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Assessing the Effects of the Spring Hunting Season Start Date on Wild Turkey Seasonal Productivity and Hunter Behavior

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To the Graduate Council:

I am submitting herewith a thesis written by Joseph Quehl entitled "Assessing the Effects of the Spring Hunting Season Start Date on Wild Turkey Seasonal Productivity and Hunter Behavior." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

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Assessing the Effects of the Spring Hunting Season Start Date on Wild Turkey Seasonal Productivity and Hunter Behavior

A Thesis Presented for the

Master of Science

Degree

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Joseph O'Hearn Quehl

December 2023

This thesis is dedicated to my dog, Rye. Hopefully, I’ll be able to afford a house with a big yard for you now!

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Abstract

Many states throughout the Southeast have documented declines in wild turkey (*Meleagris gallopavo*) harvest and estimates of recruitment in poult-per-hen ratios. Wild turkey populations are driven by seasonal productivity, so the decline in these parameters may indicate a decline in the overall population. One hypothesis as to why we are seeing a reduction in productivity and a potential population decline is that the spring hunting season is disrupting the reproductive cycle by harvesting too many males before they have had the opportunity to breed, or by harvesting dominant males and disrupting the social hierarchy of the flock. Our objectives for this study were to 1) document the effects of a two-week delay in the opening of the hunting season on wild turkey seasonal productivity; and 2) determine if hunter's behavior, success, or satisfaction changed in response to the delayed hunting season. We radio tagged 432 individual hens from 2017 to 2022 (623 hen-years) in a Before-After-Control-Impact study design to assess nesting activity and we documented 446 initial nests. Based on AIC model selection and linear mixed effect models, we documented no effect of the season start date on nest incubation initiation (nesting rate, P = 0.83), portion of eggs to hatch from a nest (P = 0.33), or nest success (β [beta] = 0.225, $SE_{\beta \text{ [beta]}}$ = 0.256). Furthermore, we documented no effect on poult survival during the first 28 days of life (Δ[delta]AICc = 10.16), or hen survival during the nesting season (Δ[delta]AICc = 6.945). Additionally, we mailed surveys to the same 2,000 turkey hunters in south-middle Tennessee, USA each year from 2017–2022. Hunters in delayed counties heard 33.6% fewer gobbles per trip (P = 0.03) after the season delay, but hunter satisfaction remained the same before and after the season delay (P = 0.18). We documented no biological reason to support a later hunting season in Tennessee. State agencies should collect vital rate data and analyze the effects of various season start dates before changing the turkey hunting season framework.

Table of Contents

List of Tables

Part I.

Part II.

Part III.

List of Figures

Part I: Introduction

The eastern wild turkey (*Meleagris gallopavo silvestris*) is a conservation success story in the United States and is a bird of cultural and economic importance (Dickson 1992, Kennamer et al. 1992, Chapagain et al. 2020). In Tennessee the wild turkey was only found in 18 of 95 counties in 1952, but after translocations efforts from 1951 to 2004, wild turkeys were found in all 95 counties (Shields et al. 2020). Since wild turkey population restoration efforts ended in 2005 in Tennessee, populations have been monitored via changes in reported spring harvest and summer poult-per-hen ratios (Shields et al. 2020).

Recently concern has been expressed that wild turkey populations are declining throughout the Southeast. State agencies and managers have seen the signs of this potential decline through declines in harvest and poult-per-hen ratios (Byrne et al. 2015, Chamberlain et al. 2022). Based on agency surveys, Chamberlain et al. (2022) reported an 18–20% decline in population size of reporting states in the U.S from 2013 to 2019. This decline has been of concern in Tennessee because of low poult-per-hen ratios, and in parts of the state, declining harvest. In 2020, Tennessee reported a poult-per-hen ratio of 1.4 (Z. Danks, Proceedings of Southeastern Association of Fish and Wildlife Agencies Wild Turkey Group Annual meeting, unpublished report), much lower than the estimated 2.0 for stable populations (Vanglider and Kurzejeski 1995). Multiple states throughout the Southeast have reported poult-per-hen ratios below the estimated 2.0 required for stable populations, and Byrne et al. (2015) documented that poults-per-hen have been declining for decades. Hen survival and reproductive rates are driving forces behind wild turkey population growth (Vanglider and Kurzejeski 1995, Londe et al. 2023), so seeing this decline in productivity is potentially concerning for many state agencies.

There has been no identified singular cause for the decline in turkey productivity throughout the Southeast. Multiple hypotheses have been proposed including increases in native and non-native predator communities (Hughes et al. 2007, Sanders et al. 2017), diseases associated with changes in land management practices (spreading of chicken litter, Gerhold et al. 2016), density-dependent population regulation (Byrne et al. 2015), potential impacts of climate change (Boone et al. 2023), and that spring hunting is negatively affecting seasonal productivity (Healy and Powell 1999, Isabelle et al. 2018). Understanding the decline in productivity is a priority for state agencies as wild turkey hunting is a popular pastime (>2,000,000 hunters annually nationwide, Chamberlain et al. 2022) and a revenue-generating activity, contributing $45 million annually in economic benefit to the state of Tennessee (Chapagain et al. 2020).

Wild turkeys are the only gamebird in the United States that is hunted during its reproductive season so timing of the hunting season potentially could impact the reproductive cycle (Borg et al. 2015). Six state agencies in the Southeast (10 states nationwide) have moved their spring hunting season five or more days later since 2017 in response to the potential effects of hunting (Southeast: AL, AR, GA, LA, OK, TN; Nationwide: MI, MT, SD, WY; Figure 1.1, Table 1.1). Many of the southeastern states have delayed their hunting season presumably to improve productivity, but there have been no studies to show a correlation between the season start date and wild turkey seasonal fecundity. This lack of information has been identified as a considerable knowledge gap in wild turkey management (Whitaker et al. 2005, Isabelle et al. 2018, Londe et al. 2023).

Regardless, there are two main tenets of this untested hypothesis: first, that hunters are removing reproductively active males prior to breeding and causing reduced productivity, and second, when a male is harvested, it may disrupt the social hierarchy of the flock and subdominant males may not be readily replacing the harvested males (Isabelle et al. 2018). One of the criticisms of this theory is that hunting season start date has remained relatively consistent for decades, and over that time, turkey populations have increased and decreased. In Tennessee, for example, the spring hunting season has started the Saturday closest to 1 April since 1986 and, during this time, turkey populations increased exponentially from the mid-1980's to 2006 (Figure 1.2). Despite the lack of data-driven support for this hypothesis, multiple state agencies have delayed their hunting season in an effort to improve wild turkey seasonal productivity in their area.

The general goal behind setting spring wild turkey hunting season start dates is to maximize hunter satisfaction and minimize the risk of hens being harvested or causing nest abandonment (Healy and Powell 1999, Casalena et al. 2016, Gonnerman et al. 2022). State agencies try to maximize hunter satisfaction by timing the hunting season with peak gobbling activity. Gobbling activity is believed to be bimodal with one peak before hens begin nesting and another peak after hens begin incubating (Hoffman 1990). Some states time their spring hunting season to coincide with the peak in gobbling prior to nest incubation because gobbling is a strong predictor of hunter satisfaction (Cartwright and Smith 1990, Gruntorad et al. 2020). To minimize the potential risk of hens being harvested, however, Healy and Powell (1999) recommended that the start date coincide with peak nest incubation initiation, so a majority of hens are incubating a nest and are less likely to be illegally or legally harvested (bearded hens) during the season. This concern, however, is not supported in the literature. Balancing hunter satisfaction and the biological needs of the hunted species is the goal of any regulation change, so understanding how the hunting season is impacting wild turkey productivity is important for conservation of the species.

The goal of this study was to investigate the impact of a later spring wild turkey hunting season and assess seasonal productivity within south-middle Tennessee. With any turkey hunting regulation change there are two types of responses; one is how the target species respond to the change and second, how hunters respond. Our first objective was to investigate how delaying the start date of the spring hunting season by two-weeks impacted seasonal productivity of wild turkey in south-middle Tennessee. Our second objective was to determine how hunters changed their behavior in response to the two-week season delay and how it affected their success, efficiency, and satisfaction. With this information, we aim to provide recommendations to state agencies about how to optimize the spring hunting season framework to provide high quality hunting opportunities while avoiding negative impacts to hen nesting rates, nest success or hatchability of wild turkey nests.

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APPENDIX

Table 1.1. Sources used to determine wild turkey hunting season start dates of each state for the given year in Figure 1.1.

State	Source for each season 2017	2022	2023
Alabama	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.outdooralabama.com/seasons-and-bag-limits/turkey-season
Arizona	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://azgfd-portal-wordpress-pantheon.s3.us-west-2.amazonaws.com/wp-content/uploads/archive/2023-Spring-Regulations_220901.pdf
Arkansas	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.huntingseasonhq.com/arkansas-hunting-seasons/
California	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://wildlife.ca.gov/News/californias-spring-wild-turkey-season-fast-approaching1
Colorado	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://cpw.state.co.us/Documents/RulesRegs/Brochure/turkey.pdf
Connecticut	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.huntersguides.com/seasons/connecticut-hunting-seasons
Delaware	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://dnrec.alpha.delaware.gov/fish-wildlife/hunting/wild-turkeys/hunting/#:~:text=The%202023%20spring%20wild%20turkey,set%20for%20April%201%2C%202023.
Florida	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://myfwc.com/hunting/turkey/hunt-without-quota-permit/#:~:text=The%202023%20spring%20wild%20turkey,and%20runs%20through%20April%2023.
Georgia	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://georgiawildlife.com/sites/default/files/wrd/pdf/hunting/2022-23%20Season%20Dates.pdf
Hawaii	https://www.outdoorlife.com/2017-spring-turkey-forecast/	https://dlnr.hawaii.gov/blog/2022/02/08/nr22-018/	NA
Idaho	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.huntingseasonhq.com/idaho-hunting-seasons/
Illinois	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www2.illinois.gov/dnr/hunting/Documents/2023%20Spring%20Turkey%20Hunting%20Information%20Insert%20Final.pdf
Indiana	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.in.gov/dnr/fish-and-wildlife/hunting-and-trapping/wild-turkey-hunting-biology-and-management/#:~:text=Indiana%20spring%20wild%20turkey%20season,April%2022%20and%2023%2C%202023.
Iowa	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.iowadnr.gov/Hunting/Turkey-Hunting
Kansas	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://ksoutdoors.com/Services/Publications/Hunting/2023-Regulations-SPRING-TURKEY
Kentucky	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://fw.ky.gov/Hunt/Pages/Spring-Turkey-Hunting.aspx#:~:text=Hunting%20Dates%20Season%20Dates,the%20first%20Saturday%20in%20April.
Louisiana	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.wlf.louisiana.gov/assets/Resources/Publications/Regulations/2022-2023-Hunting-Regs-low-res.pdf

Table 1.1 (cont.)

Maine	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.maine.gov/ifw/hunting-trapping/hunting/laws-rules/season-dates-bag-limits.html
Maryland	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://dnr.maryland.gov/huntersguide/Documents/Hunting_Seasons_Calendar.pdf
Massachusetts	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.mass.gov/info-details/wild-turkey-hunting-regulations
Michigan	https://www.outdoorlife.com/2017-spring-turkey-forecast/	https://www.michigan.gov/dnr/-/media/Project/Websites/dnr/Documents/LED/digests/Spring_Turkey_Digest.pdf?rev=51afcdb379c743f3921091fe3b76d45a	NA
Minnesota	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.eregulations.com/minnesota/hunting/turkey-hunting-seasons
Mississippi	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.huntingseasonhq.com/mississippi-hunting-seasons/
Missouri	https://www.outdoorlife.com/2017-spring-turkey-forecast/	https://mdc.mo.gov/hunting-trapping/species/turkey	NA
Montana	https://www.montanaoutdoor.com/2017/04/shoot-turkey-leave-leg-season-starts-april-8-2017/	https://fwp.mt.gov/binaries/content/assets/fwp/hunt/regulations/2022/2022-upgbrd-final-web.pdf	NA
Nebraska	https://www.outdoorlife.com/2017-spring-turkey-forecast/	http://outdoornebraska.gov/wildturkey/	NA
Nevada	http://epubs.nsla.nv.gov/statepubs/epubs/31428003031750-2017.pdf	NA	https://www.eregulations.com/nevada/hunting/small-game/wild-turkey-regulations
New Hampshire	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.wildlife.state.nh.us/hunting/hunt-dates.html
New Jersey	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.huntingseasonhq.com/new-jersey-hunting-seasons/
New Mexico	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.wildlife.state.nm.us/download/publications/rib/2022/hunting/2022_2023-New-Mexico-Hunting-Rules-and-Info.pdf
New York	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.dec.ny.gov/outdoor/29461.html
North Carolina	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.ncwildlife.org/Portals/0/Hunting/Documents/BG%20Season%20Dates/2022-23_Turkey_Season_Dates.pdf?ver=Y-8ttrkgnsy21NjBNr_VoA%3D%3D
North Dakota	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://gf.nd.gov/hunting/turkey
Ohio	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://ohiodnr.gov/discover-and-learn/safety-conservation/about-ODNR/news/ohio-wildlife-council-approves-2022-23-hunting-seasons#:~:text=Spring%202023%20wild%20turkey%20hunting%20seasons&text=April%2022%2DApril%2030%2C%202023,minutes%20before%20sunrise%20to%20sunset.

Table 1.1 (cont.)

