

Figure 3-21. Percentage of gobbling activity by eastern wild turkeys, starting one week before the opening of the wild turkey season in Georgia and ending one week after the season closed, on the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 16 March 2012-22 May 2012.

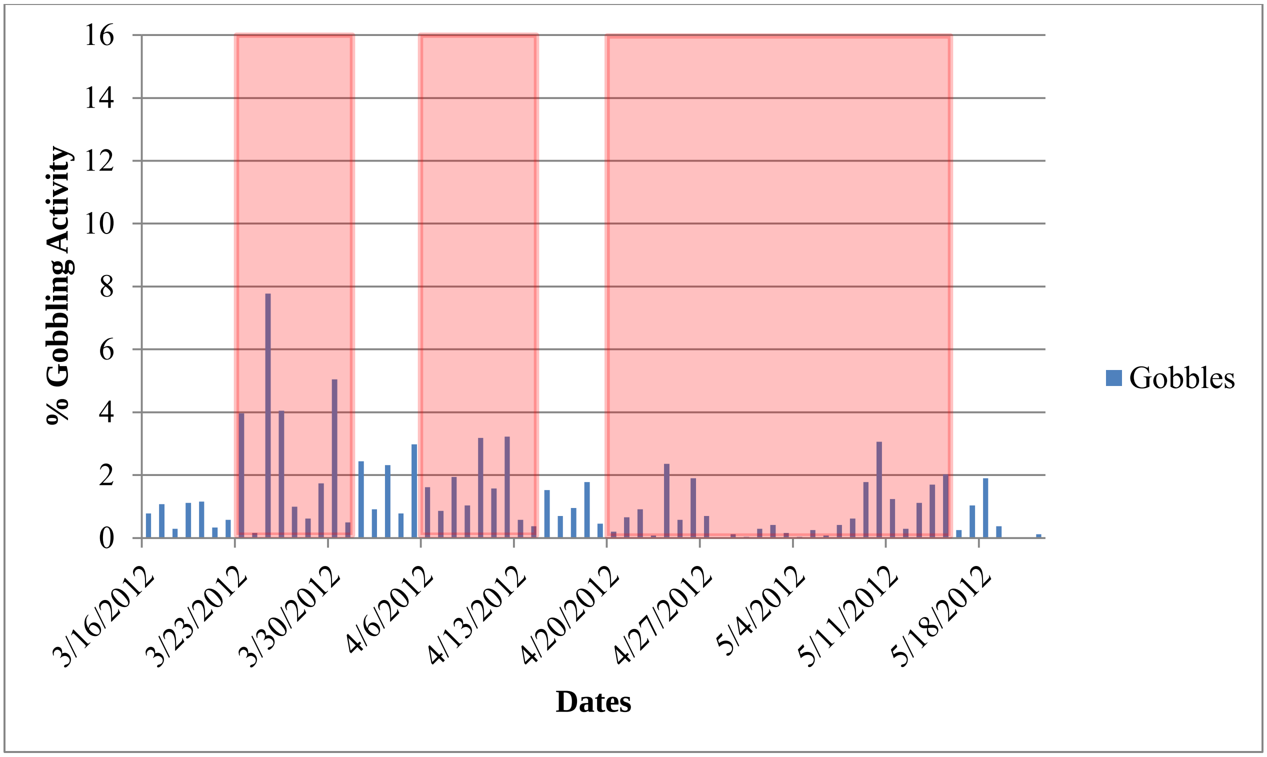

Figure 3-22. Percentage of gobbling activity by eastern wild turkeys, starting one week before the opening of the wild turkey season in Georgia and ending one week after the season closed, on Silver Lake WMA in southwestern Georgia, USA, 16 March 2012-22 May 2012. Highlighted dates outline the first quota hunt, the second quota hunt, and the general hunt on Silver Lake WMA.

CHAPTER 4

CONCLUSIONS

My study introduced new information on the use autonomous recording units to document wild turkey gobbling activity and the ability of automatic call recognition software to find and identify gobbling activity to expedite data processing. I also provided information on wild turkey gobbling activity in relation to sunrise, habitat, weather, hunting, and nesting in southwestern Georgia.

