The Effects of Prescribed Fire on Wild Turkeys in the Talladega National Forest

by

Mariah Grace McInnis

A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
December 11, 2021

Keywords: Wild Turkey, Prescribed Fire, Artificial Nest, Canopy Cover, Occupancy

Approved by

William D. Gulsby, Chair, Associate Professor of Wildlife, School of Forestry and
Wildlife Sciences, Auburn University
Robert A. Gitzen, Associate Professor of Wildlife, School of Forestry and
Wildlife Sciences, Auburn University
Bret A. Collier, Associate Professor of Wildlife Ecology, School of Renewable Natural
Resources, Louisiana State University

Abstract

Previous research on the effects of prescribed fire on wild turkeys (*Meleagris gallopavo*) has been primarily conducted on areas with burn units <300 ha in size. However, large-scale burning (i.e., >1,000 ha burn units) has become more commonplace, and information on the effects of this practice on turkeys is limited. Therefore, we examined the effects of large-scale prescribed fire on nest predation rates and occupancy of wild turkeys on the Talladega National Forest in northeast Alabama. We distributed 232 artificial turkey nests across burn units that varied in time since fire and positioned a camera trap over each nest to document nest predation during spring 2019–2020. We also used 180 baited camera sites to estimate occupancy of turkeys across the landscape during summer of each year. We observed an overall nest predation rate of 25% (58/230 nests) but found no relationship between time since fire and nest predation, likely due to high canopy cover (>90%) that limited response of understory vegetation to fire. Both male and female occupancy was greater in units burned in the current year, but female occupancy was negatively associated with areas burned 1-2 years prior. These results are contradictory to some prior reports, and offer evidence that vegetation, and therefore wildlife habitat, responses to prescribed fire are site dependent.

Acknowledgments

Funding for this project was provided by the U.S. Forest Service (USFS), along with the Alabama chapter of the National Wild Turkey Federation (NWTF). I would like to thank Ryan Shurette and Jonathan Stober with the USFS Shoal Creek Ranger district for their logistical and technical support. Extra thanks to Jonathan for rescuing our crew from flat tires and downed trees. I would like to thank my technicians who made this project possible. Nathan Crowe provided exceptional fieldwork assistance as well as keeping me sane during some particularly challenging days. Not everyone can say it was a frequent occurrence to cry from laughing during fieldwork.

I would like to thank my advisor, Dr. William Gulsby, for his guidance and mentorship during my time here at Auburn. I am grateful for the opportunity and knowledge he has provided me throughout my graduate study. I have appreciated the advice, laughs and encouragement so much. I would also like to thank my committee members Dr. Robert Gitzen and Dr. Bret Collier. Dr. Gitzen has logged an incredible amount of zoom hours with me over this past year and I am indebted to him for his knowledge, humor, and incredible patience (seriously, it’s a gift). Dr. Collier has greatly increased my understanding of wild turkey ecology and his support during my project is much appreciated.

I thank my fellow graduate students within the School of Forestry and Wildlife Sciences. I always knew I could find a willing ear to vent to if needed. I’d especially like to thank Mark Turner and Natalie Harris, who have become exceptional friends. My time here would have been way less fun without them, especially during COVID.

I would like to thank my parents (Lee and David) for their unwavering love and support during this time. I don’t know how I got so lucky to have parents such as yourselves; I would not be who I am today without you. Knowing that I have you both on my team makes me feel like I can do anything. Finally, I would like to thank my incredible husband Caleb, who believes in me more than I believe in myself. You have put your life on hold to see this dream come true for me and I can’t explain how grateful I am for you. I can’t wait to spend our life making even more of our dreams come true.

Table of Contents

List of Tables

List of Figures

CHAPTER 1

THE EFFECTS OF PRESCRIBED FIRE ON WILD TURKEY NEST SUCCESS IN THE TALLADEGA NATIONAL FOREST

ABSTRACT The eastern wild turkey (*Meleagris gallopavo*) is an economically and culturally important game bird that has recently declined in numbers across the Southeast. Prescribed fire can be used to improve nesting and brooding habitat for wild turkeys, but there are concerns that increased application of large-scale prescribed fire can directly or indirectly affect turkey nest success rates. Therefore, there is a need to improve understanding of the effects of large-scale burns on turkey reproduction; particularly how fire effects on vegetation might affect nest success rates. We implemented an artificial nest study on the Talladega National Forest in northeast Alabama, where prescribed fire is implemented across ≤ 8,000 ha annually in large (>300 ha) burn units. We monitored a total of 230 artificial turkey nests during April–May 2019 and 2020. The nest predation rate was 16% in 2019 and 35% in 2020, and the overall predation rate was 25%. Top predators included gray foxes (*Urocyon cinereoargenteus*; 10 nests), opossums (*Didelphis virginiana;* 9 nests), and coyotes (*Canis latrans*; 7 nests). We did not detect a relationship between time since fire and nest predation across both years ($P > 0.05$). In addition, we did not detect a relationship between vegetation measurements and nest predation ($P > 0.05$). Due to high canopy cover (92%) understory vegetation was limited, which influenced the lack of response from We believe these patterns were related to high canopy cover (~90%) across the study area that limited vegetation response to fire. By mediating the potential effects of fire on vegetation structure, canopy cover partly drives the degree in which fire indirectly affects nest predation risk. This is due to vegetation structure influencing the degree to which hens can conceal nests and themselves. Further research is needed to assess indirect effects of

large-scale prescribed fire on turkey nest success. Additionally, our study outlines evidence that vegetation, and therefore wildlife habitat, responses to prescribed fire are site dependent.

INTRODUCTION

Eastern wild turkeys (*Meleagris gallopavo silvestris*; hereafter, turkeys) are one of the most economically and culturally important game species in the United States (Pollentier et al. 2014). For example, in Alabama, an estimated $45 million is spent annually on spring turkey hunting (Barnett and Barnett 2008), and land managers place high importance on maintaining abundant turkey populations. However, there has recently been a stabilization or decline in some populations, specifically in the Southeast (Miller and Conner 2007, Byrne et al. 2015, Pittman and Krementz 2016, Wood et al. 2019, Chamberlain et al. 2020), which has caused concern among hunters and land managers. This decline could be due to many factors, including a lack of nesting and brood-rearing habitat (Badyaev 1995). Therefore, understanding how management practices such as prescribed fire influence turkey habitat quality is important for managers across the Southeast.

Prescribed fire limits woody plant coverage and increases herbaceous plants in the understory (Sisson et al. 1991, Sparks et al. 1998, Jones et al. 2005, Wood et al. 2018). Adult turkeys will select for recently burned areas and avoid those not burned in the past two years, partially due to the increased access to forage fire provides by reducing litter cover (Martin et al. 2012, Yeldell et al. 2017a). Regular application of fire also maintains understory vegetation at a level that conceals the female and her nest, while affording the female adequate visibility to detect predators (Wilson et al. 2005). Fire can also improve brooding habitat by facilitating movement of the female and her brood and increasing abundance of insects, which are important in the poult diet (Little et al. 2014, McCord et al. 2014). Brooding females typically select for areas burned 0-2 years prior during the day and areas burned 3-6 years prior for roosting at night (Wood et al. 2019). However, in areas with a typical post-fire dynamic, it is likely that turkeys use only the edges areas of areas burned less than one year prior to reduce predation risk until the understory provides substantial visual concealment (Kilburg et al. 2015, Yeldell et al. 2017b).

Although fire has many positive benefits for turkeys, there are still some concerns among stakeholders about the effects of burning during the early growing season (April–May), which coincides with the turkey nesting season. Despite this, several studies have found that few nests are directly destroyed during fires. For example, in North Carolina only 3.3% of monitored nests were destroyed by fire and no more than 6% of all turkey nests were exposed to fire annually (Kilburg et al., 2014). However, that study site was burned every 1–2 years, making burned units less likely to be selected by females for nesting and limiting strength of inferences. Nonetheless, females can re-nest if their nests are destroyed by fire (Moore et al. 2010), though some studies have shown that nest success decreases for subsequent nests (Badyaev 1995, Byrne and Chamberlain 2013). Overall, it appears that the direct impact of fire on turkey nests is limited. If only a small number of nests are lost, it is thought that the overall habitat benefits likely outweigh the costs (Kilburg 2014, Jones et al. 2016).

Although direct negative impacts of fire may be acceptably low, indirect effects on reproduction should also be considered. For example, vegetation changes brought about by fire may influence nest success. On average, females generally choose to nest in stands burned 2 years prior, because of the desirable vegetation conditions they provide (Seiss et al. 1990, Yeldell et al. 2017, Wood et al. 2018). Dreibelbis et al. (2016) found that only 9% of females in their study nested in areas that had not been burned during the previous 10 years. However, Pittman and Krementz (2016) found greater nest success in unburned stands (36.4%) than in burned stands (14.6%), and Kilburg et al. (2014) found greater nest survival in unburned lowlands (60%) compared to burned uplands (10%). Conversely, some studies have shown that predators such as raccoons are 62% more likely to select for unburned stands versus burned stands, suggesting that prescribed burning can reduce incidental nest predation (Jones et al., 2004). However, Jones et al. (2002) detected no difference in artificial nest success between areas burned on a two-year rotation and those left unburned. Clearly, the indirect effects of prescribed burning on nest success are context dependent.

Scale of fire may also affect nest success. For example, Pittman and Krementz (2016) found that nest success was greater in unburned versus burned units on an area where fire was implemented at the landscape scale (>10,000 ha), with average burn units >1,000 ha. The reason for this finding was unclear, as vegetation characteristics did not differ between successful and unsuccessful nests. However, based on previous literature that highlights the importance of providing multi-successional vegetation communities in close proximity for turkeys, it can be hypothesized that large-scale fires might negatively affect turkeys by simplifying the landscape (Martin et al. 2012, Pittman and Krementz 2016).

Due to the uncertainty regarding the indirect effects of burning during the nesting season or at large spatial scales on nest success, we implemented a study to examine the effects of prescribed fire on artificial turkey nest success in burn units varying in time since fire on an area where burns were conducted on a much larger than average scale (>1,000 ha). We hypothesized that effects of prescribed fires on nest predation would be driven mainly by post-fire changes in vegetation structure, with changes in predator activity also potentially contributing. We predicted that nest predation would be greatest 1-2 years post-burn due to reduced visual obstruction, lowest 3-4 years post-burn, and moderate 5-10 years post burn.