Oklahoma	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.wildlifedepartment.com/hunting/seasons
Oregon	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://myodfw.com/game-bird-hunting/seasons
Pennsylvania	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.pgc.pa.gov/HuntTrap/Law/Pages/2022-23%20Seasons%20and%20Bag%20Limits.aspx
Rhode Island	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.eregulations.com/rhodeisland/hunting/turkey-hunting
South Carolina	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.eregulations.com/southcarolina/hunting/turkey-regulations
South Dakota	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://gfp.sd.gov/turkey/
Tennessee	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.tn.gov/twra/hunting/big-game/turkey.html
Texas	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://tpwd.texas.gov/regulations/outdoor-annual/hunting/general-regulations/2022_2023_hunting_seasons
Utah	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://wildlife.utah.gov/guidebooks/2022-23_upland_turkey.pdf
Vermont	https://www.outdoorlife.com/2017-spring-turkey-forecast/	https://vtfishandwildlife.com/hunt/hunting-and-trapping-opportunities/wild-turkey	NA
Virginia	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://dwr.virginia.gov/hunting/regulations/turkey/
Washington	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://www.eregulations.com/washington/hunting/game-bird/wild-turkey-seasons
West Virginia	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://wvdnr.gov/wp-content/uploads/2022/07/2022.07.01-DNR_HuntingTrapping_Regulations.pdf
Wisconsin	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://dnr.wisconsin.gov/topic/hunt/dates
Wyoming	https://www.outdoorlife.com/2017-spring-turkey-forecast/	NA	https://wgfd.wyo.gov/Hunting/Hunt-Planner/Wild-Turkey/Wild-Turkey-Map

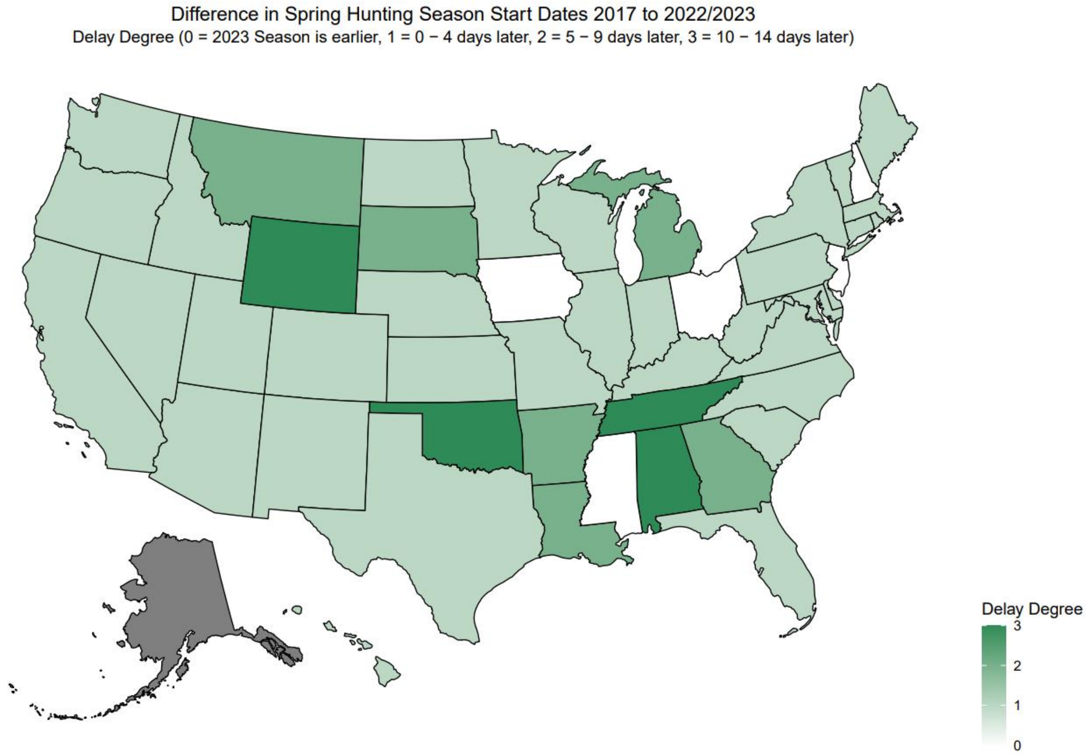

Figure 1.1. Differences in spring wild turkey hunting season start dates from the 2017 season to the 2022 or 2023 season across all states in the U.S. grouped by earlier (white, 0), 0–4 (no change, 1), 5–9 (2), 10–14 days later (3) with darker green colors representing longer season delays per state. Sources for dates can be found in Table 1.1.

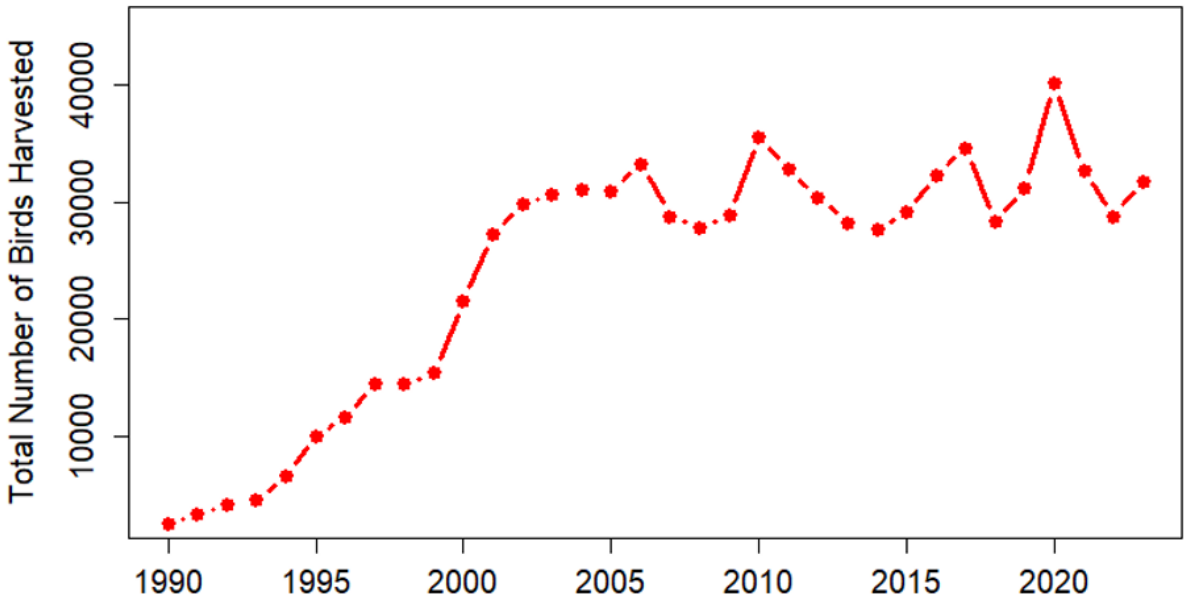

Figure 1.2. Annual reported spring harvest of wild turkeys in Tennessee from 1990–2023.

Part II: Assessing the Relationship between Spring Wild Turkey Hunting Season Dates and Wild Turkey Productivity

ABSTRACT

Ten state wildlife management agencies in the United States, including six within the Southeast, have delayed their spring wild turkey (*Meleagris* gallopavo) hunting season since 2017 by five or more days to address concerns related to potential effects of hunting on wild turkey seasonal productivity. One hypothesis posits that if the spring hunting season is too early, there may be insufficient time for males to breed hens before being harvested. We conducted an experiment to determine if delaying the wild turkey hunting season by two weeks in south-middle Tennessee would affect various reproductive rates, such as proportion of hens nesting, nesting chronology, portion of eggs to hatch, nest success, poult survival, and hen survival. In 2021 and 2022, the Tennessee Fish and Wildlife Commission experimentally delayed the spring hunting season to open 14 days later than normal in Giles, Lawrence, and Wayne counties. We monitored reproductive rates from 2017 to 2022 in these three counties as well as two adjacent counties, Bedford and Maury, that were not delayed. We used a Before-After-Control-Impact design to analyze the proportion of hens nesting, clutch size, hatchability, nest success, poult survival, and hen survival with linear mixed-effect models and AIC model selection to determine any relationship between the 14-day delay and reproductive parameters. We detected no relationship ($P > 0.05$) between the 14-day delay and any individual reproductive parameter. The traditional Tennessee start date (the Saturday closest to 1 April) has been in place since 1986 while the turkey harvest increased exponentially and more recently stabilized. Our data indicate that moving the start of the hunting season from a period prior to peak nest initiation to two weeks later to coincide with peak nest initiation and the onset of incubation resulted in similar levels of productivity in wild turkey flocks.

INTRODUCTION

Declining populations of wild turkeys is an important management issue in Tennessee and other states, because turkey hunting is a popular activity and hunters strongly prefer robust populations to provide quality hunting opportunities. Many hunters and landowners have noticed declining observations of wild turkeys on their properties in parts of Tennessee (R. Shields, Tennessee Wildlife Resources Agency, unpublished report), but causes for the perceived population declines are unknown and may differ from one area to another. Byrne et al. (2015) reported wild turkey productivity, as evidenced by poult per hen ratios, has been declining since 1990 in Tennessee and throughout the Southeast for decades. Vanglider and Kurzejeski (1995) estimated >2.0 poults per hen in the fall were required to maintain a stable population, and most states in the Southeast now are reporting ratios less than that. At the 2021 Southeast Association of Fish and Wildlife Agencies Wild Turkey Working Group meeting, agency biologists from Alabama, Georgia, Mississippi, North Carolina and Tennessee reported 1.6, 1.5, 1.7, 1.3, and 1.4 poults per hen, respectively, for 2020 (Z. Danks, Southeast Association of Fish and Wildlife Agencies Wild Turkey Working Group, unpublished report).

Multiple hypotheses have been developed to explain the decline in productivity and apparent population decline. These hypotheses include the effects of invasive species, such as feral pigs (Sanders et al. 2017) and armadillos; diseases associated with land management practices (Gerhold et al. 2016); density-dependent population regulation (Byrne et al. 2016); and the timing of the spring wild turkey hunting season (Isabelle et al. 2018). The hypothesis related to the timing of the hunting season (hereafter referred to as “the later start date hypothesis”) has led six states in the Southeast (AL, AR, GA, LA, OK, TN) to delay the start of their spring hunting season 6–14 days since 2017 (Figure 1.1, Table 1.1 for sources).

The basis for the later start date hypothesis has two potential mechanisms (Exum et al. 1987, Isabelle et al. 2016, Isabelle et al. 2018). First, if the spring hunting season starts too early, there may be a negative impact on productivity because gobblers are harvested before some hens are bred, resulting in hens that do not nest. The hunting season in Tennessee has opened on the Saturday closest to 1 April since 1986. Median nest incubation date for initial nests in Tennessee is 27 April (Johnson et al. 2022) and based on methods from Yeldell et al. (2017), egg laying has mostly begun by 13 April. Therefore, the Tennessee hunting season generally begins before laying and well before the peak of laying and incubation. The second mechanism is that harvesting dominant and presumably reproductively active males early in the breeding season may disrupt the social hierarchy. Wild turkeys establish a dominance hierarchy that correlates with breeding (Watts and Stokes 1971), and when a male is removed it may disrupt the hierarchy and interrupt breeding activity for an unknown period of time.

Although multiple states have delayed the spring hunting season to benefit reproductive success, there are no published data that supports this hypothesis. Whitaker et al. (2005) reported the hunting season did not impact nesting phenology throughout the U.S in hunted versus non-hunted populations, but they did not study the relationship between timing of hunting season and nesting phenology. From 1986 through 2020, the spring hunting season in Tennessee has opened on the Saturday closest to 1 April and ended 44 days later. During this time, based on harvest, the wild turkey population in Tennessee increased exponentially up until 2006 when it began to oscillate and stabilize, typical of a population reaching carrying capacity (del Monte-Luna et al. 2004). Poult-per-hen ratios during that period in Tennessee, however, generally declined but have more recently fluctuated (Byrne et al. 2015). Harvest has long been used as one of the main indices to gauge changes in wild turkey population growth and in some areas can be a reliable tool (Diefenbach et al. 2012). However, wild turkey harvest is impacted by factors other than just population size, including hunter effort (Butler and Wang 2022) and regulation changes (Diefenbach et al. 2012).

Although statewide harvest in Tennessee has leveled off in recent years, harvest in some areas of the state has declined, especially in several counties in south-middle Tennessee (Giles, Lawrence, Wayne), where harvest has declined by 39% from 2010 to 2022 (Tennessee Wildlife Resource Agency 2023). Turkey hunters and managers are concerned about a decline in reproductive success and associated wild turkey abundance. For the 2021 and 2022 spring turkey seasons, the Tennessee Fish and Wildlife Commission voted to delay the opening date by 14 days in three counties with some of the greatest declines in spring harvest over the past 10 years (Figure 2.1).

Our objective was to assess wild turkey productivity in south-middle Tennessee and determine if the start date of the spring hunting season is correlated with productivity. We hypothesized that the start date could potentially influence nesting rate, nesting chronology, clutch size, hatchability, nest success, poult survival, and hen survival (Table 2.1). With additional time for turkeys to breed before reproductively active males could be harvested, we hypothesized that nesting rate and hatchability would increase, and nesting would occur earlier in the spring. We also hypothesized that nest survival could increase in delayed counties because with less disruption to the mating season (males being harvested prior to breeding) more hens may nest concurrently (i.e., predator swamping hypothesis/nesting synchrony; Robinson and Bider 1988, Ims 1990). Poult survival potentially could be lower with a later hunting season because there may be less brood-rearing cover early in the growing season if hens nested earlier. We hypothesized that hen survival could increase because if a larger portion of hens are incubating a nest during the hunting season, then they may be less likely to be harvested (Healy and Powell 1999, Isabelle et al. 2018). We hypothesized clutch size would be unaffected by the later hunting season because clutch size is determined primarily by intrinsic factors, such as genetics or hen body condition, rather than extrinsic factors (Cody 1996, Thogmartin and Johnson 1999).

STUDY AREA

We conducted our study in Bedford, Giles, Lawrence, Maury and Wayne Counties in south-middle Tennessee, USA. We established two focal trapping sites strategically located in the northern and southern portions of each county where we had access to private and public lands for trapping and tracking radio-tagged turkeys and monitoring nesting and brood rearing activity (Figure 2.2). Private lands included deciduous forest, pasture/hay fields, coniferous forest dominated either by planted loblolly pine (*Pinus taeda*) or naturally occurring eastern redcedar (*Juniperus virginiana*), human development, row crop, young forest (deciduous or coniferous trees less than ten years old), and early successional plant communities dominated by shade-intolerant herbaceous plant species and colonizing woody species. Private lands throughout the 10 study sites totaled >29,000 ha and included >380 individual landowners. We also worked at Tie Camp Wildlife Management Area (WMA, 1,325 ha) in Wayne County and Yanahli WMA (5,200 ha) in Maury County Tennessee, USA. Tie Camp WMA was managed by Bascom Southern Timber Company for timber production. Yanahli WMA was managed for white-tailed deer (*Odocoileus virginianus*), wild turkey, and northern bobwhite (*Colinus virginianus*) through various management strategies. Tie Camp and Yanahli consisted of deciduous and coniferous forests, row crops, young forests, and early successional communities. The average annual rainfall in our study area was 145.8 cm and about 12.1 cm per month (U.S Climate Data 2023).

Predominant soil types included Bodine cherty silt loam and gravelly silt, Gladeville rock outcrop, Ashwood, Brandon silt loam, Biffle gravelly silt loam, and Frankstone cherty silt loam (USDA 2023).

METHODS

We trapped wild turkeys using rocket net box sets (Delahunt et al. 2011). We baited trap sites with shelled corn and monitored sites with infrared-triggered cameras (Moultrie: Model MCG-13202, Birmingham, Alabama, USA). We checked and rebaited trap sites every 2–3 days. We also used cameras to monitor flock size, bait-site visitation rates, and the age and sex ratios of flocks visiting the trap sites. Our goal was to radio-tag ≥10 hens (adults and juveniles based on availability) at each study site each year.

We banded hens with uniquely-numbered aluminum leg bands (National Band and Tag Company: style 1242FR8A, Newport, Kentucky, USA). From 2017 to 2018, we radio-tagged all hens with a very high frequency (VHF) transmitter (Advanced Telemetry Systems: Series A1500, Isanti, Minnesota, USA) via backpack harnesses (Guthrie et al. 2011). Beginning in 2019, we radio-tagged approximately three hens per site with a global positioning system (GPS) transmitter (Lotek: GPS PinPoint, Wareham, United Kingdom) and the rest with VHF transmitters. The VHF transmitters weighed ~80 grams with a life expectancy of 5.7 years, whereas the Lotek GPS transmitters weighed ~92 grams and had an expected battery life of 2.5 years. Actual GPS transmitter life was often < 2 years. All transmitters were equipped with an eight-hour mortality indicator switch. We released each bird at the trap site immediately after processing (University of Tennessee IACUC protocol #0561-0720).

We monitored each radio-tagged hen for movement, nesting activity, and survival. During the non-breeding season each year (5 August – 1 April), we downloaded locations of GPS-tagged hens weekly; GPS locations were collected at 9:00, 15:00, and 23:59 h (roost location) each day. We triangulated hens with VHF transmitters twice per week and monitored mortality. When a mortality occurred, we retrieved the transmitter and determined cause of death when possible based on field sign. Beginning 1 April of each year, we located all hens every 2–3 days to monitor for nesting activity. GPS transmitters recorded hen locations every two hours from 7:00 to 18:00 h and one roost location (23:59 h) every day. VHF transmitters were equipped with an activity switch (the radio signal varied if the hen was moving), which aided in detection of incubation.