Blumstein et al. (2011) recommended that researchers adopting autonomous recording unit (ARU) technology document their experiences and explain pitfalls and lessons learned about bioacoustics deployments and platforms. While I found that ARUs may not be able to detect gobbling activity at distances equal to that of a human observer, my findings suggest that ARUs are an effective tool to monitor and identify trends in eastern wild turkey gobbling activity by allowing for more thorough and consistent sampling of study areas during biologically significant time periods (Blumstein et al. 2011, Mennill 2011). These consistent sampling efforts provided opportunities to study the long-term changes in behavior and biodiversity of wild species in response to seasonal variation, human activity, and habitat modification (Riede 1993, Riede 1998, Blumstein et al. 2011).

Although the automated recording process provided the opportunity to save time and effort during data collection, the time required to process those recordings could be significant without the use of automated call recognition (ACR) software, which could reduce the time required for data processing. I was able to develop a recognizer file in the proprietary ACR software Song Scope that had a high and consistent detection rate across both study sites annually, but it also had a high false positive rate. Therefore, I had to devote months of time in analyzing false positives to ensure an accurate count of gobbles and, while not ideal, this process required less time than would have been necessary to listen to all recordings, but provided only a slight improvement over visually analyzing spectrograms of all recordings. The great percentage of false positives suggests that the recognizer file I created simply identified sounds within the frequency ranges of a gobble, such as crow calls, rather than actual gobbles. I noted throughout the analysis that the recognizer file was often calling crow calls a turkey gobble. This may be a result of both calls occurring within the same frequency range and the crow call resembling the peak that occurs at the beginning of a turkey gobble.

The reason for the great prevalence of false positives is unclear but it is possible that the HMM approach used by Song Scope is not appropriate to identify wild turkey gobbles. Brandes (2008) reported that HMMs could be susceptible to background noise resulting in poor classification of sounds that overlap in time but not in frequency and with wild turkey gobbling occurring between 400-1800 Hz, the lower end of the spectrum where background noise tends to occur, an HMM approach is most likely not appropriate. Future research is necessary to identify modeling approaches that reduce false positive rates.

While ARUs are an effective tool, much thought needs to go into the scope of the project before they are deployed. They can be efficient tools for data collection (Telfer and Farr 1993, Haselmayer and Quinn 2000, Hobson et al. 2002, Rempel et al. 2005, Brandes 2008), but careful consideration needs to be taken regarding how data will be processed. Automatic call recognition software has the potential to streamline data processing aspect, but may not be as efficient as expected. Thus, any efficiency gains associated with data collection may be lost during data processing.

When it comes to wild turkey research, the thorough dataset that ARUs provide present the opportunity to further our understanding of the effects of weather, nesting, and hunting on wild turkey breeding activity, an improvement over previous studies of this kind that made use of point count routes to gather gobbling data (Bevill 1975, Hoffman 1990, Kienzler et al. 1996, Norman et al. 2001, Lehman et al. 2005). Using ARUs, I collected approximately 19,800 hours of breeding season recordings of male wild turkeys across 2 study sites in 2011 and 2012 for a total of 7,754 identified gobbles. With the ability to conduct a point count survey in 14 spots every half hour, I have collected a more thorough dataset than previous studies of this kind, allowing for stronger conclusions concerning the response of gobbling activity in relation to weather, nesting, and hunting.

Timing of the breeding season on these 2 study sites agreed with previous studies conducted in this region (Bevill 1973, 1975), but I detected only a single distinct peak in gobbling activity, as has been reported (Kienzler et al. 1996, Miller et al. 1997), versus 2 distinct peaks in gobbling activity (Bevill 1975, Porter and Ludwig 1980, Hoffman 1990). These studies also found that the single peak in gobbling activity did not coincide with peak nesting activity, whereas I found that gobbling activity peaked in April 3 out of 4 times, which not only incorporated peak nest initiation, but also the second quota hunt and the first 2 weeks of the general hunt on Silver Lake. Although, in 2012, gobbling activity peaked in March on Silver Lake WMA, which preceded peak nest initiation, but did incorporate the first quota hunt on Silver Lake WMA. The spring wild turkey hunting season, as structured in the state of Georgia, incorporated all peaks in gobbling and nesting activity on both of my study sites during both years of this study, allowing for maximum hunter opportunity while minimizing hen vulnerability (Figures 4-1 and 4-2). Most of the daily peaks in gobbling activity occurred within 2 hours of sunrise which agreed with previous studies that found more gobbling occurs in morning than evening (Hoffman 1990).