STUDY AREA

We conducted our study on the Shoal Creek Ranger District of the Talladega National Forest in Calhoun and Cleburne counties, Alabama (Figure 1.1). The study area encompassed approximately 48,000 ha in the Ridge and Valley physiographic region and was managed by the U.S. Forest Service. The topography was steep, and elevation ranged from 200–730 m (Womack et al. 2011). The study area was composed of a variety of forest types, including 37% Oak-Hickory (*Quercus* spp., *Carya* spp.,), 26% loblolly pine (*Pinus taeda*), 13% longleaf pine (*Pinus palustris*), and 11% mixed pine-oak (*Quercus* spp.). The climate was subtropical, with a mean annual temperature of 16 ℃ and mean annual precipitation of 135 cm (NOAA 2020). Soils in the study area were well-drained and consisted primarily of the Tatum-Tallapoosa-Fruithurst association (NRCS 2020). Prescribed fire was used to maintain habitat for the endangered red-cockaded woodpecker (*Leuconotopicus borealis*), restore longleaf pine forest understories, and reduce wildfire fuels. The average return interval was <3.5 years on 16% (7,500 ha) of the study area. Due to adjacency of burn units, contiguous burned areas ranged in size from 199–5,488 ha and averaged 1,295 ha. On average, 60% of fires were applied during the dormant season (Jan-Mar; Stober et al. 2020).

METHODS

Artificial Nests

We distributed 115 artificial turkey nests across the study area during April–May of 2019 and 117 nests during April–May 2020. Nest sites were different between years. This timing was consistent with first nesting attempts of wild turkeys in the Southeast (Moore et al. 2010, Pittman and Krementz 2016).We categorized the study area into areas burned 1, 2, 3, 4, and 5-10 years prior, which we considered to be biologically relevant to a nesting female. We then established artificial nests at a density of approximately 1 per 202 ha within each burn class to ensure proportional representation. Specifically, we used the create random points function in ArcGISv10.6 (ESRI, Inc. Redmond, WA) to establish potential nest sites prior to conducting field work. All potential nest sites were ≥500-m apart and located 50–500 m from roads in 2019. We reduced the maximum distance between nests and roads to 250 m during 2020 because of the difficulty and time required to travel to points >250 m from roads across steep topography. In the field, we placed each nest ≤50 m from the selected point, choosing a nest site with vegetation that would provide visual obstruction from nest predators, when available. Nests consisted of three chicken eggs placed in a slight depression in the ground. In 2019 we covered each nest with a small patch of burlap around 15 cm in diameter to mimic the visual concealment created by a female sitting on the nest for a majority of the day (Lohr et al., 2020). Because nest predation rates during that year were unusually low compared to those reported in the literature (compared to both natural and artificial nests), we chose not to use burlap during 2020. We wore rubber boots and gloves to minimize human scent around the nest (Pharris and Goetz 1980, Melville 2019). We placed a camera trap 1.5–2 m from each nest at a height of 0.5–1 m, depending on the topography of the location. We used Stealth Cam DS4K (GSM Outdoors, Irving TX) and Moultrie D-80 White Flash (Moultrie Products, Birmingham AL) camera traps. Cameras were oriented north or south to avoid glare from the sun. We set each camera to its greatest motion-detecting sensitivity and retrieved it after a two-week period (Melville 2019). We deployed an average of 55 nests/week.

Data Collection

We recorded vegetation measurements at each nest site including visual obstruction, percent cover of plants by functional group, and percent canopy cover, upon returning to collect the camera traps. We estimated visual obstruction using a vegetation profile board (Nudds 1977) placed at the center of the nest bowl and viewed from a distance of 15 m and an observer height of 0.5 m. We recorded visual obstruction in all cardinal directions and averaged the readings to provide one value for the nest site (Byrne et al 2013). We measured visual obstruction for each of the six 0.5-m strata on the board on a scale of 1–5, where 1=0–20%, 2=21–40%, 3=41–60%, 4=61–80%, and 5=81%–100%. We used a 1 m^2 Daubenmire frame (Daubenmire 1959) to visually estimate percent cover of grasses, forbs, woody vegetation, and debris or bare ground. We estimated ground cover at the nest bowl location and 15 m in each cardinal direction and averaged the estimates to provide one value per nest. We estimated canopy cover using a spherical densiometer (Lemmon 1956) directly over the nest bowl and 15 m from the nest in each cardinal direction and averaged those values as well.

Scent Stations

We distributed scent stations across the study area during May of each year to estimate relative abundance of predators. We used the create random points function in ArcGIS to create 108 station locations during each year of the study. Scent stations were placed ≥0.3-km apart and adjacent to secondary roads and trails as much as possible, as predators tend to utilize roads for travel. Once at a point, we would find a nearby trail, road, or cleared area and a corresponding tree where we could place the camera facing either north or south. We then placed a fatty acid scent tablet (Wildlife Control Supplies, East Granby CT) on the ground 1.5–2 m in front of the camera to act as an attractant. Locations were baited and left for 2 nights in 2019, but due to low detection rates, we increased the duration to 4 nights during 2020. Cameras were set on time-lapse to take a photo every two minutes.

Analysis

We used logistic regression in R (v. 4.0.0, R Core Team 2020) to examine the effects of all vegetation measurements on nest predation (predated/not predated). Specifically, we examined a set of models including all combinations of time since fire, visual obstruction from 0–1 m, canopy cover, herbaceous ground cover, and woody ground cover as predictor variables, as well as a null model without any of these variables. We used year as a fixed effect in all models. We combined the 0–0.5 m and 0.5–1 m strata because vegetation at these heights is needed for concealment of the nest without hindering a female's ability to detect predators (McCord et al 2014). We used R package in MuMIn (Barton 2009) to rank models by Akaike's information criterion adjusted for small sample sizes (AICc). We also used logistic regression to examine nest predation as a function of distance to, and density of, roads within a 200 m buffer of the nest location. We used analysis of variance (ANOVA) to examine the relationship between vegetation characteristics and time since fire, with Tukey's Honest Significant Difference tests used to compare characteristics among time-since-fire groups when an overall effect was detected.

RESULTS

We monitored a total of 230 artificial turkey nests during April–May 2019 and 2020 and observed an overall predation rate of 25% (58 nests). The nest predation rate was 16% (18 nests) in 2019 and 35% (40 nests) in 2020. Species responsible for nest predation included gray foxes (*Urocyon cinereoargenteus*; 10 nests), opossums (*Didelphis virginiana;* 9 nests), coyotes (*Canis* *latrans*; 7 nests), raccoons (*Procyon lotor*; 5 nests), American crows (*Corvus brachyrhynchos*; 5 nests), wild pigs (*Sus scrofa*; 4 nests), and striped skunks (*Mephitis mephitis*; 1 nest). We observed 2 instances of secondary predation (eating ≥1 egg after the nest had been predated by another species) by armadillos (*Dasypus novemcinctus*). We were unable to identify the species responsible for depredating 17 nests due to camera malfunction. Average time to nest predation was 6.4 days, and ranged from 1–14 days. We included year as a fixed effect in all of our models predicting the effects of vegetation on nest predation because there was a significant effect of year on this parameter ($P = 0.002$), likely due to the use of burlap coverings in 2019. The null model was the most informative from our candidate set (Table 1.1). Therefore, we did not interpret parameter estimates for the covariates included in any other models.

Canopy cover averaged 92% across our study site. We did not detect a relationship between time since fire and woody cover ($F_{4,223} = 0.9$, $P = 0.45$). We detected an effect of time since fire on visual obstruction from 0–1 m ($F_{4,223} = 3.5$, $P = 0.008$), and Tukey's post-hoc test suggested visual obstruction was greater in areas burned two years, versus four years, prior (Table 1.2; $P = 0.035$). We also detected a relationship between time since fire and herbaceous cover ($F_{4,223} = 3.4$, $P = 0.01$), with herbaceous cover generally declining as time since fire increased (Table 1.2). However, Tukey post-hoc tests did not detect significant differences among groups. We detected ≥1 species of nest predator at 25% (27/107) of scent stations in 2019 and 43% (45/106) in 2020. Species included coyotes (34), gray foxes (19), raccoons (10), armadillos (3), opossums (3), bobcats (2), and wild pigs (1).

DISCUSSION

Based on previous studies (Badyaev 1995, Streich et al. 2015), we expected nest predation to be greater during years 1–2 post burn, decrease in years 3–4 post burn, and increase again in years

5–10 post burn, inversely mirroring expected changes in vegetation cover. These post fire conditions are optimal for concealing nests without inhibiting the female's ability to scan for predators. In our results we did not detect a relationship between time since fire and nest predation. Visual obstruction, and herbaceous ground cover were related to time since fire, but post-hoc tests did not indicate a consistent, statistically significant, trend. Post-fire vegetation development in a more open canopied environment is dynamic with implications for providing a degree of heterogeneity across the landscape. But in our study area, this expected pattern of vegetation response was muted: our detected differences were minor after fire. Due to this lack of vegetation response, it is not surprising that nest predation didn't differ.

We believe one of the driving forces behind our lack of vegetation response was related to high canopy cover (~90%) across the study area. Jackson et al. (2007) found that application of prescribed fire alone did not result in adequate turkey nesting cover within closed canopy stands. Others have reported that overall vegetation coverage and response to prescribed fire are lower in areas where sunlight is limiting (Lashley et al. 2011, Keene et al. 2019). Conversely, when prescribed fire is coupled with canopy reduction, vegetation responses are much greater. For example, Pack et al. (1988) saw a 63% increase in brood habitat by the third growing season on sites that were thinned before being burned. Additionally, Byrne and Chamberlain (2013) reported that in a bottomland hardwood forest with 85% canopy cover turkey nests were often associated with small breaks in the canopy, which they attributed to greater understory plant cover due to increased sunlight. They also found that nesting and nest success rates were greater following a hurricane that reduced canopy cover by 30%. Streich et al. (2015) found that for every 5% increase in canopy cover, nests were 1.12 times less likely to occur. At their study site in Georgia, average percent canopy closure was 54% at nest sites compared to 65% at random locations.