Nest Monitoring

We confirmed nesting when the hen started incubating a nest. A GPS-transmitted hen was deemed as incubating when GPS locations formed a ~25-m diameter cluster, and the cluster contained one roost location at the presumed nest site (Yeldell et al. 2017, Moscicki et al. 2023). Hens with VHF transmitters were deemed incubating when they had decreased movements and then were inactive (not moving based on the activity switch) during one triangulation (Vangilder et al. 1987, Miller et al. 1998, Thogmartin and Johnson 1999). We walked a 30-m radius circle around the nest of VHF-transmitted hens to estimate the nest location. We monitored nests for incubation from a nearby (100+ m away) observation point and checked every other day to determine if the hen was still incubating the nest. Nest incubation initiation date for VHF-transmitted hens was the median date between the last location away from the nest site and the first inactive location at the nest site. For GPS-transmitted hens, the nest incubation initiation date was the date of the first roost location at the presumed nest site. We estimated hatch date by adding 28 days to the nest incubation initiation date (Spears et al. 2005, Fuller et al. 2013). We monitored nests daily for five days prior to the estimated hatch date until the hen was no longer at the nest. If incubation of a nest lasted >32 or < 24 days, we adjusted the nest incubation initiation date based on the hatch date (28 days prior). Once the hen left the nest for >3 hours and was >250 m away from the nest, we considered the nest no longer active (Hubbard et al. 1999*a*). We located the nest and determined nest fate (hatch or fail) based on the condition of eggshells (Tyl et al. 2020). Once we located a nest, we recorded clutch size, number of hatched eggs (if applicable), GPS coordinates of the nest, nest vegetation, and a description of the nest.

Brood Monitoring

We monitored broods by tracking radio-tagged poults and conducting brood flush counts. We trapped poults within one to eight days post-hatching. Poults were captured by hand after flushing the hen before sunrise while brooding (Hubbard et al. 1999*b*, Johnson 2019). All captured poults were placed in a cooler with a heating pad to keep them warm (Hubbard et al. 1999*b*, Spears et al. 2005). We radio-tagged one to six poults within each captured brood in 2018–2022 by suturing the transmitter (Advanced Telemetry Systems: Series A1065, Isanti, Minnesota, USA) to their back (Burkepile et al. 2002, Johnson 2019). The transmitters weighed 1.3 grams and had a life expectancy of 77 days based on field testing. We released captured poults in the vicinity of the hen at first light to reunite the brood with the hen and we only documented five poults in four broods who did not reunite with the hen (< 3%).

Each tagged poult was monitored for survival by homing and circling to within 30 m of the brood, similar to locating a nest (Hubbard et al. 1999*b*). While circling the hen and brood, we listened for the poult radio signals to determine if they were alive or dead. If the poult transmitters were located near the hen, we assumed the radio-tagged poult was alive. If the poult radio signal was heard in the area, but not associated with the hen, we homed to the transmitter to determine if the poult was dead. When a poult mortality occurred, the site was examined and a cause of death was determined based on field sign (Speake et al. 1985, Peoples et al. 1995). A poult was considered missing if the radio signal was not heard during the hen/brood monitoring attempt. For the first seven days post-hatching, transmitted poults were monitored daily via circling. After day seven, transmitted poults were monitored every other day until day 28 post-hatching. In addition to monitoring via telemetry, we flushed each brood on days 14 and 28 post-hatching (Peoples et al. 1995, Hubbard et al. 1999*b*). We recorded the number of poults and hens present when flushed along with date, time, and GPS coordinates of the brood's location.

Data Analysis

We monitored reproductive rates in the five focal counties for six consecutive years, 2017–2022, and analyzed the data in a Before-After-Control-Impact study design (Smokorowski and Randall 2017). Giles, Lawrence, and Wayne counties were considered treatment counties affected by the season delay (hereafter, "delayed counties"), and Bedford and Maury were control counties (hereafter, "no-delay counties"). Reproductive rates from 2017 to 2020 were considered as before the season delay and rates from 2021 to 2022 as after the season delay.

We estimated the proportion of hens nesting, nest incubation initiation date (median and mean), clutch size, hatchability, daily nest survival, daily poult survival, and weekly hen survival. We only included initial nesting attempts in these analyses because the two-week delay coincided with the timing of initial nesting attempts. We assumed renesting was unaffected by the season opening date, which in some cases happened >2 months later. Due to nest failures during the laying stage, we may have missed nesting attempts. To account for this, we truncated the initial nesting period to 10 June of each year as this was the latest initial nest documented by GPS-tagged hens.

We defined nesting rate (NR) as the proportion of hens that incubated a nest within a given year. The proportion of hens that attempted a nest (i.e., laid ≥ 1 egg) was greater because some nests likely failed prior to incubation. We calculated NR by dividing the number of hens who incubated a nest by the number of hens alive on 1 April of each year (Norman et al. 2001, Londe et al. 2023). Hens that died and were not documented incubating a nest between 1 April and 1 May were censored from this analysis as they did not have sufficient opportunity to incubate a nest once the nesting season started (Thogmartin and Johnson 1999). We defined nest incubation initiation date (IID) as the date that the hen began incubating the nest. We used IID for initial nesting attempts to determine the mean and median date of nest incubation in each treatment before and after the season delay. We incorporated hen ID (unique identifier for each individual hen) as a random effect because some hens lived for multiple nesting seasons throughout the time of the study. Timing of nesting distributions were analyzed using four two-sample Kolmogorov-Smirnov tests (delay before, no-delay before, delay after, no-delay after) to assess changes in the distribution of IIDs. Nesting season length was calculated for three time periods: entire nesting season (first nest to begin incubation to last day of incubation for all nests); initial nest time period (first initial nest to begin incubation to the last day of incubation for the last initial nest); and the renest time period (first renest to begin incubation to the last day of incubation for the last renest). Time to renest was determined as the number of days from the initial nest attempt failing to the day the renest began incubation. Clutch size (CS) was determined by counting the number of eggs found at the nest site. Hatchability (HABY) was the proportion of eggs within a nest to hatch (Londe et al. 2023). We only included hatched nests in the clutch size and hatchability analysis because the disturbance of depredated nests made it impossible to determine the original number of eggs. We also only included initial nests because initial nests more closely aligned with the spring hunting season.

We used generalized linear mixed effect models to assess interactions between delayed counties before and after the season delay. We used a generalized linear mixed effect model with a quasibinomial error distribution to analyze nesting rate and hatchability. We chose the quasibinomial error distribution because nesting rates and hatchability are binomially distributed ratio data. We chose a Poisson error distribution for clutch size because data were discrete counts. We excluded some nests in the clutch size analysis when it was apparent those nests were partially depredated or scavenged after hatching. We analyzed nesting chronology using a linear mixed effect model that compared the ordinal date of IID for initial nests. Ordinal dates were box-cox transformed (lambda = -2, y = ordinal date^{-2}) to meet the normality assumption of linear models (Sakia 1992). We analyzed all three periods for season length (total nesting season length, length of initial nesting, and length of renesting) using three general linear models. Shapiro-Wilks tests of normality were used to test the distribution of the data for the nesting season timing models outlined above. All models were created and statistically analyzed in Program R (R Core Team 2022). For all linear models, we adopted an α-value of 0.05.

We calculated daily nest survival, daily poult survival, and weekly hen survival through the nesting season using a staggered entry approach (Pollock et al. 1989) in RMark (Laake 2013). Daily nest survival (DNS) was defined as the probability of a nest surviving one day of the incubation period (Dinsmore et al. 2002). Daily poult survival (DPS) was the probability that a poult survived each day after hatching. Hen survival was calculated across the entire nesting season (1 April–5 August), summarized into weekly survival intervals (Pollentier et al. 2014).

We used 5 August as an end date for the nesting season because that was the last date a nest was known to have been incubated in any year of our study. Survival estimates were modeled using an information-theoretic approach to evaluate potential relationships with covariates (Burnham and Anderson 2002). We incorporated four covariates in our nest survival analysis: hen age, treatment (no delay vs. delayed) interacting with timing (before vs. after), year, and ordinal date of the nest incubation initiation date. These covariates resulted in 11 a-priori models for daily nest survival. Nest success (NS) estimates were then calculated by raising each daily nest survival estimate to the 28th power assuming a 28-day incubation period (Londe et al. 2023). Poult survival was estimated using known-fate models using survival data from radio-tagged poults (Hubbard et al. 1999*b*). Seventy-one radio-tagged poults (38.7%) had unknown fates (was unable to hear poult transmitter for the entire monitoring period, i.e., missing). We adjusted poult survival estimates to account for missing poults using four-week flush count data. We assumed a missing poult was dead on the first day they went missing if no poults were observed at the brood's four-week flush. Missing poults were censored if ≥1 poult was observed at the brood's four-week flush. This method allowed us to account for any potential transmitter failure in our estimates. The poult survival analysis included the following covariates: hen age, treatment and timing interaction, year, ordinal date of the brood's hatch date, number of poults at time of trapping, and standardized mass at capture. This analysis resulted in 13 a-priori models that we used to estimate daily poult survival. Daily poult survival estimates were raised to the 28th power to estimate 28-day poult survival (Londe et al. 2023). Hen survival during the nesting season was divided into 18 weekly survival intervals that started 1 April each year and ended 5 August. We used known-fate models for this analysis, and we censored any individuals who went missing or dropped their transmitter. Covariates assessed in hen survival included age at the start of the nesting season, treatment and timing interaction, and year, which resulted in six a-priori models.

For all survival analyses (nest, poult, and hen), the model we used to test the later start date hypothesis was one that allowed survival to vary by treatment (delayed counties vs. no-delay counties) and interact with timing (2017–2020 vs. 2021–2022) and will hereafter be referred to as the “interaction model.” All other models and covariates were used to account for nuisance effects and covariates were included into the interaction model to attempt to account for any variation associated with them.

RESULTS

We captured 737 hens from 2017 to 2022 and we radio-tagged 432 with either a VHF (n = 283) or GPS (n = 149) transmitter. Of the 737 hens captured, there were 609 adults and 115 juveniles, which resulted in 371 radio-tagged adult and 61 radio-tagged juvenile hens. The 432 radio-tagged hens resulted in 623 hen-years monitored for nesting activity and each hen was monitored for an average of 1.4 nesting seasons. We monitored 176 radio-tagged hens in no-delay counties and 256 radio-tagged hens in delayed counties from 2017 to 2022, which resulted in 249 hen-years in no-delay counties and 374 hen-years in delayed counties. We monitored 158 hen-years from 2017 to 2020 and 91 hen-years from 2021 to 2022 in no-delay counties, and 242 hen-years from 2017 to 2020 and 132 hen-years from 2021 to 2022 in delayed counties.

Nesting Parameters

Nesting rates in no-delay counties were 0.74 (95% CI: 0.61, 0.86) and 0.86 (95% CI: 0.8, 0.89) before and after the season delay. In delayed counties, nesting rates averaged 0.71 (95% CI: 0.58, 0.84) before and 0.85 (95% CI: 0.78, 0.93) after the delay (Table 2.2). The generalized linear model showed no interaction between treatment groups before and after the delay for nesting rate ($n = 12$, $\beta = 0.20$, $SE_{\beta} = 0.90$, $P_{\text{Interaction, 11}} = 0.83$, Table 2.3).

Nest chronology was determined from 169 initial nests (102 before treatment, 67 after) in no-delay counties and 254 nests (157 before treatment, 97 after) in delayed counties (423 total initial nests). Peak initiation of incubation occurred during the fourth week of April for all groups. Median nest incubation initiation dates were 27 April (First: 8 April, Last: 30 May, n = 102) in no-delay counties and 27 April (First: 8 April, Last: 5 June, n = 157) in delayed counties before the season delay. After the delay, the median nest incubation date in no-delay counties was 30 April (First: 14 April, Last: 10 June, n = 67) and 25 April (First: 6 April, Last: 29 May, n = 97) in delayed counties. Median nest incubation initiation dates varied by 5–12 days across years and treatment groups (Table 2.4). Our nest incubation initiation model showed a weak but insignificant relationship between season start and nesting timing ($n = 423$, $\beta = 0.0000051$, $SE_{\beta} = 0.0000071$, $P_{\text{Interaction, 418}} = 0.07$; Table 2.3). The model predicted a 2.8-day shift later in control counties and 1.3-day shift earlier in delayed counties for adult hens after the two-week delay. The juvenile hens shifted 3.2 days later in no-delay counties and 1.5 days earlier in delayed counties. Age of incubating hen in this model was related to nest incubation initiation date, with adult hens nesting about six days earlier than juvenile hens ($\beta = -0.0000063$, $SE_{\beta} = 0.0000026$, $P_{\text{Age, 418}} = 0.01$). The two-sample Kolmogorov Smirnov tests for the distribution of IIDs did not differ between treatment groups before the season delay (Delayed-Before vs. No Delay-Before, $P = 0.26$) or after the delay (Delayed-After vs. No Delay-After, $P = 0.26$).

The entire nesting season length before the season delay averaged 101 (95% CI: 96, 106) days in no-delay counties and 110 days (95% CI: 107, 113) in delayed counties. After the season delay, the entire nesting season lasted 103 days (95% CI: 87, 119) in no-delay counties and 111 days (95% CI: 90, 131) in delayed counties (Table 2.2). The initial nesting time period lasted 68 days (95% CI: 61, 76) and 78 days (95% CI: 70, 86) before the delay in no-delay and delayed counties, respectively. After the delay, the initial nesting period increased to 72 days (95% CI: 47, 98) and 81 days (95% CI: 70, 91), in no-delay and delayed counties. The renesting period lasted 77 days (95% CI: 74, 79) and 84 days (95% CI: 74, 95) before the season delay in no-delay and delayed counties, respectively, then increased to 84 days (95% CI: 66, 102) and 86 days (47, 124) after the season delay in 2021 and 2022. The entire season length model showed no change in nesting season length that could be attributed to the season delay (n = 12, β = -1.75, SE_{β} = 9.11, $P_{\text{Interaction}, 8}$ = 0.85, Table 2.3). The initial nesting time period (n = 12, β = -0.75, SE_{β} = 12.11, $P_{\text{Interaction}, 8}$ = 0.95) and the length of renesting did not change (n = 12, β = -6.25, SE_{β} = 15.59, $P_{\text{Interaction}, 8}$ = 0.70). Renesting began 1 May for no-delay counties and 2 May for delayed counties before the season delay and 4 May and 2 May, respectively, after the delay. Across all counties and years, the average time to renest was 24 days (95% CI: 22, 26).

