5-2026

FIRE SEASONALITY EFFECTS ON WHITE-TAILED DEER IN SOUTHERN PINE WOODLANDS

Spencer Gavin Marshall

To the Graduate Council:

I am submitting herewith a thesis written by Spencer Gavin Marshall entitled "FIRE SEASONALITY EFFECTS ON WHITE-TAILED DEER IN SOUTHERN PINE WOODLANDS." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Craig A. Harper, Major Professor

We have read this thesis and recommend its acceptance:

Marcus A. Lashley, Joseph D. Clark

Accepted for the Council:
Dr. Marieke Van Puymbroeck

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

FIRE SEASONALITY EFFECTS ON WHITE-TAILED DEER IN SOUTHERN PINE WOODLANDS

A Thesis Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Spencer G. Marshall

May 2026

DEDICATION

I dedicate this thesis to Tessa Marshall for her unwavering support and encouragement she provided me throughout my time at the University of Tennessee. All that I have achieved would not have been possible if not for her willingness to go above and beyond to ensure that I accomplish my goals. I am forever grateful and truly blessed to have her in my life. I also want to thank my parents David and Jacky Wilson for always supporting my dreams and the continual words of wisdom to help guide me along the way. Finally, I would like to dedicate this thesis to my grandparents Joe and Linda Liddle. Without them, I would not be the person I am today, and for that I am thankful. Thank you all for the love you give and know that I will forever appreciate and cherish all that you have done.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank God for his boundless love and the sacrifice of his Son to forgive us of our sins. His unwavering love and mercy given to each of us is truly a blessing and nothing would be possible without him. "I am the Alpha and the Omega, the Beginning and the End, the First and the Last." Revelation 22:13.

I thank Tennessee Wildlife Resource Agency, Tennessee Valley Authority, South Carolina Department of Natural Resources, Alabama Department of Conservation and Natural Resources, Mississippi Department of Wildlife Fisheries and Parks, David Hall, and the Drummond family for providing properties for this study. I thank Bill Smith, Nathan Wilhite, Seth Bassinger, Tommy Ferguson, Travis Bennett, Med Palmer, April Atkinson, Carl Childress, and Elliot Glass for their logistical support at each of the study sites.

I am truly grateful for Dr. Craig Harper giving me the opportunity to work on this project and pushing me to strive for greatness. My time as his graduate student was the best years of my life filled with a multitude of opportunities to further my knowledge of wildlife management. I also thank Dr. Marcus Lashley and Dr. Joe Clark for their continual support and guidance. Additionally, I would like to thank Dr. James Fordyce for assisting me with my statistical analysis. Over the past 4 years, I have made lifelong friends with other graduate students, and I am thankful for the memories I made with Jake Bones, Mark Turner, Ellie Burken, and Joe Quehl, and their support.

ABSTRACT

I evaluated white-tailed deer response to the associated change in vegetation composition and structure following fire implemented during each season of the year across 9 replicated sites in Tennessee, South Carolina, Alabama, and Mississippi using videos recorded with remote cameras. I analyzed the detection rate and observed behaviors of male, female, and fawn deer in relation to understory vegetation composition, visual obstruction, forage availability, and predator presence from 2021 to 2023 following four fire treatments: dormant season (DOS), early growing season (EGS), mid-growing season (MGS), and late growing season (LGS). Male deer detection rate during antler development (May–July) in 2021 and 2023 had 4.72x and 2.91x greater detections in the EGS unit relative to the control. The trend of male deer using the most recently burn unit continued into the pre-reproductive season (August–September) in 2023 with male deer detections being 2.45x greater in the MGS unit compared to the control. Male deer spent 12% more time foraging and 35% less time vigilant during the growing season compared with female deer. The foraging rate of female deer was positively correlated with forb biomass and was greater in recently burned units, but their detection rate was greater in treatment units with greater visual obstruction below 2 m in height. Fawn detections in 2021 were 0.44x lower and in 2023 were 0.22x lower in the EGS units which was burned most recently prior to fawning season. Coyote detections were greater in treatment units with decreased visual obstruction and were positively related to doe detections. My results indicate no one season of fire or fire-return interval is best for deer because cover requirements and exposure risk to predators vary between sexes and age classes of deer during the growing season.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Pine ecosystems represent one of the most dominant cover types across the southeastern US with about 29 million ha in overstory pine species (Oswalt et al. 2019), which include loblolly (*Pinus taeda*), longleaf (*P. palustris*), and shortleaf (*P. echinata*) pines. Maximizing timber revenue has been the primary objective of most private and industrial landowners who manage pine systems. However, in recent years, there has been increased interest in restoring pine woodlands, which differ from closed-canopy pine forests in that woodlands have only 30–70% canopy cover (Grossman et al. 1998, Jin et al. 2018). Objectives for managing pine woodlands typically differ from closed-canopy pines with wildlife and native plant diversity more-important objectives associated with woodlands and economics a more-important objective associated with pine plantations.

The white-tailed deer (*Odocoileus virginianus*) is arguably the most economically and ecologically important wildlife species in the US that can benefit from pine woodland restoration. About 24 million ha are owned or leased for hunting throughout the South, and most of these properties are managed to improve habitat for deer (Macaulay 2016). Pine woodlands are defined not only by a relatively sparse canopy of trees, but also by an understory dominated by herbaceous species (Walker and Peet 1984, O'Brien at al. 2008, Hanberry et al. 2014). Although unmanaged pine stands generally offer poor food resources for deer (Turner and Harper 2024), an understory dominated by forbs greatly increases the nutritional carrying capacity (Grossman et al. 1998, Edward et al. 2004, Lashley et al. 2011, Harper et al. 2025). Stimulating understory growth also can increase visual obstruction and provide fawning cover (Mixon et al. 2009). Managing open pine woodlands for deer can benefit other game species, including wild turkey (*Meleagris gallopavo*) and northern bobwhite (*Colinus virginianus*), whose populations have declined in recent decades (Brennan 1991, Jones et al. 2010, Chamberlain et al. 2022). Additionally, burning promotes use by disturbance-dependent wildlife species, such as painted bunting (*Passerina ciris*), brown-headed nuthatch (*Sitta pusilla*), red-headed woodpecker (*Melanerpes erthrocephalus*), great-crested flycatcher (*Myiarchus crinitus*), and prairie warbler (*Setophaga discolor*), that require the open structure associated with pine woodlands that have an herbaceous understory (Block et al. 2016). Frequent disturbance is necessary to maintain an herbaceous-dominated understory and prevent hardwood encroachment.

Prescribed fire is used to restore and maintain open pine woodlands. Fire top-kills hardwood sprouts and prevents woody species from dominating the understory, which reduces coverage of herbaceous plants and forage quality for deer (Guldin 2019, Turner et al. 2025). Fire also consumes leaf litter and stimulates germination of herbaceous plants in the seedbank. Fire suppression can increase hardwood prevalence and decrease plant species diversity and resource availability for wildlife species that benefit from an herbaceous understory without a cluttered midstory (Rudolph et al. 2002, Armitage and Ober 2012). Mesic tree species succeeding into the midstory prevent pine regeneration (Chapman 1945, Ruswick, 2015). Leaves of mesophytic species create a less-flammable fuel bed as the leaves stack, much like a deck of playing cards, decreasing ventilation for fire and increasing absorbed moisture (Scarff and Westoby 2006, McDaniel et al. 2021). The chemical composition of mesophytic species, such as maples (*Acer* spp.) and yellow-poplar (*Liriodendron tulipifera*), contain fewer volatile compounds and reduced lignin content, which increase the decomposition rate compared to upland oak (*Quercus* spp.) and pine species (White 1987). Increased shade created by hardwoods limit seedbank response and growth of herbaceous vegetation, perpetuating mesic hardwood encroachment into upland pine and oak-dominated ecosystems (Haywood 2001, Alexander et al. 2021). Therefore, frequent fire is requisite to restore and maintain open pine woodlands (Matusick et al. 2020).

Fire frequency strongly affects vegetation composition and structure, influencing food and cover availability for ungulates. Burning on a 1–3-year fire-return interval generally increases the nutritional carrying capacity for white-tailed deer by increasing forage quality and availability (Edwards et al. 2004, Mixon et al. 2009, Lashley et al. 2011, 2015a). Forage quality decreases within five years of disturbance as vegetation matures and hardwood midstory plants typically shade-out understory plants thereby reducing forage availability (Nanney et al. 2018). Female deer benefit from a longer burn interval of 3–5 years by allowing more understory development, which increases fawning and escape cover (Lashley et al. 2015). Time of year when pine woodlands are burned can have major implications for white-tailed deer.

Fire restricted to a specific time of year may constrain vegetation nutrient pulses to specific windows of the growing season (Lashley et al. 2022). Typically, land managers burn during the dormant season when burn conditions, such as low relative humidity, low fuel moisture, clear skies, and consistent transport winds, are more common than during the growing season (Cronan 2015, Platt et al. 2015). However, burning restricted to the dormant season mismatches the availability of high-quality forage on the landscape when nutritional demand is greatest for white-tailed deer. Dormant-season fire causes resprouting to coincide with spring green-up, whereas fire during the growing season promotes resprouting later in summer, which extends the availability of high-quality forage when nutritional demands are still great for deer (Nichols et al. 2021, Lashley et al. 2022). Varying the season of burning can benefit deer throughout the year by extending availability of high-quality forage throughout the growing season.

The diet of white-tailed deer during the growing season is composed of about 70% forbs when they are available (Kie et al. 1980). Forbs are a common component of herbaceous understories in pine woodlands (McMahan 1964, Sambeek et al. 2007) and many of them, including partridge pea (*Chamaecrista fasciculata*), beggar's-lice (*Desmodium* spp.), and common ragweed (*Ambrosia artemisiifolia*), contain crude protein levels in excess of the 14–16% threshold required by lactating females, fawn development, and males growing antlers (Hewitt 2011, Harper et al. 2025). In fall, as warm-season herbaceous plants senesce, deer transition to consuming more woody browse, including twig ends and buds of trees and shrubs (McMahan 1964, Hewitt, 2011). Growing-season fire may initially decrease forage biomass, but resprouting vegetation is greater in nutritional content and digestibility (Nichols et al. 2021). Dormant-season fire typically top-kills young trees with thinner bark which promotes resprouting. Resprouts of species such as winged elm (Ulmus alata), blackgum (*Nyssa sylvatica*), hackberry (Celtis occidentalis), red maple (*Acer rubrum*), and yellow-poplar (*Liriodendron tulipifera*) provide young foliage that is highly digestible and selected by deer (Blair and Feduccia 1977). As foliage of woody species mature, lignification within cell walls decreases digestibility and selectivity by herbivores (Vangilder et al. 1982, Moore and Jung 2001).

Burning during the growing season can increase the availability of high-quality forage, but the reduction in vegetation height may reduce fawning cover, which increases risk of predation. McCoy et al. (2013), Kilgo et al. (2012), and Chitwood et al. (2015) reported predation was the primary cause of fawn death in the southeastern US. To minimize predation risk during fawning season, female deer avoided recently burned areas and selected areas with dense vegetation to birth fawns (Kie and Bowyer 1999, McCoy et al., 2013, Lashley et al. 2015). Although growing-season fire can initially decrease visual obstruction, forage quality is increased that season and, as the vegetation structure in the understory develops the following year, female deer may use the area as fawning cover (Main and Richardson 2002).

High-quality forage in recently burned areas should lead to increased use by herbivores, but Cherry et al. (2017) reported female deer during the fawn-rearing season avoided recently burned areas. The reduction in vegetation height following fire may promote use by some predators, especially coyote (*Canis lupus*), which may increase deer vigilance that would reduce foraging activity (Brown 1999). Variation in risk of predation between male, female, and neonates during the growing season may lead to an asymmetrical behavioral response whereby male deer may increase use of recently burned areas to forage with less perceived risk compared with lactating females or neonates. Areas with more visual obstruction may be perceived as being safer by deer and increase the amount of time spent loafing and bedding.

Burning within pine woodlands during different seasons of the year influences plant composition and structure, which not only impacts deer forage and cover availability, but also how deer perceive the landscape, which alters their behavior and movements. Previous research has investigated the effects of burning during different seasons on vegetation (Sparks et al. 1998, Barlow et al. 2010, Dixon and Robertson 2025, Zeitler et al. 2025, Bones et al. *in press*), but no study to date has investigated how fire implemented during the dormant, early growing, mid-growing, and late growing seasons can influence relative use of open pine ecosystems by deer and their predators.

We developed a field experiment across the southeastern United States to assess how white-tailed deer use of open pine woodlands changes in relation to season of fire. We hypothesized deer use of open pine woodlands treated with fire during different seasons would differ by sex and season of year. We predicted fewer female deer detections within the most recently burned units because of a lack of adequate fawning cover and greater relative use of the units by coyotes, which typically select more open conditions. We predicted greater male detections in the most recently burned units the year of treatment implementation because of greater forage quality associated with recently sprouting vegetation. We used videos of deer obtained from remote cameras to correlate deer use or avoidance during biologically important times of year with vegetation attributes to better understand deer selection for food versus cover availability. Furthermore, we quantified the relationship between characteristics of deer behavior and fire timing and vegetation. Information regarding how season of burning influences deer herbivory, cover selection, and prey behavior should provide a better understanding of the ecological role of fire when restoring and maintaining pine woodlands.

LITERATURE CITED

Alexander, H. M., C. Siegert, J. S. Brewer, J. Kreye, M. A. Lashley, J. K. McDaniel, A. K. Paulson, H. J. Renniger, and J. M. Vanner. 2021. Mesophication of oak landscapes: evidence, knowledge gaps, and future research. BioScience 71:531–542.

Armitage, D. W. and Ober, H. K. 2012. The effects of prescribed fire on bat communities in the longleaf pine sandhills ecosystem. Journal of Mammalogy 93:102–114.

Barlow, R. J., J. S. Kush, S. M. Hermann, and W. D. Boyer. 2010. Impacts of fire on longleaf pine stand dynamics with different seasonal and fire return intervals. Pages 127–132. Proceedings of the 24th Tall Timbers Fire Ecology Conference. Tall Timbers Research Station. Tallahassee, Florida, USA.

Blair, R. B., and D. P. Feduccia. 1977. Midstory hardwoods inhibit deer forage in loblolly pine plantations. The Journal of Wildlife Management 41:677–684.

Block, W. M., L. M. Conner, P. A. Brewer, P. Ford, J. Haufler, A. Litt, R. E. Masters, L. R. Mitchell, and J. Parl. 2016. Effects of prescribed fire on wildlife and wildlife habitat in selected ecosystems of North America. The Wildlife Society Technical Review 16-01. Bethesda, Maryland, USA.

Bones, J. T., S. G. Marshall, M. A. Turner, M. M. Lapp, W. D. Gulsby, J. D. Clark, E. V. Willcox, and C. A. Harper. *In Press*. Vegetation response by season of burning in pine woodlands across the southeastern US. Fire Ecology.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline. Wildlife Society Bulletin 19:544–555.

Brown, J. S. 1999. Vigilance, patch use and habitat selection; foraging under predation risk. Evolutionary Ecology Research 1:49–77.

Chamberlain, M. J., M. Hatfield, and B. A. Collier. 2022. Status and distribution of wild turkeys in the United States in 2019. Wildlife Society Bulletin 46:e1287.

Chapman, H. H. 1945. The effect of overhead shade on the survival of loblolly pine seedlings. Ecology 26:274–282.

Cherry, M. J., R. J. Warren, and M. L. Conner. 2017. Fire-mediated foraging tradeoffs in white-tailed deer. Ecosphere 8:01784.

Chitwood, C. M, M. A. Lashley, J. C. Kilgo, K. H. Pollock, C. E. Moorman, and C. S. DePerno. 2015. Do biological and bedside characteristics influence survival of neonatal white-tailed deer. PLoS One 10:e0119070.

Cronan, J. B., C. S. Wright, and M. Petrova. 2015. Effects of dormant and growing season burning on surface fuels and potential fire behavior in northern Florida longleaf pine (*Pinus palustris*) flatwoods. Forest Ecology and Management 354:318–333.

Dixon, C. M., and K. M. Robertson. 2025. Effects of fire season on flowering phenology in pine savanna. Fire Ecology 21:23.

Edwards, S. L., S. Demarais, B. Watkins, and B. K. Strickland. 2004. White-tailed deer forage production in managed and unmanaged pine stands and summer food plots in Mississippi. Wildlife Society Bulletin 32:739–745.

Grossman, D. H., D. Faber-Langendoen, A. S. Weakley, M. Anerson, P, Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. D. Patterson, and M. Pyne. 1998. International classification of ecological communities: terrestrial vegetation of the United States. The Nature Conservancy, Arlington, Virginia, USA.

Guldin, J. M. 2019. Restoration of native fire-adapted southern pine-dominated forest ecosystems: diversifying the tools in the silvicultural toolbox. Forest Science 65:508–518.

Hanberry, B. B., D. T. Jones-Farrand, and J. M. Kabrick. 2014. Historical open forest ecosystems in the Missouri Ozarks: reconstruction and restoration targets. Ecological Restoration 32:407–416.

Harper, C. A., B. K. Strickland, M. A. Lashley, M. A. Turner, J. S. Nanney, M. C. Chitwood, C. E. Moorman, N. Ellison-Neary, J. M. Brooke, and G. Street. 2025. Soil quality does not predict plant nutrition available to white-tailed deer. The Journal of Wildlife Management 89:e22722.

Haywood, J. D., F. L. Harris, and H. E. Grelen. 2001. Vegetative response to 37 years of seasonal burning on a Louisiana longleaf pine site. Southern Journal of Applied Forestry 25:122–130.

Hewitt, D. G. 2011. Biology and management of white-tailed deer. CRC Press. Boca Raton, Florida, USA.

Jin, W., H. S. He, S. R. Shifley, W. J. Wang, J. M. Kabrick, and B. K. Davidson. 2018. How can prescribed burning and harvesting restore shortleaf pine-oak woodland at the landscape scale in central United States? Modeling joint effects of harvest and fire regimes. Forest Ecology and Management 410: 201–210.

Jones, P. D., Burger, L. W. Jr., and S. Demarais. 2010. Habitat value of intensively established pine plantations for northern bobwhite. The Journal of Wildlife Management, 74:449–458.

Kie, J. G., L. D. Drawe, and G. Scott. 1980. Changes in diet and nutrition with increased herd size in Texas white-tailed deer. The Journal of Range Management 33:28–34.

Kie, J. G., and R. T. Bowyer. 1999. Sexual segregation in white-tailed deer: density-dependent changes in use of space, habitat selection, and dietary niche. Journal of Mammalogy 80:1004–1020.

Kilgo, J. C., S. H. Ray, M. Vukocich, M. J. Goode, and C. Ruth. 2012. Predation by coyotes on white-tailed deer neonates in South Carolina. The Journal of Wildlife Management 76:1420–1430.

Lashley, M. A., C. A. Harper, G. E. Bates, and P. D. Keyser. 2011. Forage availability for white-tailed deer following silvicultural treatments in hardwood forests. The Journal of Wildlife Management 75:1467–1476.

Lashley, M. A., M. C. Chitwood, R. Kays, C. A. Harper, C. S. DePerno, and C. E. Moorman. 2015. Prescribed fire affects female white-tailed deer habitat use during summer location. Forest Ecology and Management 348:220–225.

Lashley, M. A., M. C. Chitwood, J. L. Dykes, C. S. DePerno, and C. E. Moorman. 2022. Human-mediated trophic mismatch between fire, plants, and herbivores. Ecography:e06045.

Nanney, J. S., C. A. Harper, D. A. Buehler, and G. A. Bates. 2018. Nutritional carrying capacity for cervids following disturbance in hardwood forests. The Journal of Wildlife Management 82:1219–1228.

Nichols, R. A., S. Demarais, B. K. Strickland, and M. A. Lashley. 2021. Alter fire timing to recouple forage nutrient with herbivore demand. Forest Ecology and Management 500:e119646.

Macaulay, L. 2016. The role of wildlife-associated recreation in private land use and conservation: providing the missing baseline. Land Use Policy 58:218–233.

Main, M. B., and L. W. Richardson. 2002. Response of wildlife to prescribed fire in southwest Florida pine flatwoods. Wildlife Society Bulletin 30:213–221.

Matusick, G., S. J. Hudson, C. Z. Garret, L. S. Samuelson, J. D. Kent, R. N. Addington, and J. M. Parker. 2020. Frequently burned loblolly-shortleaf pine forest in the southeastern United States lacks the stability of longleaf pine forest. Ecosphere 11:e03055.

McCoy, J. C., S. S. Ditchkoff, J. B. Raglin, B. A. Collier, and C. Ruth. 2013. Factors influencing survival of white-tailed deer fawns in coastal South Carolina. Journal of Fish and Wildlife Management 4:280–289.

McDaniel, J. K., H. D. Alexander, C. M. Sieger, and M. A. Lashley. 2021. Shifting tree species composition of upland oak forest alter leaf litter structure, moisture, and flammability. Forest Ecology and Management 482:e118860.

McMahan, C. A. 1964. Food habits of deer and three classes of livestock. The Journal of Wildlife Management 28:798–808.

Mixon, M. R., S. Demarais, P. D. Jones, and B. J. Rude. 2009. Deer forage response to herbicide and fire in mid-rotation pine plantations. The Journal of Wildlife Management 73:663–668.

Moore, K. J., and H. G. Jung. 2001. Lignin and fiber digestion. Journal Range Management 54:420–430.

O'Brien, J. J., J. K. Heirs, M. A. Callaham Jr., R. J. Mitchell, and S. B. Jack. 2008. Interactions among overstory structure, seedling life-history traits, and fire in frequently burn neotropical pine forests. A Journal of the Human Environment 37:542–547.

Oswalt, S. N., W. B. Smith, P. D. Miles, and S. A. Pugh. 2019. Forest resources of the United States, 2017: A technical document supporting the Forest Service 2020 RPA Assessment. 95 pp. USDA Forest Service General Technical Report WO-97. Washington Office, Washington, DC, USA.

Platt, W. J., S. L. Orzell, and M. G. Slocum. 2015. Seasonality of fire weather strongly influences fire regimes in south Florida savanna-grassland landscapes. PLoS One 10:e0116952.

Rudolph, D. C., R. N. Conner, and R. R. Schaefer. 2002. Red-cockaded woodpecker foraging behavior in relation to midstory vegetation. Wilson Bulletin 114:235–242.

Ruswick, S. K. 2015. The response of sweetgum after top-kill in different seasons of burn. Thesis. The University of Georgia, Athens, Georgia, USA.

Sambeek, J. W., N. E. Navarrete-Tindall, H. E. Garrett, C. H. Lin, R. L. McGraw, and D. C. Wallace. 2007. Ranking the shade tolerance of forty-five candidate groundcovers for agroforestry plantings. The Temperate Agroforester 15:1–10.

Scarff, F. R., and M. Westoby. 2006. Leaf litter flammability in some semi-arid Australian woodlands. Functional Ecology 20:745–752.

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

Turner, M. A. and C. A. Harper. 2024. Vegetation composition and structure for deer and turkey in pine stands following low-intensity management. Southeastern Naturalist 23:175–193.

Turner, M. A., C. A. Harper, M. A. Lashley, B. K. Strickland, and M. Q. Wilber. 2025. Plant nutrient concentrations inform white-tailed deer diet limitations. Journal of Environmental Management 375:e124186.

Vangilder, L. D., O. Torgerson, and W. R. Porath. 1982. Factors influencing diet selection by white-tailed deer. The Journal of Wildlife Management 46:711–718.

Walker, J. and R. K. Peet. 1984. Composition and species diversity of pine-wiregrass savannas of the Green Swamp, North Carolina. Vegetation 55:163–179.

White, R. H. 1987. Effects of lignin content and extractives on the higher heating value of wood. Wood and Fiber Science 19:446–452.

Zeitler, E. F., K. M. Robertson, C. M. Dixon, and M. A. Lashley. 2025. Fire season differentially affects resprouting vigor of pyrophytic and mesophytic hardwoods in a southeastern U.S. pine savanna. Forest Ecology and Management 578:e122478.

CHATPER I. FIRE SEASONALITY EFFECTS ON WHITE-TAILED DEER IN PINE WOODLANDS OF THE SOUTHEASTERN US

ABSTRACT

Pine woodland is a declining ecological community in the southeastern United States that requires frequent fire. Prescribed fire is used to maintain pine woodlands and improve habitat for many wildlife species. The white-tailed deer (*Odocoileus virginianus*) is an herbivore of ecological and economic importance in the southeastern US, and more land in this region is managed for deer than any other species. Land managers traditionally have burned pine woodlands during the dormant season, but more recently there has been increased focus on burning during the growing season, which better mimics natural timing of fire caused by lightning. The effect of burning during different times of the year on deer resource availability may influence how fire is applied across a large geographic area and may better enhance habitat for various wildlife species. Monitoring deer and associated predator use following fire implementation during different seasons of the year would provide insight into the ecological role of fire on deer resource selection as well as predator-prey relationships in fire-adapted ecosystems. We used camera traps to collect videos of deer and their primary predators in the region (coyotes and bobcats) and evaluate their use of pine woodlands treated with prescribed fire during each season of the year (dormant, early growing, mid-growing, and late growing) on a 2-year fire-return interval at 9 replicated sites in Tennessee, Alabama, South Carolina, and Mississippi, 2020–2023. Use of fire treatments differed among male, female, and fawn deer throughout the year. Male deer detections and foraging rate were greatest in the most-recently burned unit during antler development, with 4.72x greater detections in the early growing-season treatment in 2021 and 2.91x greater in 2023 compared to control soon after fire implementation. This trend continued in 2023 with 2.45x greater detections in the mid-growing-season units compared to control soon after fire implementation. Male deer detections and time spent foraging had a positive correlation with forb biomass indicating that high-quality forage availability may be influencing landscape use during the growing season. Vigilance accounted for approximately 6% of male behaviors observed during the antler development season. We were unable to detect an annual difference in male deer vigilance between treatments indicating that male deer use may not be driven by predation risk. Female deer detections during the fawning season did not differ between treatment units each year but behavior differed by treatment and vegetation characteristics. Female deer foraging rate was greater within the more recently burned units and foraging had a positive correlation with forb biomass. Female deer spent more time loafing in areas with greater visual obstruction below 2 meter and a more dense midstory. Fawn detections were 0.44x and 0.22x less in the early growing-season treatment in 2021 and 2023, the years of treatment implementation, indicating female deer did not select recently burned areas for fawn rearing likely because of reduced fawning cover and increased visibility. Behavioral data supported these results with female deer spending more time vigilant within areas that had been burned recently with reduced visual obstruction and more time loafing in areas with greater midstory stem density and visual obstruction. We detected a positive relationship between coyotes and female deer during the fawning season indicating coyotes may actively hunt areas based on the presence of female deer. Bobcat detections had a weak positive correlation with female and fawn deer during the fawning season. Our study demonstrates that fire timing can modulate deer use, behavior, and interactions with predators in open-pine systems. Changes in behavioral response by deer dependent on sex and age indicate selective use and perceived predation risk within pine woodlands, which was driven by fire effects on vegetation conditions and relative predator use.

KEY WORDS: bobcat, coyote, fire, pine woodlands, predator, fire effects, timing of burning, white-tailed deer

Restoration of pine (*Pinus* spp.) woodlands has become a conservation focus throughout the southeastern US. Pine woodlands differ from closed-canopy forests in that woodlands have 30–70% cover of overstory pine trees, allowing sufficient sunlight to support a diverse herbaceous plant community in the understory (Grossman et al. 1998, Faber-Langendoen 2001). Historically, longleaf (*Pinus palustris*) and shortleaf pine (*Pinus echinata*) were the most widespread and ecologically important Southern pine species (Oswalt et al. 2012). Fire suppression, increased agricultural land use, and non-sustainable timber harvest during the late 19th century led to a decline in pine woodlands across the South. Subsequently, populations of species dependent on open-pine systems including red-cockaded woodpecker (*Picoides borealis*), Bachman's sparrow (*Peucaea aestivalis*), and southern fox squirrel (*Sciurus niger*) declined over the past 100 years (Hunter et al. 2001, USFWS 2003, Guill et al. 2024). The decline in pine woodlands also affects other species not particularly tied to pine woodlands, such as white-tailed deer (*Odocoileus virginianus*) and wild turkey (*Meleagris gallopavo*), as pine woodlands provide food and cover resources for both of those species during different life stages.

The white-tailed deer (hereafter deer) is arguably the most economically, ecologically, and culturally important wildlife species in the southeastern United States. Deer generate about $99 million annually in revenue for state wildlife agencies through the Pittman-Robertson tax on hunting equipment (SDP 2021). About 4 million hunters pursue deer annually, and the sale of hunting licenses provides an important revenue source for state wildlife agencies, which also enables management for nongame species (SDP 2021). More than 24 million hectares are owned or leased for deer hunting throughout the South, and many of these properties are managed specifically to improve habitat for deer (Macaulay 2016). Habitat management for deer focuses on improving food and cover for deer, but also enhances habitat for many nongame species (Kissel 2002, Lashley et al., 2015a, Harper et al. 2021).

Pine woodlands require frequent disturbance to maintain an herbaceous understory and prevent hardwood sprouts from dominating the understory. An herbaceous understory dominated by forbs provides high-quality forage for deer. Certain species, such as common obtuse-leaved tick trefoil (*Desmodium obtusum*), wrinkle-leaf goldenrod (*Solidago rugosa*), and horseweed (*Erigeron canadensis*), are selected by deer and provide necessary nutrition during the most nutrient-demanding life stages. These plants, as well as most other forbs, exceed the 14% nutritional requirement needed during fawning and antler development when nutritional demands are greatest (Hewitt 2011, Hamrick et al. 2021, Harper et al. 2025). A main objective of many landowners managing property for deer is to produce larger deer by increasing forage availability and better enable animals to realize their genetic potential (Nanney et al. 2015, Turner et al. 2025). Preferred deer food plants associated with burned pine woodlands may increase use of an area by deer, and the nutritional benefits provided for deer may increase land managers' interest to restore woodlands.

Variable fire timing can increase heterogeneity of vegetation structure, altering food and cover availability for deer. Mid-growing and late growing-season fire can reduce midstory density and increase forb coverage providing increased high-quality forage within pine woodlands (Nichols et al. 2021, Resop et al. 2023, Zeitler et al. 2025, Bones et al. *in press*). Burning immediately before or during the fawning season creates a more open and homogenous landscape, leaving fawning cover relegated to smaller patches (Lashley et al. 2014a). Such conditions may make it easier for coyotes and other predators to search and find fawns and potentially lead to a declining deer population (Chitwood et al. 2017). Characteristics of neonate deer bedding sites typically include relatively dense vegetation with reduced visibility to hide from predators (Butler et al. 2009; Chitwood et al. 2015a). Dormant-season fire may only top-kill woody stems leading to a greater presence of hardwood species in the midstory which can provide fawning and escape cover for deer, but with reduce nutritional benefit because of a less herbaceous understory (Resop et al. 2023, Zeitler et al. 2025, Bones et al. *in press*).

Although multiple studies have investigated fire effects on vegetation composition and deer use, no study has examined how varying the time of fire throughout the growing season influences vegetation attributes and deer use of pine woodlands (Lashley et al. 2015b, Lashley et al. 2015c, Cherry et al. 2017, Nichols et al. 2021, Lashley et al. 2022). Numerous studies have reported many wildlife species are attracted to an area following fire (Mason et al. 2022, Mason et al. 2025) and herbivores during the period after fire when regenerating vegetation is greater in nutritional value (Westlake et al. 2020, Zeitler et al. 2025) but no study has focused on the differential use of fire-frequented pine woodlands based on time of year or sex and age class of deer, which can influence whether food or cover requirements are more important for a given individual. Understanding the ecological role of fire seasonality on deer use of pine woodlands can guide restoration efforts to match forage and cover availability with biological requirements as they change for white-tailed deer throughout the year.