Although canopy cover may have limited variation in vegetation due to time since fire during our study, the literature suggests conditions may have been conducive to successful nesting. Specifically, woody cover averaged 24% and visual obstruction ≤1-m tall averaged 55% at our nest sites. Others have reported successful nests were in areas with 57-100% visual obstruction ≤1-m tall (Badyaev 1995, Moore et al. 2010), the low end of which is only slightly greater than the average across our sites. Streich et al. (2015) reported that nest sites had an average woody cover of 24%, the same as our average, compared to 12% at random locations. However, several have found little or no support for a link between nest success and vegetation conditions around the nest site (Thogmartin 1999, Fuller et al. 2013, Little et al. 2016, Lohr et al. 2020), which could mean that other factors, perhaps at a larger scale, are more important in predicting nest success.

Our overall rate of predation (25%) was low compared to other artificial turkey nest studies. For example, Melville et al. (2014) recorded a predation rate of 61% in East Texas and Jones et al. (2010) recorded a predation rate of 72% in South Georgia. Our predation rates were also lower than those reported for actual nests in the Southeast, which range from 60–80% (Badyaev 1995, Miller et al. 1999, Wilson et al. 2005, Byrne et al. 2013, Little et al. 2014, Pittman and Krementz 2016, Wood et al. 2019, Chamberlain et al. 2020). Artificial nest studies often overestimate predation rates (Major and Kendal 1996, Dreibelbis et al. 2011), so the low predation rate for artificial nests in our study may indicate unusually low predator abundance on the study area. Specifically, our scent station data showed only a 34% visitation rate by all predators. Gabor et al. (1994) reported a scent-station visitation rate of 41% just by raccoons in

Tennessee. In contrast, raccoons visited only 14% of our scent stations, which may have been driven by the lack of bottomland cover types on our study area preferred by raccoons during spring (Byrne and Chamberlain 2016). However, it is also possible that time of year influenced our visitation rates, as others have noted significantly lower visitation rates in spring versus fall (Conner et al. 1983).

A benefit of using artificial nests was that it allowed us to determine species-specific nest predation rates using cameras, which is a fairly new concept for artificial nests (Major and Kendal 2000). Previous studies have used quail eggs, which leads to increased small mammal predation (Hartley and Hunter 1998), or relied on tooth impressions in wax eggs, which is error prone (Jones et al. 2010). In contrast, concerns regarding female disturbance and nest abandonment often preclude researchers from establishing these rates in studies involving actual turkey nests. Overall, monitoring natural female nests likely provides more realistic data on predation rates, but not species-specific rates, whereas artificial nests likely underestimate predation rates while providing better data on species-specific rates. We suspect the lower predation rates we observed were due to the lack of visual and olfactory cues provided by the female.

We recorded several occurrences of corvid predation, which is common for artificial nests due to the lack of visual concealment of the eggs (Santisteban et al. 2012). We also recorded more incidences of gray fox (*Urocyon cinereoargenteus*), coyote (*Canis latrans*), and wild pig (*Sus scrofa*) predation than other artificial nest studies in the Southeast. We recorded a mesomammal predation rate of 26%, whereas Jones et al. (2010) reported the artificial nest predation rate by mesomammals in South Georgia was 15%, and Leimgruber et al. (1994) reported an artificial nest predation rate of 20% in Virginia, with striped skunks and raccoons being the most frequently observed predators. Outside the Southeast, Melville et al. (2014) reported an artificial turkey nest predation rate of 61% in East Texas (Melville et al. 2014), with raccoons and opossums being the most common predators. We believe our use of game cameras was likely more efficient and accurate in determining species-specific predation rates compared to those reliant on predator tracks, teeth marks, or eggshell remains, and also provided supplementary data on days to failure.

Our overall objective was to determine whether large-scale application of prescribed fire indirectly affected turkey nest success by altering vegetation conditions. Although we found no evidence of an effect of time since fire on artificial nest predation rates, others have reported that time since fire was the most important predictor of nest survival (Yeldell et al. 2017). Our site-specific findings were likely driven by high canopy closure, where vegetation response to fire is minimal regardless of fire frequency, scale, season, or intensity (Jackson et al. 2007, Lashley et al. 2011). We believe the overall low rates of nest predation we observed were likely driven by low overall predator numbers, although we are uncertain to what extent our artificial nest study mimicked predation rates on actual turkey nests. Further research is needed to assess indirect effects of large-scale prescribed fire on turkey nest success. We also recommend that future studies examining turkey nest success include canopy cover as part of any vegetation assessments.

LITERATURE CITED

Badyaev, A. V. (1995). Nesting Habitat and Nesting Success of Eastern Wild Turkeys in the Arkansas Ozark Highlands. *American Ornithological Society*, *97*(1), 221–232.

Bakner, N. W., Schofield, L. R., Cedotal, C., Chamberlain, M. J., & Collier, B. A. (2019). Incubation recess behaviors influence nest survival of Wild Turkeys. *Ecology and Evolution*, *9*(24), 14053-14065.

Wilson, W. B. (2005). Seasonal space use, habitat preference and survival of female wild turkeys in a Louisiana bottomland hardwood forest. *LSU Master's Theses. 4091*

Byrne, M. E., and Chamberlain, M. J. (2013). Nesting Ecology of Wild Turkeys in a Bottomland Hardwood Forest. *The American Midland Naturalist*, *170*(1), 95–110.

Byrne, M. E., Chamberlain, M. J., Dickson, J. G., Savage, L., and Stafford, III, N. J. (2015). Survival and Recovery Rates of Male Wild Turkeys on Private Lands in North-central Louisiana. *Journal of the Southeastern Association of Fish and Wildlife Agencies*, *1*, 110–114.

Chamberlain, M. J., Cohen, B. S., Bakner, N. W., and Collier, B. A. (2020). Behavior and Movement of Wild Turkey Broods. *Journal of Wildlife Management*, *84*(6), 1139–1152.

Chamberlain, M. J., & Leopold, B. D. (2000). Habitat Sampling And Selection By Female Wild Turkeys During Preincubation. *The Wilson Journal of Ornithology*, *112*(3), 326-331.

Cohen, B. S., Prebyl, T. J., Stafford, N. J., Collier, B. A., & Chamberlain, M. J. (2015). Space Use, Movements, And Habitat Selection Of Translocated Eastern Wild Turkeys In Northwestern Louisiana. In *Proceedings of the National Wild Turkey Symposium* (Vol. 11, pp. 165-174).

Dreibelbis, J. Z., Skow, K. L., Hardin, J. B., Peterson, M. J., Silvy, N. J., and Collier, B. A. (2016). Nest Habitat Selection By Rio Grande Wild Turkeys On The Edwards Plateau Of Texas. *National Wild Turkey Symposium*, *11*(January), 107–116.

Glitzenstein, J. S., Streng, D. R., Masters, R. E., Robertson, K. M., & Hermann, S. M. (2012). Fire-frequency effects on vegetation in north Florida pinelands: another look at the long-term Stoddard Fire Research Plots at Tall Timbers Research Station. *Forest Ecology and Management*, *264*, 197-209.

Jones, D. D., Conner, L. M., Storey, T. H., & Warren, R. J. (2004). Prescribed Fire And Raccoon Use Of Longleaf Pine Forests: Implications For Managing Nest Predation. *Wildlife Society Bulletin*, *32*(4), 1255-1259.

Jones, D. D., Conner, L. M., Warren, R. J., & Ware, G. O. (2002). The Effect Of Supplemental Prey And Prescribed Fire On Success Of Artificial Nests. *The Journal of wildlife management*, 1112-1117.

Jones, D. D., Mike Conner, L., Warren, R. J., and Glenn O. Ware. (2016). The Effect of Supplemental Prey and Prescribed Fire on Success of Artificial Nests. *Journal of Wildlife Management*, *66*(4), 1112–1117.

Kilburg, E. L., Moorman, C. E., Deperno, C. S., Cobb, D., and Harper, C. A. (2014). Wild Turkey Nest Survival And Nest-Site Selection In The Presence Of Growing-Season Prescribed Fire. *Journal of Wildlife Management*, *78*(6), 1033–1039.

Kilburg, E. L., Moorman, C. E., Deperno, C. S., Cobb, D., and Harper, C. A. (2015). Wild

Turkey Prenesting-resource Selection in a Landscape Managed with Frequent Prescribed Fire. *Southeastern Naturalist*, *14*(1), 137–146.

Little, A. R., Streich, M. M., Chamberlain, M. J., Mike Conner, L., and Warren, R. J. (2014). Eastern wild turkey reproductive ecology in frequently-burned longleaf pine savannas. *Forest Ecology and Management*, *331*, 180–187.

Lohr, A. K., Martin, J. A., Wann, G. T., Cohen, B. S., Collier, B. A., and Chamberlain, M. J. (2020). Behavioral Strategies During Incubation Influence Nest And Female Survival Of Wild Turkeys. *Ecology and Evolution*, *10*(20), 11752–11765.

MacKenzie, D. I., & Nichols, J. D. (2004). Occupancy As A Surrogate For Abundance Estimation. *Animal biodiversity and conservation*, *27*(1), 461-467.

Martin, J. A., Palmer, W. E., Michael Juhan, S., and Carroll, J. P. (2012). Wild Turkey Habitat Use In Frequently-Burned Pine Savanna. *Forest Ecology and Management*, *285*, 179–186.

McCord, J. M., Harper, C. A., and Greenberg, C. H. (2014). Brood Cover And Food Resources For Wild Turkeys Following Silvicultural Treatments In Mature Upland Hardwoods. *Wildlife Society Bulletin*, *38*(2), 265–272.

Melville, H. I., Conway, W. C., Morrison, M. L., Comer, C. E., & Hardin, J. B. (2014). Artificial Nests Identify Possible Nest Predators Of Eastern Wild Turkeys. *Southeastern Naturalist*, *13*(1), 80-91.

Miller, D. A., and Conner, L. M. (2007). Habitat Selection of Female Turkeys in a Managed Pine Landscape in Mississippi. *Source: The Journal of Wildlife Management*, *71*(3), 744–751.