We documented clutch size on 95 initial nests, including 58 nests from 2017 to 2020 (19 no-delay, 39 delayed) and 37 nests from 2021 to 2022 (9 no-delay, 28 delayed). The mean clutch size for initial nests was 9.8 (95% CI: 8.9, 10.7) and 9.1 (95% CI: 8.2, 10.0), respectively, in no-delay and delayed counties before the delay. In 2021–2022, clutch sizes increased to 12.8 (95% CI: 11.6, 14.0) and 10.2 (95% CI: 8.8, 11.6) in no-delay and delayed counties, respectively (Table 2.2). The clutch size model for the interaction of before and after the season delay in affected counties indicated no change (n = 95, β = -0.15, SE_{β} = 0.14, $P_{\text{Interaction}, 91}$ = 0.28, Table 2.3). Hatchability averaged 0.86 (95% CI: 0.82, 0.90) over all 6 years. Before the delay, hatchability was 0.91 (95% CI: 0.84, 0.99) in no-delay counties and 0.84 (95% CI: 0.78, 0.9) in delayed counties. After the delay, hatchability was 0.85 (95% CI: 0.67, 1.00) in no-delay counties and 0.87 (95% CI: 0.80, 0.94) in delayed counties (Table 2.2). The hatchability model indicated no difference before and after the season delay in delayed counties compared with no-delay counties (n = 86, β = 0.82, SE_{β} = 0.84, $P_{\text{Interaction, 82}}$ = 0.33, Table 2.3).

Survival Estimates

We estimated daily nest survival using 402 initial nests, including 246 before the season delay and 156 after the delay, with 239 nests in no-delay counties and 163 in delayed counties. Daily nest survival was 0.953 (constant survival, 95% CI: 0.947, 0.958) and equated to 0.254 (95% CI: 0.218, 0.299) nest success. The interaction model had the most support out of the 11 models analyzed and accounted for 23% of the variation. However, the β = 0.225 (95% CI: -0.276, 0.727; Table 2.5) confidence intervals overlapped zero suggesting the relationship was not statistically significant. Based on the interaction model, nest success was 0.204 (95% CI: 0.136, 0.283) before the delay and 0.194 (95% CI: 0.116, 0.289) after the delay in no-delay counties. In delayed counties, nest success was 0.287 (95% CI: 0.212, 0.352) before the delay and 0.349 (95% CI: 0.253, 0.448) after. The interaction model plus nest timing (IID × Year), hen age, and IID all ranked below the constant survival model (hereafter referred to as the "dot model," Table 2.5).

We radio-tagged 183 poults from 2018 to 2022: 58 poults in no-delay counties and 125 poults in delayed counties. We radio-tagged 81 poults in 2018–2020 and 102 poults in 2021–2022. Of the 183 poults monitored, 33 poults survived 28 days post-hatch (18.0%) and the fate of 71 poults were unknown during the 28-day monitoring period. Daily poult survival was 0.944 (95% CI: 0.934, 0.953) and 28-day poult survival was 0.202 (95% CI: 0.149, 0.262). Yearly estimates of 28-day poult survival ranged from 0.049 (2022: 95% CI: 0.01, 0.138) to 0.325 (2021: 95% CI: 0.221, 0.434). The interaction model to assess the impact of the season delay had a ΔAICc of 10.163 and explained only 0.4% of the variation (Table 2.6). The top model relating poult daily survival to various covariates was year interacting with hatch date (β = -0.0087; 95% CI: -0.022, 0.039). All other models not incorporating year or hatch date had ΔAICc >2.0 and explained very little of the variation (<0.5%). All β-value confidence intervals for year and hatch date overlapped zero in this model which suggests no relationship between year or hatch date and poult survival.

We calculated weekly survival for 587 hens throughout the 2017–2022 nesting seasons. We monitored 149 hens before the season delay and 84 after the season delay in no-delay counties. We monitored 229 hens before the season delay and 125 after the season delay in delayed counties. Weekly hen survival was 0.982 (95% CI: 0.979, 0.985) and hen nesting-season survival (18 weeks) was 0.723 (95% CI: 0.685, 0.757). The top hen survival model included hen age (β = 0.741; 95% CI: -0.021, 1.502). Weekly adult hen survival was 0.981 (95% CI: 0.978, 0.984) and seasonal survival was 0.723 (95% CI: 0.671, 0.741). Weekly juvenile hen survival was 0.991 (95% CI: 0.981, 0.996) and seasonal survival was 0.85 (95% CI: 0.711, 0.925). The season delay interaction model ranked below the dot model (ΔAICc = 6.945, weight = 0.021, Table 2.7).

DISCUSSION

Our models for all reproductive rates examined did not support the later start date hypothesis and showed no evidence that the later start date for the Tennessee spring hunting season impacted seasonal productivity. Beginning the hunting season prior to peak nest initiation showed no measurable adverse effects on wild turkey seasonal productivity. Based on the later start date hypothesis, the top three reproductive rates that we would have expected to change included the portion of hens nesting (nesting rate), nesting chronology, and hatchability (Table 2.1), none of which indicated any impact from the start date of the spring hunting season. Nesting rate and clutch size were greater in 2021 and 2022 for all five counties, regardless of when the hunting season started. Nest survival was not related to the season start date but was correlated with county group regardless of the timing of the season delay. Poult survival and hen survival were not impacted by the season start date as the interaction model had little support in both analyses.

Nesting Parameters

The portion of hens that attempt to nest should increase if timing of the hunting season was limiting reproductively active males for breeding. We found no evidence to support this expectation following a two-week delay of the Tennessee spring hunting season. Factors that influence yearly nesting rates are not well understood, but annual fluctuations are commonly observed within wild turkey populations (Vanglider and Kurzejeski 1995). Changes in hen-age ratios can influence nesting rates because juvenile hens nest at lower rates than adult hens (Vanglider and Kurzejeski 1995).

Based on the later start date hypothesis, nesting chronology should have shifted earlier in delayed counties because of the additional time for males to breed. However, after two years of a two-week delay, the nesting chronology model did not demonstrate any changes attributed to the season delay. Shifts in mean (1–2 days) and median IID (2–3 days) before and after the delay were well within the annual variation in our study area prior to the delay (No-delay: 9 days, Delayed: 4 days; 2017-2020; Table 2.4). Median IID in the no-delay counties varied by 12 days (2019 vs. 2022) over the course of the study. Variation in median IID was observed across county groups prior to the delay where median IID in no-delay counties was earlier than delayed counties in 2017-2019, but later in 2020. In the second year of the delay (2022), median IID in delayed counties was 28 April, the latest date for median IID in those counties across all six years (Table 2.4). Annual variation in nest incubation initiation could be explained by annual variability in spring phenology or rainfall prior to nest initiation (Boone et al. 2023). Age of hen was the only reliable predictor of nest incubation initiation date consistent with the literature, which indicates adult hens initiate incubation earlier than juveniles (six days earlier based on our results; Norman et al. 2001, Londe et al. 2023).

Delaying the season start date to 15 April moved peak hunting pressure (the first week of the hunting season) into the period of peak nest initiation and early stages of incubation. However, nesting season length and time of nesting did not change in relation to the spring hunting season start date, which is inconsistent with the hypothesis that nesting would occur earlier in the year or that the distribution of nests over time would contract. None of our models concluded that nesting chronology (including median nest incubation initiation date, length, distribution, or renest timing) was impacted by the delayed season start date.

Our results support our hypothesis that clutch size would be unaffected by the season delay. Clutch sizes were greater in no-delay counties compared to delayed counties ($P_{\text{Treatment, 91}} = 0.04$), but this difference was observed in all years, not just after the season delay. Estimates of clutch size and hatchability for Tennessee are comparable to previous research in the eastern wild turkey's distribution (Davis et al. 1995, Vanglider and Kurzejeski 1995, Thogmartin and Johnson 1999, Pollentier et al. 2014, Tyl et al. 2020). There are no published data that indicate clutch size is affected by extrinsic factors, but rather is influenced by genetics and hen body condition prior to egg laying (Lack 1947, Cody 1966, Thogmartin and Johnson 1999).

Hatchability did not change in response to the season delay. Based on the later start date hypothesis, hatchability should increase because more reproductively active males are available with more time to breed hens and presumably increase egg fertilization. Although hatchability can be impacted by egg fertilization rates, other factors also can cause an egg to not hatch, such as early embryonic death (Birkhead et al. 2008). Current research investigating wild turkey egg fertilization may provide a better understanding of factors influencing hatchability (Gladkowski 2023).

Survival Estimates

Daily nest survival was not impacted by the season delay even though the interaction model was the top model and explained 23% of the variation. The confidence intervals surrounding the β-value for the interaction model overlapped zero and were influenced by within-treatment variation (β = -0.453; 95% CI: -0.848, -0.059). Delayed counties experienced greater nest survival than no-delay counties, which were the counties with the greatest decline in harvest in Tennessee since 2010. Greater daily nest survival in those counties may indicate poor poult survival is contributing more to reduced fecundity or that density dependence has influenced the population and sites with lesser hen densities now have greater nest success (Byrne et al. 2015). Our nest success estimates (S(.) = 0.25) were similar to estimates from other declining populations in the Southeast (0.26 GA, Bakner et al. 2019; 0.24 SC, Lohr et al. 2020; and 0.24 LA, Crawford et al. 2021).

Ordinal date of nest incubation initiation, incubating hen age, and year received no support in the nest survival models, contrary to Keever et al. (2022), who reported nests earlier in the year were four times more likely to hatch than nests later in the year. However, Keever et al. (2022) included all nests (initial and all subsequent renests) in their analysis and did not report effect of timing on survival of initial nests, which is the parameter that should be used to indicate if timing of the opening of turkey season is influential on nest success. The number of days from initial nest abandonment/depredation to onset of the first renest in our study varied from 5 to 64 days. Previous research has reported large yearly fluctuations in daily nest survival and nest success (Roberts and Porter 1998), but year was among the lowest-ranked covariates in our study (Table 2.5). We also saw no difference in daily nest survival between nests incubated by adults vs. juveniles, contrary to Norman et al. (2001) who reported juveniles had less reproductive success than adults.

We predicted poult survival would decrease following the later hunting season start date because earlier nests could produce poults before adequate brooding cover and food were available. However, our results did not support this hypothesis with the interaction model ranking 6/13 and explaining only 0.4% of the variation. Instead, annual variation was the strongest predictor of poult survival and there was no significant effect of the two-week delay. Poult survival was estimated at 0.202 for the 28-day interval. Few contemporary survival estimates based on monitoring radio-tagged poults have been published. Radio-tagged survival estimates from the 1990s were comparable (0.24 NY: Roberts et al. 1995) or greater (0.42 IA: Hubbard et al. 1999*b*). Survival estimates based on flush counts from various locations in the U.S were generally greater than our radio-tagged estimates (0.255 MS, Miller et al. 1998; 0.27 SD, Thompson 2003; 0.34 WI, Pollentier et al. 2014; 0.35 TX, Isabelle et al. 2016; and 0.36 GA & SC, Chamberlain et al. 2020).

We predicted hen survival would increase following the season delay because more hens would be incubating during the first couple of weeks of the hunting season and therefore less likely to be harvested by hunters. However, the interaction model for hen survival through the nesting season was among the least-supported models in the model set. Some state turkey biologists have expressed a concern related to timing of the spring hunting season in that hens may be more likely to be harvested illegally if the season begins prior to peak incubation initiation (Healy and Powell 1999, Isabelle et al. 2018). In delayed counties, the hunting season start date following the delay (15 April and 16 April) more closely aligned with peak incubation initiation (21 April), but we documented no changes in hen survival. During the six years of our study, we documented only one case where we suspected a hen was harvested illegally during the hunting season, and none of the bearded hens we radio-tagged (n = 16) were legally harvested. Given these data, direct hunter-based mortality did not affect hen survival in south-middle Tennessee. Considering the extent of our study, including two public hunting areas and >380 individual private landowners, our results should be considered representative of turkey hunters at least throughout the middle Tennessee region.

MANAGEMENT IMPLICATIONS

Our data do not support the hypothesis that delaying the start date of the spring hunting season by two weeks in south-middle Tennessee would benefit wild turkey productivity. We documented no effect of the two-week delay on wild turkey productivity, poult survival or hen survival. Our results demonstrate that beginning the wild turkey hunting season during the early stages of nest initiation did not result in decreased productivity when compared to beginning the season closer to the onset of incubation. Returning the spring hunting season back to the beginning of April may provide hunters with more opportunities to hunt birds when they are actively gobbling (Chamberlain et al. 2018, see Part III). Furthermore, hunter satisfaction may decrease as hunters become aware that there is no reproductive benefit from delaying the opening of the spring turkey season. We stress that we are not suggesting that timing of the spring hunting season cannot have an effect, but that the timing of the traditional spring turkey hunting season in Tennessee (prior to peak nest initiation) has not negatively affected turkey productivity in the state. We suggest other state agencies conduct similar research to determine the effect of a delayed season on wild turkey productivity prior to making season-framework changes that could negatively affect hunter satisfaction.

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APPENDIX

Table 2.1. Hypothesized effects of a two-week season delay on wild turkey productivity and survival parameters, south-middle Tennessee, USA 2017–2022.

Rank of influence	Parameter	Hypothesized effect after delayed hunting season	Justification
1	Median Nest Incubation Initiation Date	is earlier	Males will have more time to breed, and dominant males will be on the landscape longer so hens could initiate incubation earlier.
2	Nesting Rate	increases	More time for males to breed with hens before potentially being harvested so more hens could initiate a nest.
3	IID Distribution	more contracted	Males will have more time to breed, and dominant males will be on the landscape longer so hens may be bred and nest earlier and concurrently.
4	Hatchability	increases	Males will have more time to breed, and dominant, reproductively active males will be on the landscape longer, so hens could be bred more, which could lead to more fertilized eggs within the clutch.
5	Daily Nest Survival/Nest Success	increases	With less disruption to the breeding season more nests may occur concurrently and experience greater nest survival.
6	Daily Poult Survival/Poult Success	decrease	Earlier nesting may lead to poults hatching earlier in the year. Poults on the landscape earlier in the year could result in poults having to utilize suboptimal vegetation cover and structure.
7	Hen Survival through Nesting season - Weekly estimates	increases	Hen survival may increase because more hens will be incubating nests while hunters are on the landscape and reducing the risk of illegal harvest thus increasing their survival.
8	Average Clutch Size	remains the same	Clutch size is predetermined based on genetics and hen health at the time of laying and less affected by external factors.

Table 2.2. Wild turkey reproductive rates measured from hens in south-middle, Tennessee, USA from 2017–2022, grouped by treatment and before and after the season delay.

	Treatment						Control					
	Before			After			Before			After		
Reproductive Rate	*n*	$\hat{y}$	SE	*n*	$\hat{y}$	SE	*n*	$\hat{y}$	SE	*n*	$\hat{y}$	SE
Nesting Rate$_i$	4	0.71	0.07	2	0.86	0.04	4	0.74	0.062	2	0.85	0.025
Median Nest Incubation Date$_i$	157	4/27	-	97	4/25	-	102	4/27	-	67	4/30	-
Nesting Season Length	4	110	1.548	2	111	10.5	4	101	2.345	2	103	8
Clutch Size$_i$	39	9.1	0.433	28	10.2	0.702	19	9.8	0.443	9	12.8	0.619
Hatchability$_i$	34	0.84	0.031	27	0.87	0.036	18	0.91	0.038	9	0.85	0.09
Nest Success$_i$	149	0.287	0.036	90	0.349	0.051	97	0.204	0.038	66	0.194	0.045
Poult Survival	47	0.23	0.06	78	0.206	0.045	34	0.068	0.035	24	0.364	0.10
Hen Survival	229	0.725	0.03	125	0.762	0.039	149	0.708	0.037	84	0.688	0.051

$_i$ Initial nests only

Table 2.3. Summary of results from models used to assess the effect of the spring wild turkey hunting season start date in south-middle Tennessee, USA on the eight reproductive rates of wild turkeys tested in 2017–2022 with the associated models, β-values, *P*-values and ΔAICc scores for each if applicable.