We developed a field experiment to investigate how timing of fire affects use of pine woodlands by male, female, and fawn deer in relationship to vegetation characteristics and coyote and bobcat relative use. Our study sites represented commonly managed pine systems in the southeastern United States by state wildlife agencies and private land managers. We used low-intensity prescribed fire on a 2-year fire-return interval to influence plant composition and structure and prevent hardwood stems from dominating the understory (Robertson et al. 2021). Study sites were approximately 10 ha, evenly divided into control (No fire), dormant-season (January–March), early growing-season (April–May), mid-growing-season (June–July), and late growing-season treatment (September–October) units. We burned the treatments on a 2-year fire-return interval starting with the late growing-season treatment in 2020. We monitored deer and predator use with remote cameras set to record videos. Our research objective was to evaluate white-tailed deer use based on the vegetation characteristics following burning at different times of the year. We wanted to evaluate how understory vegetation composition, visual obstruction, midstory density, and available forage biomass were related to use by deer and their associated predators throughout specific biological seasons. We divided the year into the primary growth seasons for deer: antler production (April–July), fawning (May–September), pre-reproductive season (August–September), reproductive season (October–January), and post-reproductive season (February–March) to evaluate use by adult male, adult female, and fawn deer (Jacobson and Waldham 1992, Ruth 2023, MWFP 2024, ADCNR 2024). We hypothesized deer use would differ by sex during the primary growth season based on nutritional requirements and predator avoidance. We predicted male deer would select areas with greater nutritional availability, whereas females and fawns would concentrate use in areas with more visual obstruction and a denser midstory. We predicted coyotes and bobcats would use the recently burned areas with less visual obstruction because of increased efficiency searching for prey. We further hypothesized deer would exhibit differential behavior based on vegetation characteristics influenced by season and time since fire. We predicted deer would exhibit more foraging behavior within units that were most recently burned during the antler development season to consume higher-quality forage but also would have a greater vigilance and running rate when there was less concealment cover from predators. We predicted deer would spend more time loafing and bedding within units that had not been recently burned and within the control. Additionally, we predicted female deer would spend more time vigilant and running compared to male deer to escape predators and protect offspring.

STUDY AREA

We selected nine study sites located across Alabama, Mississippi, South Carolina, and Tennessee, USA, with varying soils and physiographic characteristics (Appendix A.1). Study sites were representative of loblolly and shortleaf pine stands that had been thinned to a woodland canopy structure to restore the ecological function of supporting species dependent on open-pine systems. Basal area, percent active sunlight entering the canopy, soils, and dominant plant species varied and are provided in Appendix A.1. Two sites were located at South Carolina Department of Natural Resources property in Hampton and Newberry counties, South Carolina. The site located at Belfast Wildlife Management Area (WMA) was established in 1995 with planted loblolly pine and had been thinned twice, most recently in 2018 (Turner and Harper 2024, Bones et al. *in press*). The other site located in South Carolina was at the Webb WMA, which was planted in 1992 with loblolly pine. The Webb site had been thinned twice, most recently in 2015, and was burned on a 3–5-year fire-return interval since the most-recent thinning, but not within 3 years of data collection (Turner and Harper 2024, Bones et al. *in press*).

Three sites were in Alabama. One site was at Barbour WMA in Barbour County and was owned by the Alabama Department of Conservation and Natural Resources. The Barbour site was loblolly pine planted in 1998 and was last thinned in 2018 and had not been previously burned (Turner and Harper 2024, Bones et al. *in press*). Mason Bend was a privately owned property in Hale County, Alabama. The Mason Bend site was established in 2002 with planted loblolly pine and had not been burned prior to the study (Turner and Harper 2024, Bones et al. *in press*). Folsom was a privately owned property located in Perry County, Alabama. The Folsom site was a loblolly pine stand planted in 2005, thinned in 2020, and had not been burned prior to project implementation (Turner and Harper 2024, Bones et al. *in press*).

Triple Creek was a privately owned property located in Clarke County, Mississippi. The Triple Creek site was a loblolly pine stand planted in 1998, had been thinned twice, most recently in 2018, and had been burned once during the dormant season following the most recent thinning (Turner and Harper 2024, Bones et al. *in press*). Copiah was part of the Copiah WMA, owned by Mississippi Department of Wildlife, Fisheries, and Parks, and was a naturally regenerated loblolly/shortleaf pine stand established in 1960. The Copiah site had been thinned twice, most recently in 2014, and burned on a 3–5-year fire-return interval, most recently in 2017 (Turner and Harper 2024, Bones et al. *in press*).

Our two study sites in Tennessee were on public land owned and managed by the Tennessee Wildlife Resource Agency. Foothills was located on Foothills WMA in Blount County. The Foothills site was a naturally regenerated shortleaf-mixed hardwood stand established in 1940 and thinned in 2014 to remove hardwoods from the overstory and restore a shortleaf pine woodland (Turner and Harper 2024, Bones et al. *in press*). The Foothills site was burned during the 2017 dormant season after thinning. Bridgestone was an early successional plant community planted to shortleaf pine in 2014 at the Bridgestone Firestone Centennial

Wilderness and WMA in Van Buren County. The Bridgestone site had not been burned prior to our study.

METHODS

We compared use of fire treatments with a replicated complete block design. Each site was divided into five adjacent units, 2 ha in size. We randomly assigned a burn treatment to each unit to create a control, dormant season (January–March), early growing-season (April–May), mid-growing-season (June–July), and late growing-season treatment (September–October) at each site. We burned the treatments on a 2-year fire-return interval starting with the late growing-season treatment in 2020.

Burn treatment implementation

We implemented fire treatments with the assistance of state wildlife agency personnel and private land managers. We obtained burn permits as necessary prior to each fire treatment. We used backing fire during each fire event to establish a blackened area on the downwind side of the unit adjacent to a firebreak. We burned the remaining unburned section of the unit using backing fire unless strip-heading or flanking fire were necessary to facilitate fire spread and obtain complete burn coverage. We conducted prescribed fire when conditions would allow consumption of fine fuels but not pose danger to overstory trees. Burn prescription parameters varied based on the season of burn (Table A.3). We recorded relative humidity, in-stand wind speed, and air temperature using a Kestrel 5500 FW Fire Weather Meter Pro (Nielson-Kellerman, Boothwyn, PA, USA). We recorded maximum fire temperature using HOBO UX-100 dataloggers and 12” Type K thermocouples programmed to record, on a one-second interval, the temperature at the sampling point during the fire. Type K thermocouples (Onset Computer Corporation, Bourne, MA, USA) can record temperatures between 0–899 °C with ± 0.12 °C of accuracy. We recorded fire rate of spread based on the distance the flame front moved over a 60-second period. See Bones et al. (*in press*) for additional data as related to fire weather, fuels, and fire behavior.

Understory vegetation composition sampling

We sampled vegetation attributes in four plots that we randomly generated in ArcGIS Pro in each unit with a >25-m buffer from each other and the edge of the treatment unit. We used the point-intercept method along a 50-m transect with a random azimuth to record plant composition in the understory (Godínez-Alvarez et al. 2009). We recorded every plant species that intersected the transect on a 1-m interval. We collected relatively young and old leaves from plants considered commonly selected as forage by deer at the 12.5- and 37.5-m mark along each transect within a ½-m^2 forage square (Lashley et al. 2014b, Nanney et al. 2018, Harper et al. 2021, Powell et al. 2022, Turner et al. 2025). We collected relatively young plant tissue separately from older plant tissue as the young tissue is higher quality and more digestible than older tissue (Lashley et al. 2014b, Harper et al. 2025). We only collected plant material if it was <2 m above ground to represent what was available to deer (Beals et al. 1960). We dried the collected forages in a forced-air dryer for 72 hours at 50 °C and sent the dried forages to Custom Laboratories (Monett, Missouri) and Clemson Agricultural Service Laboratory (Clemson, South Carolina) for wet chemistry analysis of crude protein, acid detergent fiber, neutral detergent fiber, phosphorus, magnesium, and other trace minerals (Ondarza and Ward 2013).

Vegetation structure sampling methods

We recorded understory vegetation structure using a vertical profile board (Nudds 1977) at the 15- and 35-m mark along each transect from a height of 1-m above ground for a total of 8 profile board readings per treatment unit. The profile board was 0.25-meter wide by 2-m tall and was divided into 6 strata. We recorded percent visual obstruction from 0 to 5 (0 = 0%, 1 = 1–20% 2 = 21–40%, 3 = 41–60%, 4 = 61–80%, 5 = 81–100%) based on the amount of vegetation that obstructed the view at each stratum on the board. We averaged the percent visual obstruction from each stratum to estimate percent visual obstruction below 2 m as other studies have reported vegetation <2 m tall affects deer use throughout the year in pine woodlands (Lashley et al. 2015b, Kroeger et al. 2020).

Overstory/midstory sampling

We recorded species and diameter at breast height (DBH) of trees ≥11.4 cm to estimate basal area (m^2/ha) centered at the 4 permanent sampling plots in each treatment unit. We estimated midstory stems per hectare using a 5-m fixed-radius plot centered at 4 permanent sampling points. We recorded plant species, number of stems, and DBH for any tree 2.54–11.43 cm.

Remote camera monitoring wildlife use

We monitored wildlife use with Browning Strikeforce HD remote cameras set to take 10-second 1600x900 HD+ videos with a 1-minute delay between videos. We randomly selected 3 of the permanent vegetation plots per treatment unit to deploy remote cameras. We mounted each camera to a metal t-post 0.5 meters above ground with a set distance of 10 meters from a tree to standardize a detection zone for deer and other wildlife (Figure A.2). We removed woody debris and spot-sprayed vegetation using a reduced glyphosate solution (1% solution of product with 0.41% active ingredient) to limit plant growth between the camera and target tree to prevent reduced sampling efficiency and false triggers (Moll et al. 2020). We typically treated vegetation once per growing season if vegetation began to obstruct the detection lane.

We recorded all wildlife species between the camera and target tree during the 10-second video. We identified deer as male, female, or fawn. We defined fawns if they had a white-spotted pattern on the pelage (Donohue et al. 2013). As fawns lost their summer pelage in the fall, we began to identify them as male or female. We recorded the total number of deer detections that occurred during the 10-second video. We identified male deer after antler casting by the presence of pedicles. We identified a deer as unknown when we were unable to identify sex or age.

Differentiating observed behavior

We recorded the predominant activity of wildlife species during the 10-second videos and divided behavior into walking, running, loafing, vigilant, foraging, and bedding. We focused our analysis on these behaviors, which are commonly associated with food acquisition and predator avoidance (Creel et al. 2014). Predominant activity was based on the longest observed behavior for the given amount of time a wildlife species was in the camera's zone of detection for up to 10 seconds. We defined walking as any wildlife species that were moving at a normal gait. We defined running as any wildlife species that was trotting, bounding, or galloping. We defined vigilant as any wildlife species directing its attention to a certain area with ears in an alert position (Lark and Slade 2008, Lashley et al. 2015b, Stears et al. 2020). We defined foraging as any wildlife species actively eating (Owen-Smith et al. 2010). We defined bedding as any wildlife species lying on the ground. Finally, we defined loafing as any wildlife species staying within the remote camera's zone of detection that were neither vigilant, bedding, or foraging. Loafing behavior typically included grooming or mutual grooming (Hirth 1977). If the observed behavior did not fit within these defined categories, we recorded a detailed description of what occurred.

DATA ANALYSIS

We used a complete block design, repeated measure study with burn treatments as our experimental units. We used site as a random effect allowing for heterogeneity of deer detection rates because of varying deer density between study sites (Bolker et al. 2009). We summed the total number of deer detections from the 3 cameras within each unit to have a unit-level number of detections. We applied a 5-minute buffer between video events to thin data for independence between detections and prevent bias. At 5 minutes, we detected no statistical difference between detection rate of deer for a camera within a given treatment, thus indicating we had reduced bias at cameras where an individual may trigger the camera multiple times in sequential order. Macaulay et al. (2020) used a similar buffer interval of 6 minutes to reduce pseudoreplication between black-tailed deer (*Odocoileus hemionus columbianus*) detections. We recorded the number of days each camera functioned to ensure corrected exposure rate.

We performed three separate analyses to differentiate treatment and year effect versus vegetation attributes on deer use and behavior. We performed our behavioral analysis only for the growing season to compare how behavior differs when deer sexually segregate with differences in resource requirements (Bowyer 2004). We did not use vegetation covariates during the reproductive and post-reproductive season as they occur during the dormant season after leaf senescence. We compared behavioral rates between male and female deer during the growing season when nutritional demands are greatest for white-tailed deer. We divided the total number of detections by each behavioral type to calculate individual behavior rate. We divided the year into four biological seasons for male deer: antler growth season (May–July), pre-reproductive season (August–September), reproductive season (October–January), and post-reproductive season (February–April). We divided the year into three biological seasons for females and fawns: fawning/fawn rearing season (May–September), reproductive season (October–January), and post-reproductive season (February–April). We defined these biological seasons based on the state agency record of peak reproductive season dates and timing of antler development (Jacobson and Waldham 1992, Ruth 2023 MWFP 2024, ADCNR 2024). We performed a Pearson’s correlation test and considered coefficients $\geq$0.7 strongly correlated and did not incorporate them into the model together (Figure A.3). Model selection was determined by using Akaike Information Criterion (AIC) scores (Burnham and Anderson 2004). Models with a ΔAIC < 2 were considered strongly supported and selected for hypothesis testing (Burnham and Anderson 2004). We used a negative binomial generalized linear mixed-effect model to account for overdispersion within the data with vegetation composition and structure as predictor variables during the growing season and site as a random effect. We calculated the 95% confidence internal (CI) of beta (β) to check if confidence interval crossed zero. We exponentiated effect size (i.e., β) estimates to calculate the incidence rate ratio that represented the multiplicative effect of predictor variables on detection rate. We tested for statistical significance using an analysis of variance (ANOVA) with a probability threshold of $\alpha = 0.05$ (Bates al. 2023). We performed a post-hoc analysis with a Tukey’s Honest Significant Difference Test for a pairwise comparison of treatment and year effect on deer detections.

RESULTS

Effects of fire treatment on use by male deer

We recorded 54,037 deer videos over 93,052 trap nights across all sites (n = 9) averaging 0.58 deer detections per trap night. Daily rate of male deer detections was 4.72x greater (β = 1.553, 95% CI = 0.563 – 2.541, p = 0.007) in the early growing-season treatment compared to our control plots during antler development in 2021 (year of fire treatment), but not greater than the other treatments (p > 0.05) (Figure A.4). During the same period in 2022, male deer detections were 2.09x greater (β = 0.739, 95% CI = 0.119 – 1.357, p = 0.019) in the dormant season treatment and 2.42x greater (β = 0.885, 95% CI = 0.2688 – 1.5004, p = 0.004) in the late growing-season treatment compared to the control (Figure A.4). In 2023 (year of fire treatment) male deer detections during antler development were 2.9x greater (β = 1.069, 95% CI = 0.4325 – 1.706, p < 0.001) in the early growing-season treatment, 2.52x greater (β = 0.928, 95% CI = 0.288 – 1.568, p = 0.004) in the dormant season treatment, and 2.20x greater (β = 0.792, 95% CI = 0.130 – 1.454, p = 0.018) in the late growing-season treatment compared with the control (Figure A.4).

Male deer detection during antler development from 2021–2023 was marginally positively associated with forb biomass, with 1.6x greater detections for every 100 kg/ha of forb biomass (β = 0.102, 95% CI = -0.001 – 0.206, p = 0.051). Male deer detection rate was 1.73x greater for every 10% increase in grass coverage (β = 0.238, 95% CI = 0.024–0.450, p = 0.028) (Figure A.15 and Table B.5). Male detections were 0.52x lower for every 10% increase in bramble coverage (β = -0.282, 95% CI = -0.516 – -0.051, p = 0.017) (Table B.5). Male deer detections during the antler development season from 2021–2023 were classified as 23.39% (SE ± 2.4) loafing, 23.91% (SE ± 3.1) foraging, 5.05% (SE ± 0.9) vigilant, and 2.65% (SE ± 0.5) running (Table B.13). Time spent loafing by male deer was 1.93x greater in the late growing-season unit compared to control (β = 0.640, 95% CI = 0.086 – 1.194, p = 0.023) but did not differ between the other treatments (Figure A.31). We did not find a year or vegetation relationship with time spent loafing by male deer during the antler development season.

Time spent foraging by male deer during the antler development season in 2022 was 3.27x greater within the early growing-season (β = 1.185, 95% CI = 0.474 – 1.895, p = 0.001) and 2.61x greater (β = 0.960, 95% CI = 0.2455 – 1.6759, p = 0.009) in the late growing-season unit compared to control (Figure A.31). Male deer foraging rate was 4.10x greater in the early growing-season unit (p = 0.002) and 3.27x greater in the late growing-season unit (p = 0.018) compared to the mid-growing-season in 2022 (Figure A.31). Time spent foraging in the 2023 antler development season was 2.83x greater in the early growing-season unit (β = 1.043, 95% CI = 0.461 – 1.625, p = 0.045) and 2.36x greater in the dormant-season unit (β = 0.861, 95% CI = 0.256 – 1.466, p = 0.005) compared to control (β = -4.578, 95% CI = -5.477 – -3.679; Figure A.31).

Male deer foraging rate during the antler development season was 2.57x greater for every 10% increase in grass coverage (β = 0.411, 95% CI = 0.175 – 0.645, p = 0.001), 1.86x for every 10% increase in vine coverage (β = 0.269, 95% CI = 0.096 – 0.442, p = 0.002), and 2.25x for every 100 kg/ha increase in forb biomass (β = 0.177, 95% CI = 0. 0.049 – 0.304, p = 0.007; Figure A.16 and Table B.10). Foraging rate was 0.36x lower for every 10% increase in bramble coverage (β = -0.438, 95% CI = -0.763 – -0.112, p = 0.009), 0.26x for every 10% increase in visual obstruction below 2 m (β = -0.577, 95% CI = -1.007 – -0.148, p = 0.008), and 0.13x for every 100kg/ha increase in total biomass of forage plants selected by deer (β = -0.441, 95% CI = -0.756 – -0.127, p = 0.007) (Figure A.16 and Table B.10).

We were unable to detect differences of male deer vigilance rate between treatment during the antler development season because of limited sample size of vigilant males during the period. Male deer vigilance during the antler development season was 2.97x greater for every 10% increase in grass coverage ($\beta = 0.473$, 95% CI = 0.127 – 0.839, $p = 0.008$) and 1.81x for every 10% increase in vine coverage ($\beta = 0.263$, 95% CI = 0.035 – 0.499, $p = 0.026$) (Figure A.17 and Table B.10). Male deer vigilance during the antler development season was 0.40x lower for every 10% increase in bramble coverage ($\beta = -0.396$, 95% CI = -0.764 – -0.034, $p = 0.033$) and 0.23x for every 10% increase in visual obstruction below 2 m ($\beta = -0.633$, 95% CI = -1.172 – -0.099, $p = 0.020$) (Figure A.17 and Table B.10). Time spent running by male deer during the 2023 antler development season was 5.26x greater in the early growing-season unit compared to control ($\beta = 1.661$, 95% CI = 0.218 – 3.104, $p = 0.024$) (Figure A.31). Our sample size was too small to detect a relationship between time spent bedding or running and vegetation characteristics

We detected no difference in male deer detections between treatments and control during the pre-reproductive season in 2021 or 2022 (Table A.4). Male deer detections during the 2023 pre-reproductive season was 2.45x ($\beta = 0.902$, 95% CI = 0.241 – 1.563, $p = 0.007$) , 2.24x ($\beta = 0.808$, 95% CI = 0.143 – 1.472 $p = 0.017$), 2.09 ($\beta = 0.738$, 95% CI = 0.069 – 1.408, $p = 0.030$) and 2.00x ($\beta = 0.696$, 95% CI = 0.025 – 1.367, $p = 0.007$) greater in the mid-growing, early growing-, dormant-, late growing-season units respectively compared to the control (Figure A.5). Male deer detections were 2.08x greater ($\beta = 0.318$, 95% CI = 0.119 – 0.513, $p = 0.001$) for every 10% increase in grass coverage (Figure A.18 and Table B.5). Time spent loafing by male deer during the 2022 pre-reproductive season was 0.26x ($\beta = -1.345$, 95% CI = -2.265 – -0.425, $p < 0.004$) less in the mid-growing-season unit compared with the control (Figure A.32). Loafing behavior was 2.66x greater ($\beta = 0.425$, 95% CI = 0.179 – 0.674, $p < 0.001$) for every 10% increase in grass coverage and 3.15x for every 10% increase in bramble coverage within the understory ($\beta = 0.499$, 95% CI = 0.148 – 0.798, $p = 0.002$) (Figure A.19 and Table B.11). In 2023, time spent foraging was 3.09x greater ($\beta = 1.128$, 95% CI = 0.325 – 1.932, $p < 0.001$) in the early growing-season unit and 2.74x greater ($\beta = 1.010$, 95% CI = 0.205 – 1.815, $p < 0.014$) in the mid-growing season unit compared with the control (Figure A.32). Male deer vigilance during the pre-reproductive season was 1.10x greater ($\beta = 0.561$, 95% CI = 0.223 – 0.909, $p = 0.001$) for every 10% increase in grass coverage in the understory (Figure A.20 and Table B.11). We did not detect any relationship between vegetation characteristic covariates and time spent bedding or running by male deer during the pre-reproductive season. The lack of detectable relationship likely was because of a low number of detections of male deer bedding and running.

In 2021, we detected no difference in treatment use by male deer during the reproductive season (Table A.4). In 2022, detections of male deer during the reproductive season were 1.73x greater ($\beta = 0.547$, 95% CI = 0.129 – 0.966, $p = 0.010$) in the dormant-season treatment and 1.69x greater ($\beta = 0.514$, 95% CI = 0.087 – 0.940, $p = 0.018$) in the early growing-season treatment compared with control (Figure A.6). Male deer were 1.57x more likely to be detected when female deer were present ($\beta = 0.449$, 95% CI = 0.344 – 0.553, $p < 0.001$). Time spent loafing by male deer during the 2022 reproductive season was 2.23x greater in the early growing-season unit ($\beta = 0.783$, 95% CI = 0.1621 – 1.405, $p < 0.001$) and 2.18x greater in the dormant-season unit compared to the control ($\beta = 0.805$, 95% CI = 0.193 – 1.417, $p = 0.013$) (Figure A.33). Male deer time spent bedding was 7.67x in the dormant-season unit ($\beta = 2.038$, 95% CI = 0.401 – 3.674, $p = 0.014$) and 5.52x greater in the early growing-season unit ($\beta = 1.709$, 95% CI = 0.086 – 3.332, $p = 0.0389$) compared to the control in the 2022 reproductive season (Figure A.33). We did not detect a difference in male deer foraging rate during the reproductive season across treatments or years. Time spent running by male deer did not differ across treatments.

Male deer detections during the post-reproductive season in 2022 were 1.93x greater in the dormant-season treatment ($\beta = 0.660$, 95% CI = 0.175 – 1.145, $p = 0.007$) and 1.85x greater in the mid-growing-season treatment ($\beta = 0.615$, 95% CI = 0.131 – 1.100, $p = 0.010$) compared to control (Figure A.7). Sample size of male deer during the post-reproductive season was limited because of annual antler casting preventing us from subsetting detections by observed behavior.

Effects of fire treatment on use by female deer

Detections of females did not differ among treatments or control during the 2021 and 2022 fawning season ($p > 0.05$). Female deer detections during the 2023 fawning season were marginally lower ($p = 0.060$) in the mid-growing-season treatment compared to control (Figure A.8). Female deer detections were 0.66x lower for every 10% increase in grass coverage ($\beta = -0.178$, 95% CI = -0.268 – -0.089, $p < 0.001$), 0.78x for every 10% increase in shrub coverage ($\beta = -0.109$, 95% CI = -0.214 – -0.006, $p = 0.039$), and 0.72x for every 10% increase in tree coverage in the understory ($\beta = - -0.141$, 95% CI = -0.232 – -0.052, $p = 0.002$) (Table B.3). Female deer detection was 1.43x greater for every additional 100 stems per hectare in the midstory ($\beta = 0.077$, 95% CI = 0.004 – 0.150, $p = 0.036$) and 1.79x for every 10% increase of visual obstruction below 2 m ($\beta = 0.251$, 95% CI = 0.039 – 0.463, $p = 0.020$) (Figure A.21 and Table B.3). Female deer detections were 1.25x greater for every 100 kilograms per hectare increase in forb biomass ($\beta = 0.048$, 95% CI = 0.003 – 0.094, $p = 0.037$) (Figure A.21 and Table B.3). Detection rate of female deer loafing during the 2023 fawning season was 0.61x ($\beta = -$

0.478, 95% CI = -0.830 – -0.126, p = 0.037), 0.44x (β = -0.811, 95% CI = -1.172 – -0.450, p < 0.001), 0.52x (β = -0.645, 95% CI = -1.004 – -0.286, p < 0.001), and 0.48x (β = -0.717, 95% CI = -1.076 – -0.357, p < 0.001) lower in the dormant-, early growing-, late growing-, and mid-growing-season unit, respectively, compared to the control (Figure A.29). Detection rate of female deer loafing during the 2023 fawning season did not differ between treatment units. Detection rate of female deer loafing during the fawning season was 0.49x lower for every 10% increase in grass coverage (β = -0.310, 95% CI = -0.421 – -0.201, p < 0.001), 0.53x for every 10% increase in shrub coverage (β = -0.278, 95% CI = -0.401– -0.147, p < 0.001), and 0.75x for every 10% increase in tree coverage within the understory (β = -0.125, 95% CI = -0.233 – -0.019, p = 0.021; Figure A.22 and Table B.8). Detection rate of female deer loafing during the fawning season was 2.05x greater for every additional 100 stems per acre in the midstory (β = 0.156, 95% CI = 0.061 – 0.250, p = 0.001), and 3.57x for every 10% increase in visual obstruction below 2 m. (β = 0.553, 95% CI = 0.292 – 0.813, p < 0.001; Figure A.22 and Table B.8).

Female foraging was 1.71x greater (β = 0.538, 95% CI = - 0.091 – 0.986, p < 0.018) in the early growing-season treatment compared to the control in 2021 but did not differ from other treatment units (Figure A.29). Detection rate of female deer foraging during the fawning season was 0.71x lower for every 10% increase grass cover, (β = -0.149, 95% CI = -0.265 – -0.037, p = 0.009), 0.74x for every 10% increase tree coverage within the understory, (β = -0.131, 95% CI = -0.226 – -0.038, p = 0.006), and 0.36x for every 100-kg/ha increase in total biomass of forage plant species selected by deer (β = -0.225, 95% CI= -0.384 – -0.066, p = 0.006; Figure A.23 and Table B.8). Female foraging behavior during the fawning season was 1.32x greater for every 10% increase in vine cover in the understory (β = 0.123, 95% CI = 0.037 – 0.208, p = 0.005) and

1.33x for every 100-kg/ha increase in forb biomass (β = 0.061, 95% CI = 0.001 – 0.125, p = 0.054) (Figure A.23 and Table B.8).

Female deer vigilance within the treatment units during the fawning season did not differ from the control (p > 0.05; Figure A.29). Detection rate of vigilant female deer during the fawning season was 1.34x greater for every 10% increase in vine coverage (β = 0.129, 95% CI = 0.016 – 0.243, p = 0.025) (Figure A.24 and Table B.8). We detected a positive correlation between coyote detections and vigilance rate of female deer during the fawning season (β = 0.221, 95% CI = 0.059 – 0.384, p = 0.007) but we detected only a weak correlation with bobcat detections (β = 0.152, 95% CI = -0.020 – 0.302, p = 0.087). We did not detect any difference in time spent bedding by female deer between treatments and control during the fawning season. Female deer bedding was 3.02x greater for every 10% increase in visual obstruction below 2 m (β = 0.480, 95% CI = 0.013 – 0.955, p = 0.045; Figure A.25 and Table B.8). Coyote detection rate was negatively correlated with female deer bedding behavior (β = -0.412, 95% CI = -0.766 – -0.058, p = 0.023). We did not find the detection rate of female deer running differed between treatments and control during the fawning season. Detection rate of female deer running during the fawning season was 3.63x greater for every 10% increase in visual obstruction below 2 m (β = 0.561, 95% CI = 0.223 – 0.906, p = 0.001) and was 0.66x lower for every 10% increase in tree coverage in the understory (β = -0.175, 95% CI = -0.311 – -0.041, p = 0.011) (Figure A. 26 and Table B.8). Coyote detections were positively correlated with female deer running (β = -0.190, 95% CI = 0.001 – 0.382, p = 0.050).

Female deer detections during the 2021 reproductive season were 1.57x greater in mid-growing-season unit (β = 0.453, 95% CI = 0.142 – 0.763, p = 0.004) and 1.45x greater in the dormant season unit (β = 0.372, 95% CI = 0.060 – 0.685, p = 0.018) compared to control (Figure

A.9**).** We did not detect a difference in female deer detections among units during the reproductive season in 2022 ($p > 0.05$). Female deer running, loafing, and bedding during the reproductive season did not differ between treatments during each year (Figure A.30). Female vigilance during the reproductive season was 1.63x greater in the dormant-season unit in 2022 compared to the control ($\beta = 0.741$, 95% CI = 0.157 – 1.325, $p = 0.014$) but did not differ from other treatment units (Figure A.30).

Female deer detections did not differ between the treatments and control during the post-reproductive season across all years (Figure A.10). Detection rate of female deer loafing during the 2022 post-reproductive season was 0.55x less in the early growing-season unit compared to the control in 2022 ($\beta = -0.592$, 95% CI = -1.023 – -0.161, $p = 0.007$) but did not differ from other treatments (Figure A.31). In 2023, female loafing behavior was 0.59x lower in early growing-season unit ($\beta = -0.522$, 95% CI = -1.003 – -0.040, $p = 0.033$), 0.51x lower in the late growing-season unit ($\beta = -0.657$, 95% CI = -1.149 – -0.165, $p = 0.008$), and 0.52x less in the mid-growing-season unit compared to the control ($\beta = -0.652$, 95% CI = -1.148 – -0.156, $p = 0.009$) (Figure A.31). Female bedding behavior during the post-reproductive season did not differ between treatments ($p > 0.05$). Foraging rate of female deer during the post-reproductive season did not differ in 2022 between treatments and the number of detections of female deer foraging during the post-reproductive season was too small to detect any treatment level effect in 2023 ($p > 0.05$). We did not find any treatment effect on female deer vigilance during the post-reproductive season ($p > 0.05$). We did not detect any treatment or year effect on female deer running during the post-reproductive season ($p > 0.05$).

Effects of fire treatment on use by fawns

Fawn detections during the 2021 fawning season were marginally lower with 0.44x less detection in the early growing-season treatment (β = -0.8156, 95% CI = -1.679 – 0.048, p = 0.064) compared to control (Figure A.11). During the 2022 fawning season, we detected a marginal difference with fawn detection 2.12x greater (β = 0.751, 95% CI = -0.068 – 1.571, p = 0.072) in the dormant season treatment compared to control, but did not differ between treatments (p = 0.493 (Figure A.11). Fawn detections during the 2023 fawning season were 0.22x less in the early-growing season treatment (β = -1.244, 95% CI = -2.198 – -0.290, p = 0.015) compared to control (Figure A.11). Fawn detections were 0.46x lower for every 10% increase of shrub cover in the understory (β = -0.339, 95% CI = -0.608 – -0.074, p = 0.013) (Figure A.27 and Table B.7). Fawn detections were 4.73x greater for every 10 percent increase in visual obstruction <2 m (β = 0.675, 95% CI= 0.255 – 1.075, p = 0.001) (Figure A.27 and Table B.7). Detection rate of fawns loafing was too low to test for treatment level difference in 2021. Fawn loafing rate in the 2022 fawn rearing season was 5.75x greater in the dormant season unit (β = 1.750, 95% CI = 0.712 – 2.788, p < 0.001) and 2.83x greater in the mid-growing-season unit (β = 1.043, 95% CI = 0.003 – 2.083, p = 0.049) compared to control (Figure A.36). Fawn loafing rate did not vary between treatments in 2023 (Figure A.36). Fawn loafing behavior during fawning season was 2.67x greater for every 10% increase of grass coverage (β = 0.425, 95% CI = 0.166 – 0.679, p = 0.001) and 2.53x greater for every 10% increase in bramble coverage in the understory (β = 0.403, 95% CI = 0.050 – 0.760, p = 0.026) (Figure A.28 and Table B.9). We were unable to detect any treatment, year, or vegetation effects on fawn foraging, running, or vigilance during the fawning season. Bobcat (β = 0.111, 95% CI = -0.252 – 0.479, p

= 0.550) and coyote detections (β = 0.059, 95% CI = -0.276 – 0.393, p = 0.730) during the fawning season was not related to time spent loafing by fawns.