Moore, W. F., Kilgo, J. C., Carlisle, W. D., Guynn, D. C., and Davis, J. R. (2010). Nesting

Success, Nest Site Characteristics, and Survival of Wild Turkey Females in South Carolina. *2010 Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies*, 24–29.

Pharris, Larry Daniel, and R. C. Goetz. An Evaluation Of Artificial Wild Turkey Nests Monitored By Automatic Cameras. 4th National Wild Turkey Symposium, Little Rock, Arkansas (USA), 2-5 Mar 1980. National Wild Turkey Federation, 1980.

Pittman, H. T., & Krementz, D. G. (2016). Impacts Of Short-Rotation Early-Growing Season Prescribed Fire On A Ground Nesting Bird In The Central Hardwoods Region Of North America. *PloS one*, *11*(1), e0147317.

Pollentier, C. D., Hull, S. D., and Lutz, R. S. (2014). Eastern wild turkey demography: Sensitivity of vital rates between landscapes. *Journal of Wildlife Management*, *78*(8), 1372–1382.

Sparks, J. C., Masters, R. E., Engle, D. M., Palmer, M. W., and Bukenhofer, G. A. (1998). Effects of late growing-season and late dormant-season prescribed fire on herbaceous vegetation in restored pine-grassland communities. *Journal of Vegetation Science*, *9*(1), 133–142.

Spears, B. L., Wallace, M. C., Ballard, W. B., Phillips, R. S., Holdstock, D. P., Brunjes, J. H., Applegate, R., Miller, M. S., and Gipson, P. S. (2007). Habitat use and survival of preflight wild turkey broods. *The Journal of Wildlife Management*, *71*(1), 69-81.

Stober, J., Merry, K., and Bettinger, P. (2020). Analysis of fire frequency on the Talladega National Forest, USA, 1998-2018. *International Journal of Wildland Fire*, *29*(10), 943–949.

Sullivan, D. J., McEntire, K. D., Cohen, B. S., Collier, B. A., & Chamberlain, M. J. (2020). Spatial Scale and Shape of Prescribed Fires Influence Use by Wild Turkeys. *The Journal of Wildlife Management, 84*(8), 1570-1577.

Wann, G. T., Martin, J. A., & Chamberlain, M. J. (2020). The influence of prescribed fire on wild turkeys in the southeastern united states: a review and synthesis. *Forest Ecology and Management*, *455*, 117661.

Womack, B., & Carter, R. (2011). Landscape scale forest community classification in the Horseblock Mountain region of the Talladega National Forest, Alabama. *Natural Areas Journal, 31*(1), 51-64.

Wood, J. D., Cohen, B. S., Conner, L. M., Jones, J. W., Collier, B. A., and Chamberlain, M. J. (2019). Nest and Brood Site Selection of Eastern Wild Turkeys. *The Journal of Wildlife Management, 83(1):*192–204.

Wood, J. D., Cohen, B. S., Prebyl, T. J., Conner, L. M., Collier, B. A., and Chamberlain, M. J. (2018). Time-since-fire and stand seral stage affect habitat selection of eastern wild turkeys in a managed longleaf pine ecosystem. *Forest Ecology and Management*, *411*, 203–212.

Yeldell, N. A., Cohen, B. S., Little, A. R., Collier, B. A., & Chamberlain, M. J. (2017). Nest site selection and nest survival of eastern wild turkeys in a pyric landscape. *The Journal of Wildlife Management*, *81*(6), 1073-1083.

Yeldell, N. A., Cohen, B. S., Prebyl, T. J., Collier, B. A., and Chamberlain, M. J. (2017). Use of pine-dominated forests by female eastern wild turkeys immediately after prescribed fire. *Forest Ecology and Management, 398*, 226–234.

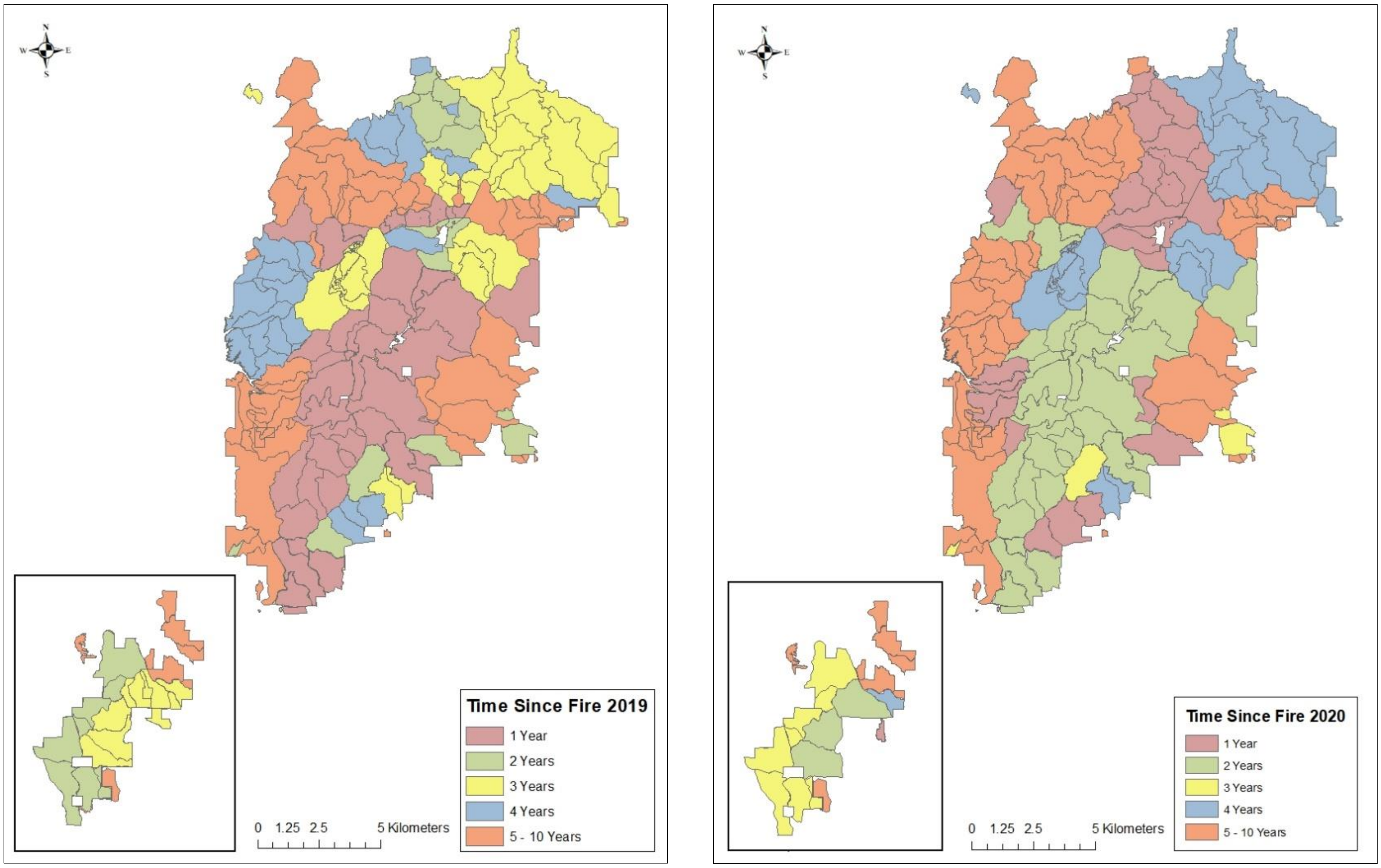

Figure 1.1. Location of study area in the Shoal Creek district of the Talladega National Forest, Alabama, USA where we examined the relationship between time since fire and nest predation on artificial wild turkey (*Meleagris gallopavo)* nests during 2019 and 2020.

Table 1.1. AICc model selection for models describing effects of visual concealment at the 0–1 m strata, canopy cover, herbaceous cover, and woody cover on artificial turkey nest success in the Shoal Creek district of the Talladega National Forest, Alabama, USA during 2019 and 2020. Only models with ΔAIC <4.0 are presented.

Model	***DF***	***logLik***	***AICc***	***ΔAIC***	***weight***
Null	2	-123.764	251.6	0.00	0.177
Visual concealment	3	-123.177	252.5	0.88	0.114
Visual concealment + Woody Cover	4	-122.357	252.9	1.31	0.092
Woody Cover	3	-123.513	253.1	1.55	0.081
Canopy Cover	3	-123.538	253.2	1.6	0.079
Canopy Cover + Visual Concealment	4	-122.659	253.5	1.92	0.068
Herbaceous Cover	3	-123.751	253.6	2.03	0.064
Canopy Cover + Visual Concealment + Woody Cover	5	-121.812	253.9	2.31	0.056
Herbaceous Cover + Visual Concealment	4	-123.12	254.4	2.84	0.043
Herbaceous Cover + Visual Concealment + Woody Cover	5	-122.19	254.6	3.07	0.038
Canopy Cover + Woody Cover	4	-123.324	254.8	3.24	0.035
Herbaceous Cover + Woody Cover	4	-123.484	255.1	3.56	0.03
Canopy Cover + Herbaceous Cover	4	-123.526	255.2	3.65	0.028
Canopy Cover + Herbaceous Cover + Visual Concealment	5	-122.651	255.6	3.99	0.024

Table 1.2. Average vegetation measurements and standard errors (SE) of canopy cover (%), visual concealment at the 0–1 m strata (%), herbaceous ground cover (%), and woody cover (%) taken at artificial nest sites varying by time since fire in the Shoal Creek District within the Talladega National Forest AL during 2019 and 2020.