Reproductive Rate	Interaction Model Formula	β	SE_{β}	*P*	ΔAICc	Model Rank	Effect of Season Delay
Nesting Rate$_{i}$	glm(NII ~ Treatment × Timing, family = Quasibinomial)	0.2028	0.8995	0.83	-	-	No Documented Effect
Nesting Season Length	lm(SeasonLength ~ Treatment × Timing)	-1.75	9.116	0.85	-	-	No Documented Effect
Nesting Chronology$_{i}$ ^{a}	lm(BC IID ~ Treatment × Timing + Age + (1|Hen ID))	0.00005	0.000007	0.06	-	-	No Documented Effect
Clutch Size$_{i}$	glm(CS ~ Treatment × Timing, family = Poisson)	-0.154	0.1428	0.28	-	-	No Documented Effect
Hatchability$_{i}$	glm(HABY ~ Treatment × Timing, family = Binomial)	0.8215	0.8423	0.33	-	-	No Documented Effect
Nest Success$_{i}$	S(~ Treatment × Timing)[28]	0.2252	0.2559	-	0	1/11	No Documented Effect
Poult Survival	S(~ Treatment × Timing + Year)[28]	-0.6579	0.4243	-	2.2211	6/15	No Documented Effect
Hen Survival	S(~ Treatment × Timing + Hen Age)[18]	0.253	0.3382	-	6.945	5/6	No Documented Effect

$_{i}$ Initial nests only

^{a} Data was transformed using a box-cox transformation with lambda = -2 ($y = IID^{-2}$)

Table 2.4. Table of yearly median nest incubation initiation dates for initial wild turkey nests in south-middle Tennessee, USA from 2017 to 2022 separated by treatment and hen age.

	Treatment			Control		
	Adult	Juvenile	All Hens	Adult	Juvenile	All Hens
2017	4/26	4/23 [a]	4/26	4/25	4/25	4/25
2018	4/28	-	4/28	4/27	5/7 [a]	4/27
2019 [b]	4/28	-	4/28	4/20	-	4/20
2020	4/24	5/12 [a]	4/24	4/29	4/19 [a]	4/29
2021	4/23	4/24	4/23	4/26	5/1	4/28
2022	4/25	5/11 [a]	4/28	5/2	5/19 [a]	5/2

[a] These estimates incorporate ≤ 3 initial nests

[b] No tagged juveniles nested in either county group

Table 2.5. AIC model results for daily nest survival with various covariates of initial wild turkey nests in south-middle Tennessee, USA from 2017–2022. Third solid line in the table indicates the models that are sister models (< 2.0 ΔAICc).

Model [a]	Number of Parameter	AICc	ΔAICc	Weight	Deviance
S(~Treatment × Timing)	4	1902.775	0.000	0.230	1894.768
S(.)	1	1903.042	0.266	0.202	1901.041
S(~Treatment × Timing + IID × Year)	14	1904.043	1.268	0.122	1875.970
S(~Treatment × Timing + Hen Age)	5	1904.486	1.711	0.098	1894.476
S(~Hen Age)	2	1904.636	1.861	0.091	1900.634
S(~Treatment × Timing + IID)	5	1904.777	2.002	0.085	1894.767
S(~IID)	2	1905.028	2.253	0.075	1901.026
S(~IID × Year)	12	1905.893	3.117	0.048	1881.838
S(~Treatment × Timing + Year)	8	1907.442	4.667	0.022	1891.417
S(~IID × Year + Hen Age)	13	1907.706	4.931	0.020	1881.643
S(~Year)	6	1909.793	7.018	0.007	1897.779

[a] Models allowed survival to vary by six covariates: treatment - dummy variable for delayed counties vs. no-delay counties, timing - dummy variable for nests in 2017–2020 or 2021–2022, nest incubation initiation date (IID), hen age (adult vs. juvenile), and year.

Table 2.6. AIC model results for daily poult survival estimates from radio-tagged poults in south-middle Tennessee, USA 2018–2022. Third solid line in the table indicates the models that are sister models (< 2.0 ΔAICc).

Model [a]	Number of Parameters	AICc	ΔAICc	Weight	Deviance
S(~Hatch Date × Year)	10	946.477	0	0.64602	926.378
S(~Treatment × Timing + Year)	7	949.006	2.529	0.18239	387.357
S(~Year)	5	949.569	3.092	0.13765	391.943
S(~Treatment × Timing + Hatch Date)	5	953.693	7.216	0.01751	943.666
S(~Treatment × Timing + Hen Age)	5	956.42	9.943	0.00448	398.794
S(~Treatment × Timing)	4	956.639	10.163	0.00401	401.022
S(~Treatment × Timing + PT)	5	957.332	10.855	0.00284	947.305
S(~Treatment × Timing + Weight)	5	958.6	12.123	0.00151	948.573
S(~Hatch Date)	2	958.908	12.432	0.00129	954.903
S(~Hen Age)	2	960.055	13.578	0.00073	408.45
S(.)	1	960.251	13.774	0.00066	410.65
S(~ PT)	2	960.4	13.924	0.00061	956.395
S(~Weight)	2	961.752	15.275	0.00031	957.747

[a] Models allowed survival to vary by seven covariates: treatment - dummy variable for delayed counties vs. no-delay counties, timing - dummy variable for nests in 2017–2020 or 2021–2022, hatch date, hen age (adult vs. juvenile), year, PT (poults trapped) - number of poults caught in each brood, and weight - mass of the poult at the time of capture standardized by age of the poults.

Table 2.7. AIC model results for weekly hen survival throughout the nesting season of hens in south-middle Tennessee, USA from 2017–2022. Third solid line in the table indicates the models that are sister models (< 2.0 ΔAICc).

Model	Number of Parameters	AICc	ΔAICc	Weight	Deviance
S(~Henage)	2	1604.49	0	0.672	700.971
S(.)	1	1607.06	2.565	0.186	705.537
S(~Treatment × Timing + Henage)	5	1608.96	4.463	0.072	699.428
S(~Year)	6	1610.32	5.824	0.037	698.787
S(~Treatment × Timing)	4	1611.44	6.945	0.021	703.913
S(~Treatment × Timing + Year)	8	1612.65	8.155	0.011	697.112

[a] Models allowed survival to vary by four covariates: treatment - dummy variable for delayed counties vs. no-delay counties, timing - dummy variable for nests in 2017–2020 or 2021–2022, hen age (adult vs. juvenile), and year.

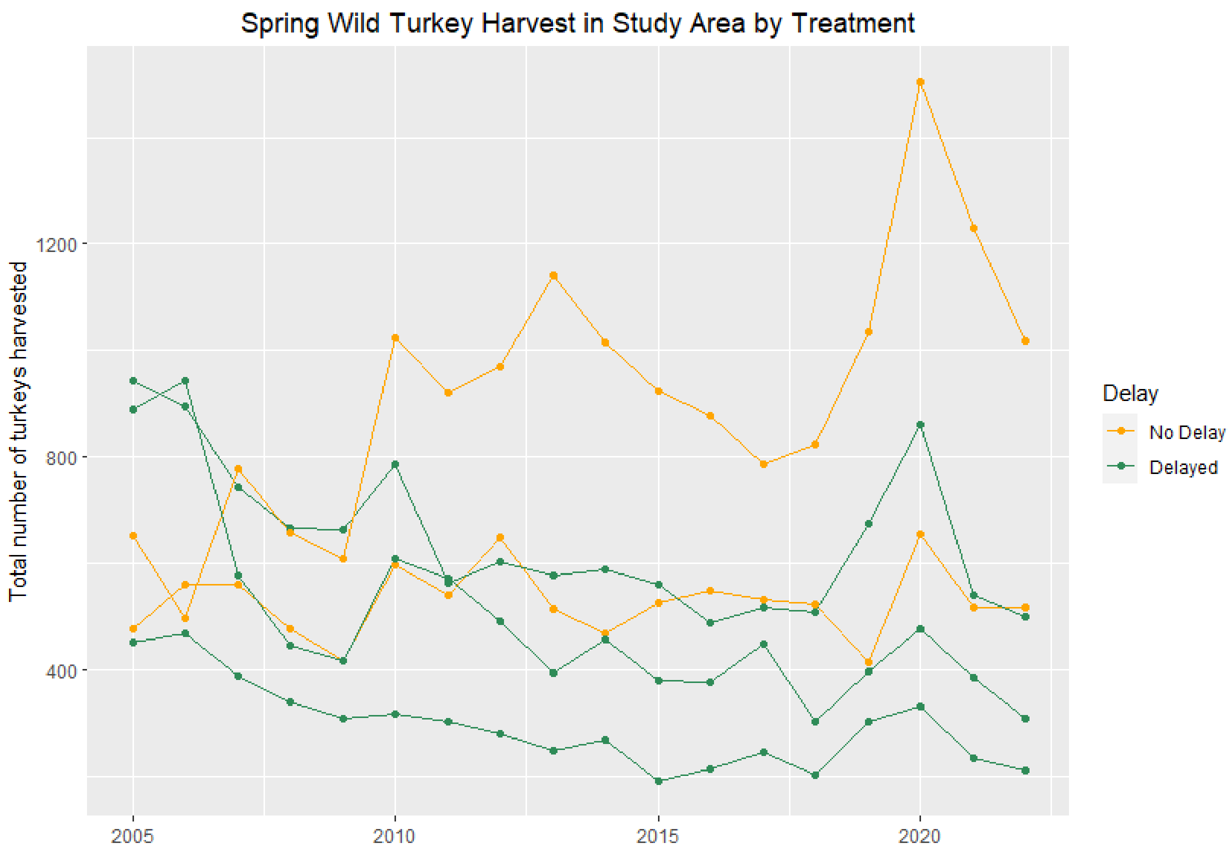

Figure 2.1. Line graph of annual spring harvest of wild turkeys in no-delay counties (Bedford, and Maury) and delayed counties (Giles, Lawrence, and Wayne) in Region 2 of south-middle Tennessee, USA, 2005–2022. The delayed counties are believed to have declining populations of wild turkeys whereas the no-delay counties are believed to be stable.

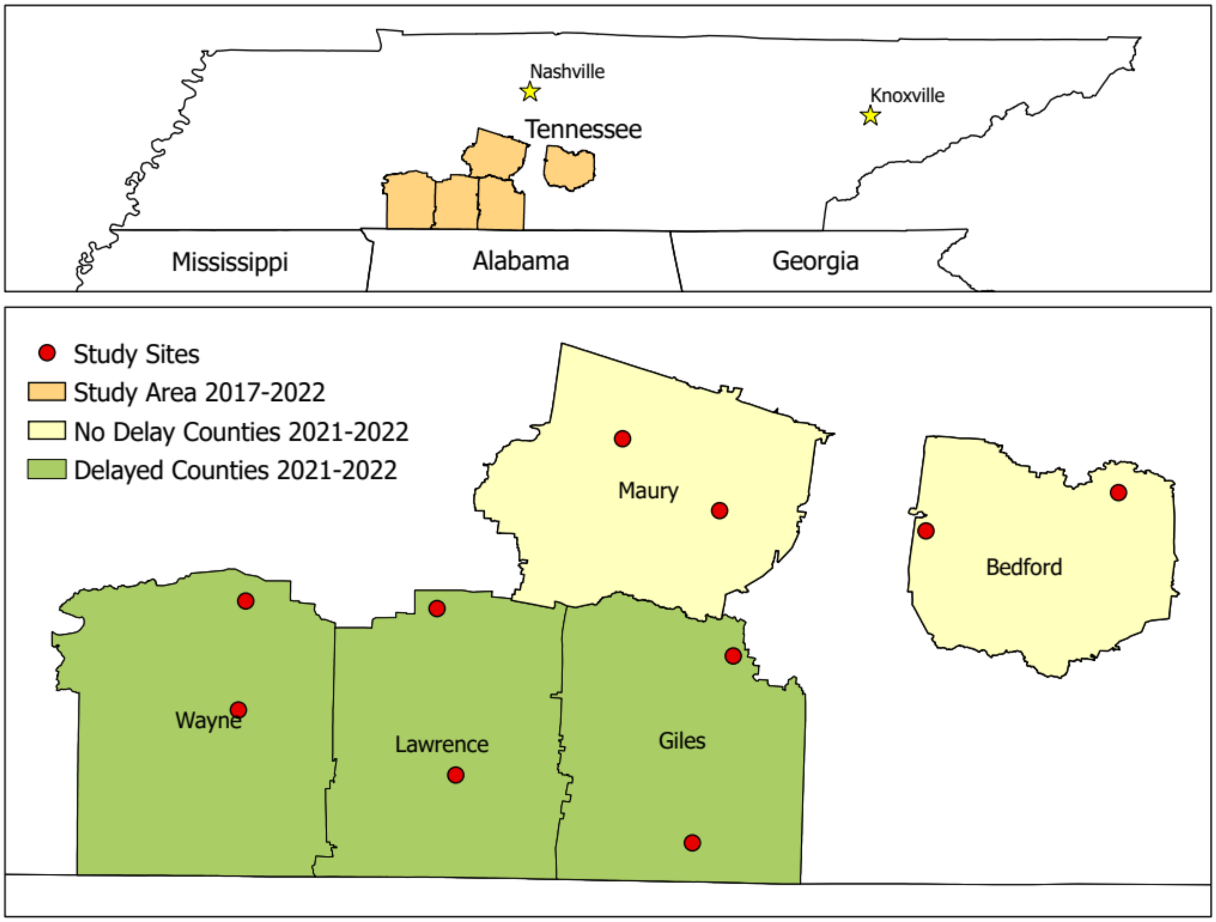

Figure 2.2. The five counties studied within south-middle Tennessee, USA with 10 study sites represented by red dots and counties separated by the start date of the spring wild turkey hunting season in 2021 and 2022.

Part III. Changes in hunter behavior, success, and satisfaction in relation to wild turkey season opening dates and season length.

ABSTRACT

Many states throughout the range of wild turkeys (*Meleagris gallopavo*) have delayed the spring wild turkey hunting season to allow reproductively active males more time to breed before being harvested and to potentially increase fecundity. Six states in the Southeast recently have delayed their spring hunting season start dates 6 to 14 days later. However, we are aware of no published data that indicate their previous season framework had a deleterious effect on wild turkey productivity. In addition to potentially affecting turkey productivity, changing the season framework may impact hunters' behavior, success, and satisfaction. Our objective was to see how hunter behavior, success, and satisfaction changed after implementing a two-week season delay and a two-week reduction in season length to the spring wild turkey hunting season in south-middle Tennessee. We conducted a survey of the same 2,000 hunters in five counties from 2017 to 2022 to document effort and harvest among hunters. We received 2,539 surveys for a response rate of 22.3%. We used a two-level structural model with generalized linear models for panel data to assess changes to hunter effort (hours spent hunting) and experience, and then assessed how the change in season framework affected satisfaction. Hunter effort in the affected counties declined by 37.6% after the delay, and the average number of gobbles heard per trip declined by 38.9%. Overall harvest was unaffected by the season delay, but hunter efficiency improved by 36.6% following the delay. Harvest, hunter efficiency, and gobbles heard were strong predictors of hunter satisfaction. We suggest state agencies consider turkey reproductive biology first when setting wild turkey hunting season frameworks, but also consider how hunter satisfaction may be affected by alternative season frameworks. Maintaining or increasing hunter satisfaction may be related to agency goals for hunter participation, retention, and recruitment.