Male versus female deer behaviors (May–September)

Time spent loafing did not differ between male and female deer May–September (β = 0.009, 95% CI = -0.072 – 0.091, p = 0.812). Male deer spent 20.2% of their time foraging whereas female deer only spent 17.8% of their time foraging (β = 0.157, 95% CI = 0.079 – 0.235, p < 0.001). Time spent vigilant differed between sexes with female deer spending an estimated 8.9% of their time vigilant whereas male deer time spent 6.2% (β= -0.392, 95% CI = -0.509 – -0.279, p < 0.001) of their time vigilant. Similarly, female deer time spent running was 3.9% and was greater than the time spent running by male deer at 2.6% (β = -0.420, 95% CI = -0.604 – -0.241, p < 0.001).

Predator relationship with deer use

Coyote detections during the 2021 and 2023 fawning season, the years of treatment implementation, were 1.93x greater in the early growing-season treatment (β = 0.660, 95% CI = 0.195 – 1.132, p = 0.005) and 1.83x greater in the mid-growing-season treatment (β = 0.6047, 95% CI = 0.134 – 1.080, p = 0.012) compared to control, but was not different from other treatment units (Table A.6). Coyote detection rate did not differ between treatment units and control in 2022. We detected a positive relationship between coyote and female deer detections during the fawning season across all years (β = 0.185, 95% CI = 0.065 – 0.305, p = 0.002). Coyote detections during the fawning season were 1.49x greater for every 10% increase in grass coverage (β = 0.174, 95% CI= 0.015 – 0.333, p = 0.030) and 1.68x for every 10% increase in bramble coverage (β = 0.234, 95% CI = 0.053 – 0.416, p = 0.010). We compared AIC weight of visual obstruction relationship below 1, 1.5, and 2 meters with coyote detections and found the best fitting relationship with visual obstruction <2 m (Table B.12). Coyote detections were 0.33x lower for every 10% increase in visual obstruction <2 m (β = -0.475, 95% CI = -0.7473 – -0.2046, p < 0.001).

No relationship was supported between bobcat detections and vegetation composition or structure during the fawning season. Bobcat detections during the 2021 fawning season were 3.50x greater in the late growing season compared to control (β = 1.253, 95% CI = 0.3846 – 2.1215, p = 0.005). Bobcat detections were 1.78x greater in the mid-growing-season unit compared to the control (β = 0.228, 95% CI = 0.047 – 1.115, p = 0.005) in 2022. We did not detect a relationship between detection rate of bobcats and male deer (β = 0.001, 95% CI = -0.658 – 0.557, p = 0.985). There was weak evidence of a positive correlation between bobcat detection rate and detection rate of female deer (β = 0.124, 95% CI = -0.001 – 0.250, p = 0.053) and fawn deer (β = 0.082, 95% CI = -0.012 – 0.179, p = 0.090) during the fawning season.

DISCUSSION

Female deer detections were greatest in areas with greater forb biomass and visual obstruction <2 m, partitioning their time between areas with greater nutrition and areas where fawns were located. Comparatively, male deer detection during the antler development season was greatest in the most-recently burned unit, and males spent more time foraging and less time vigilant compared to female deer. Our results supported our hypothesis that deer use would vary by sex during the primary growth season based on nutritional requirements and predator avoidance. Our results are consistent with other studies that suggest temporal and sexual segregation of white-tailed deer based on nutritional and cover requirements (McCullough et al. 1989, Bowyer 2004, Biggerstaff et al. 2017, Cherry et al. 2017, Johnson et al. 2023). We hypothesized female deer would use areas with greater visual obstruction <2 m for fawning cover, but our detection data alone did not show a greater use of a certain treatment unit. The behavioral data provided a more nuanced understanding of habitat partitioning with female deer foraging more in the units that were more recently burned and loafing within the units that had not been burned recently, which had greater visual obstruction and midstory stem density. Both male and female deer spent more time foraging within the units that were most recently burned and had greater kg/ha of forb biomass. We detected fawns most in treatments with greater visual obstruction, supporting their use of the hider strategy to avoid predators (DeYoung and Miller 2011). Coyote detections were positively correlated with female deer detections. We detected a positive correlation between coyote detections and female detections, and a week positive correlation between bobcat detections and female and fawn deer detections. Coyotes are more of an opportunistic predator than bobcats (Witczuk et al. 2015) and frequented the recently burned treatments that had less visual obstruction during the fawning season.

We expected increased use of the early growing-season treatment by male deer in the summer immediately following the fire treatment because of increased nutrition available from freshly resprouting vegetation (Nichols et al. 2021, Lashley et al. 2022, Resop et al. 2023). Male deer selected recently burned treatments during antler growth when nutrient demands are greatest. Biomass of deer forage is immediately reduced following fire, but resprouting occurs within two weeks and the resprouting vegetation is greater in crude protein, calcium, and phosphorous, nutrients critical for antler development (Hewitt 2011, Rainer et al. 2021, Lashley et al. 2022, Turner and Harper 2024). For maximum antler growth, male deer diet should contain at least 16.00% crude protein, 0.17% calcium, and 0.26% phosphorous (McCullough and Ullrey 1983, Grasman and Hellgren 1993, Hewitt 2011). The enhanced digestibility of freshly resprouting vegetation declines as plants age (Short et al. 1975, Lashley et al. 2014b). Turner and Harper (2024) reported increased deer use of areas burned during the early growing season for about 2 months before returning to pre-burn levels by late summer. The positive relationship between time male deer spent foraging and forb biomass also was expected because forbs contain greater nutrient concentrations and deer select them when available over other plants (Nanney et al. 2018, Harper et al. 2025), and greater forb availability leads to larger deer (Turner and Harper 2024, Turner et al. 2025). The negative relationship with total biomass indicated male deer were foraging in areas with greater forage quality rather than quantity, which is consistent with deer behavior where nutrition is limited (Lashley et al. 2015a). Male deer detections in the early growing-season treatment declined nearly in half from the antler-growing season to the pre-reproductive season. Male use of the early growing-season treatment during the antler growing season was reduced the year following fire, but still greater than control, and increased again in the same growing season of the following fire (Table A.4). This trend of increased male use following fire continued with more detections in the mid-growing-season unit during the pre-reproductive season in 2023. Because males had a greater detection and foraging rate in the year of prescribed fire, our results support the hypothesis that the reason male deer increased use of the recently burned treatment was to forage on young, resprouting vegetation that was more digestible and nutritious than older vegetation.

Our results partially support the pyric herbivory hypothesis wherein herbivores are attracted to an area following recent fire (Fuhlendorf et al. 2010, Cherry et al. 2018, Westlake et al. 2020). We detected an asymmetrical response to fire during the growing season based on sex and age of deer. Adult male deer are less susceptible to predation compared to female deer and fawns during the growing season, which may allow males to spend more time in recently burned areas with greater forage quality even with increased exposure risk to predators (Kilgo et al. 2012, Gulsby et al. 2018). Predators can influence spatiotemporal patterns of prey species such that prey species avoid areas with greater perceived predation risk (Lashley et al. 2015c, Cherry et al. 2017, Creel et al. 2017, Gulsby et al. 2017). Kie and Boyer (1999) and McCoy et al. (2013) reported females and fawns experienced increased predation in areas where cover was lacking, which explains why fawn detections were lower in the early-growing season unit the growing season after the treatment was burned. Our detection rate of females during the fawning season also was greater in areas with increased visual obstruction, which was primarily associated with increased midstory stems that developed the year following fire. Fawn detections during the fawning season were lowest within the recently burned early growing-season treatment and increased with greater visual obstruction. A potential reason we did not detect a treatment effect on female deer use is habitat segregation. Female deer selectively foraged in recently burned areas while away from fawns. Deer exhibit a "hider" strategy until fawns are about 4–6 weeks old (DeYoung and Miller 2011). The female leaves her offspring alone in relatively dense cover, which reduces scent that could attract predators (Lent 1974, Chitwood et al. 2017). If recently burned areas are in proximity to relatively dense cover, the female has greater access to high-quality forage to better meet the greater nutritional requirements during lactation (Lashley et al. 2022). Coyote use of recently burned treatments aligns with the Optimal Foraging Theory (MacArthur and Pianka 1966), which suggests coyotes are advantageously using these areas because of reduced energy exerted in navigating sparse vegetation and searching burned patches for prey, thus increasing foraging efficiency (Schrecengost et al. 2009, Doherty et al. 2022). Stevenson et al. (2019) suggested coyotes selected recently burned pine forests compared to densely vegetated areas because of greater prey density. Blackberries are a primary non-prey food item in the coyote's diet in the southeastern US, which could explain the positive relationship between coyote detections and bramble coverage (Schrecengost et al. 2008). Additionally, the positive relationship between grass coverage and coyote detections could potentially be explained by greater small mammal prey density associated with increased herbaceous cover in pine woodlands (Sparks et al. 1998, Schrecengost et al. 2008, Kelly et al. 2015). We did not detect a relationship between coyote and fawn detections but instead a positive relationship with female detections. Coyotes commonly prey upon fawns, but their strategy for finding them may be more related to the adult female. The hider strategy theorizes that fawns are safer remaining still in dense cover than running to escape. Females move more on the landscape during this time, and coyotes may track them to locate neonates instead of searching specifically for the neonate (Kilgo et al. 2012).

The effects of scale and frequency of fire on white-tailed deer reproductive success is important to consider when using fire to manage pine woodlands. The lack of adequate fawning cover may increase susceptibility to predation and lead to population decline (Kilgo et al. 2012, Chitwood et al. 2015c). Cherry et al. (2017) and Lashley et al. (2015a) suggested deer avoided recently burned areas during the fawn-rearing season to decrease predation risk at the expense of reduced access to high-quality forage. Chitwood et al. (2017) suggested the hider strategy may be maladaptive in populations where fawning cover is limiting, and coyotes are the primary predator. Similar relationships have been documented for other ungulates species. Murrow et al. (2009) study reported black bear (*Ursus americanus*) predation was a contributing factor to poor elk (*Cervus canadensis*) calf recruitment because the study area was composed of less than 1% early successional plant communities wherein cow elk and calves frequented, making it easier for bears to locate calves. Coyotes in the southeastern United States are the primary source of fawn mortality: 52% (Nelson et al. 2015), 46% (Chitwood et al. 2015a), and 40% (Edge et al. 2023). Lashley et al. (2014a), Chitwood et al. (2017), Gulsby et al. (2017), and Edge et al. (2023) suggested a homogenous landscape tends to isolate fawning cover in smaller patches. Smaller patches of fawning cover may create ecological traps where female deer choose to birth their offspring (Chitwood et al. 2017), but predators are more successful in locating offspring because of small patch size. Moreover, summer core ranges of female deer increased to locate concealment cover and reduce predation risk when a greater proportion of their home range was burned (Lashley et al. 2015c). Heterogeneity of vegetation types should decrease predation risk and potentially the core seasonal home range (Gulsby et al. 2017, Hasapes and Comer 2017). Core areas of fawns <1 month old averaged 5.8 ha, and female core area 1-month post parturition averaged 8.40 ha (Hasapes and Comer 2017). Where deer are a focal species, burn units smaller than a summer core area size would better disperse fawning and concealment cover with better foraging areas. Implementing fire in different areas on a 1–3-year fire-return interval whereby some areas are burned annually, some biannually, and every 3 years would increase vegetation diversity, provide habitat for a wider suite of wildlife species, and maintain high-quality forage for deer in the more frequently burned areas and better cover for fawning and bedding in less-frequently burned areas. Extending the burn interval beyond 3 years would lead to a predominately woody understory, decreased herbaceous cover, and overall degrade the woodland condition, which requires an herbaceous-dominated understory (Grossman et al. 1998, McIntyre et al. 2019, Robertson et al. 2021). Our results illustrate how no single season of burning or fire-return interval is optimal for deer throughout the year, which aligns with management objectives aimed at restoring fire regimes to mimic natural timing and frequency of disturbance in pine woodlands.

Our results indicate how burning at various seasons is beneficial for restoring the ecological service fire provides in open pine ecosystems for a native ungulate species. Human-mediated fire over much of the past century has not matched the previous historic phenology of fire caused both by lightning and humans (Frost 1998, White and Harley 2015, Rother et al. 2020, Lashley et al. 2022). This mismatch of fire timing has led to a deviation in the ecological conditions present in open pine systems (Miller et al. 2019, Visser and Gienapp 2019). Implementing fire at various seasons of the year can more closely resemble the timing of fire events that occurred prior to European colonization (Barden 1997, Fowler and Konopik 2007). Creating heterogenous conditions through fire events occurring at varying intervals and seasons ensures food and cover requirements of a popular generalist species, such as deer (Lashley et al. 2015c, Nichols et al. 2021, Lashley et al. 2022), but also may increase habitat for more specialist species that benefit from one or more of the varied seral stages that benefit deer during some time of year (Walker et al. 2004, Thatcher et al. 2006, Knapp et al. 2009, Harper et al. 2021).

Our study provides useful insight on the complex role fire has on white-tailed deer use of southern pine ecosystems.

LITERATURE CITED

Alabama Department of Conservation and Natural Resource. 2024. The Alabama rut. https://www.outdooralabama.com/sites/default/files/Hunting/Deer%20Hunting/Alabama%20Rut%20Map%202022%20Web.pdf. Accessed 31 May 2024.

Bates, D., M. Maechler, B. Boker, and S. Walker. 2023. Package ‘lme4’ linear mixed-effect models using ‘Eigen’ and S4. R package version 1.1-35.3. Retrieved from https://cran.r-project.org/web/packages/lme4/lme4.pdf.

Barden, L. S. 1997. Historic prairies in the piedmont of North and South Carolina, USA. Natural Areas Journal 17:149–152.

Beals, E., G. Cottam, and R. Vogl. 1960. Influence of deer on vegetation of the Apostle Islands, Wisconsin. The Journal of Wildlife Management 24:66–80.

Biggerstaff, M. T., M. A. Lashley, M. C. Chitwood, C. E. Moorman, and C. S. DePerno. 2017. Sexual segregation of forage patch use: support for the social-factors and predation hypotheses. Behavioural Processes 136: 36–42.

Bolker, B. M., M. E. Brooks, C. J, Clark, S. W. Geange, J. R. Poulsen, M. H. Stevens, and J. S. White. 2009. Generalized linear mixed models: a practical guide for ecology and evolution. Trends in Ecology and Evolution 24:127–135.

Bones, J. T., S. G. Marshall, M. A. Turner, M. M. Lapp, W. D. Gulsby, J. D. Clark, E. V. Willcox, and C. A. Harper. *In Press*. Vegetation response by season of burning in pine woodlands across the southeastern US. Fire Ecology.

Bowyer, R. T. 2004. Sexual segregation in ruminants: definitions, hypotheses and implications for conservation management. Journal of Mammalogy 85:1039–1052.

Butler D. A., S. P., Haskell, W. B. Ballard, M. C. Wallace, C. M. Britton, and M. H. Humphrey. 2009. Differences in timing of parturition, birthing sites, and bedding sites of fawns in sympatric populations of deer. Southwest Naturalist 54:261–271.

Burnham, K. P., and D. R. Anderson. 2004. Multimodel inference understanding AIC and BIC in model selection. Sociological Methods and Research. 33:261–304.

Cherry, M. J., R. J. Warren, and M. L. Conner. 2017. Fire-mediated foraging tradeoffs in white-tailed deer. Ecosphere 8:e01784.

Cherry, M. J., R. B. Chandler, E. P. Garrison, D. A. Crawford, B. D. Kelly, D. B. Shindle, K. G. Godsea, K. V. Miller, and M. L. Conner. 2018. Wildfire affects space use and movement of white-tailed deer in a tropical pyric landscape. Forest Ecology and Management 409:161–169.

Chitwood, M. C, M. A. Lashley, J. C. Kilgo, K. H. Pollock, C. E Moorman, and C. S. DePerno. 2015a. Do biological and bedsite characteristics influence survival of neonatal white-tailed deer? PLoS One 10:e0119070.

Chitwood, M. C., M. A. Lashley, J. C. Kilgo, C. E. Moorman, and C. S. DePerno. 2015b. White-tailed deer population dynamics and adult female survival in the presence of a novel predator. The Journal of Wildlife Management 79:211–219.

Chitwood, M. C., M. A. Lashley, C. E. Moorman, and C. S. DePerno. 2017. Setting an evolutionary trap: could the hider strategy be maladaptive for white-tailed deer? Journal of Ethology. 35:251–257.

Creel, S. E., P. Schuette, and D. Christianson. 2014. Effects of predation risk on group size, vigilance, and foraging behavior in an African ungulate community. Behavioral Ecology 25:773–784.

Creel, S., E. Droge, J. M'soka, D. Smit, M. Becker, D. Christianson, and P. Schuette. 2017. The relationship between direction predation and antipredator response: a test with multiple predator and multiple prey. Ecology 98:2081–2092.

DeYoung, R. W., and K. V. Miller. 2011. White-tailed deer behavior. In Hewitt D. G. (Ed.) Biology and management of white-tailed deer pp 311–351. CRC Press. Boca Raton, FL, USA.

Doherty, T. S., W. L. Geary, C. J. Jolly, K. J Macdonald, V. Miritis, D. J. Watchorn, M. J. Cherry, M. L. Conner, T. M. Gonzalez, S. M. Legge, E. G. Ritchie, C. Stawski, and C. R. Dickman. 2022. Fire as a driver and mediator of predator–prey interactions. Biological Reviews 97:1539–1558.

Donohue, R. N., D. G. Hewitt, T. E. Fulbright, C. A. DeYoung, A. R. Litt, and D. A. Draeger. 2013. Aggressive behavior of white-tailed deer at concentrated food sites as affected by population density. The Journal of Wildlife Management 77:1401–1408.

Edge, A. C., J. P. Rosenberger, C. J. Yates, A. R. Little, C. H. Killmaster, K. L. Johannsen, D. A. Osborn, J. C. Kilgo, K. V. Miller, and G. J. D'Angelo. 2023. White-tailed deer (*Odocoileus virginianus*) fawn survival and the influence of landscape characteristics on fawn predation risk in the Southern Appalachian Mountains, USA. PLoS One 18:e0288449.

Faber-Langendoen, D. 2001. Plant communities of the Midwest: Classification in an ecological context. Association for Biodiversity Information. Arlington, VA, USA.

Fowler, C., and Evelyn Konopik. 2007. The history of fire in the southern United States. Human Ecology Review 14:165–176.

Frost, C. C. 1998. Presettlement fire frequency regimes of the United States: a first approximation. Pages 70–81 in Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tall Timber Fire Ecology Conferences Proceedings No. 20. Tall Timbers Research Station. Tallahassee, Florida, USA.

Fuhlendorf, S. D., D. E. Townsend, D. R. Elmore, and D. M. Engle. 2010. Pyric-herbivory to promote rangeland heterogeneity: evidence from small mammal communities. Rangeland Ecology and Management 63:670–679.

Godínez-Alvarez, H., J. E. Herrick, M. Mattocks, D. Toledo, and J. Van Zee. 2009. Comparison of three vegetation monitoring methods: their relative utility for ecological assessment and monitoring. Ecological Indicators. 9:1001–1008.

Guill, M. H., J. D. Crus, M. Puckett, S. D. Klopfer, B. Martin, and M. W. Ford. 2024. Southern fox squirrel and eastern gray squirrel interactions in a fire-maintained ecosystem. Journal of the Southeastern Association of Fish and Wildlife Agencies 11:215–222.

Gulsby, W. D., J. C. Kilgo, M. Vukovich, and J. A. Martin. 2017. Landscape heterogeneity reduces coyote predation on white-tailed deer. The Journal of Wildlife Management 81:601–609.

Gulsby, W. D., M. J. Cherry, J. T. Johnson, M. L. Conner, and K. V. Miller. 2018. Behavioral response of white-tailed deer to coyote predation risk. Ecosphere :e02141.

Grasman, B. T., and E. C. Hellgren. 1993. Phosphorous nutrition in white-tailed deer: Nutrient balance, physiological responses, and antler growth. Ecology 74:2279–2296.

Grossman, D. H., D. Faber-Langendoen, A. S. Weakley, M. Anerson, P, Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. D. Patterson, and M. Pyne. 1998.

International classification of ecological communities: terrestrial vegetation of the United States. The Nature Conservancy, Arlington, Virginia, USA.

Hamrick, B., B. Strickland, and S. Demarais. 2021. A guide to common native deer forages in Mississippi and the southeast. Mississippi State University Extension p3618, Starkville, Mississippi, USA.

Harper, C. A., J. W. Gefellers, D. A. Buehler, C. E. Moorman, and J. M. Zobel. 2021. Plant community response and implications for wildlife following control of a nonnative perennial grass. Wildlife Society Bulletin 45:618–629.

Harper, C. A., B. K. Strickland, M. A. Lashley, M. A. Turner, J. S. Nanney, C. M. Chitwood, C. E. Moorman, N. Ellision-Neary, J. M. Brooke, and G. M. Street. 2025. Soil quality does not predict plant nutrition available for white-tailed deer. The Journal of Wildlife Management 89:e22722.

Hasapes, K. S., and C. E. Comer. 2017. White-tailed deer fawn survival, home range, and habitat composition in northwest Louisiana. Wildlife Society Bulletin 41:499–507.

Hewitt, D. G. 2011. Biology and management of white-tailed deer. CRC Press. Boca Raton, Florida, USA.

Hirth, D. H. 1977. Social behavior of white-tailed deer in relation to habitat. Wildlife Monographs 53:3–55.

Hunter, W.C., D. A. Buehler, R. A. Canterbury, J. L. Confer, and P. B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. Wildlife Society Bulletin 29:440–455.

Jacobson, H. A., and S. J. Waldhalm. 1992. Antler cycles of a white-tailed deer in Mississippi. Antler Development in Cervidae*,* Springer-Verlag. New York, New York, USA.

Johnson, J. T., R. B. Chandler, M. L. Conner, M. J. Cherry, C. H. Killmaster, K. L. Johannsen, and K. V. Miller. 2023. Assessing the implications of sexual segregation when surveying white-tailed deer *Odocoileus virginianus*. Wildlife Biology 2023:e01077.

Kelly, J. D., W. D. Gulsby, C. H. Killmaster, J. W. Bowers, and K. V. Miller. 2015. Seasonal and spatial variation in diets of coyotes in central Georgia. Journal of the Southeastern Association of Fish and Wildlife Agencies 2:296–302.

Kie J. G., and Bowyer, R. T. 1999. Sexual segregation in white-tailed deer: density-dependent changes in use of space, habitat selection, and dietary niche. Journal of Mammalogy 8:1004–1020.

Kilgo, J. C., H. S., Ray. M. Vukovich, M. J. Goode, and C. Ruth. 2012. Predation by coyotes on white-tailed deer neonates in South Carolina. The Journal of Wildlife Management 76:1420–1430.

Kissel, R. E., C. G. Wieberg, L. Hansen, and J. Beringer. 2002. Deer antler characteristics in relation to land use and spatial-temporal factors in Missouri. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 56:322–330.

Knapp, E. E., B. L. Estes, and C. N. Skinner. 2009. Ecological effect of prescribed fire season: a literature review and synthesis for managers. United States Department of Agriculture. Forest Service, Pacific Southwest Research Station. General Technical Report: 80 p., Albany, California, USA.

Kroeger, A. J., C. E. Moorman, M. A. Lashley, M. C. Chitwood, C. A. Harper, and C. S. DePerno. 2020. White-tailed deer use of overstory hardwoods in longleaf pine woodlands. Forest Ecology and Management 464:e118046.

Lark, A. M., and N. A. Slade. 2008. Variation in vigilance in white-tailed deer (*Odocoileus virginianus*) in northeastern Kansas. The American Midland Naturalist 159:76–74.

Lashley M. A., M. C. Chitwood, A. Prince, M. B. Elfelt, E. L. Kilburg, C. S. DePerno, and C. E. Moorman. 2014a. Subtle effects of a managed fire regime: a case study in the longleaf pine ecosystem. Ecological Indicators 38:212–217.

Lashley, M. A., M. C. Chitwood, C. A. Harper, C. E. Moorman, and C. S. DePerno. 2014b. Collection, handling, and analysis of forages for concentrate selectors. Wildlife Biology Practices 10:6–15.

Lashley, M. A., M. C. Chitwood, C. A. Harper, C. E. Moorman, and C. S. DePerno. 2015a. Poor soils and density-mediated body weight in deer: forage quality or quantity. Wildlife Biology 21:213–219.

Lashley, M. A., M. C. Chitwood, C. A. Harper, C. S. DePerno, and C. E. Moorman. 2015b. Variable in fire prescriptions to promote wildlife in the longleaf pine ecosystem. Fire Ecology 11:62–79.

Lashley, M. A., M. C. Chitwood, R. Kays, C. A. Harper, C. S. DePerno, and C. E. Moorman. 2015c. Prescribed fire affects females white-tailed deer habitat use during summer lactation. Forest Ecology and Management 348:220–225.

Lashley, M. A., M. C. Chitwood, J. L. Dykes, C. S. DePerno, and C. E. Moorman. 2022. Human-mediated trophic mismatch between fire, plants, and herbivores. Ecography 2022:e06045.

Lent, P. C. 1974. Mother-infant relationships in ungulates. In: Geist V, Walther F (eds) Symposium on the behaviour of ungulates and its relation to management. IUCN, Morges, pp 14–55.

MacArthur, R. H., and E. R. Pianka. 1966. On optimal use of a patchy environment. The American Naturalist 100:603–609.

Macaulay, L. T. 2016. The role of wildlife-associated recreation in private land use and conservation: providing the missing baseline. Land Use Policy 58(15):218–233.

Macaulay, L. T., R. Sollmann, and R. H. Barret. 2020. Estimating deer populations using camera traps and natural marks. The Journal of Wildlife Management 84:301–310.

Mason, D. S., C. Baruzzi, and M. A. Lashley. 2022. Passive directed dispersal of plants by animals. Biological Reviews 97:1908–1929.

Mason, D. S., K. M. Robertson, P. G. Hahn, E. M. Bruna, J. L. Willis, and M. A. Lashley. 2025. Fire enables passive directed seed dispersal by birds. Current Biology 36:28–37.

McCoy, J. C., S. S. Ditchkoff, J. B. Raglin, B. A. Collier, and C. Ruth. 2013. Factors influencing survival of white-tailed deer fawns in coastal South Carolina. Journal of Fish and Wildlife Management 4:280–289.

McCullough, D. R., and D. E. Ullrey. 1983. Proximate mineral and gross energy composition of white-tailed deer. The Journal of Wildlife Management 47:430–441.

McCullough, D. R., D. H. Hirth, and S. J. Newhouse. 1989. Resource partitioning between sexes in white-tailed deer. The Journal of Wildlife Management 53:277–283.

McIntyre, K. R., M. L. Conner, S. B. Jack, E. M. Schlimm, and L. L. Smith. 2019. Wildlife habitat condition in open pine woodlands: field data to refine management targets. Forest Ecology and Management 437:282–294.

Miller, R. G., R. Tangney, N. J. Enright, J. B. Fontaine, D. J. Merritt, M. K. Ooi, K. X. Ruthrof, and B. P. Miller. 2019. Mechanisms of fire seasonality effects on plant populations. Trends in Ecology and Evolution 34:1104–1117.

Mississippi, Wildlife, Fisheries, and Parks. 2024. Mississippi white-tailed deer simulated mean conception date map. https://www.mdwfp.com/wildlife-hunting/deer-program/deer-breeding-date-map/. Accessed 31 May 2024.

Moll, R. M., W. Ortiz-Calo, J. D. Cepek, P. D. Lorch, P. M. Dennis, T. Robison, and R. A. Montgomery. 2020. The effects of camera-trap viewshed obstruction on wildlife detection: implications for inference. Wildlife Research 47:158–165.

Murrow, J. L., J. D. Clark, and K. E. Delozier. 2009. Demographics of an experimentally released population of elk in Great Smoky Mountains National Park. The Journal of Wildlife Management 73:1261–1268.

Nanney, J. S., A. S. Willcox, A. E. Houston, and C. A. Harper. 2015. Influence of a quality deer management program on hunter knowledge, perceptions and satisfaction. Journal of the Southeastern Association of Fish and Wildlife Agencies 2:247–254.

Nanney, J. S., C. A. Harper, D. A. Buehler, and G. A. Bates. 2018. Nutritional carrying capacity for cervids following disturbance in hardwood forests. The Journal of Wildlife Management 82:1219–1228.

Nelson M. A., M. J. Cherry, M. B. Howze, R. J. Warren, and L. M. Conner. 2015. Coyote and bobcat predation on white-tailed deer in a longleaf pine ecosystem in southwestern Georgia. Journal of Southeast Associate Fish Wildlife Agency. 2:208–213.

Nichols, R. A., S. Demarais, B. K. Strickland, and M. A. Lashley. 2021. Alter fire timing to recouple forage nutrients with herbivore nutrient demands. Forest Ecology and Management 500:119646.

Nudds, T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife Society Bulletin 5:113–117.

Ondarza, M. B., and R. Ward. 2013. Accurate analysis: NIRS versus wet chemistry. Hoard's Dairyman. W. D. Hoard and Sons Company, Fort Atkinson, Wisconsin, USA.

Oswalt, C. C., J. A. Cooper, D. G. Brockway, H. W. Brooks, J. L. Walker, K. F. Connor, S. N. Oswalt, and R. C. Conner. 2012. History and current condition of longleaf pine in the southern United States. USDA Forest Service General Technical Report SRS-166. Southern Research Station, Asheville, NC, USA.

Owen-Smith, N., J. M. Fryxell, and E. H. Merrill. 2010. Foraging theory: upscaled: the behavioral ecology of herbivore movement. Philosophical Transaction of The Royal Society B 365:2267–2278.

Powell, B. L., D. A. Buehler, C. E. Moorman, J. M. Zobel, and C. A. Harper. 2022. Vegetation structure and food availability following disturbance in early successional plant communities. Wildlife Society Bulletin https://doi.org/10.1002/wsb.1372.

Rainer, N., S. Demarais, B. K. Strickland, and M. Lashley. 2021. Alter fire timing to recouple forage nutrients with herbivore nutrient demands. Forest Ecology and Management 500:e119646.

Resop, L., S. Demarais, B. Strickland, R. B. Iglay, R. Nichols, and M. Lashley. 2023. Plan species-specific response and community association with fire season. Forest Ecology and Management 529:e120724.

Robertson, K. M., S. M. Hermann, and E. L. Staller. 2021. Frequent prescribed fire sustains old field loblolly pine–shortleaf pine woodland communities: results of a 53-year study. Journal of Forestry 119:1–8.

Rother, M. T., J . M. Huffman, C. H. Guiterman, K. M. Robertson, and N. Jones. 2020. A history of recurrent, low-severity fire without fire exclusion in southeastern pine savannas, USA. Forest Ecology and Management 475:e118406.

Ruth, C. 2023. Record of South Carolina white-tailed deer 1906–2023. SCDNR. https://www.dnr.sc.gov/wildlife/deer/alltime.html#:~:text=Historic%20reproductive%20data%20collected%20by,October%206%20to%20November%2016. Accessed 31 May 2024.