Time Since Fire	***Canopy Cover (%)***	***Visual Concealment 0–1 m (%)***	***Herbaceous Cover (%)***	***Woody Cover (%)***	***% Depredated***
1 Year	92.01 (1.20)	54 (0.12)	14.45 (1.94)	23.44 (1.52)	21
2 Year	91.05 (1.55)	62 (0.12)	11.60 (1.52)	22.81 (1.70)	33
3 Year	89.64 (2.83)	52 (0.19)	13.46 (2.90)	21.85 (2.38)	14
4 Year	91.70 (2.64)	50 (0.15)	7.17 (1.75)	17.66 (2.01)	12
5-10 Years	94.29 (1.24)	60 (0.11)	7.26 (1.02)	20.53 (1.52)	21

CHAPTER 2

THE EFFECT OF PRESCRIBED FIRE ON WILD TURKEY OCCUPANCY IN THE TALLADEGA NATIONAL FOREST

ABSTRACT

Historically, much of the Southeastern landscape was maintained by frequent fire, which limited canopy closure, reduced undesirable woody vegetation, increased structural heterogeneity, and increased the amount and diversity of grasses and forbs. Many species, including wild turkeys (*Meleagris gallopavo*), benefited from these post-fire effects. However, recent declines in turkey population numbers has raised concerns among land managers due to the economic and cultural importance of the species across the Southeast. Such concern has raised questions surrounding current management techniques, specifically the increase in large-scale prescribed burning taking place despite a lack of adequate research investigating potential negative consequences. To address this information gap, we conducted our study on the Talladega National Forest in northeast Alabama where contiguous burn units averaged 1,295 ha. We utilized 180 baited camera sites across the study area to examine wild turkey occupancy in areas varying in time since fire during summer of 2019–2020. We used a multi-scale occupancy approach at weekly and daily temporal scales, to determine frequency and intensity of use within 300 m of the bait station. We found a negative effect on female occupancy at the weekly scale as presence of 1–2-year burns increased, and a positive effect at the daily scale as presence of burns conducted the current year increased. With males we observed a positive effect of weekly occupancy as presence of burns conducted the current year increased. Consequently, our results seem to show that the expected positive benefits of fire are ephemeral across our study area as only burns conducted in the current year were used more intensively by both sexes. This could be attributed

to either the large size of the burns, high canopy cover on our study area (>90%) that was limiting vegetation response, or both. Therefore, our research helps fill an information gap related to large-scale prescribed burning on landscapes with high canopy cover.

INTRODUCTION

In the United States, eastern wild turkeys (*Meleagris gallopavo silvestris*; hereafter, turkeys) are one of the most culturally and economically important game species. In Alabama alone, turkey hunting is responsible for bringing in $45 million annually (Barnett and Barnett 2008). Maintaining productive turkey populations is of utmost importance to land managers across the country. However, recently some states have reported declines in turkey numbers (Miller and Conner 2007, Byrne et al. 2015, Pittman and Krementz 2016, Wood et al. 2019, Chamberlain et al., 2020). This decline in population has led to a series of questions concerning potential factors affecting turkey populations, and how to better manage for the species.

Several of our questions center around the use of prescribed fire, which is one of the primary tools used to manage turkey habitat. Turkeys select for small-scale (≤ 300 ha) burn units almost immediately post-fire (Yeldell et al. 2017a, Wood et al. 2018). Conversely, turkeys are less likely to use areas as the time since they were last burned increases (Cohen et al. 2019). However, little is known regarding how turkey use of burned areas is affected by the scale of fire. Much of the Southeastern landscape is adapted to frequent, low-intensity fire, but only a small fraction is treated with prescribed fire annually (Wann et al. 2020). Accordingly, some land managers, on public land in particular, have recently begun implementing burns on a much larger scale (≥1,000 ha) to restore these fire-adapted ecosystems (Pittman and Krementz 2016).

While some are concerned that burning at such a large scale could negatively affect turkey populations, information is lacking (Wann et al. 2020).

One way that large-scale burns could affect turkey populations is by directly or indirectly decreasing nest success, which is one of the most important factors affecting population growth in wild turkeys (Roberts and Porter 1996, Hughes 2004). Evidence suggests that small scale fires rarely destroy wild turkey's nests and along with renesting, likely mitigate the direct impacts of prescribed fire (Kilburg et al. 2014, Jones 2016). However, nest success rates are most affected by nest predation (Badyaev 1995, Roberts and Porter 1998a, Hughes 2004, Byrne et al. 2013) which is mitigated by adequate visual concealment. Therefore, large-scale fire could indirectly affect nest success by decreasing the quantity or quality of nesting habitat across large areas. For example, Pittman and Krementz (2016) found that nest success was greater in unburned areas on a study area where fire was implemented on a landscape scale (>1,000 ha). Others have expressed concern that large-scale burning could lead to increased energy expenditure and decreased reproductive fitness by causing females to increase the area searched for nesting habitat (Orain and Wittenberger 1991, Badyaev 1996, Pittman 2014). Finally, because distribution and availability of resources likely drive frequency and distance of recess movements during incubation (Conley et al. 2015), females may avoid nesting in the core of large, homogeneous, recently burned areas. Conversely, females nesting in those areas may be required to take more frequent, longer, recesses which could decrease nest success (Conley et al. 2015, Bakner et al. 2019).

Large-scale fire could also negatively affect turkey populations by increasing the distance between nesting and brood-rearing habitat. Once the clutch hatches, brooding females select for areas with less woody vegetation and more grasses and forbs that provide visual concealment of poults while allowing increased mobility and foraging opportunities for poults (Little et al. 2014, Wann et al. 2020). However, at night, broods often return to areas resembling nesting habitat for roosting (Spears et al. 2007). Therefore, greater distances between these vegetation types likely decrease brood survival, as distance moved away from the nest site during the first three days post-hatch is associated with lower brood survival (Chamberlain et al. 2020). Further, large-scale burning may affect brood success by decreasing foraging opportunities for poults, which require diets rich in insects. Specifically, large-scale burning may negatively affect recolonization of insects because of their limited mobility (Swengel 2001), or by decreasing the amount of edge around burned areas, which is associated with greater insect abundance (Mutz et al. 2017).

In support of these hypotheses, telemetry studies generally show that turkeys prefer areas treated with smaller-scale burns. For example, Cohen et al. (2019) found that the probability of females using burned areas declined as distance to adjacent unburned stands increased. Yeldell et al. (2017b) reported similar findings for females and concluded that smaller burn units benefitted turkeys by increasing available edge. Finally, Sullivan et al. (2020) found that daily use of recently burned areas declined as scale increased regardless of burn shape. Therefore, although turkeys rely on a variety of cover types throughout their life cycle, it is apparent that the distribution of those cover types is also important.

When prescribed fire is implemented on a landscape-scale, the multi-successional vegetation communities turkeys require become less evenly distributed, potentially affecting multiple aspects of their life history. However, limited data are available from extensive landscapes being managed with large-scale prescribed fires. Therefore, we conducted a study to examine turkey occupancy at multiple temporal scales (weekly and daily) across the Talladega

National Forest in northeast Alabama, where contiguous burned areas averaged 1,295 ha (Stober et al. 2020).

METHODS

We created 90 baited camera sites across the study area during June–July 2019 and 90 during June–July 2020. Points were not replicated from the previous year. We chose this time period as it was conducive to brood rearing season in the Southeast which is between June and July 31st (Little et al. 2014), and we wanted to increase our chances of capturing broods on camera. We used the create random points function in ArcGISv10.6 (ESRI, Inc. Redmond, WA) to create potential bait site locations and kept them ≥4 km apart to reduce duplication. A deployment schedule was used to ensure the entirety of the study area was surveyed at the same time and 40 camera traps were deployed representationally each week. Once at a location we found a suitable open area ≤50 m of the point that was also adjacent to a tree where we could attach a camera facing north or south to reduce glare. We trimmed back vegetation to increase the probability of turkeys locating the bait, increase access to forage, and make it easier to identify turkeys on camera. Sites were baited with 2.5 gallons of cracked corn and raked until evenly distributed. We left the bait out for 5 days before returning to re-bait the site and set up each camera on time lapse to take a photo every 4 minutes from 0530 to 2030 CST, which encompassed the period from about 30 min before sunrise to 30 min after sunset, for five days. We used Stealth Cam DS4K (GSM Outdoors, Irving TX) and Moultrie D-80 White Flash (Moultrie Products, Birmingham AL) camera traps.

After collection of all cameras, images were downloaded and analyzed for the presence of turkeys. When present, turkeys were recorded by sex and age class (male/female, adult/poult). Identification was based on physical characteristics (plumage, body size, beard/spur presence;

Barnett and Barnett 2008). If poults were observed, they were categorized into three different age classes based on size and coloration. Any turkeys that could not be identified were classified as unknown.

Analysis

We examined patterns of turkey occupancy with multi-scale modeling (Mackenzie and Nichols 2004, Pavlacky et al. 2012), but focused on occurrence at two temporal scales rather than multiple spatial scales. Specifically, we focused on week-level occupancy (i.e., probability of turkeys being present in the area at any point during the five days of a survey at a camera station; Psi), and conditional daily-scale occupancy (i.e., probability of a turkey being present per survey day, conditional on the site being occupied at the weekly scale; theta). We interpreted weekly-scale occupancy as reflecting whether the camera station and surrounding neighborhood was within the weekly home ranges of ≥1 turkey. We interpreted conditional daily-scale occupancy as reflecting frequency of use of the camera-station patch (300-m radius) itself. The 300 m buffer represents the average daily range of a female turkey (Cohen et al. 2016). We created binary hourly scale detection/non-detection data after binning detections within each of the 16 daylight hours that cameras were operational at each station each day. For each station, the resulting detection history for each sex was a string of 80 (5 days x 16 hours per day) binary values. Initial modeling indicated strong positive hour-to-hour autocorrelation in detection data at the hourly time scale. Therefore, we interpreted initial hourly detection probability each day (probability of detection conditional on the site being occupied that day) and hourly recapture probability (probability of a detection in hour t+1 of a given day conditional on there being detection in hour t) as largely reflecting attraction to the station bait.

Separate analyses were conducted for female and male turkey occupancy, with models fit using maximum likelihood in program MARK through package RMark (Laake 2013). With our multi-scale formulation, logit-scale relationships were specified for weekly occupancy, conditional daily occupancy, and hourly detection probabilities. We used a sequential modeling approach, first examining candidate models for hourly detection probability, then for week-level occupancy, then for conditional daily occupancy.