INTRODUCTION

Hunter satisfaction with the hunting season can strongly influence hunter recruitment and retention (Everett and Nelson 2015) and is not just correlated with successful harvest. The "multiple satisfaction framework" (Hendee 1974) states that hunter satisfaction is impacted by sociocultural factors, such as tradition or comradery, and experiential factors such as harvesting game (Hayslette et al. 2010, Watkins et al. 2018). Understanding factors that influence hunter satisfaction can be useful for state agencies because of the impact satisfaction has on hunter retention and recruitment (Mehmood et al. 2003, Fulton and Manfredo 2004, Burnke and Hunt 2008). Conservation dollars are generated through license sales which can be used to manage wild turkeys as well as many other species. Therefore, it is important for state agencies and other stakeholder groups to understand the factors that drive hunter satisfaction so revenue can be generated for wildlife management and high-quality hunting opportunities can be provided.

The number of wild turkey (*Meleagris gallopavo*) hunters, similar to other types of hunters, has declined in terms of license sales and hunter retention. Chamberlain et al. (2022) reported a 16% decline in spring wild turkey license sales nationwide from 2013 to 2019. In 2016, the U.S Fish and Wildlife Service's (USFWS) national survey of fishing, hunting, and wildlife recreation reported that there were 2 million wild turkey hunters that accounted for 115 million hunter days, which is second only to deer hunters (9.2 million hunters and 133 million hunter days, U.S Department of Interior 2016). There also was a 25% decline in annual revenue generated from hunting from 2011 to 2016 (U.S Department of Interior 2016). The decline in hunters and revenue should be very concerning to state wildlife agencies. Multiple factors can influence hunter satisfaction, such as harvesting game, opportunity to harvest game, and seeing game (Brunke and Hunt 2008, Ryan and Shaw 2011, Gruntorad et al. 2020). Declining game population sizes can negatively affect harvest (Roberts and Crimmins 2010) and therefore potentially reduce hunter satisfaction. Watkins et al. (2018) reported 65% of wild turkey hunters in Tennessee were concerned about a potential decline in the wild turkey populations. This perceived decline is supported by Byrne et al. (2015) who reported a general decline in poult-per-hen ratios throughout the Southeast, including Tennessee since 1990.

In addition to the decline in turkey hunter participation, there also is concern that the decline in wild turkey productivity indicated by poult-per-hen ratios is resulting in declining wild turkey numbers. Johnson et al. (2022) monitored productivity in south-middle Tennessee from 2017 to 2018 and reported relatively low estimates of initial nesting rates (nesting rate = 0.76) and nest success (nest success = 0.31), further suggesting productivity of wild turkeys is low in that area of Tennessee. A leading hypothesis related to the decline in productivity is that the spring hunting season in many states begins too early and is negatively impacting productivity by harvesting males before they have had a chance to breed, and disrupting the flock's social hierarchy (Isabelle et al. 2018). Six southeastern states (Alabama, Arkansas, Georgia, Louisiana, Oklahoma, Tennessee) have delayed their hunting season in response to this hypothesis. However, a later hunting season could negatively impact the hunting experience if the season is misaligned with peak gobbling activity. Hearing gobbling birds has been identified as the leading factor associated with turkey hunter satisfaction in several studies (Cartwright and Smith 1990, Wakefield et al. 2019, Wightman et al. 2019, Gruntorad et al. 2020). Therefore, a later hunting season may negatively impact hunter satisfaction if peak gobbling activity no longer occurs during the hunting season.

From 1986 to 2020, the spring hunting season in Tennessee began on the Saturday closest to April 1. For the 2021 and 2022 spring seasons, the Tennessee Fish and Wildlife Commission voted to delay the hunting season and reduce the season length by 14 days in several counties, (including Giles, Lawrence, and Wayne counties) because of perceived population declines and to determine if delaying the season might affect seasonal productivity and ultimately population size. The experimental delayed season was implemented during the 2021 and 2022 spring wild turkey hunting seasons. Our objective was to investigate how a 14-day delay in the opening and a shortening of the spring turkey hunting season affected hunter effort, hunter success, hunter efficiency, and hunter satisfaction. We tested three specific hypotheses relative to hunter behavior and the season delay (Table 3.1):

1) Hunter effort would decrease because the season was reduced from 44 to 30 days.
2) Hunter success and efficiency would increase because male turkeys would be more responsive to calling by hunters as more hens begin incubating.
3) Hunter satisfaction would remain the same because, hunter efficiency may increase (hypothesis #2); thereby, increasing hunter satisfaction. But decreased gobbling activity, the shorter season, and reduced effort (hypothesis #1) would potentially decrease hunter satisfaction simultaneously.

STUDY AREA

Our study area was five counties in south-middle Tennessee: Bedford, Giles, Lawrence, Maury, and Wayne (hereafter referred to as “the five focal counties”). These five counties consist of a mix of rural and urban communities with human population sizes ranging from 16,427 to 102,878, with 49.1% of the population being comprised of males (Tennessee Department of Labor and Workforce Development, 2022). The demographic characteristics of our respondents are typical for turkey hunters throughout Tennessee (Watkins et al. 2018, Table 3.2).

In 2012, there were ~120,700 wild turkey hunters in Tennessee (Schexnayder et. al 2013), and based on license sales from 2022, there were 23,650 hunters living in one of the five focal counties who had a big game license enabling them to turkey hunt (albeit not specifically for turkey hunting). About 19.6% of wild turkey hunters in Tennessee reside in one of the five focal counties. There are 30,000–40,000 turkeys harvested by hunters each year in Tennessee, and 2,550 birds were harvested in the five focal counties in 2022, which represented 8.9% of the statewide harvest (Tennessee Wildlife Resource Agency, unpublished data). We chose to include the five focal counties in our study because Giles, Lawrence, and Wayne counties were perceived to have the greatest decline in population size in the state based on harvest, and Bedford and Maury counties were perceived to be stable and increasing. We assessed responses from hunters in Giles, Lawrence, and Wayne counties (hereafter, referred to as "delayed counties"), and compared their responses to hunter responses in Bedford and Maury counties (hereafter, referred to as "no-delay counties") before and after the season delay (2017–2020 vs. 2021–2022) to test our research hypotheses.

METHODS

We conducted a survey every year from 2017 to 2022. We randomly selected 1,600 people (320/county) who lived in one of the five focal counties and had a license to hunt wild turkeys in Tennessee. In addition to these original 1,600 people, we randomly selected 400 additional people (80/county) who reported harvesting a bird in one of the five focal counties to ensure our sample contained successful hunters, unsuccessful hunters, and non-resident hunters. These same 2,000 individuals randomly selected in 2016 were continually surveyed each consecutive year unless they specifically asked to be removed from the survey mailing list (<1% of respondents).

The survey had 30–38 questions each year and was broken down into four sections. The first section focused on their current season turkey hunting in Tennessee, the second section assessed their opinions surrounding spring turkey hunting regulations, the third documented their perceptions of turkey populations in the five focal counties, and the last section requested their demographic information. Our surveys were modeled after Watkins et al. (2018), and questions in each section were modified each year to accommodate new regulatory changes, new researcher hypotheses, or to address respondent confusion about specific questions.

The mailing protocol for our survey followed Dillman (2006). Surveys were mailed to respondents within ten days of the close of the spring hunting season. We included a cover letter with the survey which outlined the purpose of the survey with a pre-paid postage envelope to return the completed survey. We mailed a reminder postcard one week after the initial mailing if we had not received a completed survey. We mailed an additional copy of the survey with a reminder letter if we had not received a completed survey two weeks after sending the initial survey and cover letter. All mailings and surveys were conducted with an approved University of Tennessee Institutional Review Board human subjects research protocol (#UTK IRB-17-03689-XM).

Analytical Methods

We calculated hunter effort and birds seen or heard on a per-trip basis, whereby a trip was defined as one individual leaving their place of residence to go hunting and returning. A hunter could have ≥1 trip per day if they returned home and went hunting again later that day. We derived hunter effort by taking the number of trips spent hunting in each county and multiplying it by the average time spent per trip. We calculated hunter efficiency by dividing the hunter's effort by the number of birds harvested which resulted in a metric of hours per harvested bird.

Hunter success was the number of birds harvested by a hunter in a season. Each respondent reported the number of juveniles (hereafter referred to as “jakes”), and the number of adults (hereafter referred to as “toms”) they saw on a typical trip. They also reported how many individual gobbles they heard per typical trip. We removed some surveys because of incomplete answers or individuals who reported implausible responses (e.g., a trip >24 hours, seeing >50 jakes or toms per trip, the number of gobbles heard/trip >200). Hunter season satisfaction and satisfaction with the regulation change (delaying the start date) were both determined by a self-reported hunter assessment on of how satisfied they were on a scale of one (extremely unacceptable/dissatisfied) to five (extremely acceptable/satisfied) and then converted to a three-part scale of one to three.

The study was set up in a Before-After (2017–2020, 2021–2022), Control-Impact (no-delay, delay) study design (Smokorowski and Randall 2017). We used generalized linear models for panel data to maintain the longitudinal nature of the study, which allowed responses to vary by the start date of the spring hunting season (Fulton and Manfredo 2004, Bartolucci et al. 2015). We ran these models in Program R (R Core Team 2022) and used the pglm package (Croissant 2022). The models were run in a structured modeling framework with two levels of analysis (Fulton and Manfredo 2004, Figure 3.1). The first level was a suite of a-priori models whereby the dependent variable was each of the metrics described above, and the independent variable was the interaction between the treatment group (delayed counties vs. no-delay counties) and timing (before the season delay vs. after the season delay). The second level to these models used hunter satisfaction as the dependent variable and the above metrics as the independent variables. The structured model framework allowed the assessment of the direct effects of the season delay (Level 1) and potential indirect effects of the season delay on hunter satisfaction (Level 2).

We tested our hypotheses by evaluating the significance of the interaction term in the experimental design for various response metrics. We evaluated four response metrics with our analyses: hunter effort, hunter success, hunter efficiency, and experiential factors, and how the season start date impacted them. Hunter effort (total hours spent hunting) was modeled using one generalized linear model for panel data. We modeled hunter efficiency (hours spent to harvest a bird = effort / number of birds harvested) using one interaction model. If a hunter reported effort in both county groups within the same year/survey, we treated them as two separate hunters one who hunted in no delay counties and one who hunted in delayed counties. We did this in order to maintain our study design comparing impacted hunters to control hunters before and after the season delay. This was only done for effort and efficiency and all other metrics hunters were not duplicated. Hunter success was modeled with a single model of the number of birds harvested in a season. We also ran individual models to evaluate three experiential response metrics: the average number of toms seen per trip, gobbles heard per trip, and jakes seen per trip. Hunter satisfaction was converted from a five part scale to a three-part, one (unsatisfied) to three (satisfied) scale in order to meet the parallel assumption of logistic regression with ordinal data. We used a generalized linear model for panel data with a negative binomial distribution to analyze all hunter effort, hunter success, hunter efficiency, and experiential models because all of these models were based on count data. We analyzed hunter satisfaction with a generalized linear model for panel data with an ordinal logit distribution because hunter satisfaction was based on an ordinal scale of one to three. For the second level of the analysis, all of the above metrics then were related to hunter satisfaction using the same type of linear models with an ordinal logit distribution. We tested the parallel assumption of logistic regression using the brant package in Program R for all second-level models.

RESULTS

We received 2,539 surveys from 2017 to 2022, with an average of 423 per year, providing an average response rate of 22.3% from 2017 to 2022, which ranged from 36.2% in 2017 to 17% in 2022. Of these responses, 1,763 respondents hunted turkeys in one of the five focal counties, with an average of 294 hunters surveyed in our study area each year. If we adjust the response rates for hunters who hunted in these counties, we had an average response rate of 15.2% across the six years, ranging from 8.4% to 27.0%. After censoring surveys, we used 1,581 hunter surveys in our analysis.

We received 562 surveys from hunters who reported hunting in one of the two no-delay counties with 455 before the season delay (2017–2020) and 107 after the delay (2021–2022). We received 1019 surveys of hunters who reported hunting in a delayed county with 833 before the delay and 186 after the delay. In no-delay counties, we surveyed 342 individual hunters (Before: 263, After: 79). We surveyed 604 individual hunters in delayed counties over the six years (Before: 463, After: 141).

Hunter Effort

Delayed-county hunters averaged 44.5 (SE: 1.2) hours hunting in a delayed county per season, with a decline of 21.9 hours (Before: 52.8, SE: 1.9, After: 30.9, SE: 2.1; Table 3.3; Figure 3.2) after the season was delayed. Hunters in no-delay counties averaged 38.3 hours per season, with a decline of 4.2 hours (Before: 38.1, SE: 1.8, After: 33.9, SE: 3.2) after the delay (n = 1836; df = 1832; P = 0.07; Table 3.4). Although the interaction was not significant, the decline in hours hunted was 421% greater in delayed counties than no-delay counties. Effort declined in all counties from the 2017–2020 hunting season to the 2021–2022 hunting seasons (β = 0.41, SE_{β}: 0.06, P = < 0.00001).

Hunter Success

We received 855 surveys from hunters who reported harvesting at least one turkey. Out of the 1,581 respondents, 50% reported harvesting zero turkeys per year, 28.3% reported harvesting one bird, 12.1% harvested 2 birds, and 9.6% harvested 3+ birds per year (limited out). Hunters in delayed counties harvested 0.1 fewer birds after the delay (Before: 0.9, SE: 0.04, After: 0.8, SE: 0.07; Table 3.3; Figure 3.3). Harvest in no-delay counties was similar with 0.9 (SE: 0.05) birds harvested before the delay and 1.0 (SE: 0.1) after (n = 1581; df = 1577; Interaction term: P = 0.29; Table 3.4).

Hunter Efficiency

Spring turkey hunters who harvested a turkey spent 38.1 (SE: 1.4) hours on average to harvest one turkey. Hunters in delayed counties reported 16.7 fewer hours (Before: 44.4, SE: 2.3, After: 27.7, SE: 2.9; -37.6%) to harvest a bird after the season delay. Hunter efficiency in no-delay counties also improved after the delay as hunters required 3.0 fewer hours (Before: 33.6, SE: 1.8, After: 30.6, SE: 2.1; -8.9%; Table 3.3; Figure 3.4) to harvest a bird (n = 877; df = 873; P = 0.68; Table 3.4). Regardless of county, hunter efficiency increased during the 2021–2022 hunting seasons across all counties compared to the 2017–2020 season ($\beta = 0.32$, SE_{β}: 0.096, P = 0.0007).

Experiential Metrics

Delayed-county hunters saw 0.2 fewer toms per trip after the delay (Before: 2.6, SE: 0.1, After: 2.4, SE: 0.3; Table 3.3; Figure 3.5), whereas hunters in no-delay counties saw 0.8 more toms per trip after the delay (Before: 3.3 SE: 0.2, After: 4.1, SE: 0.4; n = 1581; df = 1577; Interaction term: P = 0.06; Table 3.4). Delayed-county hunters heard 3.5 fewer gobbles per trip after the delay (Before: 9.0, SE: 0.5, After: 5.5, SE: 0.7; Table 3.3; Table 3.3; Figure 3.6) whereas hunters in no-delay counties heard 2.4 more gobbles per trip after the delay (n = 1581; df = 1577; Interaction term: P = 0.04, Table 3.4). In delayed counties, hunters saw 2.9 jakes per trip (SE: 0.1) before and 3.1 jakes (SE: 0.3; Table 3.3; Figure 3.7) after the delay. Hunters in no-delay counties saw 4.1 jakes per trip (SE: 0.2) before and 4.2 jakes (SE: 0.5) after the delay (n = 1581; df = 1577; Interaction term: P = 0.54; Table 3.4).