Schrecengost, J. D., J. C. Kilgo, D. Mallard, H. S. Ray, and K. V. Miller. 2008. Seasonal food habitats of the coyote in the South Carolina Coastal Plain. Southeastern Naturalist 7:135–144.

Schrecengost, J. D., J. C. Kilgo, H. S. Ray, and K. V. Miller. 2009. Home range, habitat use and survival of coyotes in western South Carolina. The American Midland Naturalist 162:346–355.

Short, H. L., R. M. Blair, and E. A. Epps Jr. 1975. Composition and digestibility of deer browse in southern forests. United States Department of Agriculture, Southern Forest Experiment Station. Forest Service Research Paper SO-111. Asheville, North Carolina, USA.

Southeast Deer Partnership. 2021. Economic, Social, and Conservation Benefits of Deer Hunting in the Southern United States. Harrisonburg, Virginia, USA.

Sparks, J. C., R. E. Masters, D. M. Engle, M. W. Palmer, and G. A. Bukenhofer. 1998. Effects of late growing-season and late dormant-season prescribed fire on herbaceous vegetation in restored pine-grassland communities. Journal of Vegetation Science 9:133–14.

Stears, K., M. H. Schmitt, C. C. Wilmers, and A. M. Shrader. 2020. Mixed-species herding levels the landscape of fear. Proceeding Biological Science 287:e20192555.

Stevenson, E. R., M. A. Lashley, M. C. Chitwood, J. E. Garabedian, M. B. Swingen, C. S. DePerno, and C. E. Moorman. 2019. Resource selection by coyotes (*Canis latrans*) in a longleaf pine (*Pinus palustris*) ecosystem: effects of anthropogenic fires and landscape features. Canadian Journal of Zoology 97:165–171.

Thatcher, B., D. Krementz, and M. Woodrey. 2006. Henslow's sparrow winter-survival estimate and response to prescribed burnings. The Journal of Wildlife Management 70:198–206.

Turner, M. A., and C. A. Harper. 2024. Understory composition and structure influences deer and turkey habitat in southern pine stands. Southeastern Naturalist 23:175–193.

Turner, M. A., C. A. Harper, M. A. Lashley, B. K. Strickland, and M. Q. Wilber. 2025. Plant nutrient concentration inform white-tailed deer diet limitations. Journal of Environmental Management 375:e124186.

United States Fish and Wildlife Service. 2003. Red-cockaded woodpecker (*Picoides borealis*) recover plan: second revision. U. S. Fish and Wildlife Service, Atlanta, Georgia, USA.

Visser, M. E., and P. Gienapp. 2019. Evolutionary and demographic consequences of phenological mismatches. Nature Ecology and Evolution 3:879–885.

Walker, J. W., D. W. Robinson, and J. B. Grand. 2004. Influences fire on Bachman's sparrow. an endemic North American songbird. The Journal of Wildlife Management 68:1114–1123.

Westlake, S. M., D. Mason, A. Lazaro-Lobo, P. Burr, J. R. McCollum, D. Chance, and M. A. Lashley. 2020. The magnet effect of fire on herbivores affects plan community structure in a forested system. Forest Ecology and Management 458:e117794.

White, C. R., and G. L. Harley. 2016. Historical fire in longleaf pine (*Pinus palustric*) forest of south Mississippi and its relation to land use and climate. Ecosphere 7:e01458.

Witczuk, J., S. Pagacz, J. Gliwicz, and L. S. Mills. 2015. Niche overlap between sympatric coyotes and bobcats in highland zones of Olympic Mountains, Washington. Journal of Zoology 297:176–183.

Zeitler, E. F., K. M. Robertson, C. M. Dixon, and M. A. Lashley. 2025. Fire season differentially affects resprouting vigor of pyrophytic and mesophytic hardwoods in a southeastern U.S. pine savanna. Forest Ecology and Management 578:e122478.

APPENDIX

APPENDIX A: CHAPTER TABLES AND FIGURES

Table A.1. Physiographical and geographical overview of study sites (n = 9) in Tennessee, Alabama, Mississippi, and South Carolina, USA, October 2020–July 2023.

Sites	County/State	Physiographic Providence	Basal Area (m^2/ha)	Aspect Slope	Percent Sunlight (%)	Soil	Coordinates
Barbour	Barbour, AL	Coastal Plain	8	Southwest 15–45%	58	Luverne-Springhill complex, sandy loam	31°58'5.50"N, 85°21'2.69"W
Belfast	Newberry, SC	Piedmont Uplands	12	South 2–6%	50	Cecil sandy clay loam	34°16'53.29"N, 81°53'13.77"W
Bridgestone	Van Buren, TN	Cumberland Plateau	N/A	North, 5–12%	100	Lonewood silt loam	35°46'46.94"N, 85°18'55.24"W
Copiah	Copiah, MI	Eastern Gulf Coastal Plain	15	South 2–5%	45	Loring silt loam, Lormand-Smithdale association	31°48'25.63"N, 90°40'46.94"W
Folsom	Perry, AL	Eastern Gulf Coastal Plain	9	Southeast 2–5%	53	Bama fine sandy loam	32°38'40.76"N, 87°25'33.42W
Foothills	Blount, TN	Tennessee Valley and Ridge	8	Southeast 50–70%	66	Ramsey stony fine sandy loam	35°36'25.70"N, 84°1'36.80"W
Mason Bend	Hale, AL	Eastern Gulf Coastal Plain	10	N/A 0–2%	16	Cahab find sandy loam	32°45'46.22"N, 87°48'12.52"W
Triple Creek	Jasper, MI	Eastern Gulf Coastal Plain	10	North 2–5%	52	Savannah fine sandy loam	32°0'22.11"N, 88°55'9.70"W
Webb	Hampton, SC	Coastal Plain Sea Island	11	N/A 0–2%	56	Eulonia find sandy loam	32°38'8.59"N, 81°22'29.88"W

Table A.2. Season and year when treatments were implemented in chronological order at study sites (n = 9) in Tennessee, Alabama, Mississippi, and South Carolina, USA, October 2020–July 2023.

Treatments	Months	Year
Late growing	September – October	2020
Dormant	January – March	2021
Early growing	April – May	2021
Mid-growing	June – July	2021
Late growing	August – October	2022
Dormant	January – March	2023
Early growing	April – May	2023
Mid-growing	June – July	2023

Table A.3. Mean ± SE fire temperature (Celsius), air temperature (Celsius), in-stand wind speed (kilometers per hour), and fire rate of spread (meters/hour) recorded at all study sites (n = 9) during two iterations of burn treatments in Tennessee, Alabama, Mississippi, and South Carolina, USA, October 2020–July 2023.

Treatments	Fire Temperature (C°)	Air Temperature (C°)	In-Stand Wind Speed (kph)	Relative Humidity (%)	Rate of Spread (m/hr)
Dormant	175.68 ± 30.17	20.18 ± 1.68	10.26 ± 2.41	39.69 ± 9.35	78.87 ± 21.87
Early growing	135.58 ± 17.46	25.21 ± 0.77	10.99 ± 2.59	39.50 ± 9.31	73.10 ± 21.09
Mid-growing	116.48 ± 9.08	32.65 ± 0.73	4.20 ± 0.98	57.72 ± 13.60	36.49 ± 9.12
Late growing	133.95 ± 33.23	25.89 ± 1.20	8.57 ± 2.01	40.67 ± 9.58	48.43 ± 15.28

Table A.4. Average ± SE daily detection rate of male deer in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during antler development (May–July), pre-reproductive (August–September), reproductive (October–January), and post-reproductive season (February–March) at all study sites (n = 9) in Tennessee, Alabama, Mississippi, and South Carolina, USA, July 2021–August 2023). Letters indicate significant difference between fire treatment units during the given biological season for a given year.

Female Deer Detections (Detections/Day)											
Season	**Year**	**CON**		**DOS**		**EGS**		**MGS**		**LGS**	
Fawning	2021	0.477 ± 0.119	A	0.394 ± 0.082	A	0.456 ± 0.095	A	0.609 ± 0.165	A	0.386 ± 0.074	A
Reproductive	2021	0.300 ± 0.051	B	0.436 ± 0.074	A	0.375 ± 0.077	AB	0.499 ± 0.110	B	0.359 ± 0.058	AB
Post-reproductive	2022	0.245 ± 0.040	A	0.276 ± 0.058	A	0.224 ± 0.041	A	0.237 ± 0.050	A	0.245 ± 0.033	A
Fawning	2022	0.417 ± 0.120	A	0.394 ± 0.069	A	0.354 ± 0.084	A	0.392 ± 0.088	A	0.352 ± 0.071	A
Reproductive	2022	0.363 ± 0.074	A	0.478 ± 0.093	A	0.415 ± 0.087	A	0.356 ± 0.058	A	0.389 ± 0.082	A
Post-reproductive	2023	0.334 ± 0.091	A	0.273 ± 0.071	A	0.258 ± 0.052	A	0.261 ± 0.060	A	0.268 ± 0.052	A
Fawning	2023	0.452 ± 0.095	A	0.369 ± 0.079	A	0.366 ± 0.076	A	0.305 ± 0.056	A	0.395 ± 0.059	A

Table A.5. Average ± SE daily detection rate of female deer in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during fawning/fawn rearing season (May–September), reproductive (October–January), and post-reproductive (February–March) at all study sites (n = 9) in Tennessee, Alabama, Mississippi, and South Carolina, USA, July 2021–August 2023). Letters indicate significant difference between fire treatment units during the given biological season and year.

		Male Deer Detections (Detections/Day)									
Seasons	**Year**	**CON**		**DOS**		**EGS**		**MGS**		**LGS**	
Antler	2021	0.022 ± 0.006	B	0.055 ± 0.026	AB	0.156 ± 0.074	A	0.046 ± 0.016	AB	0.077 ± 0.054	AB
Pre-reproductive	2021	0.067 ± 0.025	A	0.104 ± 0.034	A	0.087 ± 0.027	A	0.144 ± 0.051	A	0.083 ± 0.029	A
Reproductive	2021	0.133 ± 0.030	A	0.180 ± 0.031	A	0.175 ± 0.043	A	0.176 ± 0.037	A	0.127 ± 0.032	A
Post-reproductive	2022	0.051 ± 0.017	A	0.104 ± 0.039	A	0.064 ± 0.016	A	0.089 ± 0.024	A	0.059 ± 0.018	A
Antler	2022	0.06 ± 0.029	B	0.094 ± 0.016	AB	0.102 ± 0.036	AB	0.078 ± 0.024	AB	0.135 ± 0.053	A
Pre-reproductive	2022	0.135 ± 0.038	A	0.173 ± 0.032	A	0.153 ± 0.042	A	0.129 ± 0.047	A	0.105 ± 0.032	A
Reproductive	2022	0.151 ± 0.041	B	0.238 ± 0.050	A	0.263 ± 0.069	A	0.222 ± 0.049	AB	0.167 ± 0.033	AB
Post-reproductive	2023	0.069 ± 0.019	A	0.100 ± 0.028	A	0.076 ± 0.024	A	0.100 ± 0.037	A	0.080 ± 0.034	A
Antler	2023	0.077 ± 0.038	B	0.138 ± 0.035	A	0.192 ± 0.073	A	0.128 ± 0.058	AB	0.122 ± 0.038	AB
Pre-reproductive	2023	0.024 ± 0.014	B	0.129 ± 0.039	A	0.115 ± 0.023	A	0.195 ± 0.095	B	0.094 ± 0.027	AB

Table A.6. Average ± SE daily detection rate of fawns in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during fawning/fawn rearing season (May–September) and reproductive (October–January) at all study sites (n = 9) in Tennessee, Alabama, Mississippi, and South Carolina, USA, July 2021–August 2023. Letters indicate significant difference between fire treatment units during the given biological season and year.

		Fawn Detections (Detections/Day)									
Season	**Year**	**CON**		**DOS**		**EGS**		**MGS**		**LGS**	
Fawning	2021	0.127 ± 0.035	A	0.110 ± 0.034	A	0.063 ± 0.024	A	0.144 ± 0.039	A	0.085 ± 0.028	A
Reproductive	2021	0.015 ± 0.007	B	0.040 ± 0.030	AB	0.018 ± 0.011	AB	0.044 ± 0.020	A	0.028 ± 0.012	AB
Fawning	2022	0.082 ± 0.030	A	0.137 ± 0.035	A	0.079 ± 0.043	A	0.104 ± 0.031	A	0.059 ± 0.022	A
Reproductive	2022	0.012 ± 0.006	B	0.035 ± 0.013	A	0.026 ± 0.011	AB	0.031 ± 0.019	AB	0.017 ± 0.010	AB
Fawning	2022	0.098 ± 0.040	B	0.057 ± 0.029	A	0.021 ± 0.008	AB	0.055 ± 0.023	AB	0.061 ± 0.021	AB

Table A.7. Average ± SE coyote in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during fawning/fawn rearing season (May–September) at all study sites (n = 9) in Tennessee, Alabama, Mississippi, and South Carolina, USA, July 2021–August 2023.

		Coyote Detections (Detections/Day)									
Season	**Year**	**CON**		**DOS**		**EGS**		**MGS**		**LGS**	
Fawning	2021	0.003 ± 0.003	A	0.017 ± 0.009	A	0.013 ± 0.006	A	0.010 ± 0.005	A	0.013 ± 0.008	A
Fawning	2022	0.012 ± 0.007	A	0.016 ± 0.008	A	0.014 ± 0.007	A	0.019 ± 0.008	A	0.010 ± 0.004	A
Fawning	2023	0.019 ± 0.009	A	0.013 ± 0.006	A	0.028 ± 0.013	A	0.027 ± 0.013	A	0.019 ± 0.008	A

Table A.8. Average ± SE bobcat in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during fawning/fawn rearing season (May–September) at all study sites (n = 9) in Tennessee, Alabama, Mississippi, and South Carolina, USA, July 2021–August 2023.

		Bobcat Detections (Detections/Day)									
Season	**Year**	**CON**		**DOS**		**EGS**		**MGS**		**LGS**	
Fawning	2021	0.007 ± 0.005	A	0.016 ± 0.006	AB	0.010 ± 0.005	AB	0.018 ± 0.013	AB	0.027 ± 0.014	B
Fawning	2022	0.015 ± 0.008	A	0.016 ± 0.007	AB	0.012 ± 0.006	AB	0.026 ± 0.011	B	0.009 ± 0.005	AB
Fawning	2023	0.014 ± 0.008	A	0.010 ± 0.006	A	0.012 ± 0.007	A	0.021 ± 0.013	A	0.013 ± 0.005	A

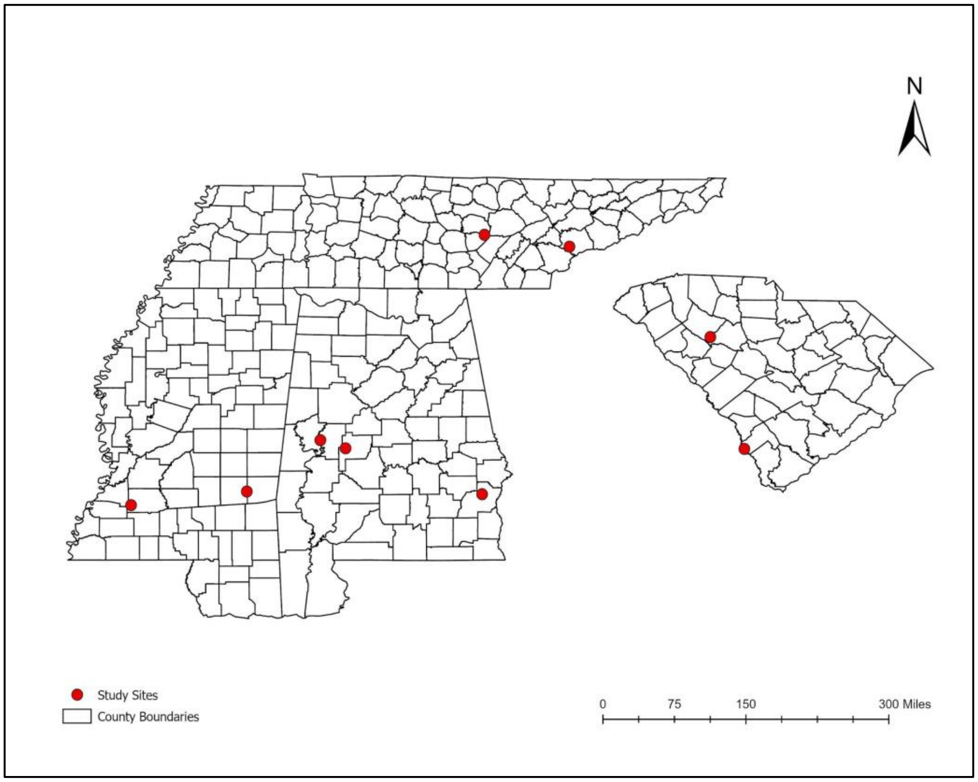

Figure A.13. Map of study sites (n = 9) indicated by red dots located in Alabama, Mississippi, South Carolina, and Tennessee, USA.

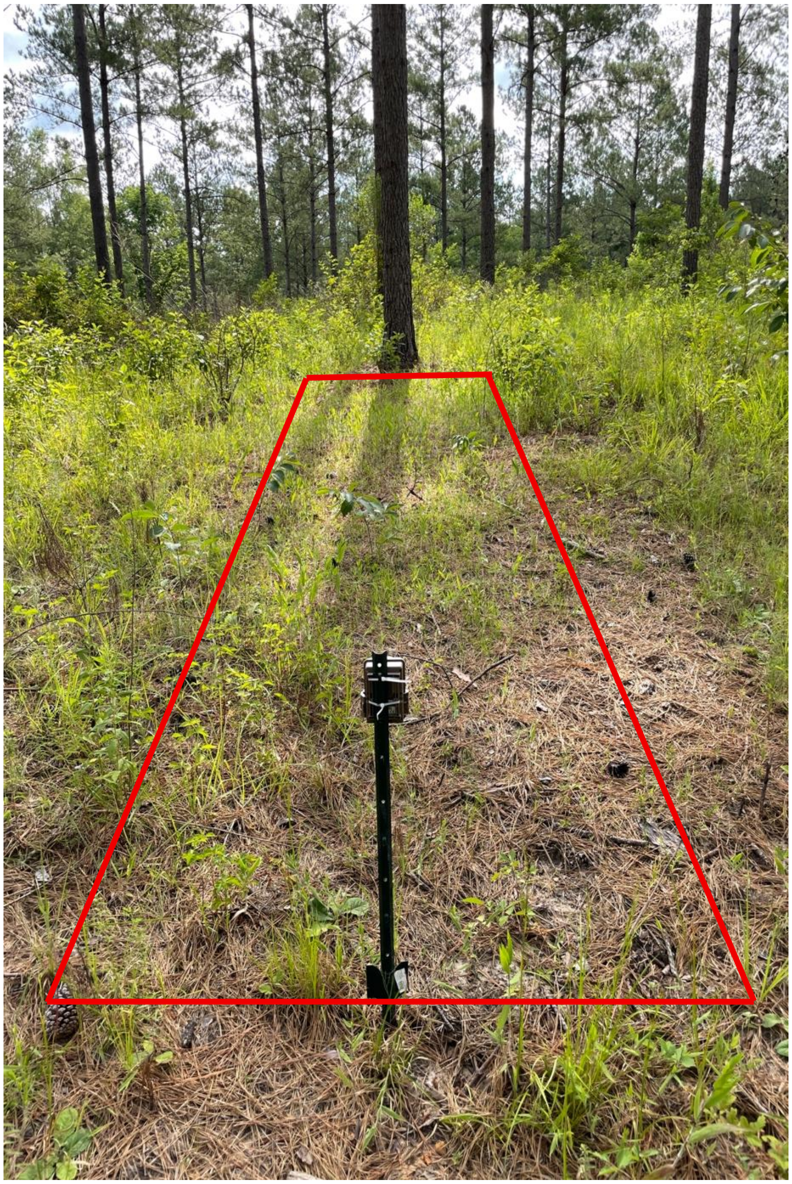

Figure A.14. Example of camera sampling point located at permanent sampling points one, two, and four, totaling 135 camera sampling points, within each unit at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA, July 2021–August 2023.

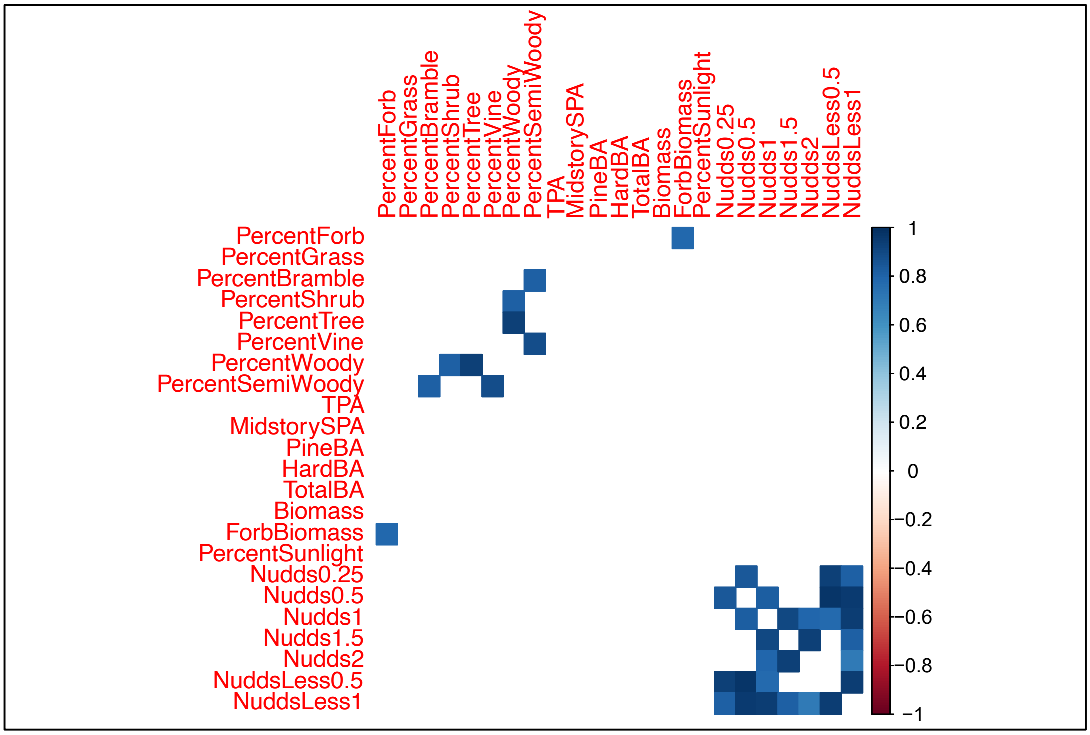

Figure A.15. Correlation coefficient test between predictor variables showing variables that have coefficient value greater or equal to 0.7 in blue and are not included together within the same model.

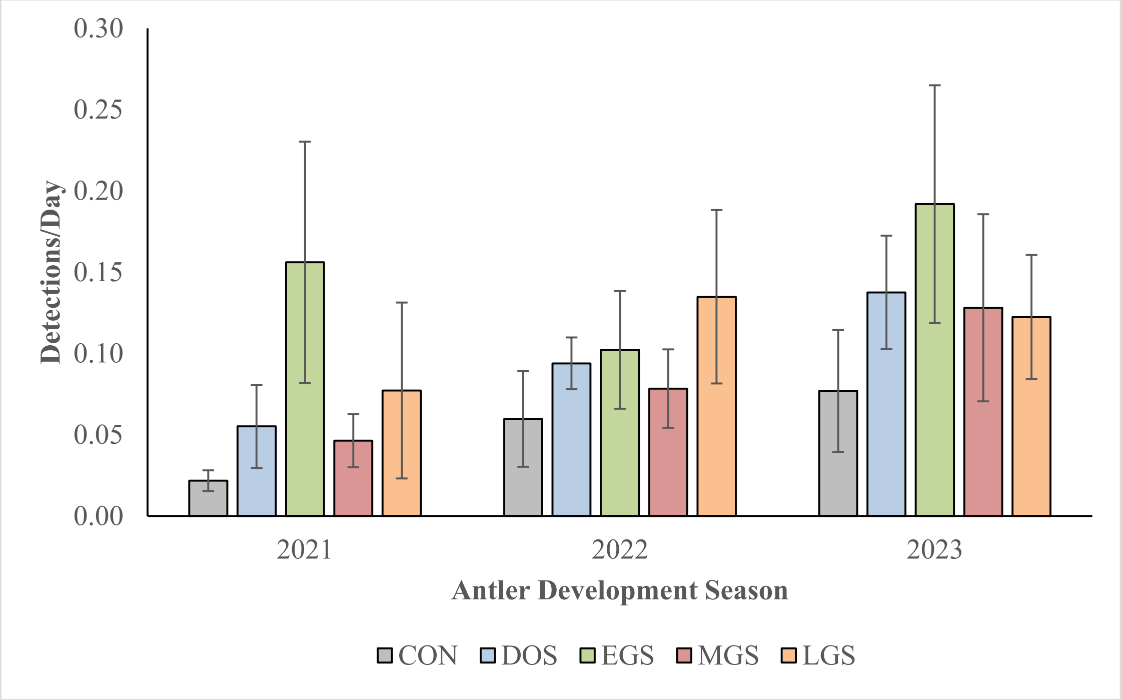

Figure A.16. Average male deer detections per day in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during antler growing season (May–July), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

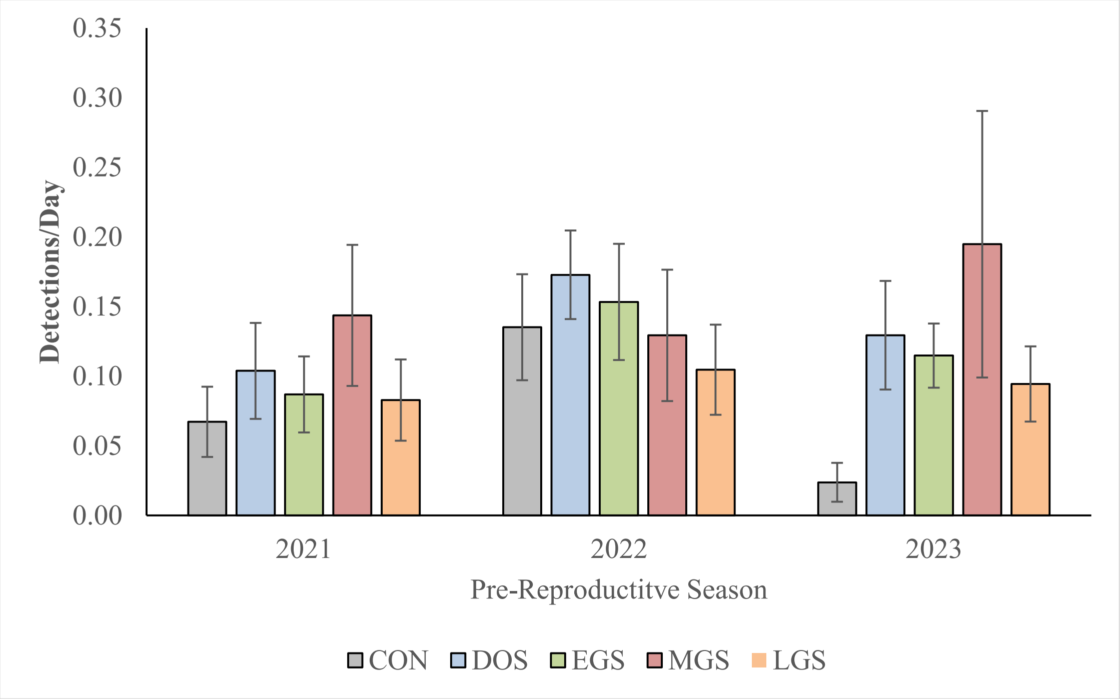

Figure A.17. Average male deer detections per day in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the pre-reproductive season **(**August–September), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

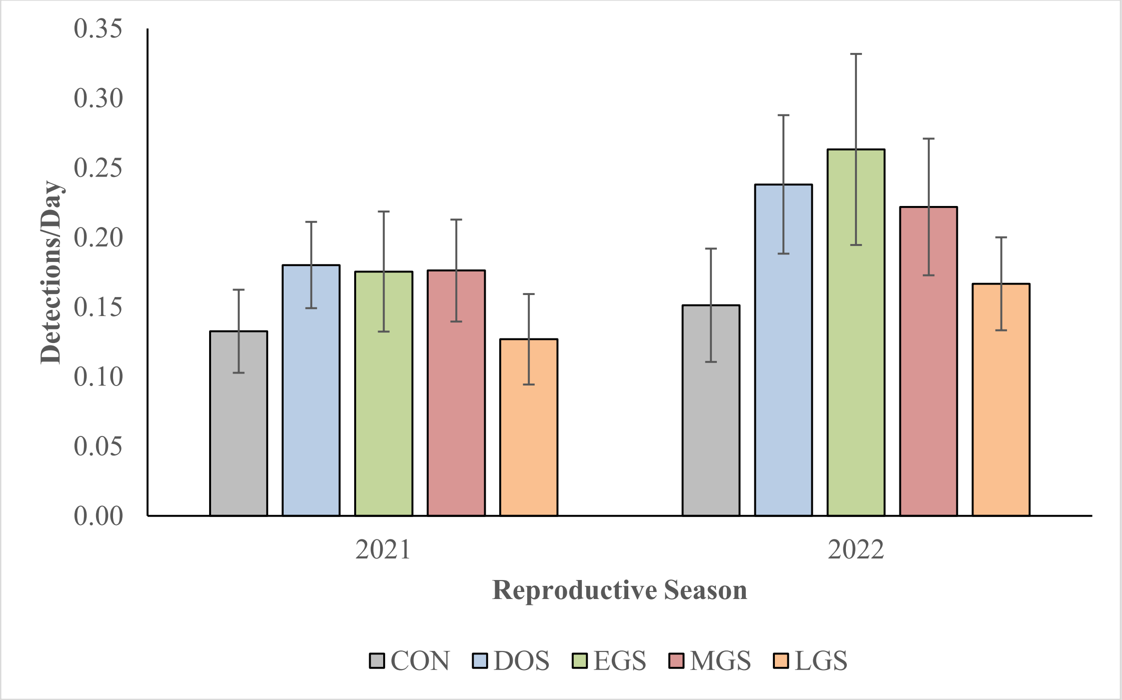

Figure A.18. Average male deer detections per day in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the reproductive season (October–January), 2021–2022, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

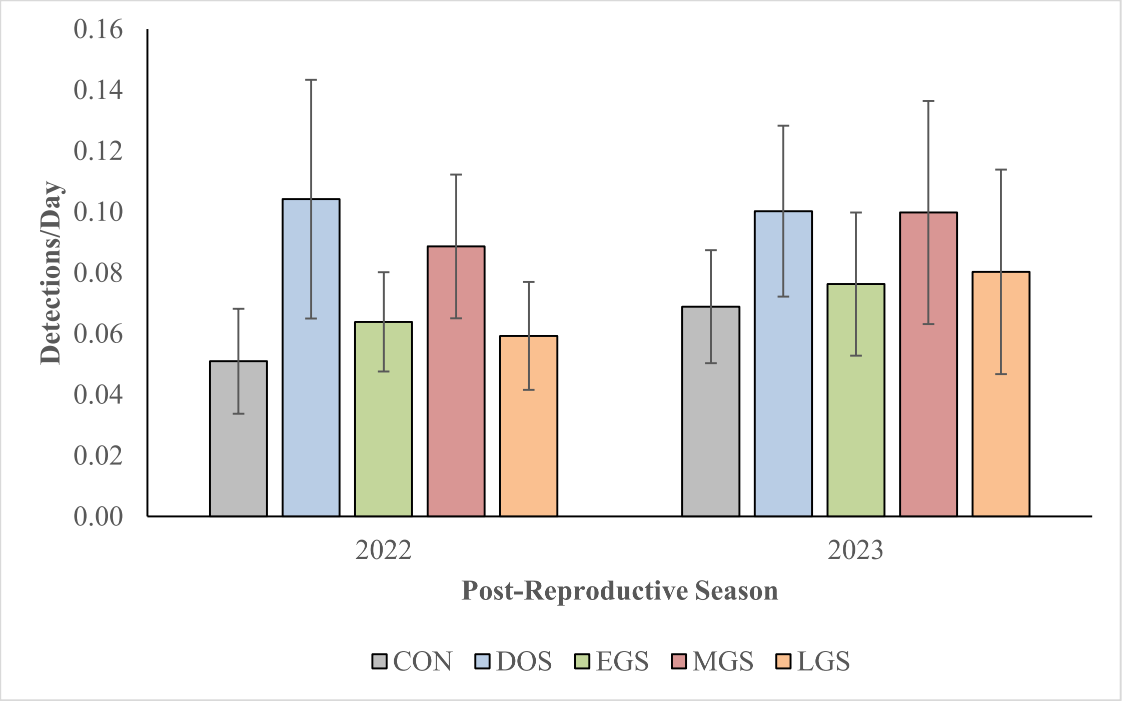

Figure A.19. Average male deer detections per day in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the post-reproductive season (February–April), 2022–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