In the first step of analysis, we examined covariates allowing for within-day hourly autocorrelation and diurnal variation in detection probability. We examined hourly scale temporal autocorrelation in detection with an hourly scale recapture variable that was 1 if a turkey of that sex had been detected the previous hour of that day, 0 otherwise. Based on a previous Alabama study, we allowed for temporal variation in detection probability during the 18-hour survey day with a quartic (4th degree polynomial) effect of time of day (Keller et al. 2019). For each sex we examined four detectability models (intercept only model vs. models with an hourly-scale recapture and/or a polynomial time-of-day effect on occupancy). At this first stage of analysis, we evaluated whether there was evidence of temporal autocorrelation in occupancy from day to day (Nichols et al .2004, Rodenhouse et al. 2016). Specifically, like our modeling of hourly autocorrelation, we examined a daily scale recapture binary covariate indicating whether turkeys of that sex had been detected at the station the previous day, set to 0 for the first day of sampling at each site. We used Akaike's Information Criterion adjusted for small sample sizes (AICc) to compare models for hourly detection probability and those within and without daily-scale autocorrelation. Based on the number of competing models, we selected ≥1 final model for modeling detection probability in the next steps of the sequential approach

In the second step of the analysis for each sex, we examined relationships between weekly occupancy and models incorporating combinations of 6 covariates. Three covariates involved characteristics of the camera-station point (years since the last fire at that location, distance to edge of a patch in another time-since-fire category (log10-transformed), and station elevation (as elevation largely reflected locally variable topography). Additional covariates measured characteristics of the neighborhood around the camera station, defined as a 300-m radius circle centered on the station. Within each station's neighborhood, we used a GIS layer provided by the U.S. Forest Service to quantify the proportion of area burned 0 (that year), 1, 2, 3, 4, 5-10, and >10 years prior. For analysis, we condensed these categories to three variables: proportion of area burned that year, proportion burned 1-2 years earlier, and an index of heterogeneity in time since fire within the neighborhood. Specifically, we indexed heterogeneity with Pielou's evenness index (Pielou 1966), using the neighborhood proportions of the 7 observed time-since-fire categories. A value close to zero for a station indicated that one category made up ~100% of the area in the circle, whereas a value of 1 indicated that each of the 6 categories contributed ~16.7% of the buffered area.

Using these 6 covariates, we formed a set of 12 alternative models for weekly occupancy (intercept only model, 6 single-variable models, and 5 models with combinations of 2 or 3 variables selected to avoid included correlated pairs of variables and represent biologically meaningful alternatives). We used AICc to select ≥1 candidate final model for use in the third stage of the sequential analysis. At the third step of analysis for each sex, we examined patterns of conditional daily occupancy. We examined the same general models for daily occupancy as described above for modeling weekly occupancy.

RESULTS

During both 2019 and 2020 we collected and interpreted a total of 214,700 time-lapse images. Turkeys were detected in 6,383 images (2.97%). Among images where turkeys were detected, adult females were most frequent, observed in 2,891 images (45.3%). Males were observed in 2,392 images (41.2%), and turkeys in the unknown category were observed in 729 images (11.4%). Poults were found the least often, occurring in 131 images (2%). Between the classes of poults, poult class 2 had the most occurrences with 87 detections (66.4%), followed by poult class 3 which had 44 detections (33.6%). No occurrences were detected for poult class 1 and all poult classes were subsequently left out of the analysis due to inadequate sample size.

Females were detected at 71 out of 177 sites. Those 71 sites had an average of 3.2 days with detections (SD = 1.6; range 1-5, with 27% having females detected on only 1 of the 5 survey days, and 30% having female detections all 5 survey days). Males were detected at 33 out of 177 sites. Those 33 sites had an average of 3.9 (SD = 1.3; range 1-5 days, with 6% having males detected on only 1 out of the 5 survey days, and 48% having detections all 5 survey days). Poults were detected at 6 out of 177 sites. Those 6 sites had an average of 2.2 days with detections (SD = 1.2; range 1-4, with 50% having poults detected on only 1 of the 5 survey days, and 0% detected on all 5 survey days).

The top model for females at week-level occupancy (i.e., probability of turkeys being present in the area any time during the five days of a survey at a camera station; Psi) was presence of the neighborhood that had 1-2 years post burn and for males the top model included presence of burns in the neighborhood conducted during the current year (Table A.1). Top models for females at the conditional daily-scale occupancy (i.e., probability of a turkey being present per survey day, conditional on the site being occupied at the weekly scale; Theta) was the presence of both burns conducted during the same year, and the amount of evenness of time since burn categories (Table A.2). For females, there was high positive correlation in conditional daily-scale occupancy with detection at the site the previous day. For males, models with this daily-scale autocorrelation effect did not converge, and the top model of conditional daily-scale occupancy included the intercept only model (Table 2.2). Female conditional daily occupancy was positively influenced as proportion of area burned the current year increased and negatively influenced at the weekly scale as proportion of areas burned 1–2 years prior increased (Fig. 2.1). For males, weekly occupancy was positively influenced by presence of burns conducted the current year (Fig. 2.1) For both females and males, detection probability per hour was related to time of day (Fig. 2.1) and whether a detection occurred the previous hour.

DISCUSSION

We hypothesized that turkey occupancy probability would decrease as time since fire increased and increase with increasing evenness in time since fire around camera sites. Specifically, although turkeys select for areas burned 0–2 years prior (Little et al. 2016, Yeldell 2017a, Cohen et al. 2019), proximity to edges and areas burned less recently are also important due to the escape cover they provide. Access to such cover would be especially important on our study area where landscape-scale burns potentially create large homogenous areas lacking cover. Consistent with our predictions, we observed that both male and female occupancy increased with area burned the current year. However, we also found that female occupancy was inversely related to evenness in time since fire and the area burned 1–2 years prior, which contradicted our hypotheses.

Burns conducted in the current year had a positive effect on female daily occupancy. In addition, the likelihood that a male turkey would be present at a site at any point during the week was also positively affected by area burned in the current year. Several studies have reported that turkeys are attracted to areas immediately post burn, with both males and females avoiding areas not burned in the past two years (Little et al. 2016, Yeldell 2017a, Cohen et al. 2019). This is likely due to the increased foraging opportunity resulting from decreased leaf litter and exposure of arthropods (Martin et al. 2014), as well as the associated increase in forb and grass cover, which are important insect attractors. In addition, plant species diversity is greater in the year units are burned (Pittman 2014).

Contrary to our prediction, weekly female occupancy declined as area burned 1–2 years prior increased. This is surprising considering previous research that shows conditions 1–2 years post-burn are attractive for both males and females because they continue to provide post-fire benefits (Glitzenstein et al. 2012, Little et al. 2016). We believe our finding may be related to a site-specific tradeoff between foraging opportunity and cover. Burns that occurred in the current year (zero-year burns) lacked cover but provided sufficient foraging opportunity so that females were willing to expose themselves to greater risk. Studies on other prey species have shown that animals are sometimes willing to increase risk exposure or alter their use of those areas to lower risk periods when those areas also contain abundant forage (Creel et al. 2008). This may be especially true for female turkeys with broods, as they require a high protein diet during early development. However, as time since fire increased to 1–2 years, the tradeoffs between food availability and predation risk no longer favored use of these areas. Typically, areas burned 1–2 years prior still contain adequate forage, and greater cover, than areas burned in the current year, with cover for turkeys peaking at about 3 years post-burn (Wood et al. 2019). However, canopy cover averaged >90% across our study area (Chapter 1), limiting vegetation responses to fire. Thus, we hypothesize leaf litter accumulation and limited vegetation response in areas burned 1-

2 years prior created conditions where foraging opportunities were lower, and cover from predators only slightly greater, than in areas burned in the current year.

We also predicted a positive influence of the proportion of area burned 1–2 years prior on male occupancy, but only observed a positive relationship between male turkey occupancy and proportion of area burned in the current year at the weekly scale. Male turkey selection is similar to that of females during the breeding period (March-April on our study area) but may change as peak incubation occurs around early to mid-April (Chamberlain et al. 2018). Studies examining wild turkey movement often focus on females due to their greater impact on population growth, and none have examined male turkey movement and selection on landscapes where large-scale fire occurs. Understanding male movement relative to large-scale prescribed fire is an important component of discerning large-scale fire impacts to turkey demography. For example, Cohen et al. (2019) found that both males and females loafed more in burned areas as time since fire increased, showing that it is possible for male behavior to be altered depending on post fire conditions. However, our results offer limited evidence for an effect of large-scale prescribed fire on male occupancy, with the exception being their attraction to areas burned in the current year.

We predicted that increased evenness in time since fire within 300 m buffers would have a positive effect on female occupancy due to the increase in heterogeneity that would translate to interspersion of forage and cover for turkeys, especially females with poults. Instead, we found the opposite; females were less likely to be present at the daily scale as evenness within a stand increased. These results contradict current literature surrounding how turkeys interact with edges of burn units. For example, Cohen et al. (2019) and Yeldell et al. (2017) found that the probability of turkeys using a burned area decreased with distance to unburned area, likely because of a lack of escape cover. Additionally, insect availability is greater at the edges of burned areas versus in the interior due to faster insect recolonization along the edges (Mutz et al. 2017). We believe our findings to the contrary are most likely a product of conditions on our study area. Specifically, vegetation metrics did not vary consistently among areas burned at different times (Chapter 1), which means that our assumption that high evenness would lead to high heterogeneity in vegetation conditions was not supported. In addition, evenness was a significant predictor of conditional daily occupancy, but this was only after capturing the negative influence of 1–2 year burns at the weekly scale and positive influence of zero year burns at the daily scale.

Our multi-scale temporal occupancy analysis gave us insight into whether turkeys were likely passing through areas, versus intensely using the site. This provided important insight into potential benefits our covariates were or were not providing. Consequently, our results seem to show that the expected positive benefits of fire are ephemeral across our study area as only burns conducted in the current year were used more intensively by both sexes. This could be attributed to either the large-scale size of the burns, high canopy cover limiting vegetation response, or both. Therefore, our research helps fill an information gap related to large-scale prescribed burning on landscapes with high canopy cover. Reduced habitat quality can result in increased space use of turkeys (Chamberlain and Leopold, 2000), so future research on this study area utilizing telemetry could indicate how movement differs across units varying in time since fire. Such a study would provide additional information regarding trade-offs that turkeys, particularly females, are making. Additionally, future research should focus on determining the ideal burn size and spatial arrangement to help managers make better informed decisions about how to apply fire to the landscape.