Gobbling counts were similar between sites annually, with both sites experiencing an approximately 60% increase in gobbling activity during the second year. The cause of the increase in gobbling activity between 2011 and 2012 is unclear, but with the increase occurring on both sites, this suggests that a regional climactic factor was responsible. It's been determined that increasing photoperiod is ultimately responsible for breeding behavior in wild turkeys (Margolf et al. 1947, Lewis 1967, Schleidt 1968), but changes in weather can also affect gobbling activity (Bevill 1973, Porter and Ludwig 1980). Above-average temperatures occurred during the winter prior to the 2012 breeding season which may have stimulated more frequent gobbling activity, beginning approximately a week earlier on each site. While males may have responded to the warmer temperatures, it seems females did not as the mean initial nesting dates for 2012 did not differ from 2011 (Williams 2012).

I was surprised that only a few ARUs recorded most of the gobbling activity, prompting investigation into habitat variables that could explain this variation. It has been determined that wild turkeys need well-dispersed water sources (Wheeler 1948, Schorger 1966, Hurst 1981, Hurst and Dickson 1992, Porter 1992). With both sites having abundant water resources, I did not expect that proximity to water would be important when establishing sample sites. However, the importance of availability of water appears to be evident on the Jones Center where, 5 out of 7 ARUs appeared to have the necessary habitat types for wild turkey, but were > 1,000-m from water and recorded < 10% of the gobbling during this study. Ruttinger (2013) found that 66 out of 72 male wild turkey roosts in 2011 and 2012, across both study sites, were located within 600-m of water. Ruttinger (2013) also determined that gobblers on both of these study sites selected for stands of mature pine for roost sites; Hoffman (1990) found that most gobbling occurs on the roost, and I found that that 78% of all gobbling activity occurred within the first 2 hours of sunrise. On Silver Lake WMA, water did not appear to be a limiting factor, but rather presence of > 80% mature pine seemed to be a limiting factor. The 2 ARUs that recorded the most gobbling activity on Silver Lake WMA met this requirement. On both sites, the ARUs that recorded the most gobbling activity were within 600-m of water. Taking these findings into consideration, future studies of gobbling activity should consider distance to water in the sampling design.

When modeling the effects of weather, hunting, and nesting on gobbling activity, mean daily temperature, mean daily wind speed, and mean daily barometric pressure were important predictors of gobbling activity. Mean gobbling activity was greatest on days when temperatures averaged 15 ˚C. Activity appeared to increase as average temperatures approached 21 ˚C and subsequently decreased when temperatures averaged >21 ˚C. Mean daily gobbling activity changed significantly as mean daily wind speeds increased, displaying a general trend of increasing gobbling activity as wind speed increased. A wind speed of 6 kph may represent a critical point at which gobbling activity either begins to decrease, possibly to avoid a potential increased predation risk, or detection of gobbling activity begins to decrease due to increased background noise (Bevill 1975, Healy 1992, Kienzler et al. 1996). Some of the most active days for gobbling activity occurred when wind speeds were between 3-5 kph.