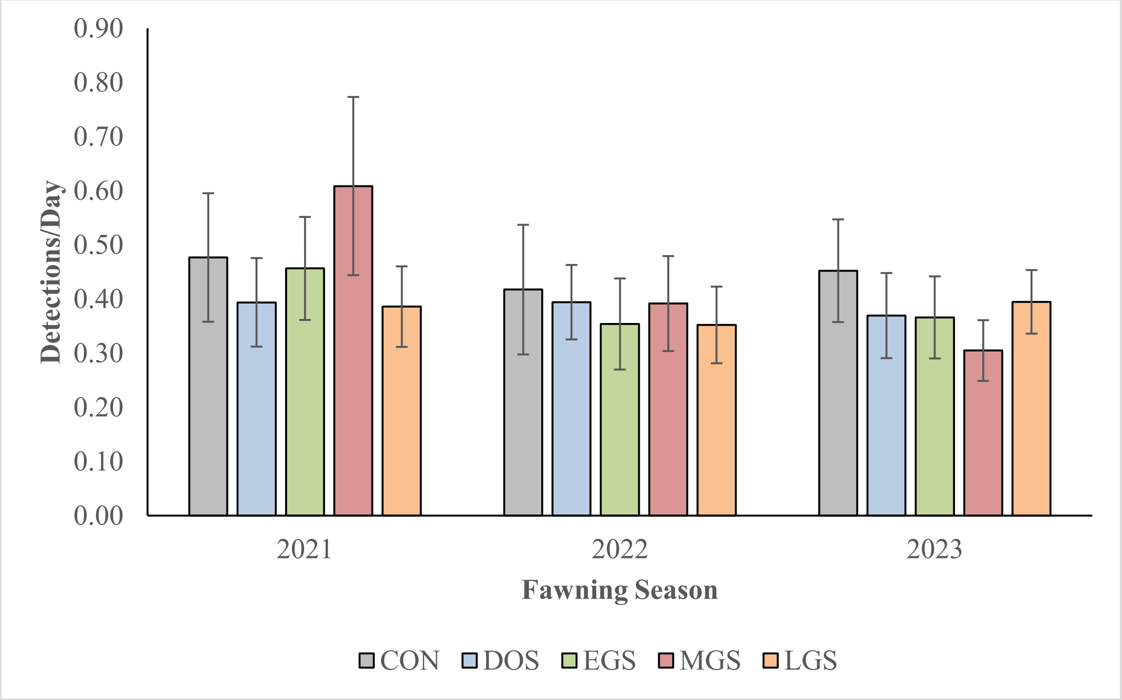

Figure A.20. Average female deer detections per day in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the fawning season (May–September), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

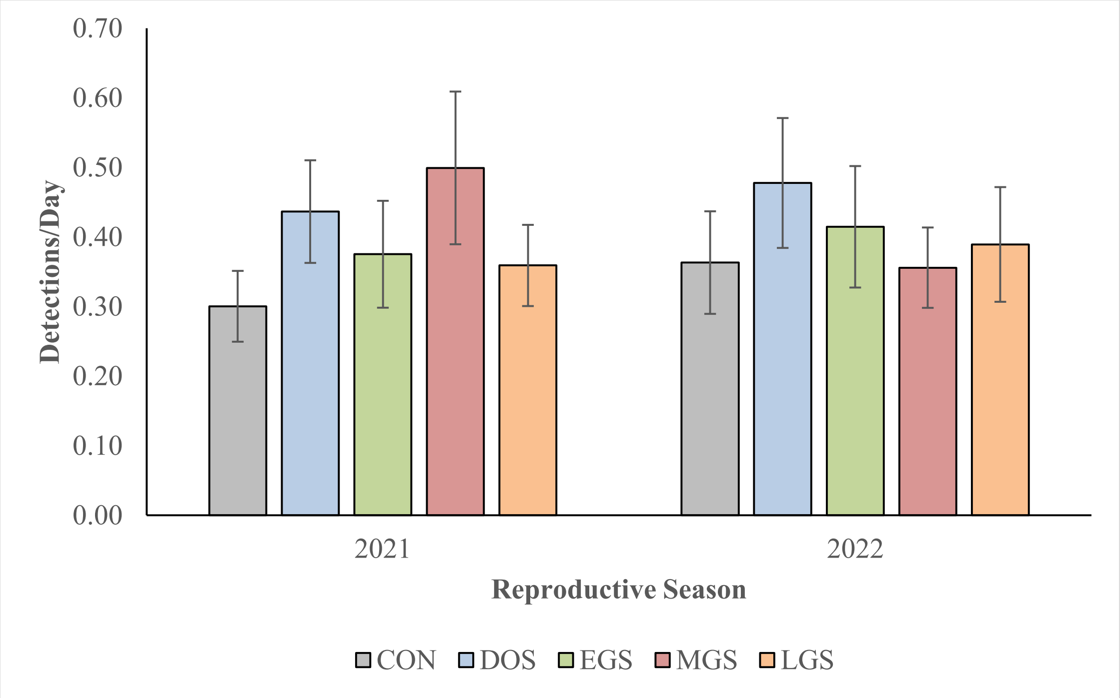

Figure A.21. Average female deer detections per day in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the reproductive season (October–January), 2021–2022, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

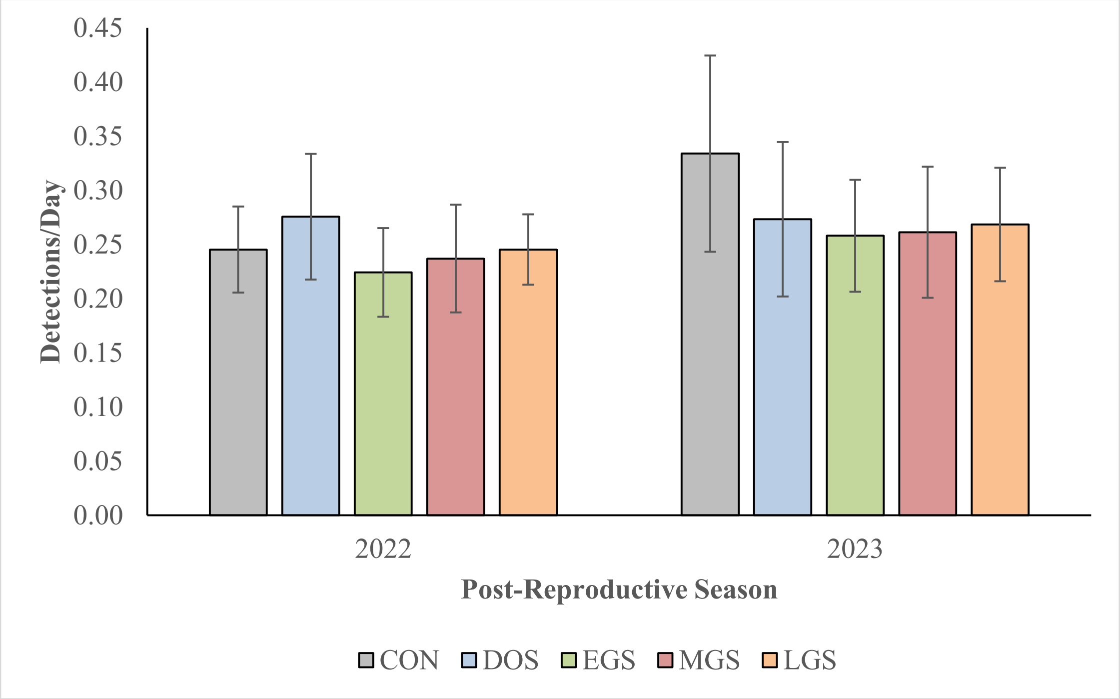

Figure A.22. Average female deer detections per day in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the post-reproductive season (February–April), 2022–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

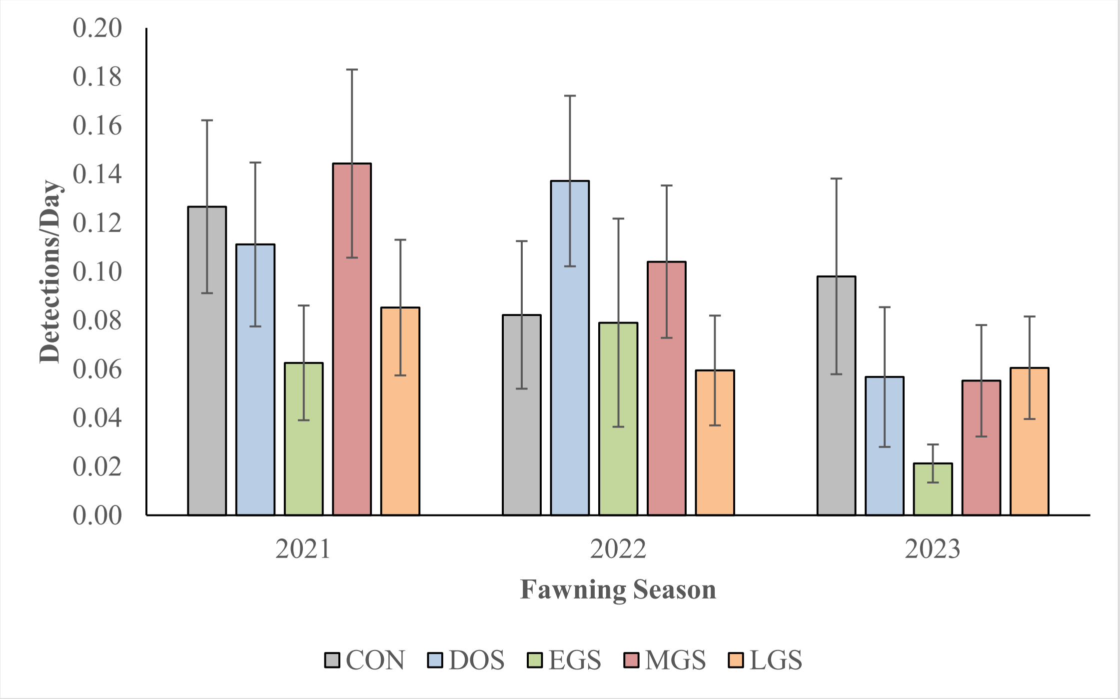

Figure A.23. Average fawn deer detections per day in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the fawning season (May–September), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

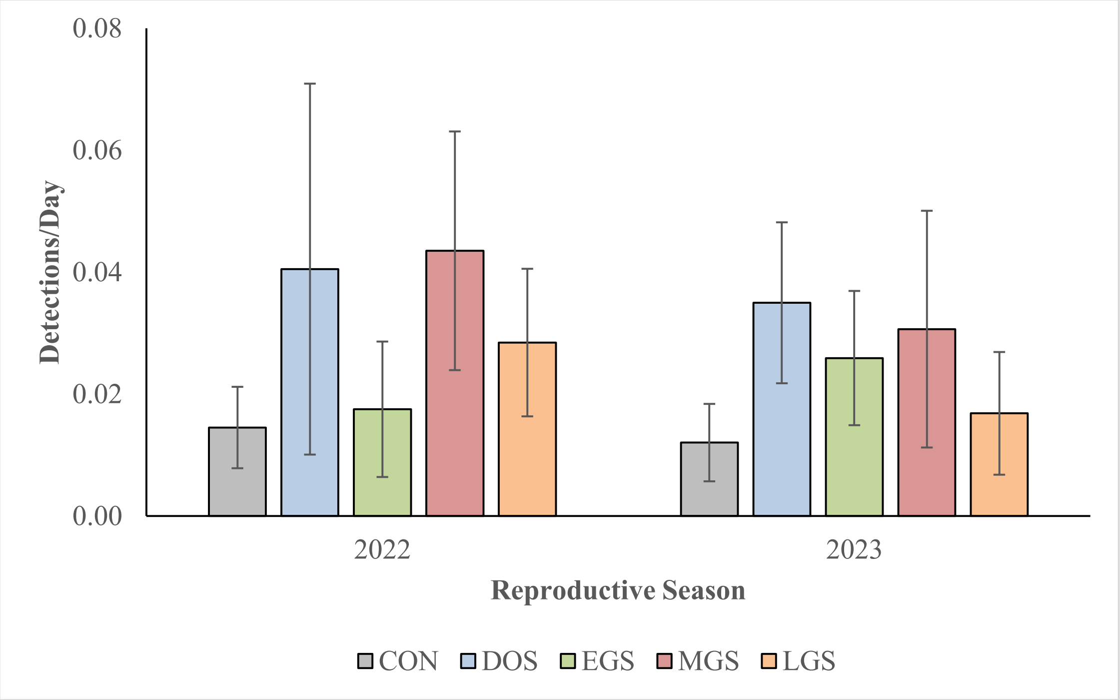

Figure A.24. Average fawn deer detections per day in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the reproductive season (October–January), 2021–2022, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

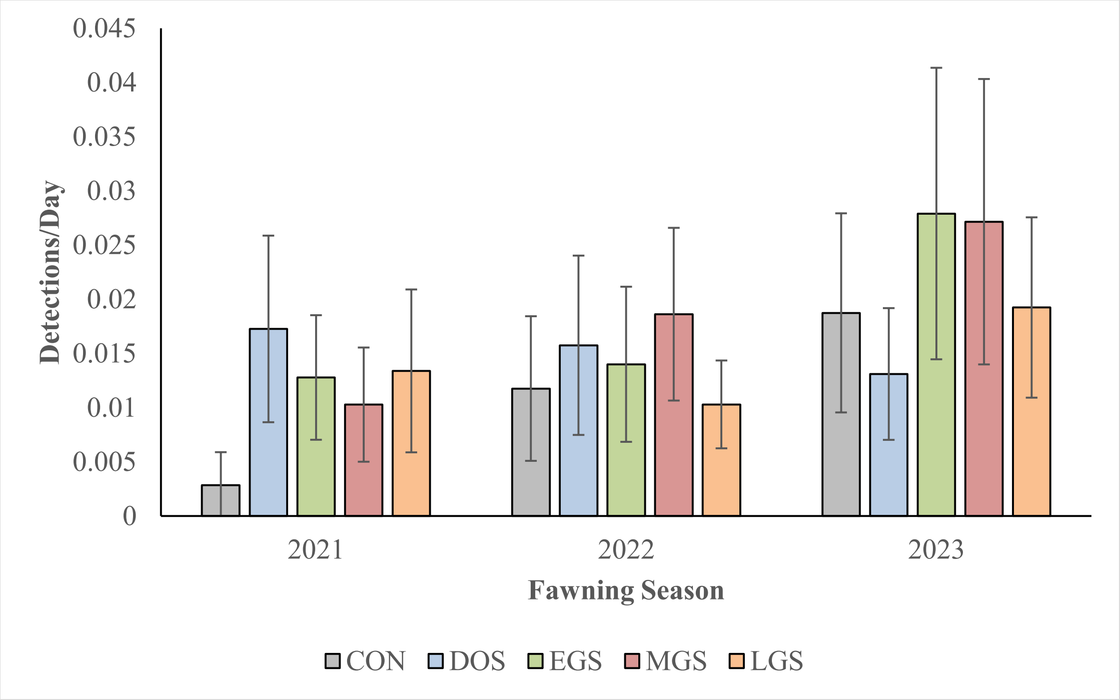

Figure A.13. Average coyote detections per day in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the fawning season (May–September), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

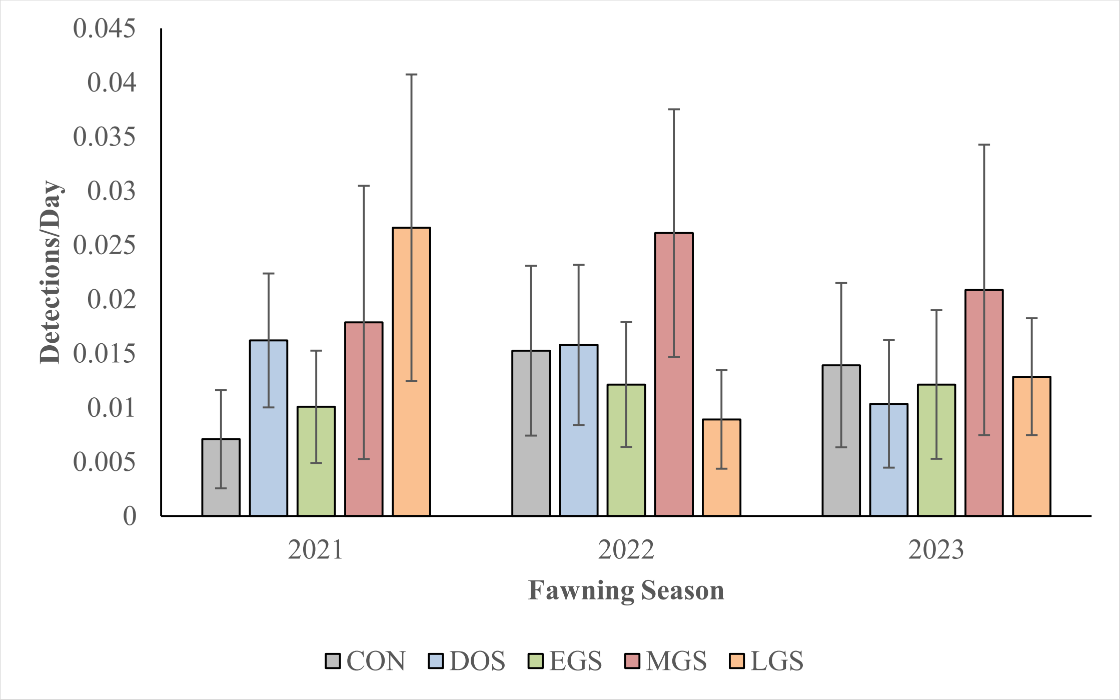

Figure A.14. Average bobcat detections per day in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the fawning season (May–September), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

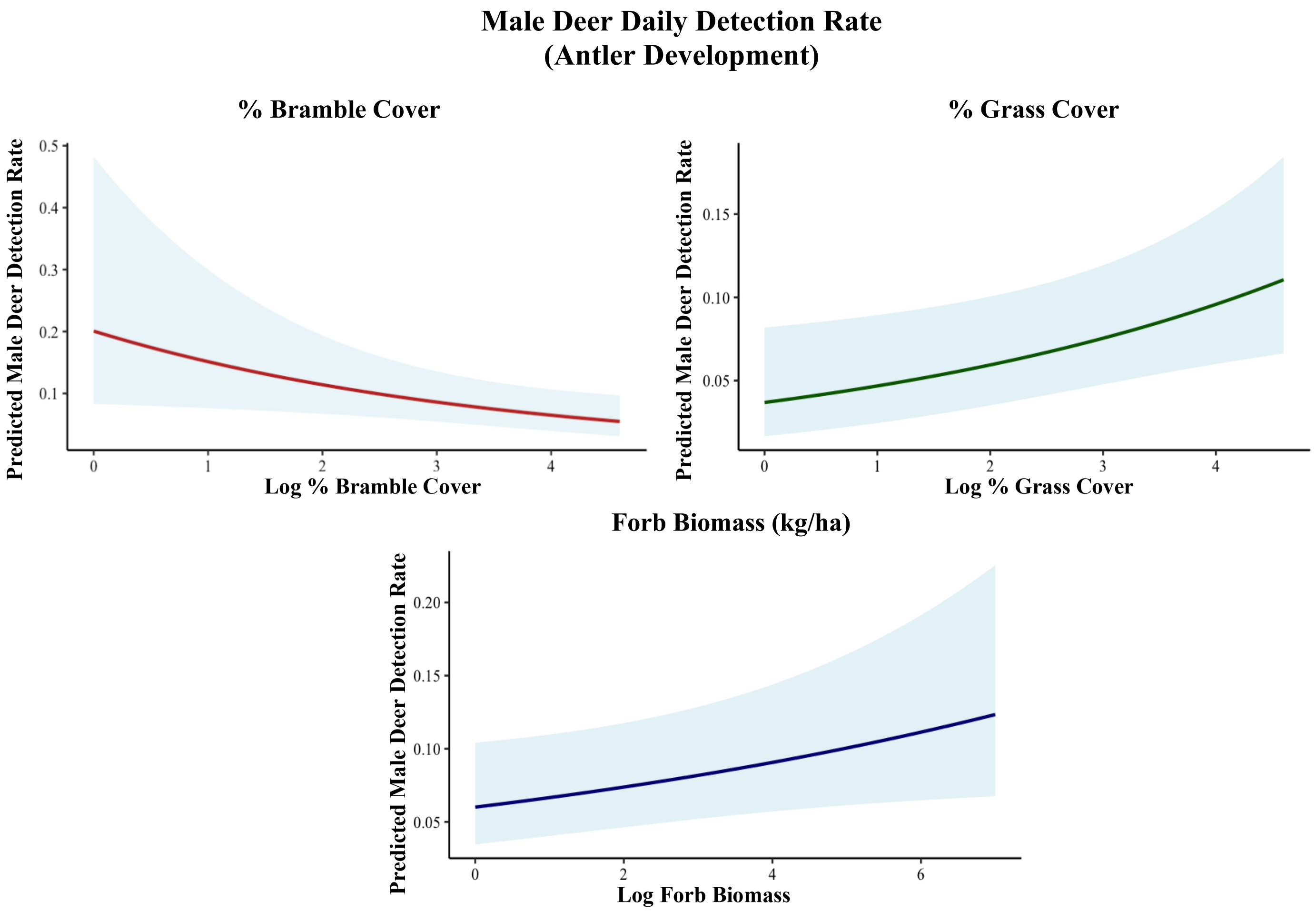

Figure A.15. Predicted male deer daily detection rate during the antler development season (May–July) in response to percent bramble coverage, percent grass cover, and forb biomass on the log scale.

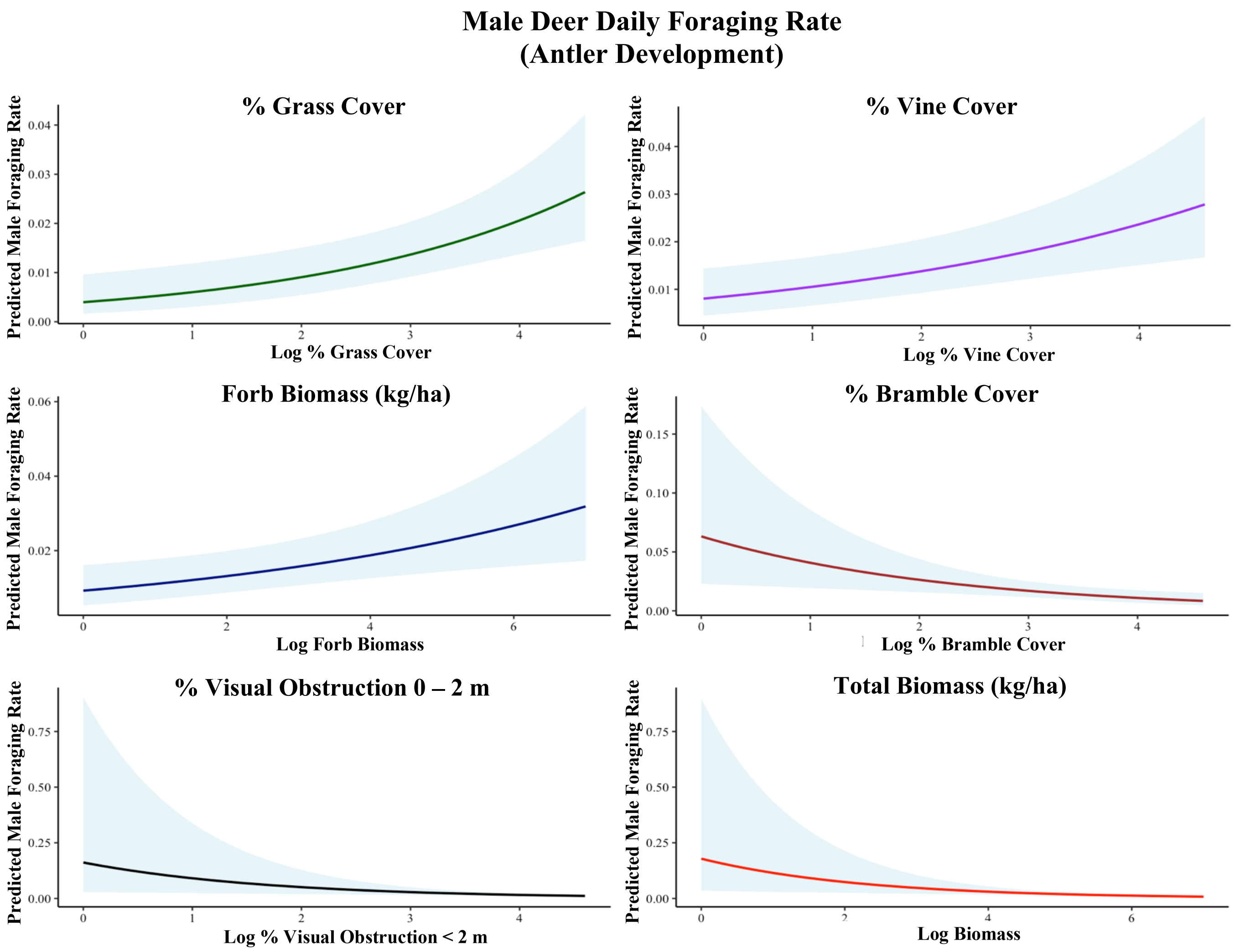

Figure A.16. Predicted male deer daily foraging rate during the antler development season (May–July) in response to percent grass, vine, bramble coverage, percent visual obstruction <2 m, total biomass and forb biomass on the log scale.

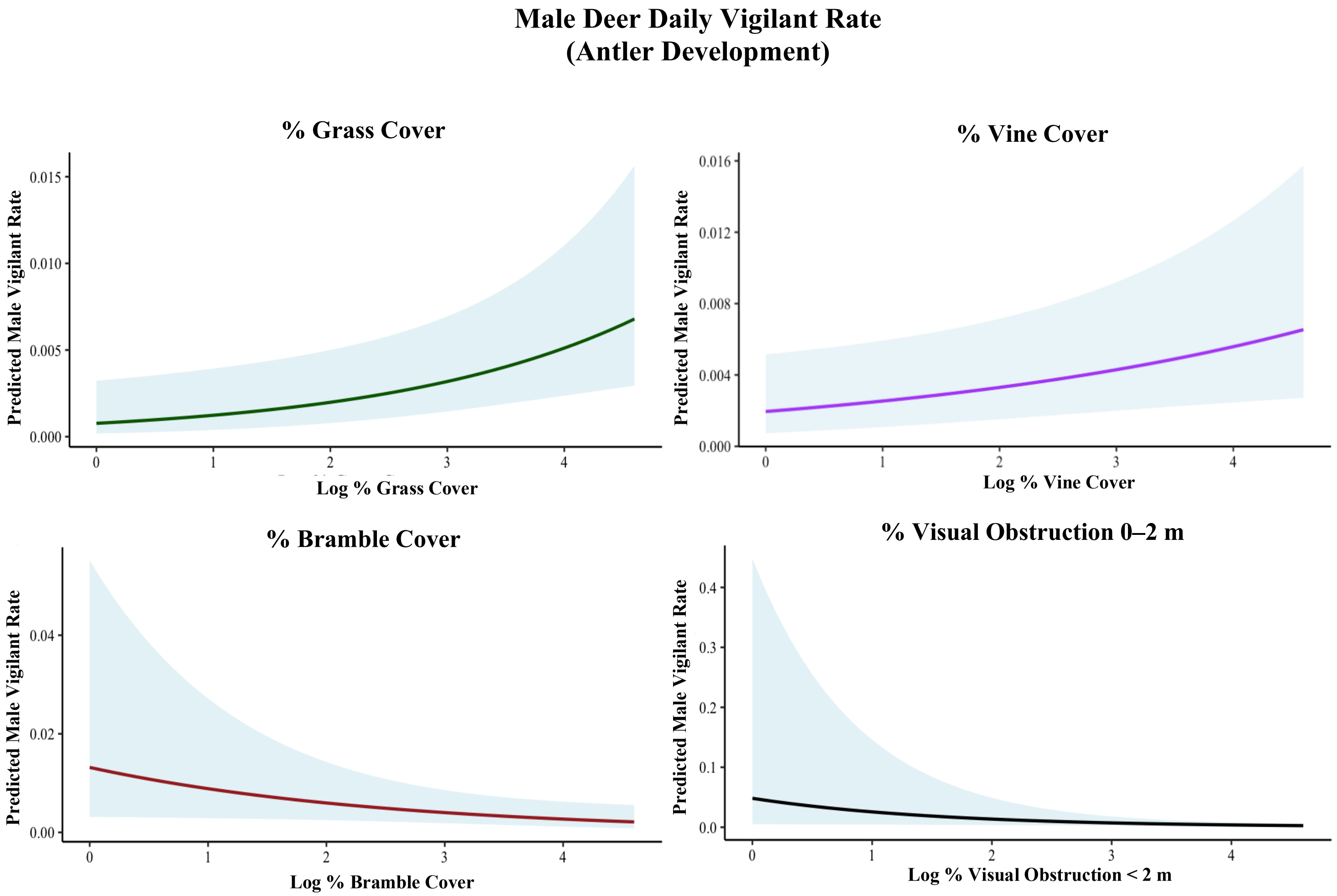

Figure A.17. Predicted male deer daily vigilant rate during the antler development season (May–July) in response to percent grass, vine, bramble coverage, and percent visual obstruction <2 m on the log scale.

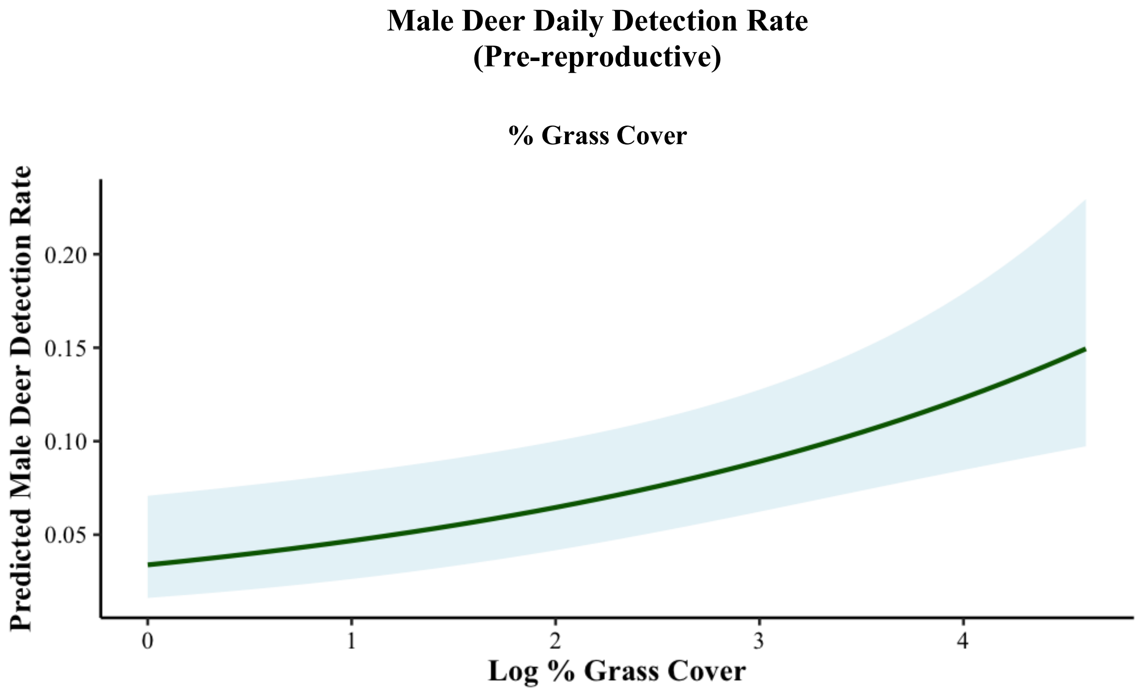

Figure A.18. Predicted male daily detection rate during the pre-reproductive season (August–September) in response to percent grass coverage on the log scale. Percent tree coverage and had a 95% confidence interval crossing zero indicating no discernible relationship.