LITERATURE CITED

Badyaev, A. V. (1995). Nesting habitat and nesting success of eastern wild turkeys in the Arkansas Ozark Highlands. *The Condor*, *97*(1), 221-232.

Badyaev, A. V., & Faust, J. D. (1996). Nest site fidelity in female wild turkey: potential causes and reproductive consequences. *The Condor*, *98*(3), 589-594.

Bakner, N. W., Schofield, L. R., Cedotal, C., Chamberlain, M. J., & Collier, B. A. (2019). Incubation recess behaviors influence nest survival of Wild Turkeys. *Ecology and Evolution*, *9*(24), 14053-14065.

Barnett, S. W., and V. S. Barnett. 2008. The Wild Turkey in Alabama. Alabama. Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries, Montgomery, AL.

Byrne, Michael E., and Michael J. Chamberlain. 2013. Nesting Ecology of Wild Turkeys in a Bottomland Hardwood Forest. *The American Midland Naturalist* 170(1): 95–110

Byrne, Michael E et al. 2015. Survival and Recovery Rates of Male Wild Turkeys on Private Lands in North-Central Louisiana. *Journal of the Southeastern Association of Fish and Wildlife Agencies* 1: 110–14.

Chamberlain, M. J., & Leopold, B. D. (2000). Habitat sampling and selection by female wild turkeys during preincubation. *The Wilson Journal of Ornithology*, *112*(3), 326-331.

Chamberlain, M. J., Wightman, P. H., Cohen, B. S., & Collier, B. A. (2018). Gobbling activity of eastern wild turkeys relative to male movements and female nesting phenology in South Carolina. *Wildlife Society Bulletin*, *42*(4), 632-642.

Chamberlain, Michael J., Bradley S. Cohen, Nicholas W. Bakner, and Bret A. Collier. 2020. Behavior and Movement of Wild Turkey Broods. *Journal of Wildlife Management* 84(6): 1139–52.

Cohen, B. S., Prebyl, T. J., Stafford, N. J., Collier, B. A., and Chamberlain, M. J. (2016). Space Use, Movements, And Habitat Selection Of Translocated Eastern Wild Turkeys In Northwestern Louisiana. *Proceedings of the National Wild Turkey Symposium* (Vol. 11).

Cohen, B. S., Prebyl, T. J., Collier, B. A., & Chamberlain, M. J. (2019). Spatiotemporal variability of fire characteristics affect animal responses in pyric landscapes. *Fire Ecology*, *15*(1), 1-17.

Conley, M. D., Oetgen, J. G., Barrow, J., Chamberlain, M. J., Skow, K. L., & Collier, B. A. (2015). Habitat selection, incubation, and incubation recess ranges of nesting female Rio Grande wild turkeys in Texas. In *Proceedings of the National Wild Turkey Symposium* (Vol. 11, No. 117).

Creel, S., Winnie Jr, J. A., Christianson, D., & Liley, S. (2008). Time and space in general models of antipredator response: tests with wolves and elk. *Animal Behaviour*, *76*(4), 1139-1146.

Glitzenstein, J. S., Streng, D. R., Masters, R. E., Robertson, K. M., and Hermann, S. M. (2012). Fire-frequency effects on vegetation in north Florida pinelands: Another look at the long-term Stoddard Fire Research Plots at Tall Timbers Research Station. *Forest Ecology and Management*, *264*, 197-209.

Jones, David D., L. Mike Conner, Robert J. Warren, and Glenn O. Ware. 2016. The Effect of Supplemental Prey and Prescribed Fire on Success of Artificial Nests. *Journal of Wildlife*

Management 66(4): 1112–17

Keller, Skylar R. 2019. Comparing Camear Survey Methods for Monitoring Eastern Wild Turkey Populations. Thesis, Auburn University, Auburn, USA.

Kilburg, E. L., Moorman, C. E., Deperno, C. S., Cobb, D., and Harper, C. A. (2014). Wild turkey nest survival and nest-site selection in the presence of growing-season prescribed fire. *Journal of Wildlife Management*, *78*(6), 1033–1039.

Laake, J. L. (2013). RMark: an R interface for analysis of capture-recapture data with MARK.

Little, Andrew R. et al. 2014. "Eastern Wild Turkey Reproductive Ecology in Frequently-Burned Longleaf Pine Savannas." *Forest Ecology and Management* 331: 180–87.

MacKenzie, D. I., & Nichols, J. D. (2004). Occupancy as a surrogate for abundance estimation. *Animal Biodiversity And Conservation*, *27*(1), 461-467.

Miller, Darren A, and L Michael Conner. 2007. Habitat Selection of Female Turkeys in a Managed Pine Landscape in Mississippi. *The Journal of Wildlife Management* 71(3): 744–51.

Mutz, J., N. Underwood, and B.D. Inouye. 2017. time since disturbance affects colonization dynamics in a metapopulation. *Journal of Animal Ecology* 86: 1065–1073

Orians, G. H., & Wittenberger, J. F. (1991). Spatial And Temporal Scales In Habitat Selection. *The American Naturalist*, *137*, S29-S49.

Pavlacky, D.C., Jr., Blakesley, J.A., WHITE, G.C., Hanni, D.J. and Lukacs, P.M. (2012), Hierarchical Multi-Scale Occupancy Estimation For Monitoring Wildlife Populations. *The Journal of Wildlife Management*, 76: 154-162.

Pielou, E. C. (1966). The Measurement Of Diversity In Different Types Of Biological Collections. *Journal of theoretical biology*, *13*, 131-144.

Pittman, H.T. 2014. Effects of Large Scale Growing Season Prescribed Burns on Movement, Habitat Use, Productivity, and Survival of Female Wild Turkey on the White Rock Ecosystem Restoration Project of the Ozark-St. Francis National Forest. Dissertation, University of Arkansas, Fayetteville, AR.

Pittman, H. T., & Krementz, D. G. (2016). Impacts Of Short-Rotation Early-Growing Season Prescribed Fire On A Ground Nesting Bird In The Central Hardwoods Region Of North America. *PloS one*, *11*(1), e0147317.

Roberts, S. D., and W. F. Porter. 1996. Importance of Demographic Parameters to Annual Changes in Wild Turkey Abundance. *Proceedings of the National Wild Turkey Symposium* 7:15–20.

Spears, B. L., M. C. Wallace, W. B. Ballard, R. S. Phillips, D. P. Holdstock, J. H. Brunjes, R. Applegate, M. S. Miller, and P. S. Gipson. 2007. Habitat Use and Survival of Preflight Wild Turkey Broods. *Journal of Wildlife Management* 71:69-81.

Stober, Jonathan, Krista Merry, and Pete Bettinger. 2020. "Analysis of Fire Frequency on the Talladega National Forest, USA, 1998-2018." *International Journal of Wildland Fire* 29(10): 943–49.

Sullivan, D. J., McEntire, K. D., Cohen, B. S., Collier, B. A., & Chamberlain, M. J. (2020). Spatial Scale and Shape of Prescribed Fires Influence Use by Wild Turkeys. *The Journal of Wildlife Management*, *84*(8), 1570-1577.

Swengel, A. B. 2001. A Literature Review Of Insect Responses To Fire, Com- Pared To Other Conservation Managements Of Open Habitats. *Biodiversity and Conservation* 10:1141–1169.

Wann, G. T., Martin, J. A., and Chamberlain, M. J. (2020). The Influence Of Prescribed Fire On Wild Turkeys In The Southeastern United States: A Review And Synthesis. *Forest Ecology and Management*, *455*, 117661.

Wood, Jeremy D. et al. 2018. Time-since-Fire and Stand Seral Stage Affect Habitat Selection of Eastern Wild Turkeys in a Managed Longleaf Pine Ecosystem. *Forest Ecology and Management* 411: 203–12.

Wood, J. D., Cohen, B. S., Conner, L. M., Jones, J. W., Collier, B. A., and Chamberlain, M. J. (2019). Nest and Brood Site Selection of Eastern Wild Turkeys. *The Journal of Wildlife Management, 83(1):*192–204.

Wright, W. J., Irvine, K. M., & Rodhouse, T. J. (2016). A goodness-of-fit test for occupancy models with correlated within-season revisits. *Ecology and Evolution*, *6*(15), 5404-5415.

Yeldell, N. A., Cohen, B. S., Little, A. R., Collier, B. A., & Chamberlain, M. J. (2017a). Nest site selection and nest survival of eastern wild turkeys in a pyric landscape. *The Journal of Wildlife Management*, *81*(6), 1073-1083.

Yeldell, N. A., Cohen, B. S., Prebyl, T. J., Collier, B. A., and Chamberlain, M. J. (2017). Use of pine-dominated forests by female eastern wild turkeys immediately after prescribed fire. *Forest Ecology and Management*, *398*, 226–234.