Hunter Satisfaction

Hunter satisfaction was not directly impacted by the season delay (n = 1581; df = 1577; Interaction term: P = 0.18; Table 3.4), but satisfaction in delayed counties was historically less than satisfaction in no-delay counties ($P < 0.0001$). Hunter satisfaction across all hunters from 2017–2022 was 2.0, which equates to a neutral reaction to the hunting season. Hunter satisfaction in delayed counties before the season delay was 1.9 (slightly unsatisfied; SE: 0.03) and was 1.8 (slightly unsatisfied ;SE: 0.06) after the delay. Hunters in no-delay counties generally were more satisfied with their hunting season with an average satisfaction of 2.2 (slightly satisfied; SE: 0.04) before, and 2.3 (slightly satisfied; SE: 0.08) after the delay (Figure 3.8). However, the insignificant interaction term indicated the season delay did not have a direct effect on hunter satisfaction.

Hunter satisfaction was not correlated with hunter effort, but was more strongly correlated with hunter success, hunter efficiency, and experiential metrics ($P_{Effort} = 0.15$; $P_{Success} < 0.001$; $P_{Efficiency} < 0.01$; $P_{Experiential} < 0.01$; Table 3.4; Figure 3.9). We documented negligible support for the relationship between hunter effort and satisfaction, with a P-value of 0.15.

The β estimate confidence intervals for the model of hunter effort predicting hunter satisfaction overlapped zero, β = -0.002, (95% CI: -0.005, 0.001). The beta estimate for hunter success (β = 0.92; 95% CI: 0.74, 1.10) reflected a positive relationship between hunter success and satisfaction. The β estimates for hunter efficiency were -0.01 (95% CI: -0.015, -0.005), suggesting that with decreasing hunter efficiency (i.e., more time required to harvest a bird), there was a slight decrease in hunter satisfaction. The toms-seen and gobbles-heard models documented positive relationships with hunter satisfaction, with β estimates of 0.18 (95% CI: 0.14, 0.23) and 0.03 (95% CI: 0.02, 0.04), respectively. The number of jakes seen per trip also was positively correlated with hunter satisfaction (β = 0.15; 95% CI: 0.11, 0.18).

Satisfaction with the Season Delay

From 2017 to 2022, 1,634 hunters answered a question about their support for a season delay with 1055 delayed-county hunter surveys (Before: 854, After: 201) and 579 from no-delay counties (Before: 477, After: 102). Prior to the season delay in 2021, delayed-county hunters reported being "neutral" or "acceptable" of shortening the hunting season to 36 days with an average acceptability score of 2.2 (SE: 0.03). No-delay hunters reported a similar acceptability of 2.1 (SE: 0.04). Satisfaction of hunters in delayed counties dropped by 0.1 after the season delay occurred, whereas satisfaction of hunters in no-delay counties increased by 0.3 after the delay (Delayed: 2.1, SE: 0.06, No-Delay: 2.4, SE: 0.06; n = 1634; df = 1630; Interaction term: P = 0.004; Figure 3.10). Satisfaction related to changing the season framework remained in the same category of "neutral" or "acceptable/satisfied" regardless of county or year.

DISCUSSION

Hunter satisfaction was positively correlated with experiential metrics, such as gobbles heard per trip, which was correlated with the timing of the spring hunting season. Hunters were more satisfied with their hunting season if they saw or heard more turkeys or if the birds were easier to hunt successfully (efficiency). Schroeder et al. (2019) and Gruntorad et al. (2020) reported similar results that seeing game had the greatest influence on satisfaction. However, these studies did not measure hunter effort or efficiency. Hunter effort was not a strong predictor of hunter satisfaction in our study. Most successful turkey hunters in Tennessee harvest only one turkey (50% harvested no birds and 28.3% harvested one bird) so more time spent in the woods often equates to less efficiency. We observed a decline in hunter effort of 41.5% in delayed counties, but a decline also was observed in control counties (11%). Hours spent hunting were not an important predictor of satisfaction, so this decline likely did not influence hunter satisfaction. The reduction in effort may have been a response to the 14-day season delay or the 14-day reduction in season length or both factors combined.

Hunter success did not change in response to the season delay as hunters in delayed counties harvested the same number of birds (approximately one) before and after the delay. Hunter satisfaction was more strongly related to harvest, which has been documented by others (Fulton and Manfredo 2004, Schroeder 2014, Gruntorad et al. 2020).

Hunter efficiency was a significant predictor of hunter satisfaction but was not explicitly affected by the season delay. We observed changes before and after the season delay in hunter efficiency but these changes were observed in both county groups. There was a greater increase in efficiency in delayed counties compared to no-delay counties. By opening the season in mid-April, toms may be more susceptible to calling by hunters because more hens are incubating. The majority of turkey hunters kill only one bird and may quit hunting after harvesting a bird thus efficiency increased. The increase in hunter efficiency in no-delay counties may reflect changes in hunting conditions and/or an increase in the tom population.

Our experiential models indicated fewer gobbles heard by hunters in delayed counties, whereas hunters in no-delay counties saw/heard more birds. These differences coincided with greater overall satisfaction in no-delay counties. The most substantial change in the experiential metrics was in the number of gobbles heard per typical trip. Hunters reported 39% fewer gobbles per trip in delayed counties, whereas hunters in no-delay counties reported a 21% increase. Previous research has identified factors such as weather (Wightman et al. 2022), changes in population size (Palumbo et al. 2019), and hunter activity (Wakefield et al. 2019, Wightman et al. 2023) as factors influencing gobbling activity. There was little evidence that any of these factors, however, accounted for the differences in gobbles heard between delay and no-delay counties. Gobbling activity in both county groups were similar prior to the season delay, with hunters reporting 9.0 gobbles per trip in delayed counties and 11.4 in no-delay counties (P = 0.17). Therefore, a reduction in gobbling in delayed counties suggests the delayed hunting season likely began after peak gobbling activity. The decrease in gobbles heard supports our hypothesis that a later hunting season caused hunters to hear fewer gobbles per trip and potentially caused the hunting season to exclude peak gobbling activity. Gobbling activity/gobbles heard per trip was correlated with hunter satisfaction similar to results reported elsewhere (Diefenbach et al. 2011, Schroeder 2014, Gruntorad et al. 2020).

We detected a positive relationship between gobbles heard and hunter satisfaction and a negative relationship between gobbles heard and season start date, but we did not see any direct changes to hunter satisfaction. One reason for this is that there may be other confounding factors influencing hunter satisfaction that we did not test for such as, perceived population size (Watkins et al. 2018) or crowding (Gruntorad et al. 2020) that may have influenced hunters' experiences. Hunter satisfaction is influenced by many factors and can vary by typology of the hunter (Watkins et al. 2018). Another explanation would be that a combination of changes occurred that alone were not statistically significant, but together may have increased hunter satisfaction and balanced out the negative effect on gobbles heard (i.e., statistically insignificant increases in hunter efficiency and jakes seen per trip).

Although we did not document a change in hunter satisfaction with the season delay, other factors positively and negatively correlated with hunter satisfaction were affected by the season delay (i.e., gobbles heard and hunter efficiency). In addition, after the season delay in 2021 and 2022, affected hunters were slightly less satisfied with the regulatory change, whereas hunters in no-delay counties were slightly more satisfied.

MANAGEMENT IMPLICATIONS

Wild turkey management is unique because the wild turkey is the only gamebird species in the U. S. that is hunted during the breeding season, such that hunting activity could negatively affect reproductive rates or seasonal productivity. Turkey hunting-season frameworks must be set such that they do not have a deleterious effect on the species' reproductive behavior and ultimately population growth. Beyond that, consideration for hunter satisfaction is important to maintain hunter involvement, recruitment, and for some species, management of the population. We documented that a two-week delay in the opening date and a reduction in the season length of the spring wild turkey season in three counties of south-middle Tennessee did not influence hunter satisfaction directly. However, these regulation changes could indirectly affect satisfaction, as hunters heard fewer gobbles per trip (negative) and increased their hunter efficiency (positive), both of which are strong predictors of hunter satisfaction. There was a strong perception among turkey hunters in the delayed counties that the turkey population had declined considerably compared to several years prior, and hunters wanted some agency action to reverse the decline

(Watkins et al. 2018, R. Shields, Tennessee Wildlife Resources Agency, unpublished reports). However, after two years of the season delay, hunters in delay counties were less accepting of the delay, likely because they heard fewer gobbles and did not perceive any net benefit from the delay. We recommend state agencies use hunter satisfaction data when determining the timing of the hunting season, but primarily consider how timing of the hunting season may affect reproductive success after analyzing vital rate data in relation to season opening date and length.

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APPENDIX

Table 3.1. Table of hypothesized effect the season delay would have on hunters from south-middle Tennessee, USA from 2017–2022.

Metrics	Hypothesized effect on affected hunters	Justification
Hunter Effort	decrease	Hunter effort in delayed counties may decrease because there are 14 less days and hunters may hunt elsewhere during that time period.
Hunter Efficiency	increase	Hunter efficiency may increase because males will be more responsive to calls since more hens have begun incubating nests.
Toms Seen/Trip	decrease	We would expect the number of toms seen to decrease in these counties because birds might be gobbling less during this time of year and subsequently may be harder to find.
Jakes Seen/Trip	increase	The basis behind the theory of a later start date would be that there is a reproductive benefit to starting to hunt later in the year. If this is true in subsequent years, we could see more jakes out on the landscape.
Gobbles Heard/Trip	decrease	We would expect gobbling activity to decrease in these effected counties as a later hunting season may exclude the peak in gobbling activity for our focal area.
Hunter Satisfaction	remain the same	Hunter satisfaction will remain the same because of reduced gobbling but may also increase as birds might be more responsive to calling and therefore easier to harvest and both potential outcomes could balance each other out and result in no change.

Table 3.2. Demographic information of the hunters in Bedford, Giles, Lawrence, Maury or Wayne counties, TN, USA that responded to our survey at least once from 2017–2022.

		2017		2018		2019		2020		2021		2022		All Years	
		n	% Resp.	*n*	% Resp.	*n*	% Resp.	*n*	% Resp.	*n*	% Resp.	*n*	% Resp.	*n*	% Resp.
Age	≤ 45 years old	234	43.5	138	38.4	94	33.7	89	32.2	55	33.1	42	30.0	652	37.09
	46–60 years old	241	44.8	164	45.7	129	46.2	123	44.6	61	36.7	53	37.9	771	43.9
	61–70 years old	57	10.6	55	15.3	50	17.9	57	20.7	45	27.1	38	27.1	302	17.2
	71–80 years old	4	0.7	2	0.6	6	2.2	7	2.5	2	1.2	7	5.0	28	1.6
	>81 years old	0	0.0	0	0.0	0	0.0	0	0.0	1	0.6	0	0.0	1	0.1
	Declined to answer	2	0.4	0	0.0	0	0.0	0	0.0	2	1.2	0	0.0	4	0.2
Gender	Male	505	93.9	341	95.0	262	93.9	255	92.41	156	94.0	128	91.4	1647	93.7
	Female	22	4.1	12	3.3	11	3.9	10	3.6	5	3.0	8	5.7	68	3.9
	Declined to answer	11	2.0	6	1.7	6	2.2	11	4.0	5	3.0	4	2.9	43	2.4
Income	< 50,000	163	30.3	83	23.1	62	22.2	58	21.0	27	16.3	33	23.6	426	24.2
	50,000–99,999	188	34.9	135	37.6	108	38.7	95	34.4	52	31.3	31	22.1	609	34.6
	100,000–149,999	92	17.1	60	16.7	50	17.9	41	14.9	37	22.3	33	23.6	313	17.8
	150,000–199,999	26	4.8	18	5.0	11	3.9	25	9.1	9	5.4	7	5.0	96	5.5
	200,000–249,999	4	0.7	3	0.8	6	2.2	2	0.7	2	1.2	2	1.4	19	1.1
	≥ 250,000	9	1.7	7	2.0	7	2.5	6	2.2	6	3.6	6	4.3	41	2.3
	Declined to answer	56	10.4	53	14.8	35	12.5	49	17.8	33	19.9	28	20.0	254	14.4
Total Respondents		538	30.6	359	20.4	279	15.9	276	15.7	166	9.4	140	8.0	1758	

Table 3.3. Wild turkey hunter metrics in south-middle Tennessee, USA from 2017–2022. Averages separated and organized by treatment and before and after the season delay (2021–2022).

	Treatment [a]						Control [b]					
	Before [c]			After [d]			Before [c]			After [d]		
Metric (*x*)	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE
Hunter Effort	932	52.8	1.9	189	30.9	2.1	587	38.1	1.8	128	33.9	3.2
Hunter Efficiency	432	44.4	2.3	85	27.7	2.9	291	33.6	2.2	69	30.6	4.4
Hunter Success	833	0.9	0.04	186	0.8	0.07	455	0.9	0.05	107	1.0	0.1
Toms Seen	833	2.6	0.1	186	2.4	0.3	455	3.3	0.2	107	4.1	0.4
Gobbles Heard	833	9.0	0.5	186	5.5	0.7	455	11.4	0.7	107	13.8	1.9
Jakes Seen	833	2.9	0.2	186	3.1	0.5	455	4.1	0.2	107	4.2	0.5
Hunter Satisfaction (1–3)	833	1.9	0.03	186	1.8	0.06	455	2.2	0.04	107	2.3	0.08

[a] This refers to the county group that had a two-week delay in the 2021 and 2022 spring hunting season (Giles, Lawrence, and Wayne)
[b] This refers to the county group that was unaffected by the regulatory changes in 2021 and 2022 (Bedford, and Maury)
[c] Only referring to surveys from 2017–2020
[d] Only referring to surveys from 2021–2022

Table 3.4. Models run on hunter surveys from 2017–2022 in south-middle Tennessee, USA, with model used, summary statistics, significance, and effect attributed by the season delay. Red lettering signifies a decrease and green lettering signifies an increase based on averages and model output. "Timing" is a dummy variable to signify whether the survey was before (2017–2020) or after (2021–2022) the season delay and "Treatment" was another dummy variable to denote whether the survey was from a hunter in a delayed or no-delay county.