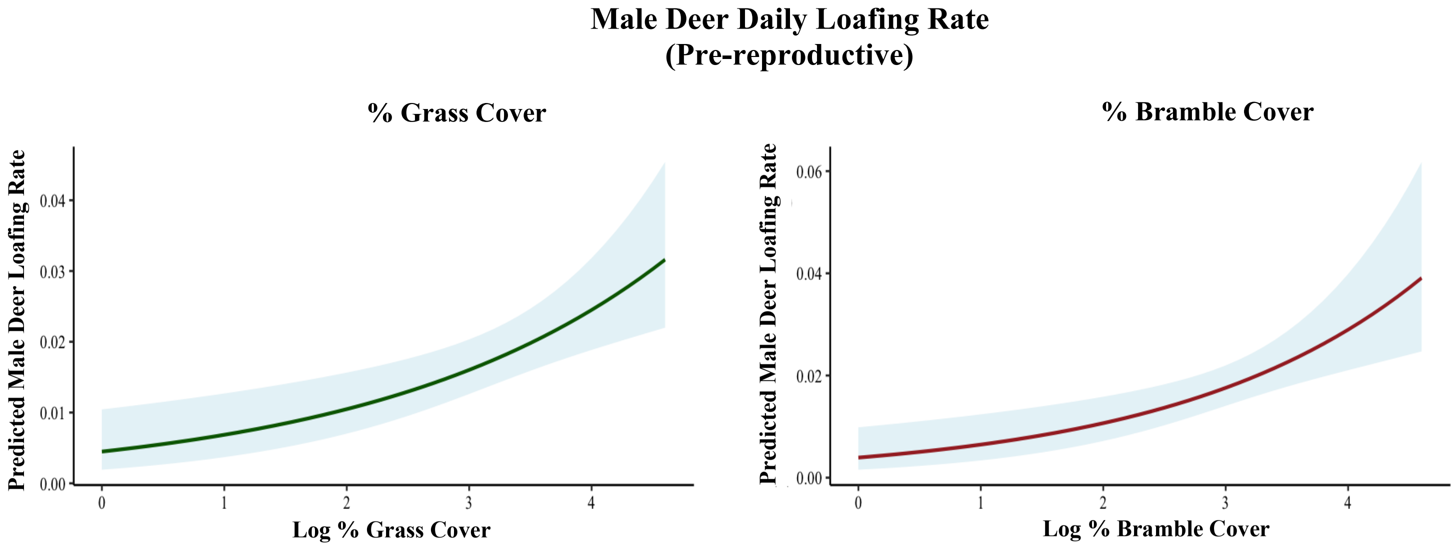

Figure A.19. Predicted male daily loafing rate during the pre-reproductive season (August–September) in response to percent grass and bramble coverage on the log scale. Percent tree coverage and percent visual obstruction <2 m had a 95% confidence interval crossing zero indicating no discernible relationship.

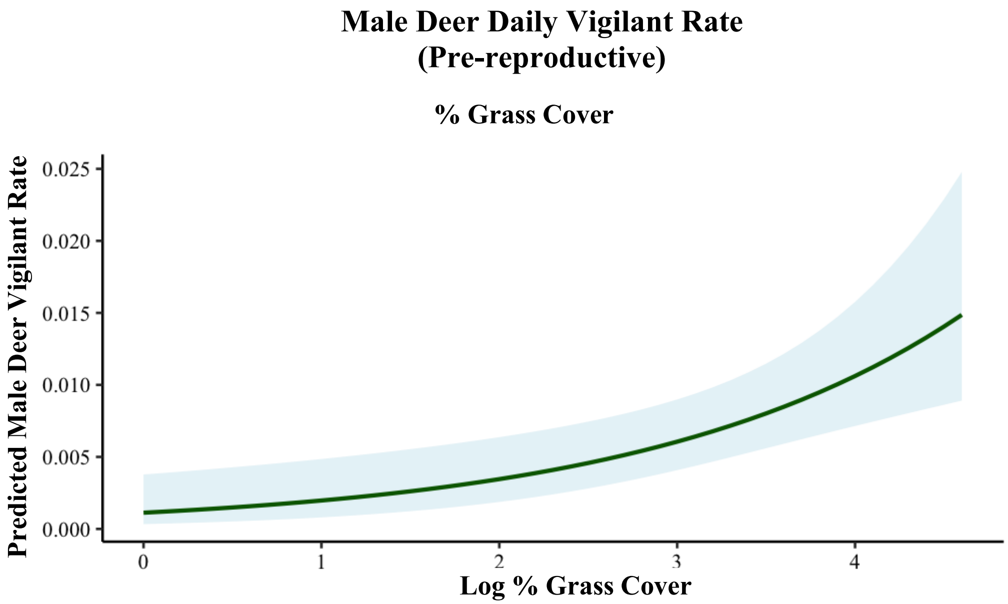

Figure A.20. Predicted male daily vigilant rate during the pre- reproductive season (August–September) in response to percent grass on the log scale. Percent shrub coverage and total biomass had a 95% confidence interval crossing zero indicating no discernible relationship.

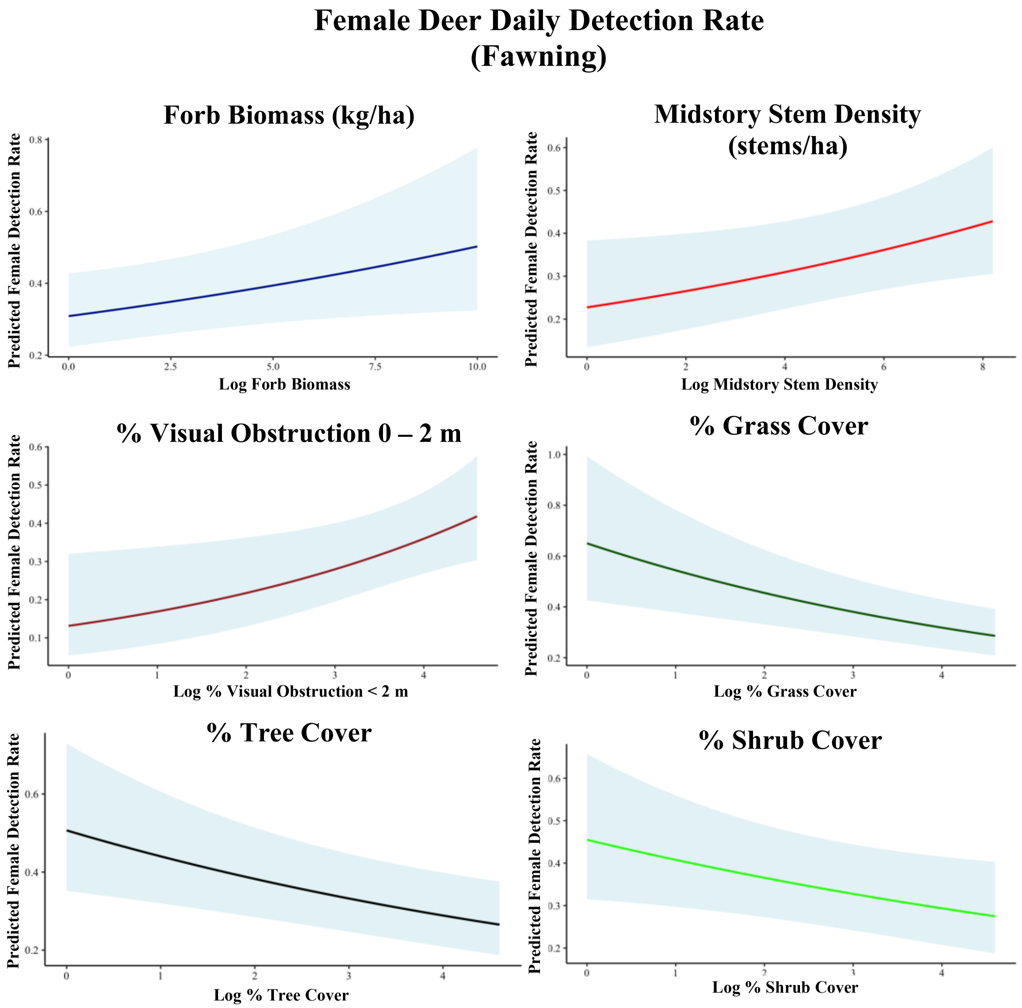

Figure A.21. Predicted female deer daily detection rate during the fawning season (May–September) in response to percent grass, tree, shrub coverage, percent visual obstruction <2 m, midstory stem density (stems/ha), and forb biomass on the log scale.

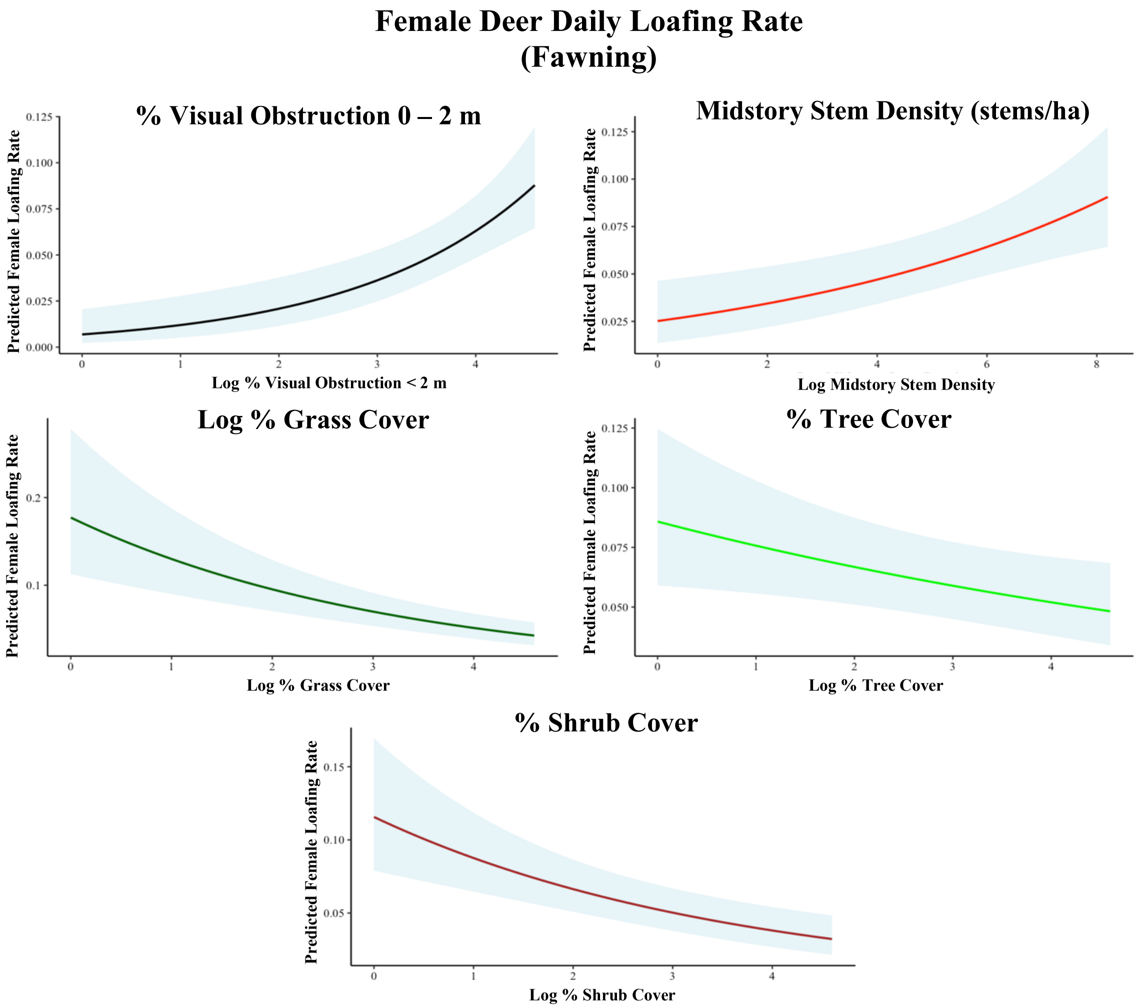

Figure A.22. Predicted female deer daily loafing rate during the fawning season (May–September) in response to percent visual obstruction <2 m, midstory stem density (stems/ha), and percent coverage of grass, tree, and shrub on the log scale.

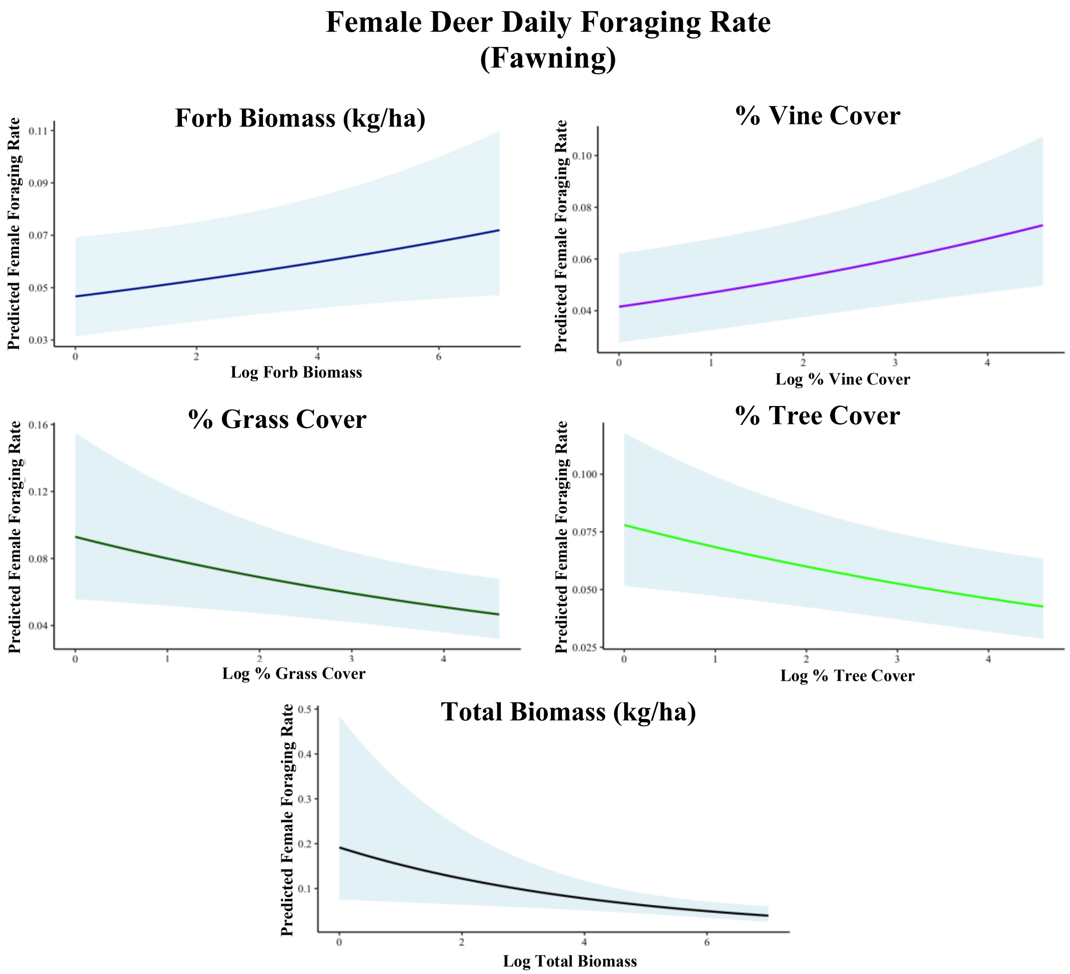

Figure A.23. Predicted female deer daily foraging rate during the fawning season (May–September) in response to percent vine, grass, tree coverage, forb biomass (kg/ha), and total biomass (kg/ha) on the log scale.

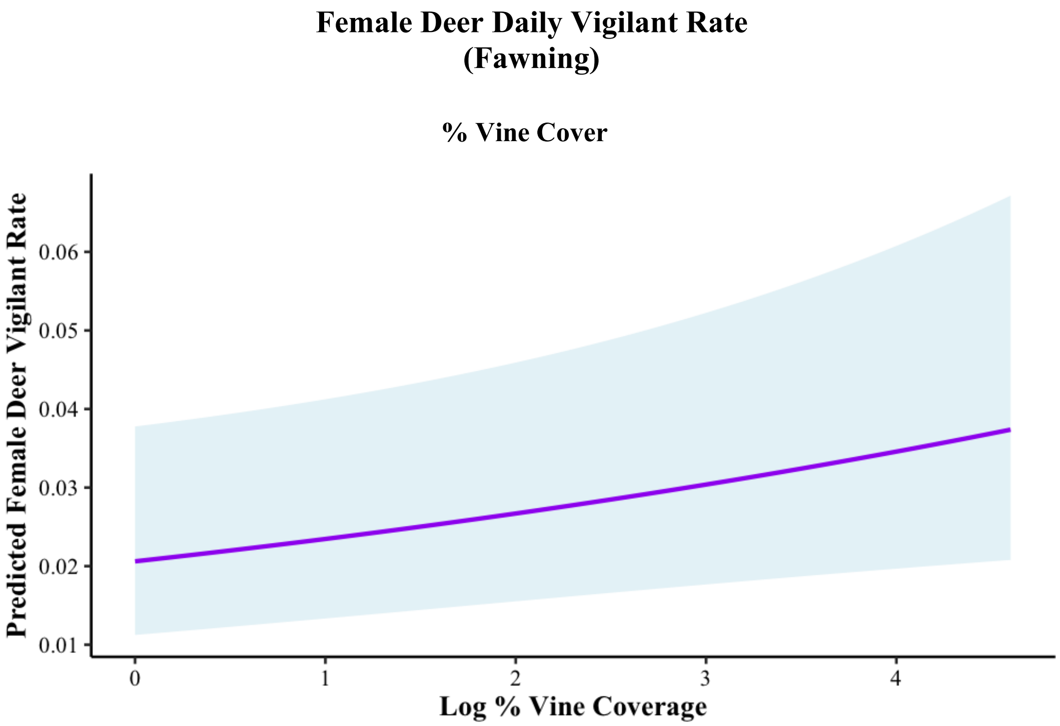

Figure A.24. Predicted female deer daily vigilant rate during the fawning season (May–September) in response to percent vine coverage on the log scale.

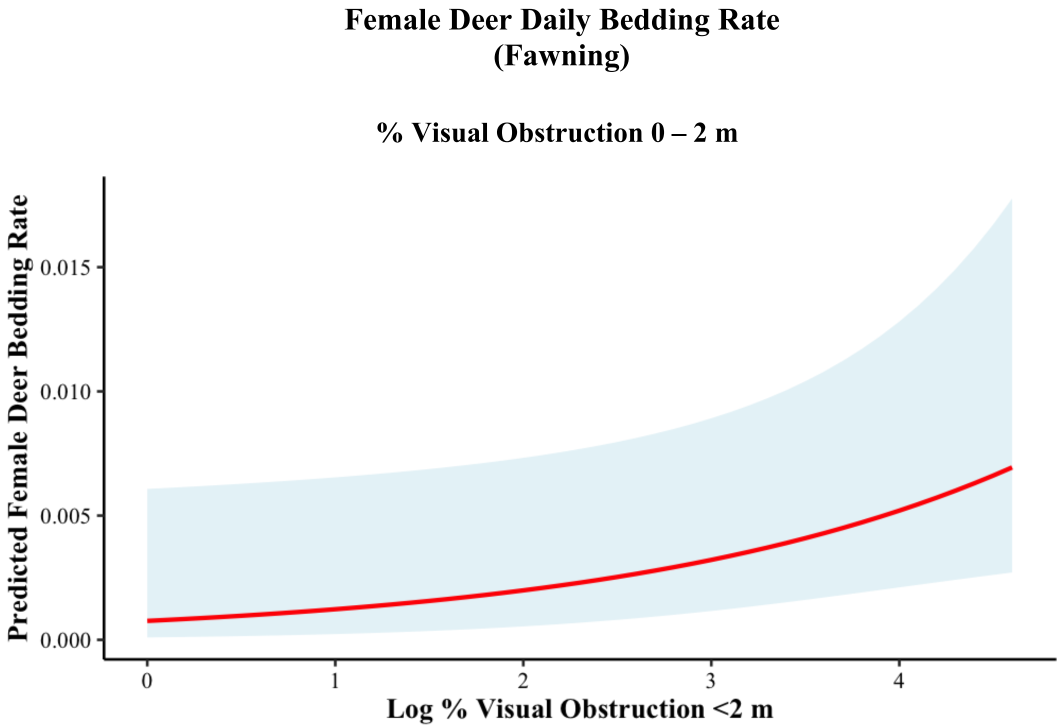

Figure A.25. Predicted female deer daily bedding rate during the fawning season (May–September) in response to percent visual obstruction <2 m on the log scale.

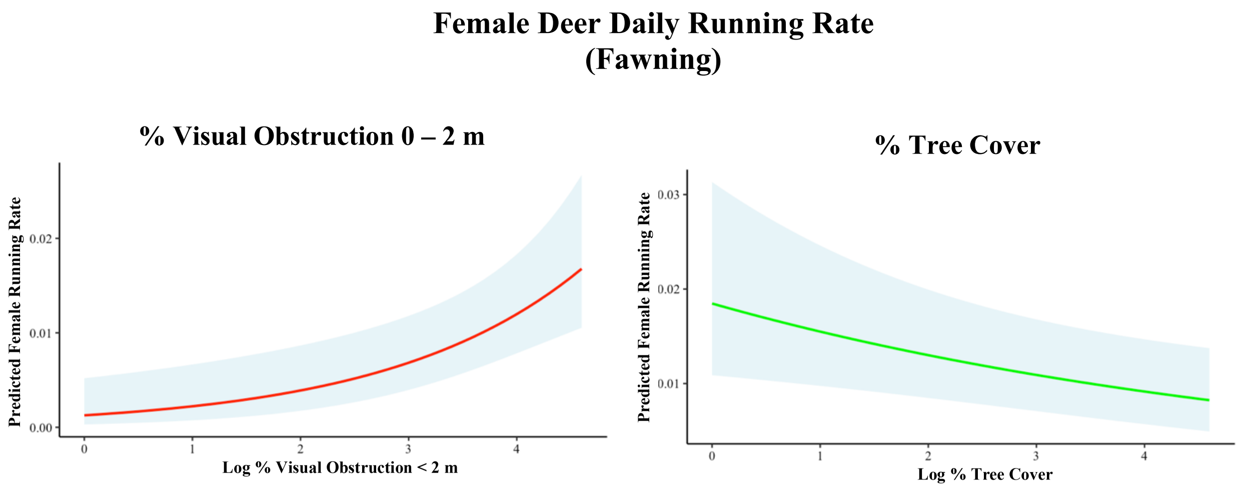

Figure A.26. Predicted female deer daily running rate during the fawning season (May–September) in response to percent visual obstruction <2 m and percent tree cover in the understory on the log scale.

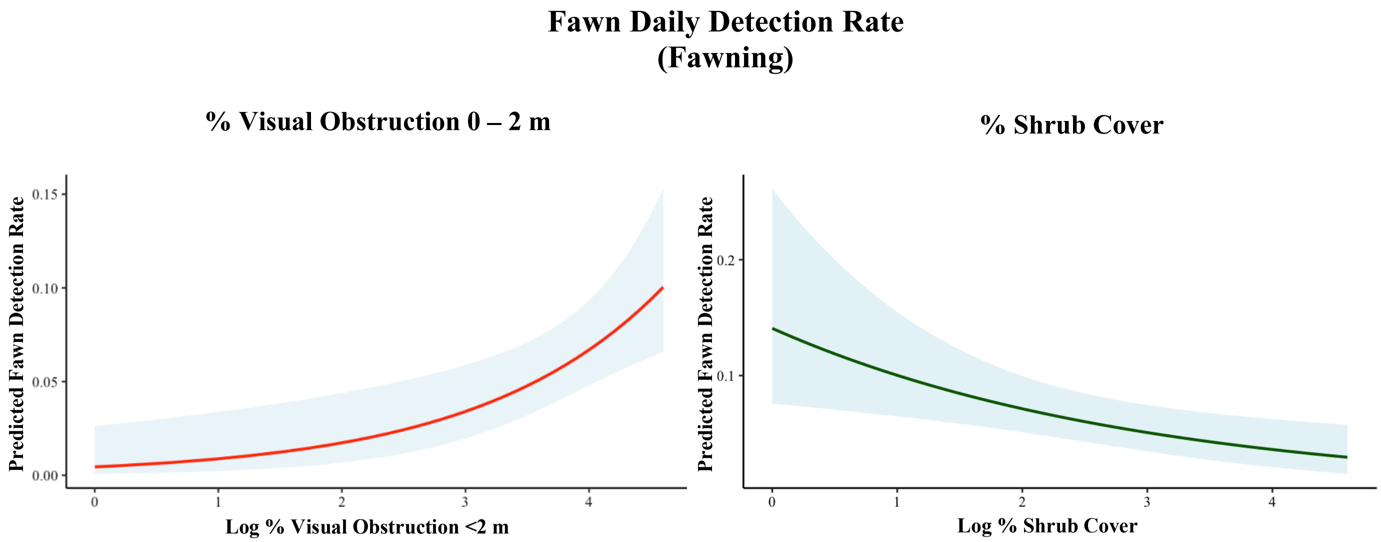

Figure A.27. Predicted fawn daily detection rate during the fawning season (May–September) in response to percent visual obstruction <2 m and percent shrub coverage in the understory on the log scale.

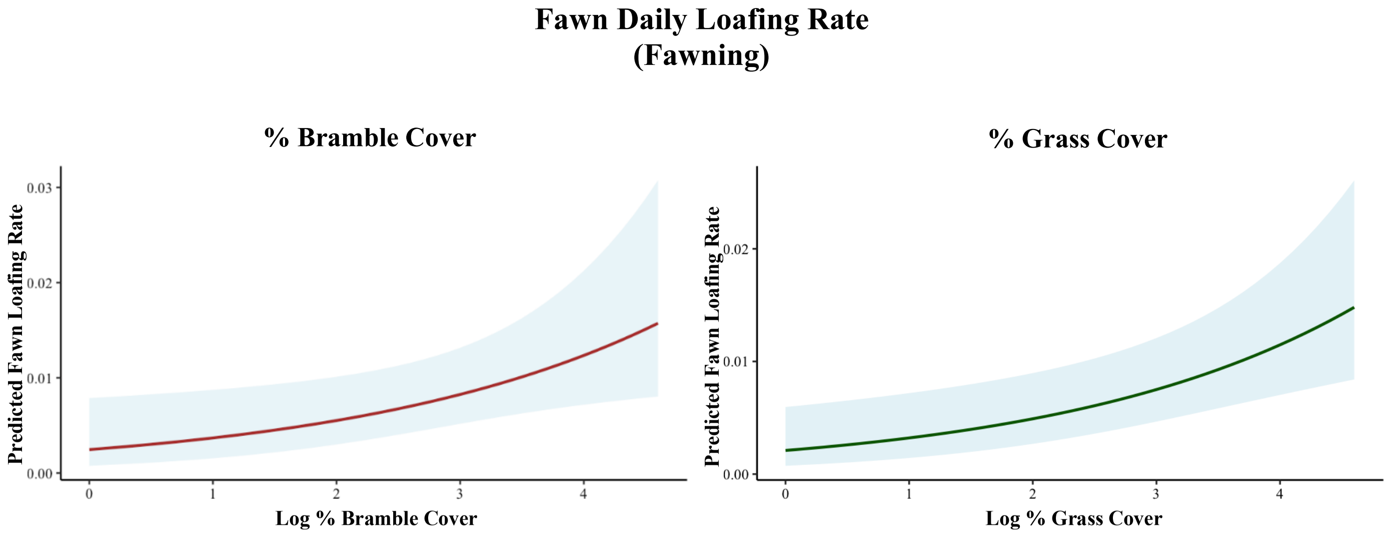

Figure A.28. Predicted fawn daily loafing rate during the fawning season (May–September) in response to percent bramble and grass coverage in the understory on the log scale.