The finding that mean daily gobbling activity increased as wind speeds increased supported the finding that mean daily gobbling activity appeared to increase as mean daily barometric pressure decreased. Low barometric pressure is often associated with days characterized by higher winds and rain as opposed to high barometric pressure, typically experienced on days where the atmosphere is stable, with little to no wind and sunny skies. Additional support was lent by the finding that barometric pressure was significantly lower on rainy days versus days without rain in this dataset. These findings are in contrast to previous findings that state most gobbling occurs on clear, sunny days versus cloudy, rainy days (Bevill 1975, Healy 1992, Kienzler et al. 1996). This finding may also suggest turkeys are cueing in on the lower barometric pressure, gobbling more preceding the oncoming weather disturbance, rather than gobbling during the rain events themselves. Finally, gobbling activity decreased as the breeding season progressed and when we take into consideration that the Jones Center had 32-44% more gobbling activity than Silver Lake WMA, after the opening of the general hunt on the WMA, gobbling activity decreasing as the breeding season progressed may reflect a harvest and /or hunting effect that is occurring on Silver Lake WMA but not on the Jones Center.

Even so, these findings were inconclusive in regards to the effects of peak nesting and hunting pressure on gobbling activity. While there is concern for the potential negative effects of hunting on breeding activity, the lack of solid findings may suggest that hunting isn't negatively affecting gobbling activity and thus, breeding activity. Previous studies suggested that peaks in gobbling activity were positively associated with nest initiation (Bailey and Rinell 1967, Bevill 1975, Porter and Ludwig 1980) and negatively associated with hunting pressure (Kienzler et al. 1996, Lehman et al. 2005). Other studies found no relationship between nest initiation and gobbling activity (Kienzler et al. 1996, Miller et al. 1997) and found that hunting pressure was positively related to gobbling activity (Miller et al. 1997). With respect to hunting, I do not have data regarding daily hunting pressure on the WMA because hunters only had to sign in once at the beginning of the season. Additionally, I lack understanding of daily trends in location of hunting pressure on the WMA. I believe that better understanding these 2 variables will enhance conclusions drawn in future research. With that being said, I know that on Silver Lake WMA, a total of 182 hunters harvested 22 males during the 2 years of this study.

Continued research on the potential impacts of hunting and nesting on wild turkey gobbling activity should include a variety of different public and private lands, incorporating variable hunting seasons that are open to the general public earlier in the year, with greater potential to impact breeding activity. Additionally, future studies should quantify daily, spatially explicit hunting pressure. Hunting pressure may not be perceived by the entire turkey population, but instead, perceived by isolated pockets where pressure is greater on a daily basis. Better understanding the amount of hunting pressure required to negatively affect gobbling activity and on what spatial scale that effect is perceived is important in future research. To address these questions, specific locations should be targeted by ARUs and varying densities of hunters to investigate the effect of hunting pressure on gobbling activity on smaller spatial scales. Future studies should continue to use ARUs to sample more consistently across study sites and throughout days, providing a more complete picture of gobbling activity throughout the day and season.

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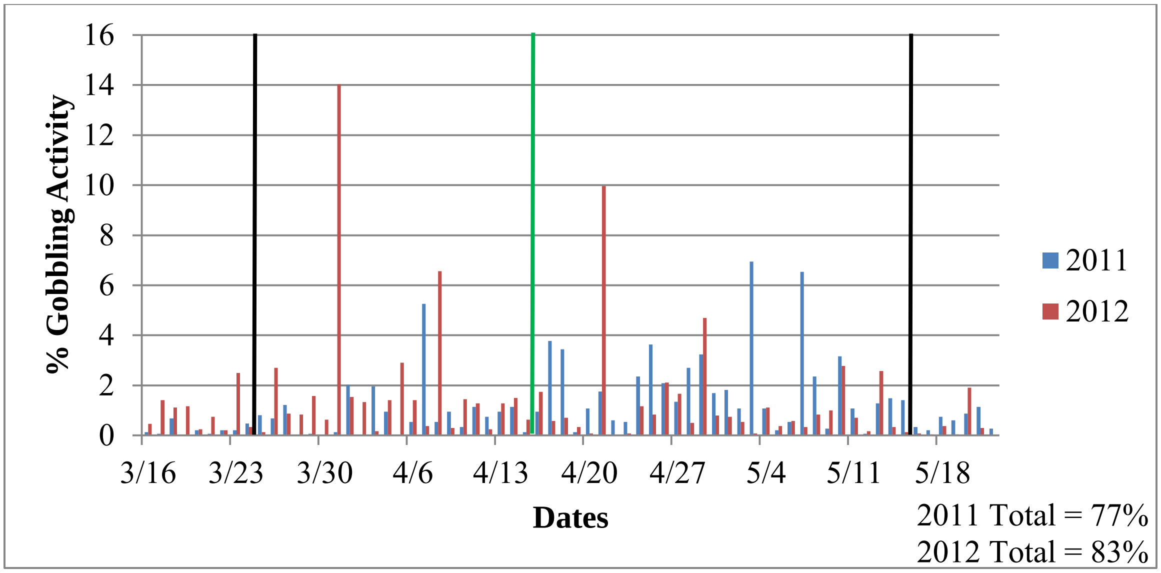