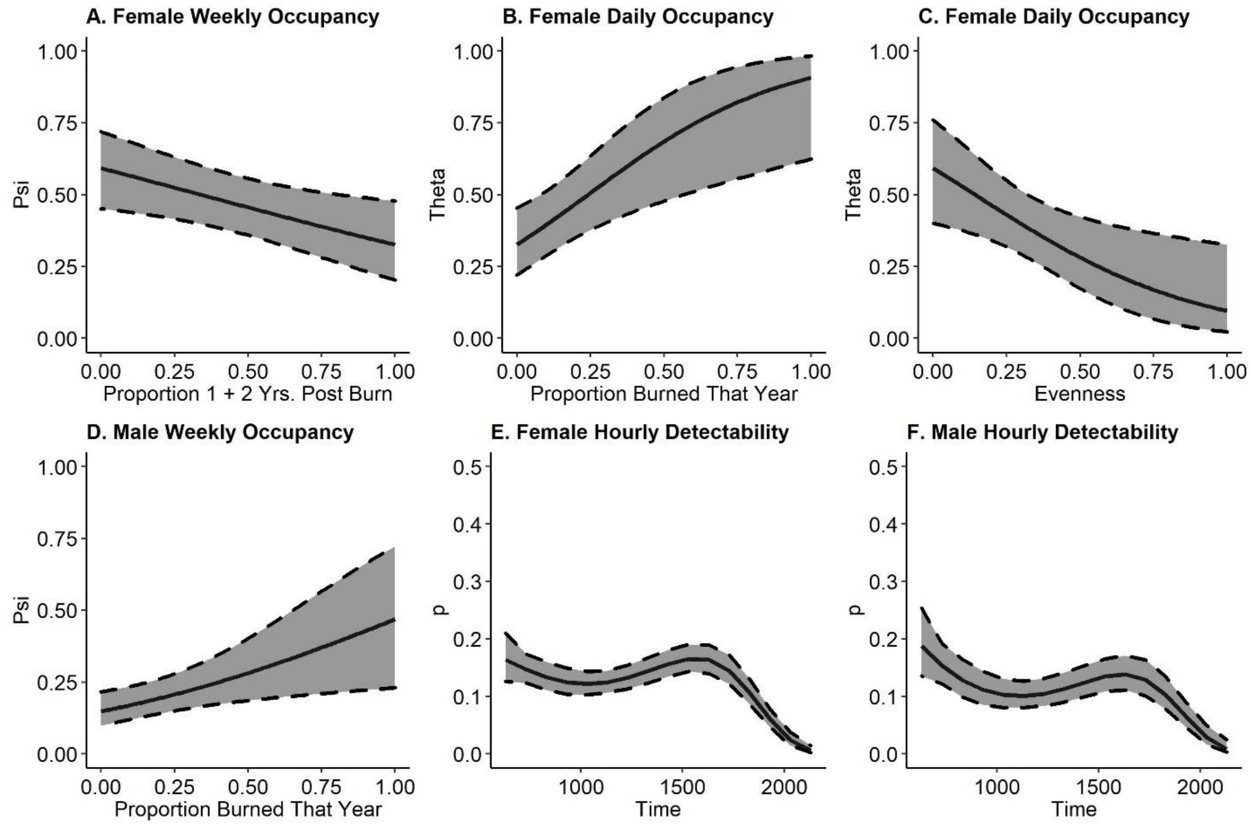

Fig. 2.1 Model-fitted relationships from top-ranked models for turkey occupancy and detection probability from camera surveys in the Talladega National Forest, Alabama, USA. A) Estimated female weekly occupancy vs. proportion of neighborhood in one- and two-year-old burns. B) Female conditional daily occupancy vs. proportion of neighborhood burned the same year, with neighborhood evenness fixed at its overall mean value (0.26). C) Female conditional daily occupancy vs. neighborhood evenness, with proportion burned the same year variable held fixed at its overall mean value (0.14). D) Male weekly occupancy vs. proportion burned the same year. E&F) Hourly female and male detection probability by hour from 5:30 am to 9:30 pm. Estimated male conditional daily occupancy = 0.93 (95%CL: 0.76, 0.98). Conditional daily occupancy estimates assume occupancy at the weekly scale but no occupancy the previous survey day. Detection probability estimates for each hour assume no detections the previous hour.

Table 2.1 Model selection results for multi-scale occupancy modeling of female and male turkeys in the Talladega National Forest, Alabama, USA 2019-2020. Psi = probability of occupancy at week scale; Theta = probability of occupancy at the day scale conditional on weekly occupancy; p = probability of detection at hour scale conditional on daily occupancy. Additional models (see Table 2 in appendix) that did not converge for males are omitted.

	Psi	*Theta*	*p*	*k*	*Deviance*	*AICc*	**Δ** *AICc*	*Weight*
Females								
	(onetwo)	(AR_1 + zero + evenness)	(recap(k-1)+Time4)	12	3612.66	3638.56	0.00	0.66
	(.)	(AR_1 + zero + evenness)	(recap(k-1)+Time4)	11	3618.56	3642.16	3.60	0.11
	(onetwo)	(AR_1 + zero)	(recap(k-1)+Time4)	11	3619.04	3642.64	4.08	0.09
	(onetwo)	(AR_1 + zero + onetwo + log10distance)	(recap(k-1)+Time4)	13	3615.02	3643.25	4.69	0.06
Males								
	(zero)	(.)	(recap(k-1)+Time4)	9	2010.34	2029.42	0.00	0.28
	(zero)	logdist	(recap(k-1)+Time4)	10	2009.82	2031.14	1.73	0.12
	(zero)	(zero)	(recap(k-1)+Time4)	10	2010.13	2031.46	2.04	0.10
	(zero)	timesince	(recap(k-1)+Time4)	10	2010.20	2031.52	2.11	0.10
	(zero)	onetwo	(recap(k-1)+Time4)	10	2010.31	2031.64	2.22	0.09
	(zero)	(evenness)	(recap(k-1)+Time4)	10	2010.34	2031.66	2.25	0.09
	(.)	(evenness)	(recap(k-1)+Time4)	9	2013.07	2032.15	2.73	0.07
	(.)	(.)	(recap(k-1)+Time4)	8	2016.35	2033.20	3.79	0.04
	(zero)	zero + onetwo	(recap(k-1)+Time4)	11	2010.71	2034.31	4.90	0.02

APPENDIX

Table A.1 Multi-scale occupancy modeling of weekly occupancy (Psi) of female and male turkeys in the Talladega National Forest, Alabama, USA 2019-2020. For this analysis step, conditional daily occupancy was modeled with an intercept-only, while p was modeled with recapture and time of day effects [recap(k-1) = 1 if detected the previous hour of that survey day, 0 otherwise; Time4 = 4th order polynomial effect of time of day].

	Psi	*Theta*	*p*	*k*	*Deviance*	*AICc*	*Δ AICc*	*weight*
Females								
	(onetwo)	(AR_1)	(recap(k-1)+Time4)	10	3627.82	3649.15	0	0.48
	(zero + onetwo)	(AR_1)	(recap(k-1)+Time4)	11	3627.01	3650.61	1.46	0.23
	(onetwo x evenness)	(AR_1)	(recap(k-1)+Time4)	12	3626.97	3652.88	3.73	0.07
	(zero)	(AR_1)	(recap(k-1)+Time4)	10	3631.95	3653.28	4.13	0.06
	(.)	(AR_1)	(recap(k-1)+Time4)	9	3634.35	3653.43	4.28	0.06
Males								
	(zero)	(.)	(recap(k-1)+Time4)	9	2010.34	2029.42	0	0.37
	(zero + onetwo)	(.)	(recap(k-1)+Time4)	10	2009.48	2030.81	1.39	0.18
	(zero x evenness)	(.)	(recap(k-1)+Time4)	11	2008.17	2031.77	2.35	0.11
	(timesinceburn)	(.)	(recap(k-1)+Time4)	9	2013.17	2032.25	2.83	0.09
	(onetwo)	(.)	(recap(k-1)+Time4)	9	2013.79	2032.87	3.46	0.06
	(.)	(.)	(recap(k-1)+Time4)	8	2016.35	2033.2	3.79	0.06
	(evenness)	(.)	(recap(k-1)+Time4)	9	2014.14	2033.22	3.8	0.05

Table A.2 Multi-scale occupancy preliminary examination of auto-regressive conditional daily occupancy and hourly detectability covariates of female and male turkeys in the Talladega National Forest, Alabama, USA 2019-2020. AR_1 = binary covariate for conditional daily occupancy, = 1 if detected the previous day of session, 0 on Day 1 or not detected; recap(k-1) = 1 if detected the previous hour of that survey day, 0 otherwise; Time4 = 4th order polynomial effect of time of day.

	Psi	***Theta***	***p***	***k***	***Deviance***	***AICc***	***Δ AICc***	***weight***
Females								
	(.)	(AR_1)	(recap(k-1)+Time4)	9	3634.4	3653.4	0	1
	(.)	(.)	(recap(k-1)+Time4)	8	3691.8	3708.7	55.2	0
	(.)	(.)	(Time4)	7	3808.7	3823.4	170	0
	(.)	(.)	(recap(k-1))	4	3838.4	3846.6	193.2	0
	(.)	(AR_1)	(.)	4	3911.7	3919.9	266.5	0
	(.)	(.)	(.)	3	3969.1	3975.3	321.8	0
Males								
	(.)	(.)	(recap(k-1)+Time4)	8	2016.3	2033.2	0	1
	(.)	(.)	(recap(k-1))	4	2090.9	2099.1	65.9	0
	(.)	(.)	(Time4)	7	2094.2	2108.9	75.7	0
	(.)	(AR_1)	(.)	4	2155.7	2163.9	130.7	0
	(.)	(.)	(.)	3	2169.4	2175.5	142.3	0
	(.)	(AR_1)	(recap(k-1)+Time4)	9	could not fit model successfully			

Table A.3 Logit-scale beta estimates for highest ranked multi-scale occupancy model for female and male turkeys in the Talladega National Forest, Alabama, USA 2019-2020.

	Parameter	***β***	***SE***	***LCL***	***UCL***
Females					
	Psi:(Intercept)	0.37	0.29	-0.20	0.94
	Psi:onetwo	-1.10	0.46	-2.00	-0.20
	Theta:(Intercept)	-0.04	0.40	-0.81	0.74
	Theta:rday	2.99	0.58	1.85	4.13
	Theta:zero	3.01	1.00	1.04	4.97
	Theta:evenness	-2.62	1.06	-4.69	-0.56
	p:(Intercept)	-1.63	0.16	-1.94	-1.32
	p:recap	1.22	0.11	1.01	1.44
	p:Time	-0.13	0.17	-0.46	0.20
	p:I(Time^2)	-0.01	0.05	-0.11	0.09
	p:I(Time^3)	0.01	0.01	-0.01	0.02
	p:I(Time^4)	0.00	0.00	0.00	0.00
Males					
	Psi:(Intercept)	-1.75	0.24	-2.21	-1.29
	Psi:zero	1.62	0.65	0.36	2.89
	Theta:(Intercept)	2.64	0.76	1.15	4.14
	p:(Intercept)	-1.47	0.20	-1.85	-1.08
	p:recap	1.36	0.16	1.05	1.67
	p:Time	-0.25	0.22	-0.67	0.17
	p:I(Time^2)	0.00	0.07	-0.13	0.13
	p:I(Time^3)	0.01	0.01	-0.01	0.02
	p:I(Time^4)	0.00	0.00	0.00	0.00