Female Deer Daily Behavior Rates (Fawning Season)

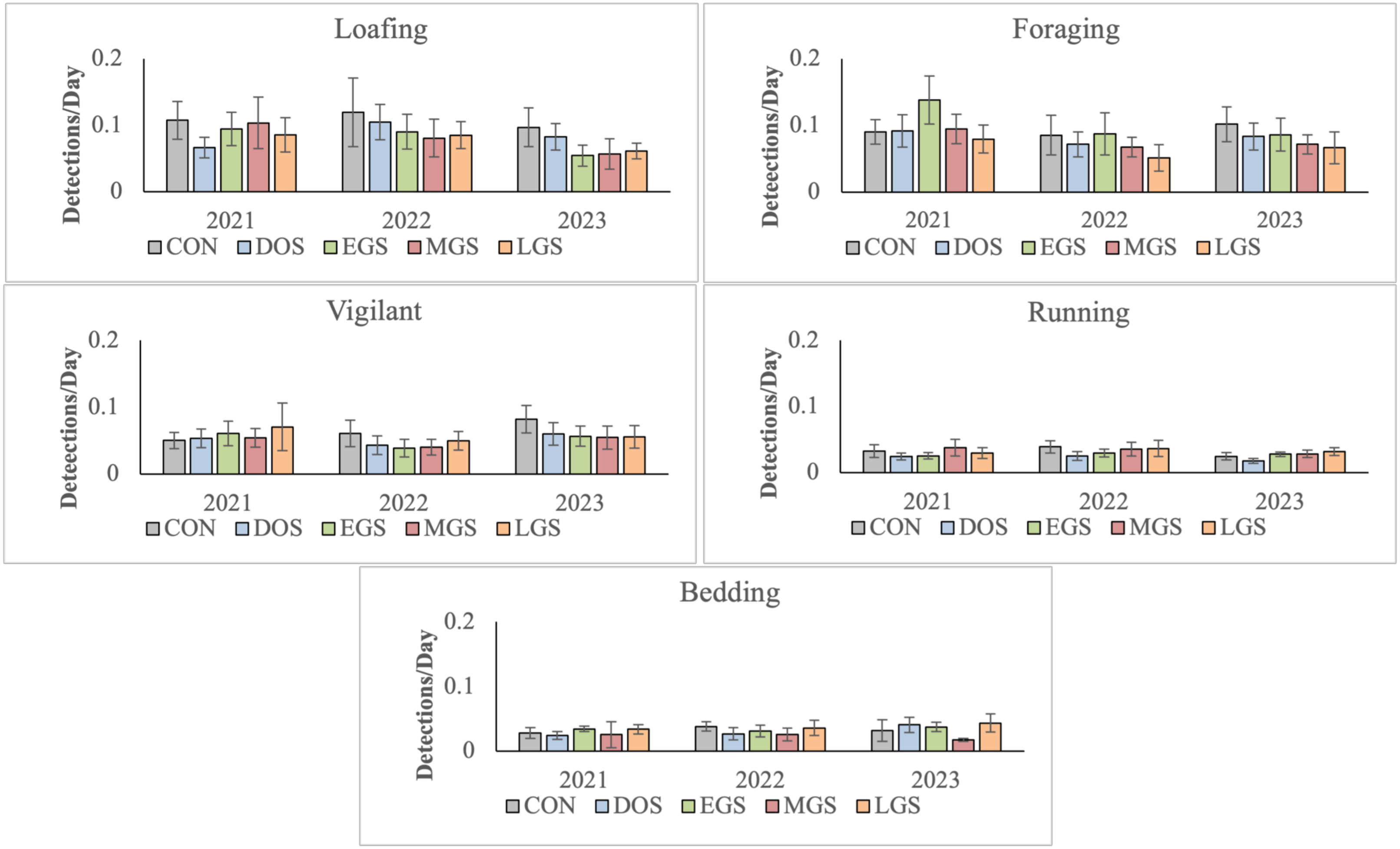

Figure A.29. Average daily female deer behavior detection rates in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the fawning season (May–September), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

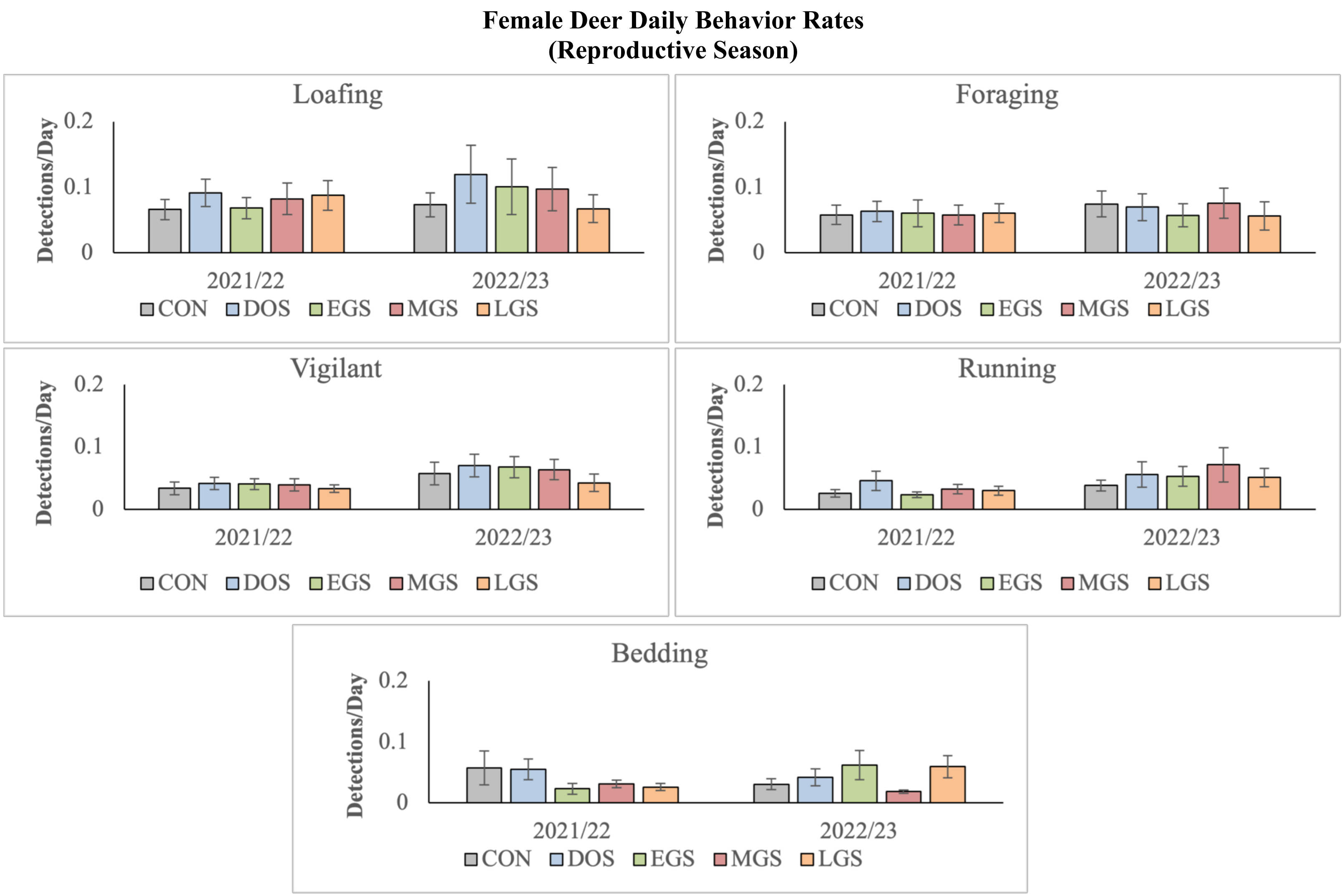

Figure A.30. Average daily female deer behavior detection rates in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the reproductive season (October–January), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

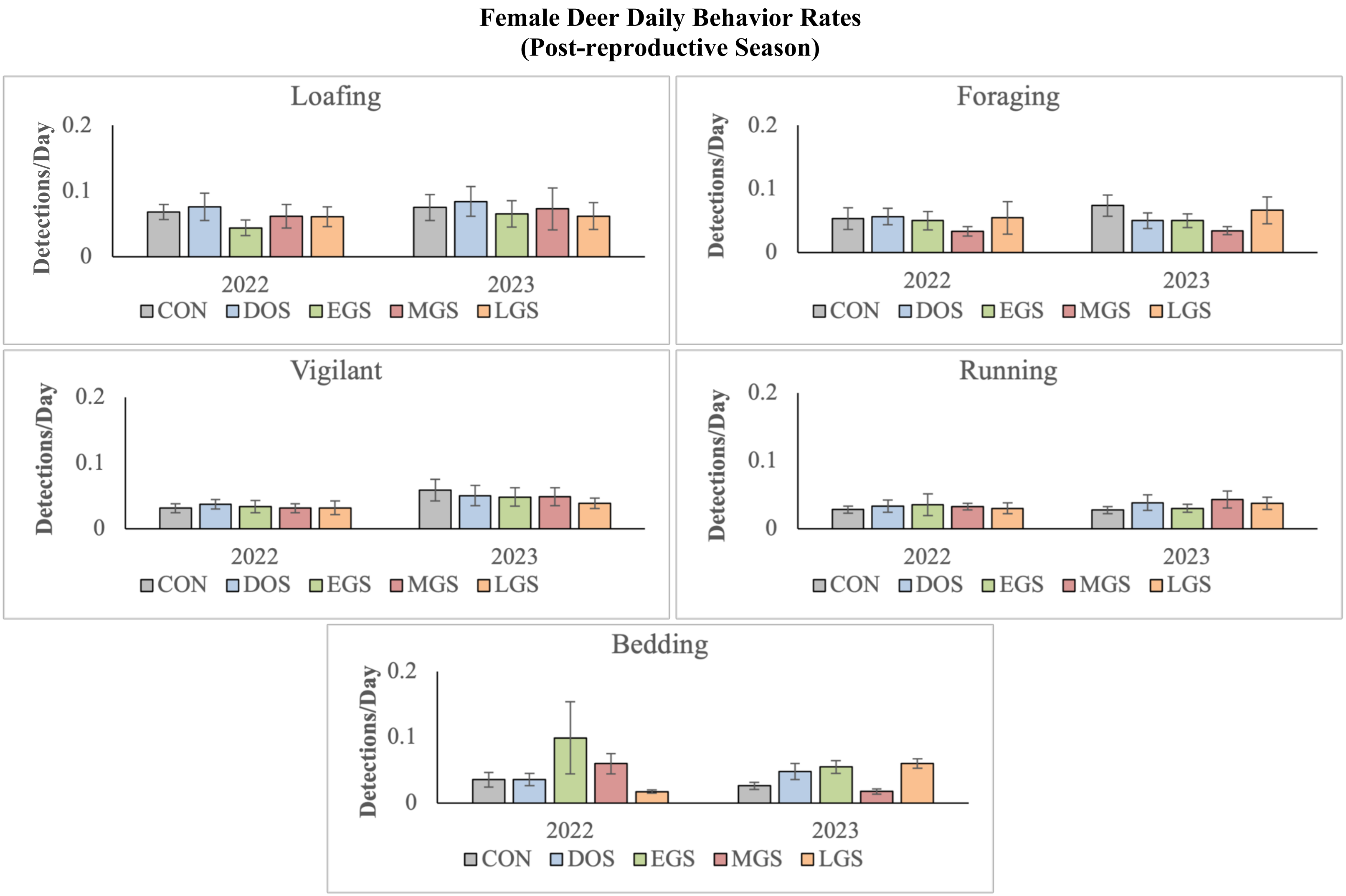

Figure A.31. Average daily female deer behavior detection rates in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the post-reproductive season (February–April), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

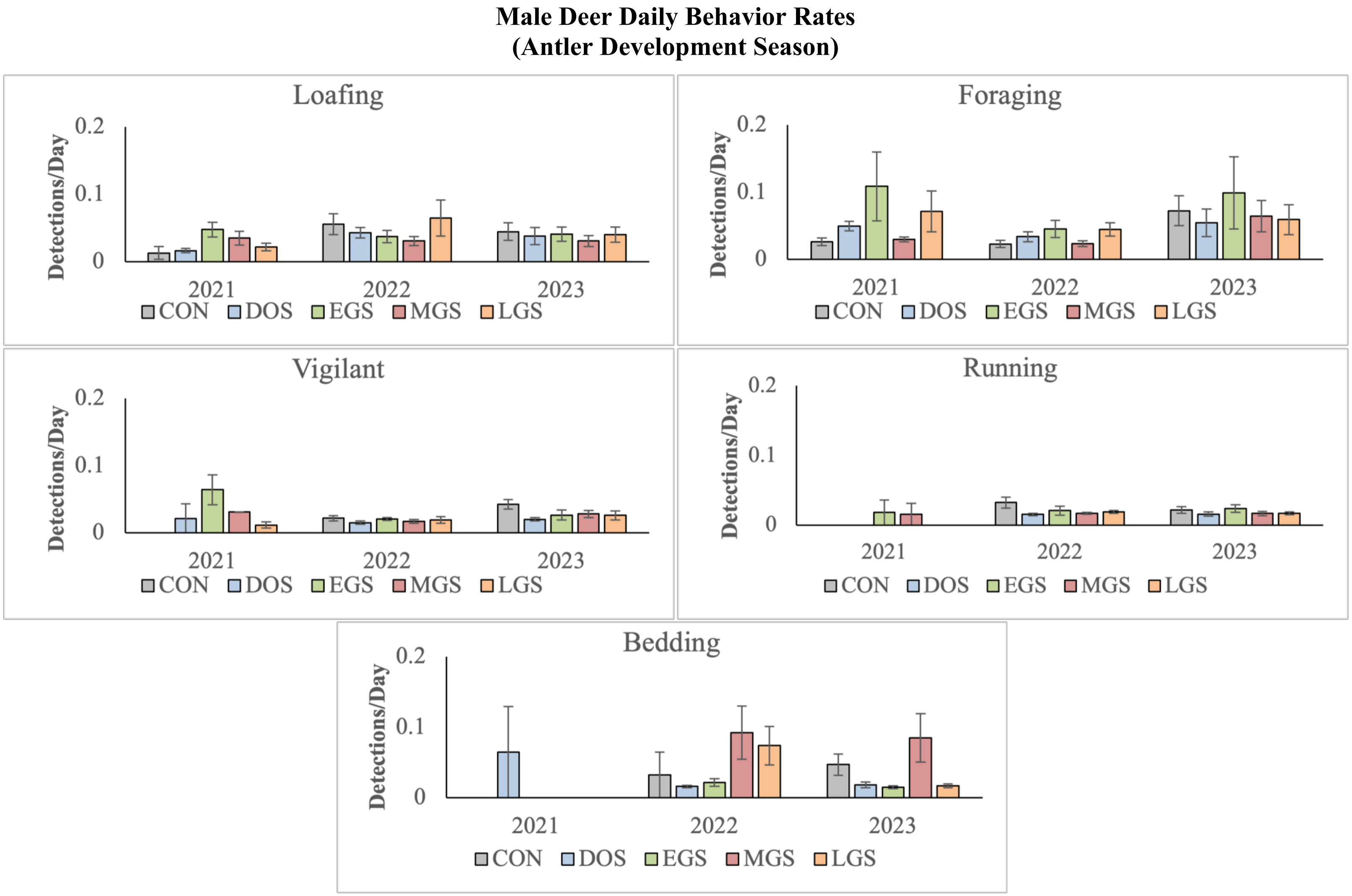

Figure A.32. Average daily male deer behavior detection rates in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the antler development season (May–July), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA

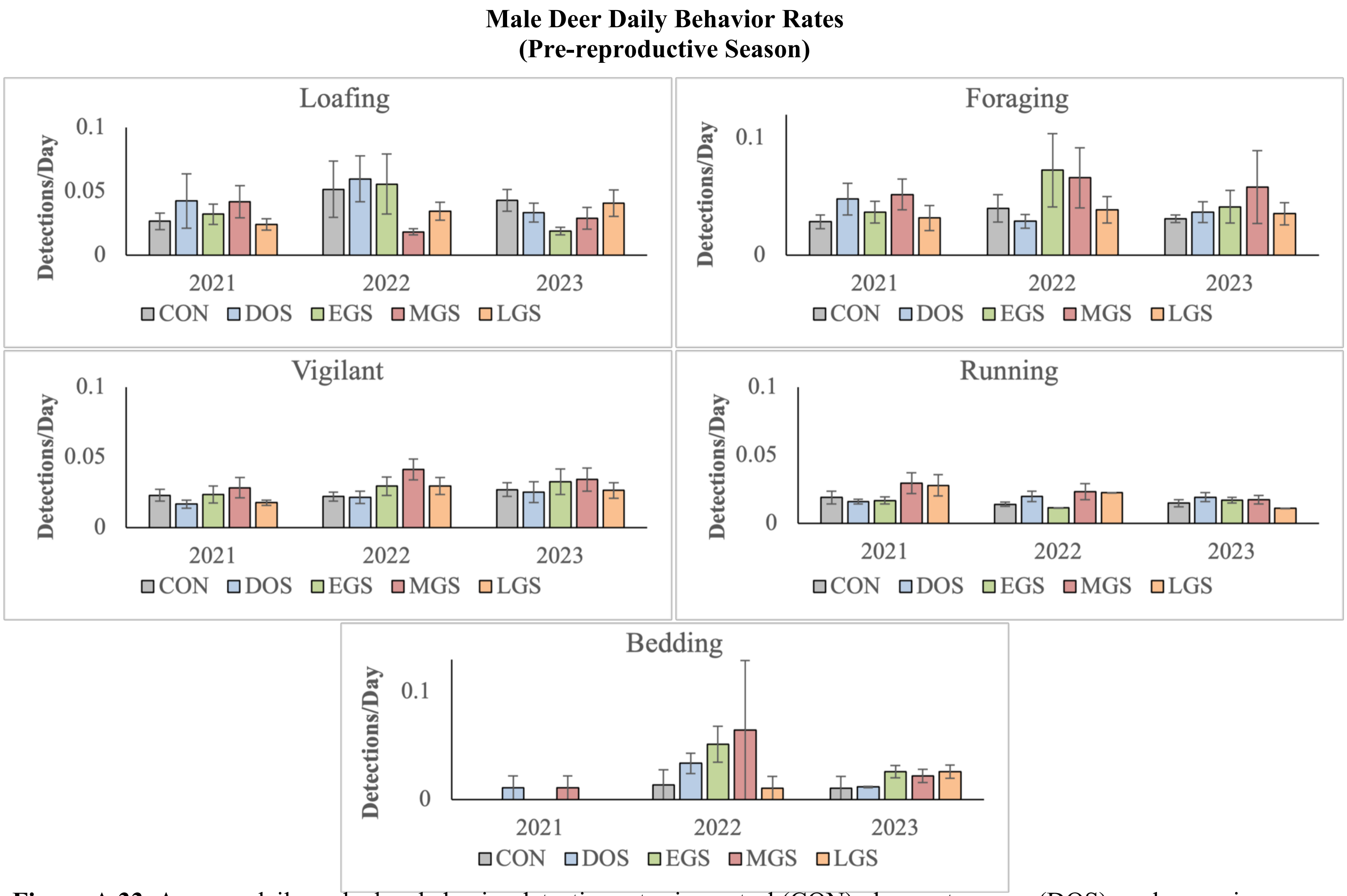

Figure A.33. Average daily male deer behavior detection rates in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), late growing-season (LGS) fire treatment units during the pre-reproductive season (August–September), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

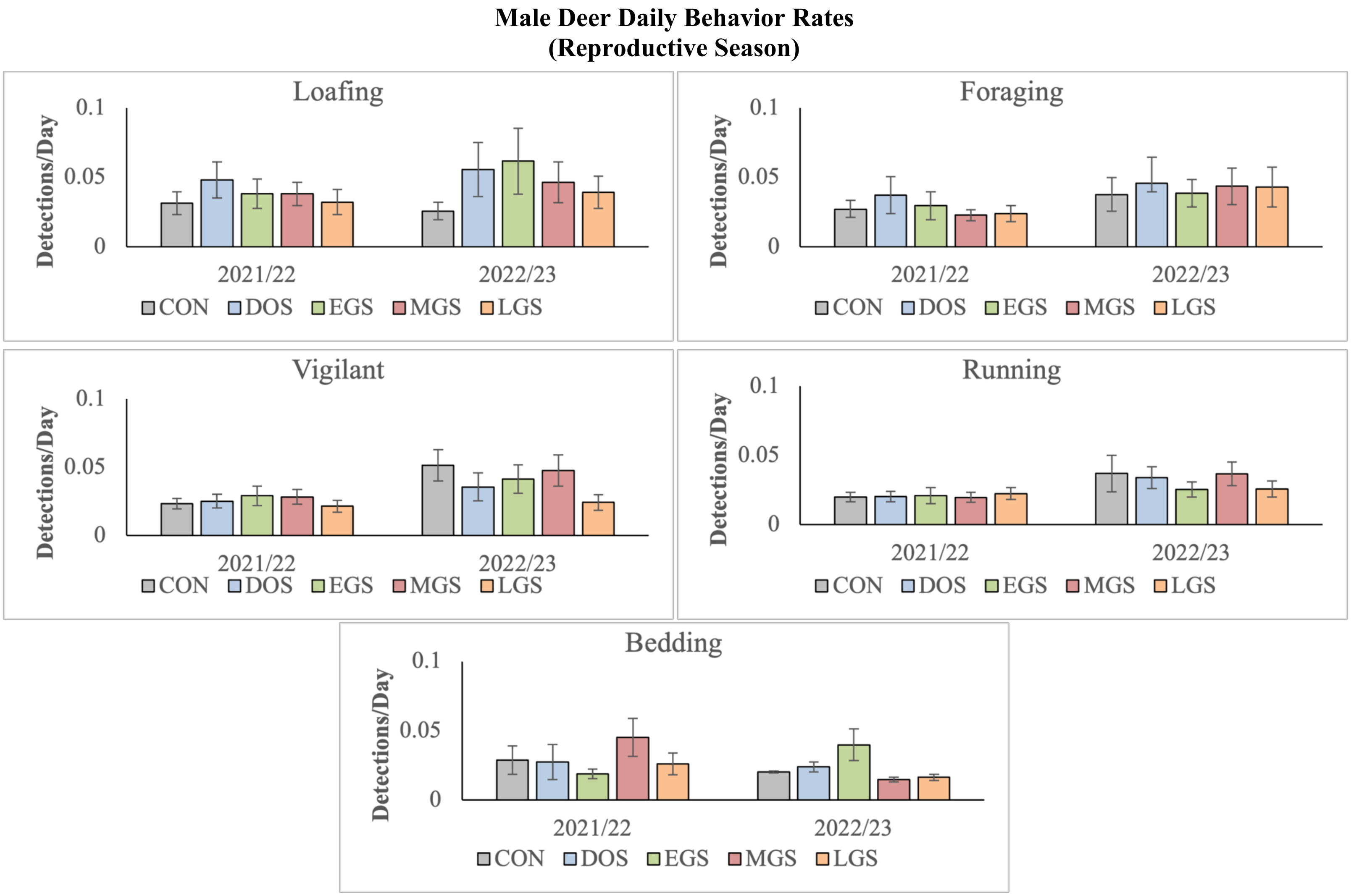

Figure A.34. Average daily male deer behavior detection rates in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the reproductive season (October–January), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

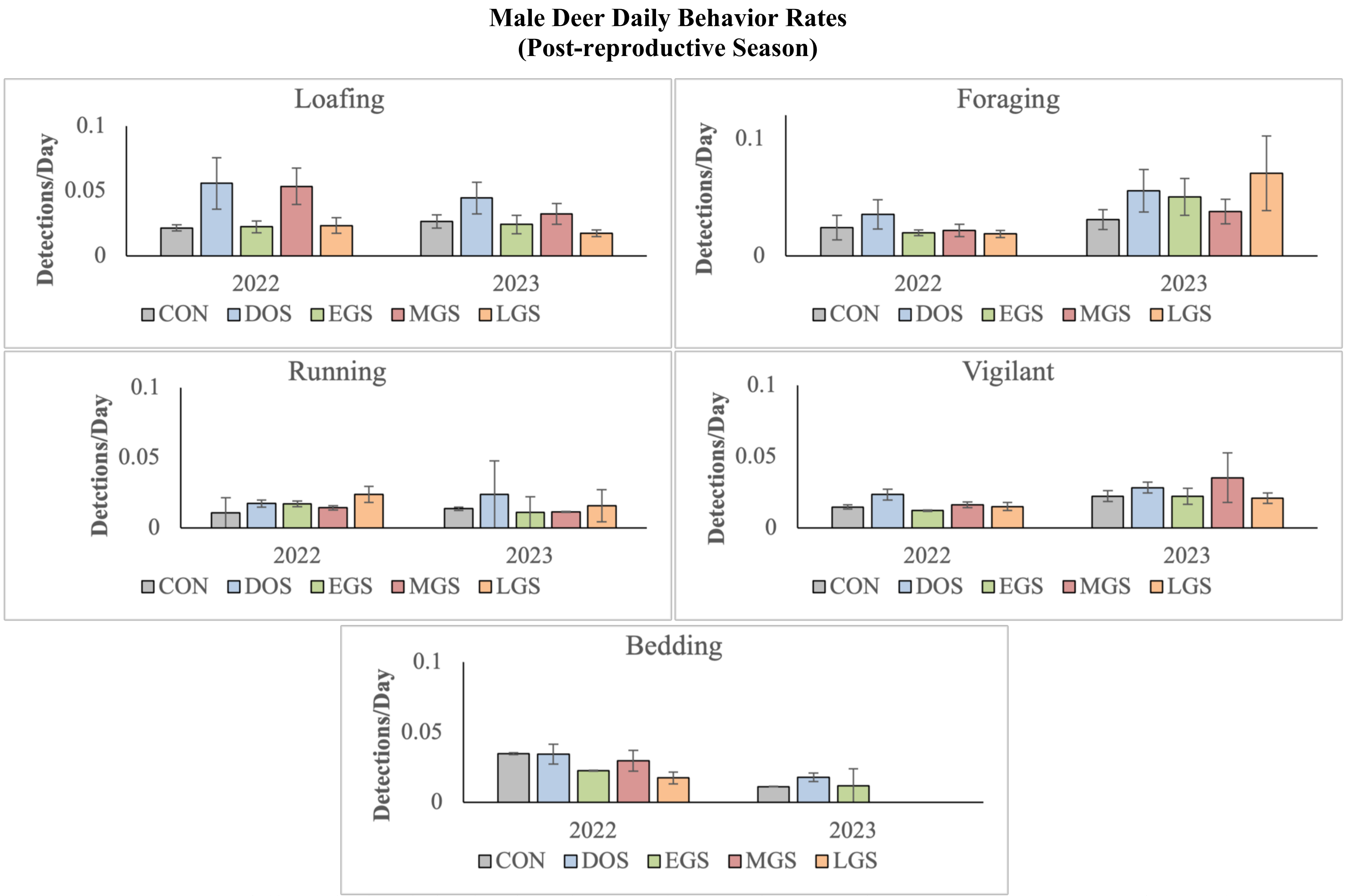

Figure A.35. Average daily male deer behavior detection rates in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the post-reproductive season (February–April), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

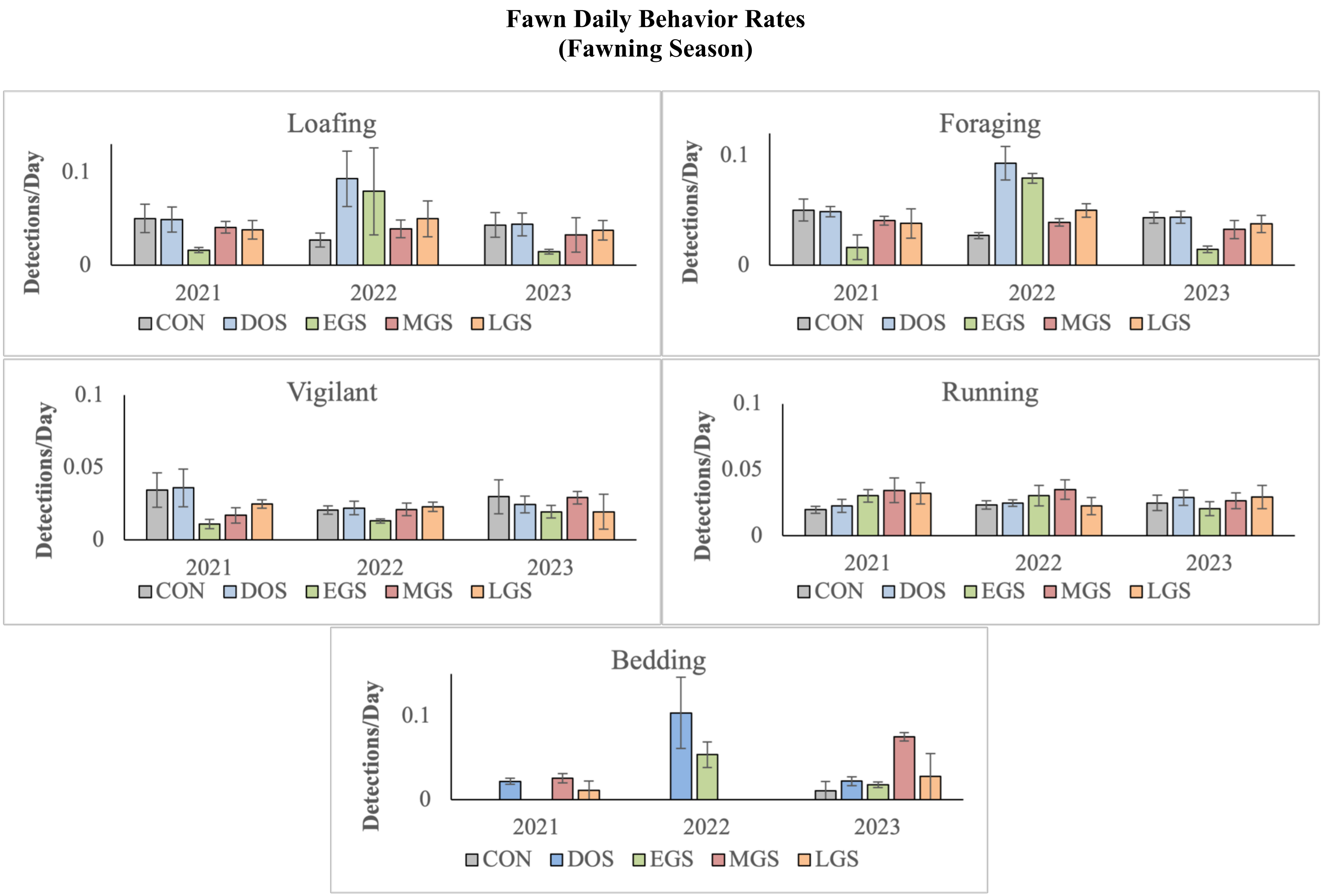

Figure A.36. Average daily fawn behavior detection rates in control (CON), dormant-season (DOS), early growing-season (EGS), mid-growing-season (MGS), and late growing-season (LGS) fire treatment units during the fawning season (May–September), 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

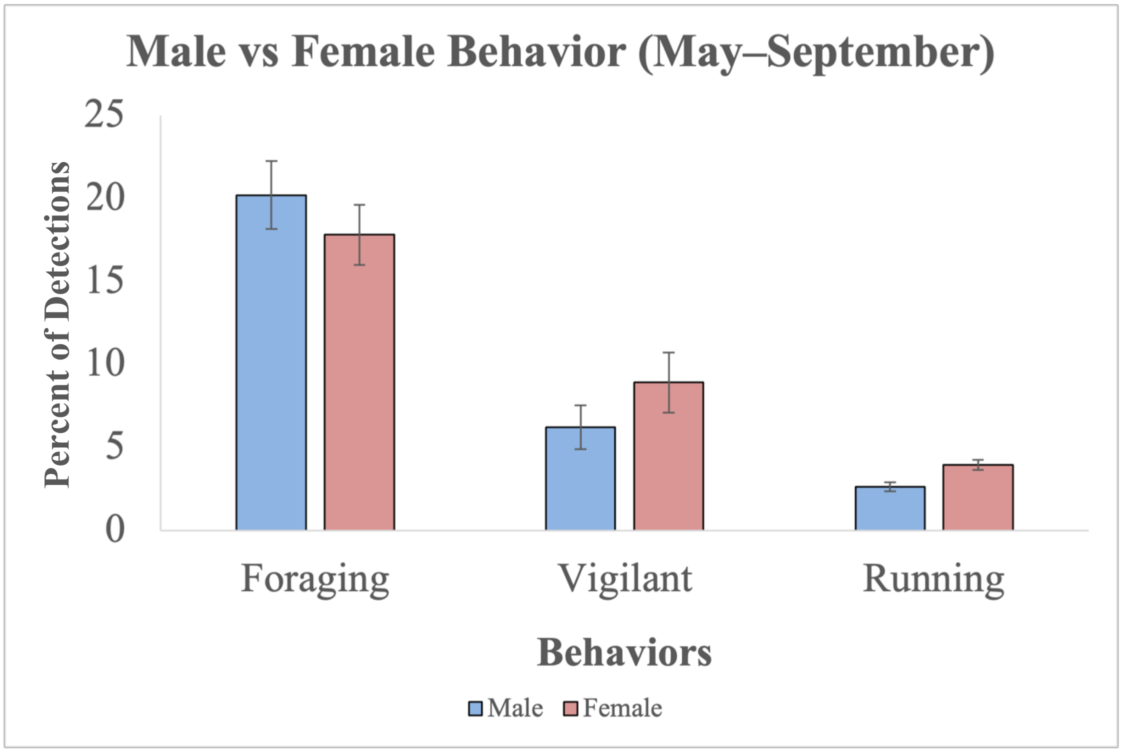

Figure A.37. Male versus female detections spent foraging, vigilant, and running during the months of May–September, 2021–2023, at nine study sites in Tennessee, Alabama, Mississippi, and South Carolina, USA.

APPENDIX B: ADDITIONAL INFORMATION FOR CHAPTER I

Table B.1. Top five predominant plant species at nine study sites across Tennessee, Alabama, Mississippi, and South Carolina, USA, June–July, 2020–2023.