Figure 4-1. Percentage of gobbling activity by eastern wild turkeys during both years of the study on the Joseph W. Jones Ecological Research Center in southwestern Georgia, USA, 16 March-22 May. The black lines indicate the average opening and closing dates of the spring turkey hunting season in Georgia while the green line indicates the average nest initiation date on the Jones Center during the 2 years of this study. Totals reported in the bottom right of the graph represent the percentage of gobbling activity that took place on site within the confines of the hunting season each year.

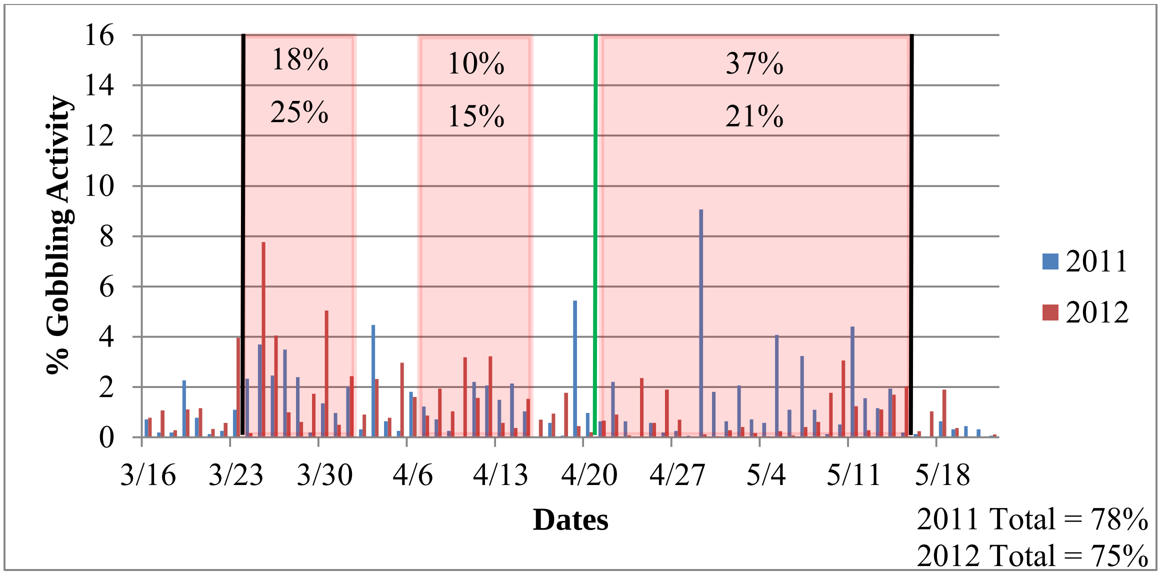

Figure 4-2. Percentage of gobbling activity by eastern wild turkeys during both years of the study on Silver Lake WMA in southwestern Georgia, USA, 16 March-22 May. The black lines indicate the average opening and closing dates of the spring turkey hunting season in Georgia while the green line indicates the average nest initiation date on Silver Lake WMA during the 2 years of this study. The first red box indicates the average dates of the first quota hunt on site, the second red box indicates the average dates of the second quota hunt, and the third red box indicates the average dates of the general hunt. The first line of percentages represents the percentage of total breeding season gobbling activity that took place during each hunt in 2011 while the second line represents the 2012 hunts. Totals reported in the bottom right of the graph represent the percentage of gobbling activity that took place on site within the confines of the hunting season each year.