Sites	Common Name	Scientific Name	Life form
Barbour	Loblolly pine	*Pinus taeda*	Tree
	American beautyberry	*Callicarpa americana*	Shrub
	Muscadine	*Vitis rotundifolia*	Vine
	Panicgrasses	*Panicum* spp.	Grass
	Saw-tooth blackberry	*Rubus pensilvanicus*	Bramble
Belfast	Loblolly pine	*Pinus taeda*	Tree
	Saw-tooth blackberry	*Rubus pensilvanicus*	Bramble
	Muscadine	*Vitis rotundifolia*	Grass
	Spike uniola	*Chasmanthium laxum*	Grass
	Trailing lespedeza	*Lespedeza repens*	Forb
Bridgestone	Shortleaf pine	*Pinus echinata*	Tree
	Spike uniola	*Chasmanthium laxum*	Grass
	Povertygrass	*Danthonia spicata*	Grass
	Broomsedge	*Andropogon virginicus*	Grass
	Saw-tooth blackberry	*Rubus pensilvanicus*	Bramble
Copiah	Loblolly pine	*Pinus taeda*	Tree
	Spike uniola	*Chasmanthium laxum*	Tree
	Saw-tooth blackberry	*Rubus pensilvanicus*	Bramble
	Broomsedge	*Andropogon virginicus*	Grass
	Japanese climbing fern	*Lygodium japonicum*.	Fern
Folsom	Loblolly pine	*Pinus taeda*	Tree
	Saw-tooth blackberry	*Rubus pensilvanicus*	Bramble
	Muscadine	*Vitis rotundifolia*	Vine
	Dogfennel	*Eupatorium capillifolium*	Forb
	Panicgrasses	*Panicum* spp.	Grass
Foothills	Shortleaf pine	*Pinus echinata*	Tree
	Blackgum	*Nyssa sylvatica*	Tree
	Broomsedge	*Andropogon virginicus*	Grass
	Lowbush blueberry	*Vaccinium angustifolium*	Shrub
	Red maple	*Acer rubrum*	Tree
Mason Bend	Loblolly pine	*Pinus taeda*	Tree
	Saw-tooth blackberry	*Rubus pensilvanicus*	Bramble
	Muscadine	*Vitis rotundifolia*	Vine
	Virginia creeper	*Parthenocissus quinquefolia*	Vine
	Poison ivy	*Toxicodendron radicans*	Vine
Triple Creek	Loblolly pine	*Pinus taeda*	Tree
	Sedge spp.	*Carex spp.*	Sedge
	American beautyberry	*Callicarpa americana*	Shrub
	Panicgrasses	*Panicum* spp.	Grass
	Rush spp.	*Juncus spp.*	Rush
Webb	Loblolly pine	*Pinus taeda*	Tree
	Panicgrasses	*Panicum* spp.	Grass
	Spike uniola	*Chasmanthium laxum*	Shrub
	Muscadine	*Vitis rotundifolia*	Vine
	Rush spp.	*Juncus spp.*	Rush

Table B.2. Akaike Information Criteria test to find best fitting model for female deer detections during the fawning (May–September) and post-reproductive (February–April) season showing covariates, number of parameter (*K*), Akaike Information Criteria (AIC), Delta AIC values, AIC Weight, and log-likelihood (log(L). Covariates have been log transformed to scale data with predictor variable.

Female deer					
Model	**K**	**AIC**	**ΔAIC**	**AIC Weight**	**log(L)**
Fawning season					
loggrass+logshrub+logtree+logmspa+logforbbiomass+lognuddless2+(1|Site)	9	5047.99	0	0.36	-2514.84
loggrass+logbramble+logshrub+logtree+logmspa+(1|Site)	8	5050.43	2.45	0.11	-2517.09
logforb+loggrass+logbramble+logshrub+logtree+(1|Site)	8	5056.26	8.27	0.01	-2520.00
logforb+loggrass+logbramble+logshrub+logtree+(1|Site)	9	5056.69	8.70	0	-2519.19
logforb+loggrass+logbramble+logtree+(1|Site)	7	5058.02	10.04	0	-2521.92
logforb+loggrass+logbramble+(1|Site)	6	5062.90	14.91	0	-2525.38
loggrass+(1|Site)	4	5063.60	15.62	0	-2527.77
logshrub+(1|Site)	4	5066.26	18.27	0	-2529.09
logtree+(1|Site)	4	5068.72	20.74	0	-2530.33
(1|Site)	3	5069.42	21.44	0	-2531.69

* loggrass = % grass coverage, logshrub = % shrub coverage, logtree = % tree coverage, logmspa = midstory stems per acre, lognuddless2 = % visual obstruction < 2 meters, logforb = % forb coverage, logbramble= % bramble coverage, logvine = % vine coverage, Site = study site, logforbbiomass = kg/ha of forb bioimass

Table B.3. Analysis of variance results including beta estimates (*β*), standard error (SE), 95% confidence interval (CI), and p-values for top model of female deer detections when vegetation had a significant effect during a biological season.

Female deer					
Variable	**β Estimate**	**SE**	**95% CI**		**P-value**
Fawning season					
logDoe	-1.450	0.390	-2.215	-0.682	<0.001
loggrass	-0.178	0.045	-0.268	-0.089	<0.001
logshrub	-0.109	0.053	-0.214	-0.006	0.039
logtree	-0.141	0.046	-0.232	-0.052	0.002
logmspa	0.077	0.037	0.004	0.149	0.036
logforbbiomass	0.049	0.023	0.003	0.094	0.036
lognuddless2	0.251	0.108	0.038	0.462	0.020

* logDoe = Detection rate of female deer, loggrass = % grass coverage, logshrub = % shrub coverage, logtree = % tree coverage, logmspa = midstory stems per acre, lognuddless2 = % visual obstruction < 2 meters, logforbbiomass = kg/ha of forb biomass

Table B.4. Akaike Information Criteria test to find best fitting model for male deer detections during the antler development season (May–July), showing covariates, number of parameter (*K*), Akaike Information Criteria (AIC), Delta AIC values, AIC Weight, and log-likelihood (log(L). Covariates have been log transformed to scale data with predictor variables.

Male deer					
Model	**K**	**AIC**	**ΔAIC**	**AIC Weight**	**log(L)**
Antler-growing season					
logforbbiomass+loggrass+logbramble+(1|Site)	6	1826.00	0	0.43	-906.86
loggrass+logbramble+(1|Site)	5	1827.64	1.64	0.19	-908.72
loggrass+(1|Site)	4	1829.54	3.54	0.07	-910.70
logforb+loggrass+logbramble+(1|Site)	6	1829.56	3.56	0.07	-908.64
logforb+loggrass+logbramble+logshrub+(1|Site)	7	1830.74	4.74	0.04	-908.18
logbramble+(1|Site)	4	1831.32	5.32	0.03	-911.59
logshrub+(1|Site)	4	1831.53	5.53	0.03	-910.66
logforb+loggrass+(1|Site)	5	1831.64	5.64	0.03	-908.63
logforb+loggrass+logbramble+logtree+(1|Site)	7	1831.78	5.78	0.02	-911.82
logforb+loggrass+logtree+logmspa+(1|Site)	7	1832.06	6.06	0.02	-908.84
(1|Site)	3	1875.91	49.91	0	-934.92

* loggrass = % grass coverage, logshrub = % shrub coverage, logtree = % tree coverage, logmspa = midstory stems per acre, lognuddless2 = % visual obstruction < 2 meters, logforb = % forb coverage, logbramble= % bramble coverage, logvine = % vine coverage, Site = study site, logforbbiomass = kg/ha of forb biomass

Table B.5. Akaike Information Criteria test to find best fitting model for male deer detections during the pre-reproductive season (August–September) showing covariates, number of parameter (*K*), Akaike Information Criteria (AIC), Delta AIC values, AIC Weight, and log-likelihood (log(L). Covariates have been log transformed to scale data with predictor variables.

Pre-reproductive season					
loggrass+logtree+lognuddless2+(1|Site)	6	1619.32	0	0.36	-803.49
logforb+loggrass+logbramble+(1|Site)	6	1621.33	0.74	0.21	-804.49
loggrass+logtree+logbiomass+logforbbiomass+logmspa+(1|Site)	7	1622.93	2.34	0.09	-804.24
logforb+loggrass+logbramble+logshrub+(1|Site)	7	1623.38	2.78	0.07	-804.46
logforb+loggrass+logbramble+logshrub+logtree+(1|Site)	8	1624.03	3.43	0.05	-803.72
logforb+loggrass+logbramble+logshrub+logtree+logvine+(1|Site)	9	1624.92	4.33	0.03	-809.09
logforb+loggrass+logbramble+logshrub+logtree+logvine+logmspa+(1|Site)	10	1626.97	6.37	0.01	-803.03
(1|Site)	3	1740.23	119.63	0	-867.07

* loggrass = % grass coverage, logshrub = % shrub coverage, logtree = % tree coverage, logmspa = midstory stems per acre, lognuddless2 = % visual obstruction < 2 meters, logforb = % forb coverage, logbramble= % bramble coverage, logvine = % vine coverage, Site = study site, logforbbiomass = kg/ha of forb biomass

Table B.6. Analysis of variance results including beta estimates (*β*), standard error (SE), 95% confidence interval (CI), and p-values for top model of male deer detections when vegetation had a significant effect during a biological season.

Male deer					
Variable	**β Estimate**	**SE**	**95% CI**		**P-value**
Antler-growing season					
logMale	-2.714	0.545	-3.783	-1.634	<0.001
logforbbiomass	0.102	0.052	-0.001	0.206	0.051
loggrass	0.238	0.108	0.024	0.450	0.028
logbramble	-0.282	0.118	-0.516	-0.051	0.017
Pre-reproductive season					
logMale	-3.606	0.425	-4.434	-2.756	<0.001
loggrass	0.318	0.100	0.119	0.513	0.001
logtree	0.097	0.071	-0.044	0.234	0.172

* logMale = Detection rate of male deer, loggrass = % grass coverage, logtree = % tree coverage, logforbbiomass = kg/ha of forb biomass, logbramble = % bramble coverage

Table B.7. Akaike Information Criteria test to find best fitting model for fawn detections during the fawning season (May–September) showing covariates, number of parameter (*K*), Akaike Information Criteria (AIC), Delta AIC values, AIC Weight, and log-likelihood (log(L). Covariates have been log transformed to scale data with predictor variable.

Fawn deer					
Model	**K**	**AIC**	**ΔAIC**	**AIC Weight**	**log(L)**
Fawning season					
logshrub+lognuddless2+(1|Site)	5	2773.65	0	0.70	-1381.77
logshrub+lognuddless2+logmspa+(1|Site)	6	2775.59	1.94	0.26	-1381.72
logbramble+(1|Site)	4	2780.63	6.98	0.02	-1386.28
logshrub+(1|Site)	4	2781.04	7.39	0.02	-1386.48
(1|Site)	3	2956.79	183.14	0	-1475.37

* logshrub = % shrub coverage, lognuddless2 = % visual obstruction < 2 meters, logmspa = midstory stems per acre, logbramble = % bramble coverage, Site = study site

Table B.8. Analysis of variance results including beta estimates (*β*), standard error (SE), 95% confidence interval (CI), and p-values for top model of fawn detections when vegetation had a significant effect during a biological season.

* logFawn = Fawn detection rate, lognuddless2 = % visual obstruction < 2 meters,

Fawn deer					
Variable	**β Estimate**	**SE**	**95% CI**		**P-value**
Fawning season					
logFawn	-4.661	0.810	-6.222	-3.029	<0.001
logshrub	-0.339	0.136	-0.608	-0.074	0.013
lognuddless2	0.675	0.208	0.255	1.075	0.001

logshrub = % shrub coverage

Table B.9. Analysis of variance results including beta estimates (*β*), standard error (SE), 95% confidence interval (CI), and p-values for top model of female deer loafing and foraging behavior when vegetation had a significant effect during the fawning season (May–September).

Female deer during fawning season—Vegetation effect					
Variable	**β Estimate**	**SE**	**95% CI**		**P-value**
Loafing					
logLoafing	-3.938	0.445	-4.813	-3.063	<0.001
loggrass	-0.310	0.056	-0.421	-0.201	<0.001
logshrub	-0.278	0.066	-0.401	-0.147	<0.001
logtree	-0.125	0.054	-0.233	-0.019	0.021
logmspa	0.156	0.048	0.061	0.250	0.001
Foraging					
logForaging	-1.318	0.424	-2.155	-0.908	<0.001
loggrass	-0.149	0.058	-0.265	-0.037	0.009
logtree	-0.131	0.048	-0.226	-0.038	0.006
logvine	0.123	0.044	0.037	0.208	0.005
logbiomass	-0.225	0.081	-0.384	-0.066	0.006
logforbbiomass	0.061	0.032	0.001	0.125	0.054

* logLoafing = detection rate of female deer loafing, logForaging = detection rate of female deer foraging, logVigilant = detection rate of female deer vigilance, logRunning = detection rate of female deer running, logBedding = detection rate of female deer bedding, loggrass = % grass coverage, logtree = % tree coverage, lognuddless2 = % visual obstruction < 2 meters, logforb = % forb coverage, logbramble= % bramble coverage, logvine = % vine coverage, logforbbiomass = kg/ha of forb biomass

Table B.10. Analysis of variance results including beta estimates (*β*), standard error (SE), 95% confidence interval (CI), and p-values for top model of female deer vigilant, running, and bedding behavior when vegetation had a significant effect during the fawning season (May–September).

Female deer during fawning season—Vegetation effect					
Variable	**β Estimate**	**SE**	**95% CI**		**P-value**
Vigilant					
logVigilant	-3.324	0.376	-4.097	-2.562	<0.001
logbramble	-0.114	0.095	-0.302	-0.072	0.233
logtree	-0.083	0.054	-0.201	0.073	0.113
logvine	0.129	0.058	0.016	0.243	0.025
Running					
logRunning	-6.235	0.663	-7.561	-4.958	<0.001
lognuddless2	0.561	0.174	0.223	0.906	0.001
logtree	-0.175	0.069	-0.311	-0.041	0.011
Bedding					
logBedding	-7.179	1.079	-9.363	-5.096	<0.001
lognuddless2	0.480	0.239	0.013	0.955	0.045

* logVigilant = detection rate of female deer vigilance, logRunning = detection rate of female deer running, logBedding = detection rate of female deer bedding, loggrass = % grass coverage, logtree = % tree coverage, lognuddless2 = % visual obstruction < 2 meters, logforb = % forb coverage, logbramble= % bramble coverage, logvine = % vine coverage, logforbbiomass = kg/ha of forb biomass

Table B.11. Analysis of variance results including beta estimates (*β*), standard error (SE), 95% confidence interval (CI), and p-values for top model of fawn deer behavior when vegetation had a significant effect during the fawning season (May–September).

Fawn deer during fawning season—Vegetation effect					
Variable	**β Estimate**	**SE**	**95% CI**		**P-value**
			Loafing		
logLoafing	-7.424	0.762	-8.926	-5.927	<0.001
loggrass	0.425	0.130	0.166	0.679	0.001
logbramble	0.403	0.180	0.050	0.760	0.025

logLoafing = detection rate of fawn deer loafing, loggrass = % grass coverage, logbramble = % bramble coverage

Table B.12. Analysis of variance results including beta estimates (β), standard error (SE), 95% confidence interval (CI), and p-values for top model of male deer behavior when vegetation had a significant effect during antler development season (May–July).

Male deer during antler developing season—Vegetation effect					
Variable	**β Estimate**	**SE**	**95% CI**		**P-value**
Foraging					
logForaging	-0.758	1.026	-2.624	1.396	0.463
loggrass	0.411	0.120	0.175	0.645	0.001
logbramble	-0.438	0.166	-0.763	-0.112	0.008
logvine	0.269	0.088	0.096	0.442	0.002
lognuddless2	-0.577	0.219	-1.007	-0.148	0.008
logbiomass	-0.441	0.160	-0.756	-0.127	0.006
logforbbiomass	0.177	0.065	0.049	0.304	0.007
Vigilant					
logVigilant	-4.032	1.204	-6.445	-1.699	<0.001
loggrass	0.473	0.181	0.127	0.839	0.008
logbramble	-0.396	0.186	-0.764	-0.034	0.032
logvine	0.263	0.118	0.035	0.499	0.026
lognuddless2	-0.633	0.273	-1.172	-0.099	0.020
Bedding					
logBedding	-12.722	2.233	-17.535	-8.643	<0.001
loggrass	1.214	0.489	0.316	2.263	0.013
logtree	0.765	0.331	0.114	1.436	0.021

*logForaging = detection rate of male deer foraging, logVigilant = detection rate of male deer vigilance, logBedding = detection rate of male deer bedding, loggrass = % grass coverage, logtree = % tree coverage, lognuddless2 = % visual obstruction < 2 meters, logbramble= % bramble coverage, logvine = % vine coverage, logforbbiomass = kg/ha of forb biomass, logbiomass = kg/ha of biomass

Table B.13. Analysis of variance results including beta estimates (*β*), standard error (SE), 95% confidence interval (CI), and p-values for top model of male deer behavior when vegetation had a significant effect during pre-reproductive season (August–September).

Male deer during pre-reproductive season—Vegetation effect					
Variable	**β Estimate**	**SE**	**95% CI**		**P-value**
Loafing					
logLoafing	-5.605	0.939	-7.422	-3.726	<0.001
loggrass	0.424	0.125	0.179	0.674	<0.001
logbramble	0.499	0.167	0.147	0.798	0.002
logtree	0.195	0.114	-0.028	0.423	0.089
lognuddless2	-0.456	0.254	-0.959	0.042	0.073
Vigilant					
logVigilant	-4.582	0.954	-6.485	-2.714	<0.001
loggrass	0.561	0.174	0.223	0.909	0.001
logbiomass	-0.303	0.163	-0.622	0.020	0.062
logshrub	-0.262	0.142	-0.543	0.019	0.064

* logLoafing = detection rate of male deer loafing, logVigilant = detection rate of male deer vigilance, loggrass = % grass coverage, logtree = % tree coverage, lognuddless2 = % visual obstruction < 2 meters, logbramble= % bramble coverage, logbiomass = kg/ha of biomass

Table B.14. Akaike Information Criteria test to find best fitting model for coyote detections during the fawning season showing covariates, number of parameter (*K*), Akaike Information Criteria (AIC), Delta AIC values, AIC Weight, and log-likelihood (log(L). Covariates have been log transformed to scale data with predictor variables.

Coyote					
Model	**K**	**AIC**	**ΔAIC**	**AIC Weight**	**log(L)**
		Fawning Season			
lognuddless2	4	1785.10	0.00	0.52	-888.52
lognuddless1.5	4	1786.50	1.39	0.26	-889.21
lognuddless1	4	1788.10	2.99	0.12	-890.01
lognuddless0.5	3	1788.96	3.86	0.07	-890.45
(1|Site)	2	1790.46	5.36	0.04	892.21

* lognuddless2 = % visual obstruction < 2 m, lognuddless1.5 = % visual obstruction < 1.5 m, lognuddless1 = % visual obstruction < 1 m, lognuddless0.5 = % visual obstruction < 0.5 m, Site = study site

Table B.15. Average ± SE of loafing, foraging, running, walking, vigilant, bedding, and other behavior observed by female deer in the control, dormant-season, early growing-season, mid-growing-season, and late growing-season fire treatment units during fawning/fawn rearing season (May–September) at all study sites (n = 9) in Tennessee, Alabama, Mississippi, and South Carolina, USA, July 2021–August 2023.

Percent time spent by female deer during fawning season								
Unit	**Year**	**Loafing**	**Foraging**	**Running**	**Walking**	**Vigilant**	**Bedding**	**Other**
Control	2021	26.53 ± 2.93	18.55 ± 3.04	4.73 ± 2.16	35.35 ± 5.47	8.93 ± 2.52	5.78 ± 4.13	0.13 ± 0.13
Dormant	2021	20.76 ± 3.23	22.77 ± 5.13	4.65 ± 0.98	37.86 ± 5.07	8.57 ± 2.77	5.27 ± 2.66	0.10 ± 0.10
Early growing	2021	22.15 ± 3.38	25.56 ± 4.89	1.84 ± 0.67	38.21 ± 3.66	11.29 ± 3.10	0.80 ± 0.66	0.15 ± 0.10
Mid-growing	2021	22.67 ± 4.82	17.46 ± 2.68	3.21 ± 0.75	41.48 ± 4.34	8.94 ± 2.81	4.87 ± 2.22	1.36 ± 0.81
Late growing	2021	18.36 ± 2.40	24.44 ± 3.09	2.67 ± 0.72	41.10 ± 3.80	7.90 ± 2.37	3.63 ± 1.17	1.90 ± 1.41
Control	2022	23.61 ± 3.89	16.97 ± 2.83	3.76 ± 0.88	43.20 ± 3.90	10.41 ± 2.56	1.66 ± 0.74	0.37 ± 0.21
Dormant	2022	30.86 ± 4.29	16.06 ± 9.48	5.13 ± 1.49	37.61 ± 3.94	7.00 ± 1.36	3.05 ± 1.53	0.29 ± 0.15
Early growing	2022	22.31 ± 4.81	22.66 ± 3.84	4.33 ± 1.32	41.55 ± 4.12	6.47 ± 1.06	2.63 ± 1.10	0.03 ± 0.03
Mid-growing	2022	27.71 ± 2.90	13.14 ± 2.89	5.41 ± 0.79	43.73 ± 3.74	7.65 ± 1.41	2.19 ± 0.81	0.17 ± 0.14
Late growing	2022	26.55 ± 4.40	15.12 ± 2.94	4.57 ± 1.56	42.66 ± 4.12	8.30 ± 1.44	2.07 ± 1.04	0.72 ± 0.35
Control	2023	30.17 ± 4.14	19.97 ± 4.33	4.28 ± 0.91	33.89 ± 2.23	9.22 ± 2.46	1.92 ± 0.89	0.55 ± 0.20
Dormant	2023	19.28 ± 4.36	19.85 ± 4.97	1.68 ± 0.47	39.61 ± 3.48	17.17 ± 3.69	1.61 ± 0.70	0.79 ± 0.36
Early growing	2023	15.44 ± 3.68	18.92 ± 4.36	3.36 ± 0.94	46.57 ± 4.75	13.63 ± 3.38	1.65 ± 1.00	0.42 ± 0.18
Mid-growing	2023	20.15 ± 4.37	19.93 ± 2.76	8.42 ± 2.38	39.40 ± 2.38	10.85 ± 2.56	1.09 ± 0.50	0.15 ± 0.15
Late growing	2023	15.13 ± 3.60	17.98 ± 2.55	4.08 ± 0.91	51.88 ± 3.32	8.60 ± 1.76	2.19 ± 1.75	0.14 ± 0.10

Table B.16. Average ± SE of loafing, foraging, running, walking, vigilant, bedding, and other behavior observed by male deer in the control, dormant-season, early growing-season, mid-growing-season, and late growing-season fire treatment units during the antler development season (May–July) at all study sites (n = 9) in Tennessee, Alabama, Mississippi, and South Carolina, USA, July 2021–August 2023.

Percent time spent by male deer during antler development								
Unit	**Year**	**Loafing**	**Foraging**	**Running**	**Walking**	**Vigilant**	**Bedding**	**Other**
Control	2021	8.33 ± 8.33	44.44 ± 15.91	0	47.22 ± 18.47	0	0	0
Dormant	2021	8.39 ± 4.21	50.04 ± 17.82	0	33.16 ± 19.04	2.11 ± 2.11	6.32 ± 6.32	0
Early growing	2021	19.65 ± 7.13	26.35 ± 7.82	4.17 ± 4.17	40.57 ± 12.85	9.27 ± 6.02	0	0
Mid-growing	2021	49.52 ± 16.91	8.33 ± 5.46	2.86 ± 2.86	35.71 ± 17.22	3.57 ± 2.48	0	0
Late growing	2021	23.62 ± 19.2	17.69 ± 7.68	0	53.06 ± 16.18	5.62 ± 3.92	0	0
Control	2022	21.84 ± 9.62	27.4 ± 11.57	3.40 ± 2.77	45 ± 12.69	1.95 ± 1.03	0.41 ± 0.41	0
Dormant	2022	24.55 ± 2.78	15.72 ± 2.84	7.18 ± 4.19	43.66 ± 4.28	5.81 ± 3.11	3.08 ± 1.48	0
Early growing	2022	21.48 ± 4.2	33.51 ± 4.54	5.67 ± 4.07	35.67 ± 5.42	0.71 ± 0.52	2.36 ± 2.36	0.61 ± 0.43
Mid-growing	2022	25.72 ± 7.04	6.07 ± 2.07	2.48 ± 1.82	57.55 ± 8.02	3.74 ± 2.25	4.13 ± 2.81	0.32 ± 0.32
Late growing	2022	28.05 ± 6.53	16.88 ± 3.50	1.60 ± 1.04	47.04 ± 8.85	3.09 ± 0.96	2.82 ± 1.85	0.53 ± 0.53
Control	2023	29.59 ± 11.56	22.20 ± 11.19	1.35 ± 0.87	39.89 ± 16.99	3.77 ± 2.57	2.72 ± 1.82	0.49 ± 0.49
Dormant	2023	25.87 ± 9.97	25.54 ± 5.61	2.55 ± 0.91	37.29 ± 6.64	6.39 ± 2.91	1.3 ± 1.02	1.07 ± 0.92
Early growing	2023	15.57 ± 3.53	30.75 ± 6.28	2.88 ± 1.39	43.27 ± 5.22	6.51 ± 2.85	0.42 ± 0.23	0.61 ± 0.31
Mid-growing	2023	24.42 ± 6.72	13.65 ± 4.23	3.7 ± 1.82	38.14 ± 4.68	14.98 ± 5.48	4.41 ± 2.37	0.69 ± 0.43
Late growing	2023	24.20 ± 7.50	20.16 ± 6.17	1.88 ± 1.03	44.61 ± 8.24	8.3 ± 3.33	0.55 ± 0.36	0.3 ± 0.3

Table B.17. Average ± SE of loafing, foraging, running, walking, vigilant, bedding, and other behavior observed by fawn deer in the control, dormant-season, early growing-season, mid-growing-season, and late growing-season fire treatment units during the fawning season (May–September) at all study sites (n = 9) in Tennessee, Alabama, Mississippi, and South Carolina, USA, July 2021–August 2023.

Percent time spent by fawns during fawning season								
Unit	**Year**	**Loafing**	**Foraging**	**Running**	**Walking**	**Vigilant**	**Bedding**	**Other**
Control	2021	30.70 ± 9.1	14.15 ± 2.36	12.46 ± 6.54	38.28 ± 7.07	4.41 ± 1.69	0	0 ± 0
Dormant	2021	17.43 ± 6.69	39.21 ± 12.14	15.09 ± 3.02	24.66 ± 6.13	2.17 ± 1.49	1.44 ± 0.73	0 ± 0
Early growing	2021	29.12 ± 7.31	10.44 ± 2.60	9.5 ± 3.81	50.47 ± 6.16	0.48 ± 0.48	0 ± 0	0 ± 0
Mid-growing	2021	21.97 ± 5.40	9.30 ± 2.90	23.13 ± 5.01	29.11 ± 6.49	11.12 ± 7.39	5.37 ± 4.95	0 ± 0
Late growing	2021	19.30 ± 6.62	11.39 ± 5.94	17.88 ± 6.15	37.98 ± 11.38	6.87 ± 4.21	6.58 ± 6.21	0 ± 0
Control	2022	20.74 ± 8.59	26.12 ± 13.91	7.38 ± 3.60	39.87 ± 9.84	5.88 ± 3.50	0	0 ± 0
Dormant	2022	32.39 ± 9.39	11.06 ± 6.49	19.95 ± 11.61	26.54 ± 4.78	8.29 ± 4.89	1.15 ± 1.15	0.63 ± 0.63
Early growing	2022	35.41 ± 12.42	5.66 ± 4.50	14.7 ± 3.78	34.38 ± 7.09	9.35 ± 3.78	0.51 ± 0.51	0 ± 0
Mid-growing	2022	28 ± 5.66	10.58 ± 2.28	23.46 ± 6.25	30.67 ± 6.07	6.81 ± 2.17	0 ± 0	0.48 ± 0.48
Late growing	2022	24.79 ± 6.84	2.55 ± 1.75	26.96 ± 7.59	27.75 ± 11.24	17.95 ± 10.89	0 ± 0	0 ± 0
Control	2023	6.37 ± 3.64	8.31 ± 4.45	28.42 ± 5.37	46.14 ± 5.81	8.68 ± 6.24	2.08 ± 2.08	0 ± 0
Dormant	2023	23.46 ± 9.37	4.00 ± 2.65	22.6 ± 6.24	39.49 ± 6.33	7.5 ± 5.70	2.38 ± 2.38	0.58 ± 0.58
Early growing	2023	28.06 ± 9.81	0.83 ± 0.83	31.67 ± 11.3	21.39 ± 13.14	8.06 ± 5.17	10 ± 10	0 ± 0
Mid-growing	2023	16.49 ± 6.7	6.44 ± 3.24	20.93 ± 9.78	41.03 ± 15.72	14.31 ± 7.98	0.81 ± 0.81	0 ± 0
Late growing	2023	32.06 ± 4.60	5.85 ± 3.96	16.54 ± 7.09	35.19 ± 3.53	6.77 ± 4.87	2.86 ± 2.86	0.74 ± 0.74

CONCLUSION

Fire is a common disturbance practice used to restore and maintain fire-dependent ecosystems. Pine woodland restoration efforts in the southeastern United States aim to restore the ecological function these ecosystems provide on the landscape for open pine woodland-dependent species, as well as other species that may use and benefit from them and are popular among landowners. The white-tailed deer is the most hunted and managed game species in the eastern United States, and management practices beneficial to deer could be implemented across a large geographic area and impact many other wildlife species. When restoring fire to pine woodlands, managers should consider resource requirements of deer throughout the year. Our study results indicate season of burning has a differential effect on vegetation composition and structure and thereby influences deer behavior and use of pine woodlands. Our study provided a more nuanced understanding of pyric herbivory theory as we detected an asymmetrical response to fire between sexes based on season of implementation. Male deer responded most positively following fire in the early portion of the growing season as resprouting vegetation was most digestible and selected while they were growing antlers with elevated nutrient requirements. This pattern of foraging continued into late summer following fire implemented during the mid-portion of the growing season. Male deer spent more time foraging than female deer during the growing season, which indicated a trade-off for females during the fawning season. Male deer behavior exhibited less risk associated with predation compared to female deer. Male deer used recently burned areas to access higher-quality forage and exhibited less vigilant behavior even though they were more likely to encounter coyotes in those areas. Coyote detections were greater in the early growing-season treatment units immediately following fire. Our results support the optimal foraging theory with coyotes choosing to travel in recently burned areas which requires less energetic demand compared to moving through dense vegetation to find prey. Female deer exhibited a greater perceived risk of predation within recently burned areas during the fawning season as female deer spent less time loafing and more time vigilant compared to the year following fire. Female deer selected areas with greater visual obstruction and a more developed midstory for their fawns. Other life history requirements than food availability must be taken into consideration when trying to understand species response to fire.

Reducing burn-unit size such that units are smaller than a female deer core range size during the fawning season may help increase fawn survival. Additionally, dispersing smaller burn units through the growing season over a management area could provide high-quality forage to more animals during the period of their greatest nutritional requirements. Moreover, it likely would promote greater vegetation and wildlife diversity. We believe our results clearly indicate no one season of fire or fire-return interval is best, and varying the timing of burning throughout the year is critical to better match stochastic disturbance events, which is more similar to historic disturbance caused by lightning and humans. Finally, our study results provide clear evidence of trade-offs associated with predator-prey interaction and availability of suitable cover and food resources.

VITA

Spencer G. Marshall was born in Galax, Virginia. Most of his time spent in the Blue Ridge Mountains included hunting white-tailed deer and fly fishing for native brook trout. His passion for the outdoors led him to pursue his Bachelor of Science in Fish and Wildlife Conservation with a concentration in Wildlife Conservation and minor in Forestry from Virginia Polytechnic Institute. After completing his degree from Virginia Polytechnic Institute, he pursued his Master of Science degree from The University of Tennessee, Knoxville.