Model Used	df	Beta (β)	*P*	Effect of Season Delay
pglm (Hunter Effort ~ Timing x Treatment)	1832	-0.17	0.07	No Documented Effect
pglm(Hunter Success ~ Timing x Treatment)	1577	-0.19	0.28	No Documented Effect
pglm(Hunter Efficiency ~ Timing x Treatment)	873	-0.06	0.68	No Documented Effect
pglm(Toms Seen/Trip ~ Timing x Treatment)	1577	-0.25	0.07	No Documented Effect
pglm(Jakes Seen/Trip ~ Timing x Treatment)	1577	0.10	0.54	No Documented Effect
pglm(Gobbles Heard/Trip ~ Timing x Treatment)	1577	-0.27 [a]	0.04	Significant impact (-)
pglm(Hunter Satisfaction ~ Timing x Treatment)	1577	-0.43	0.18	No Documented Effect
pglm(Hunter Satisfaction ~ Hunter Effort)	1832	-0.002	0.15	No Documented Effect
pglm(Hunter Satisfaction ~ Hunter Success)	1580	0.92 [a]	<0.0001	Significant impact (+)
pglm(Hunter Satisfaction ~ Hunter Efficiency)	873	-0.01 [a]	<0.0001	Significant impact (+)
pglm(Hunter Satisfaction ~ Toms Seen/Trip)	1580	0.18 [a]	<0.0001	Significant impact (+)
pglm(Hunter Satisfaction ~ Jakes Seen/Trip)	1580	0.15 [a]	<0.0001	Significant impact (+)
pglm(Hunter Satisfaction ~ Gobbles Heard/Trip)	1580	0.03 [a]	<0.0001	Significant impact (+)

[a] These beta values confidence intervals are statistically significant (95% confidence intervals do not overlap zero)

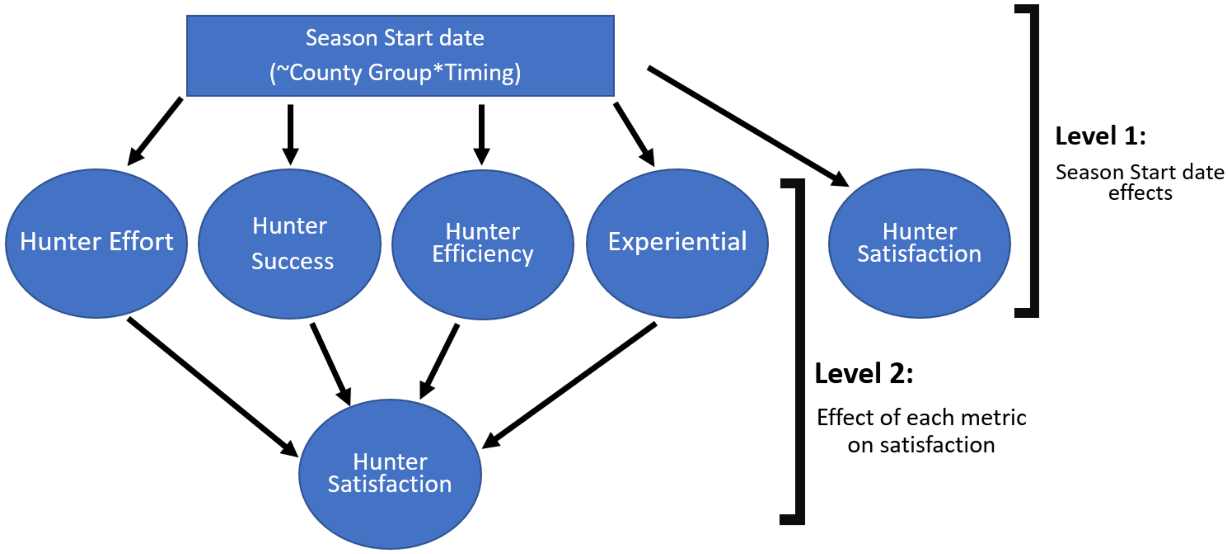

Figure 3.1. Conceptual model of structural design used to determine direct effects of the season delay as well as indirect effects on wild turkey hunter satisfaction in south-middle Tennessee, USA, 2017–2022. Each blue circle represents a suite of metrics, and each black arrow represents a separate generalized panel linear model.

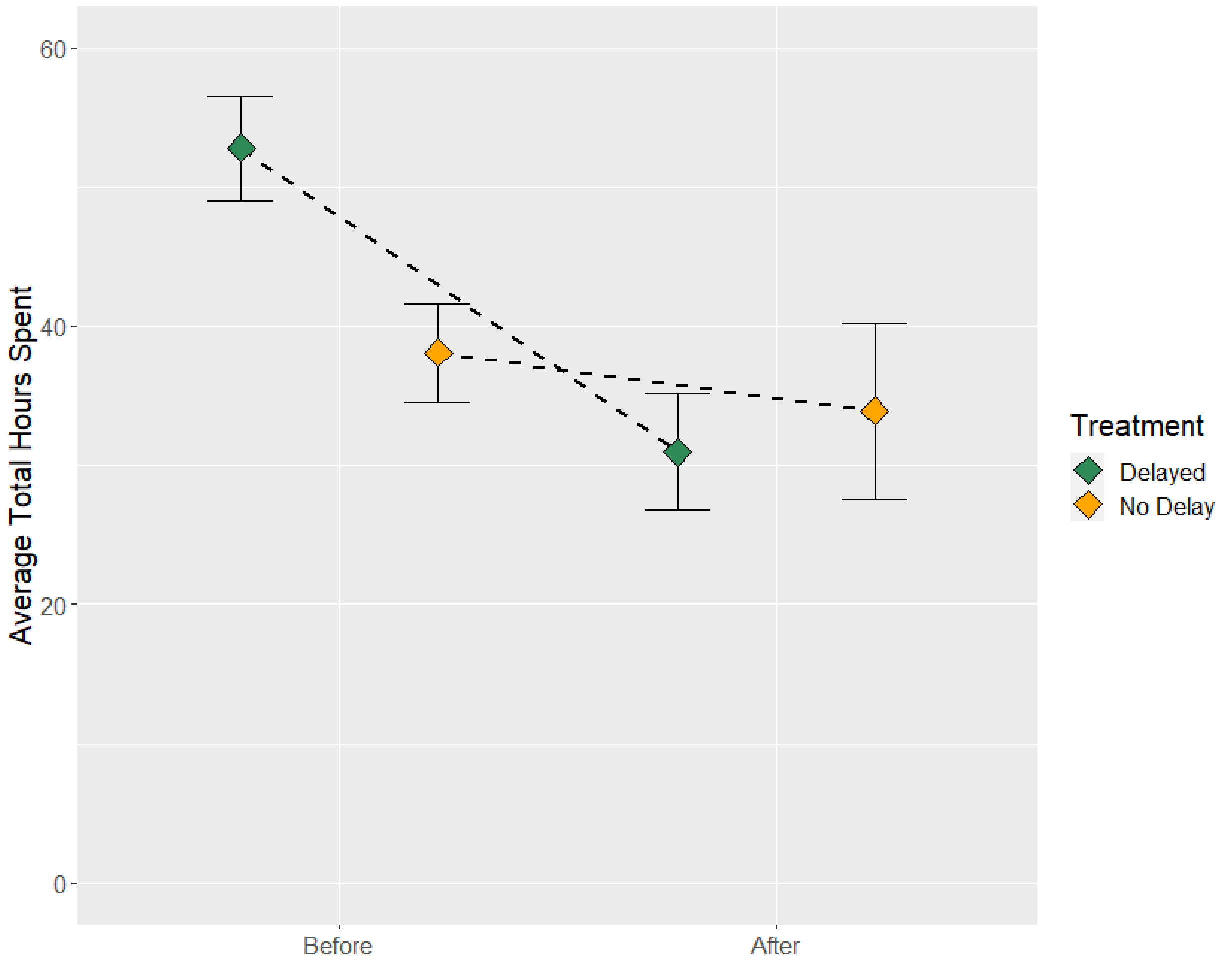

Figure 3.2. Average hunter effort of spring wild turkey hunters in south-middle Tennessee, USA from 2017–2022 with 95% confidence intervals of each. Hunter effort was calculated for each treatment group, delayed counties (Before: n = 932, After: n = 189) and no-delay counties (Before: n = 587, After: n = 128).

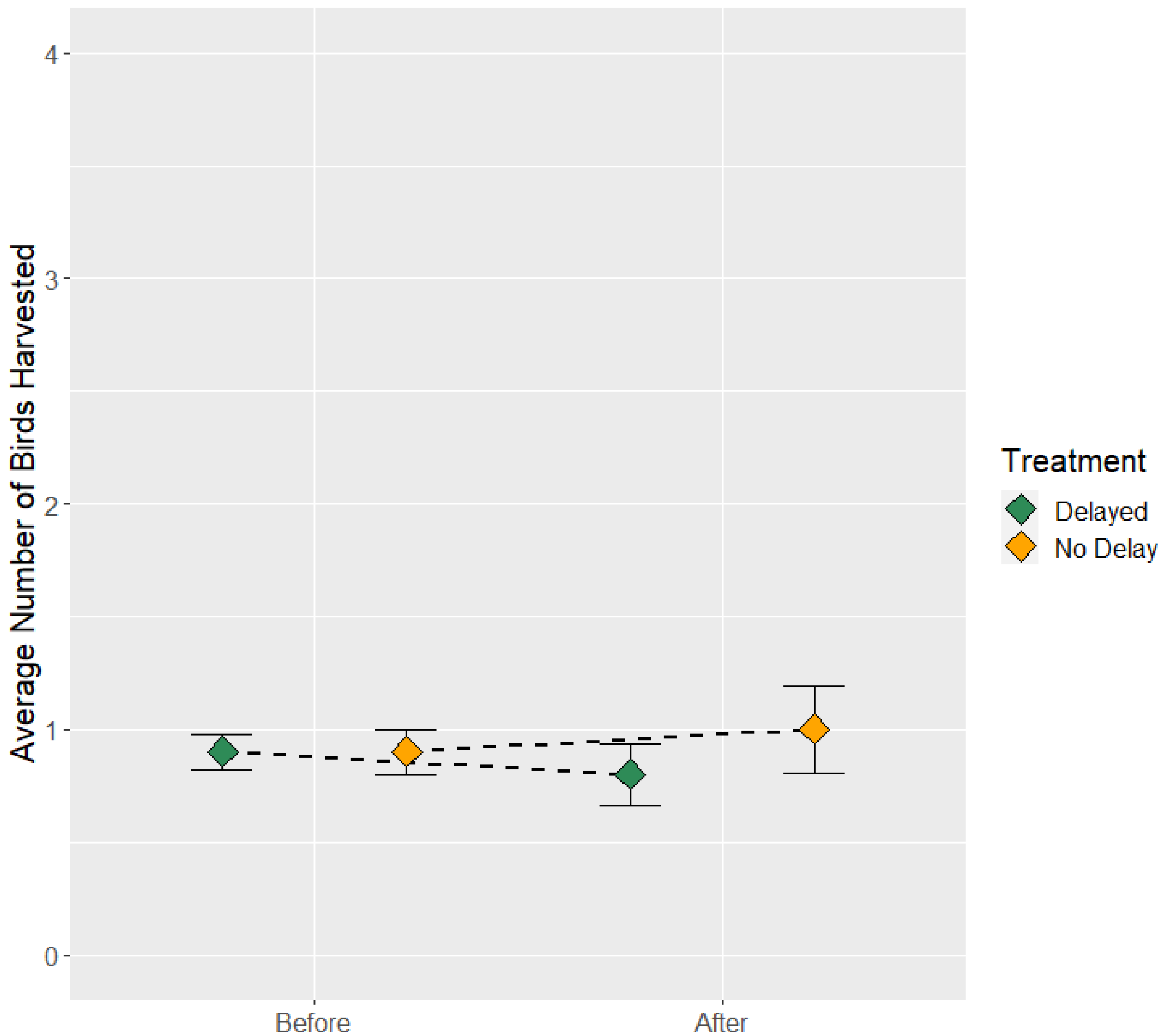

Figure 3.3. Average harvest of spring wild turkey hunters in south-middle Tennessee, USA from 2017-2022 with 95% confidence intervals of each. Harvest was calculated for each treatment group, delayed counties (Before: n = 833, After: n = 186) and no-delay counties (Before: n = 455, After: n = 107).

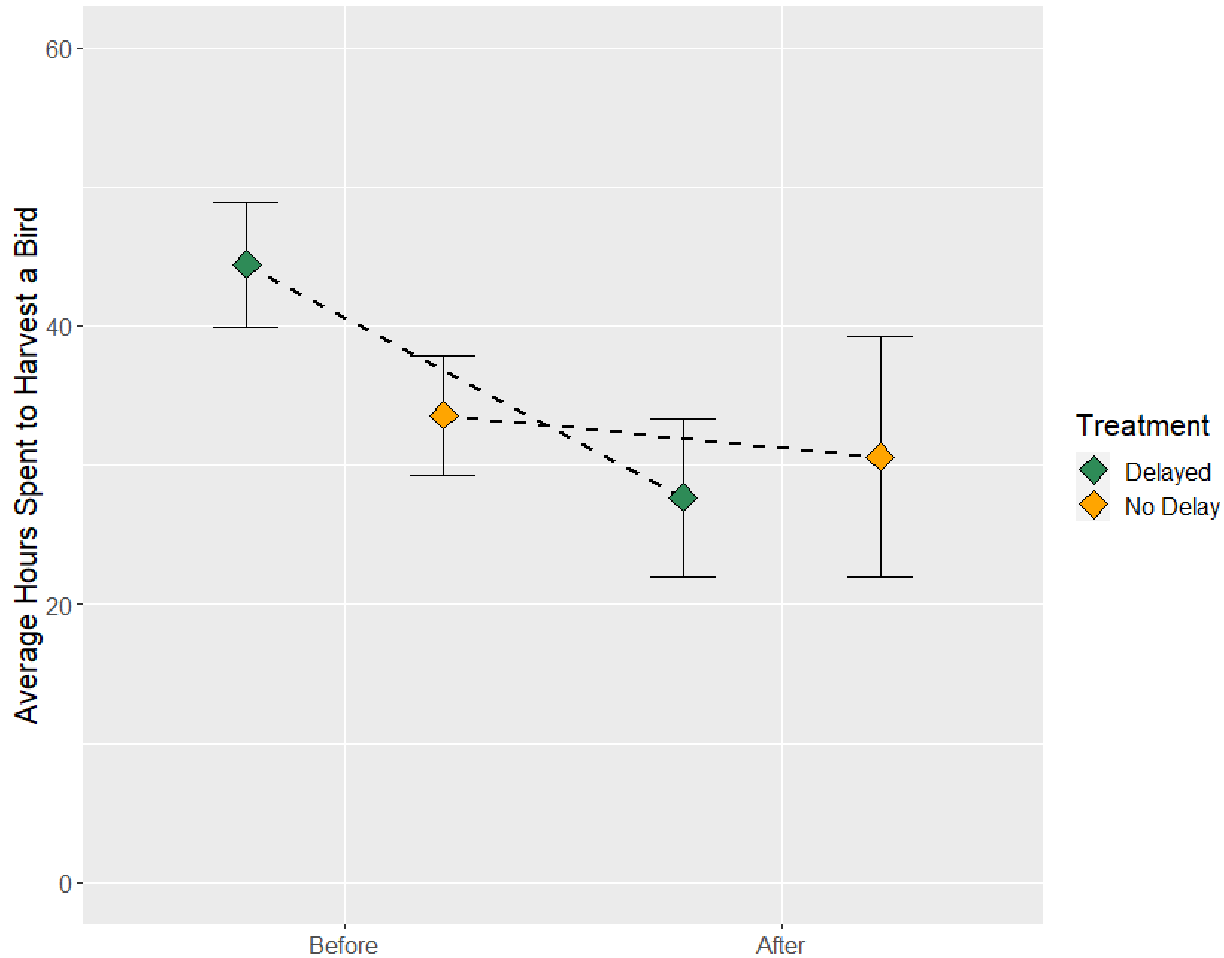

Figure 3.4. Average hunter efficiency of spring wild turkey hunters in south-middle Tennessee, USA from 2017–2022 with 95% confidence intervals of each. Hunter efficiency was calculated for each treatment group, delayed counties (Before: n = 432, After: n = 85) and no-delay counties (Before: n = 291, After: n = 69).

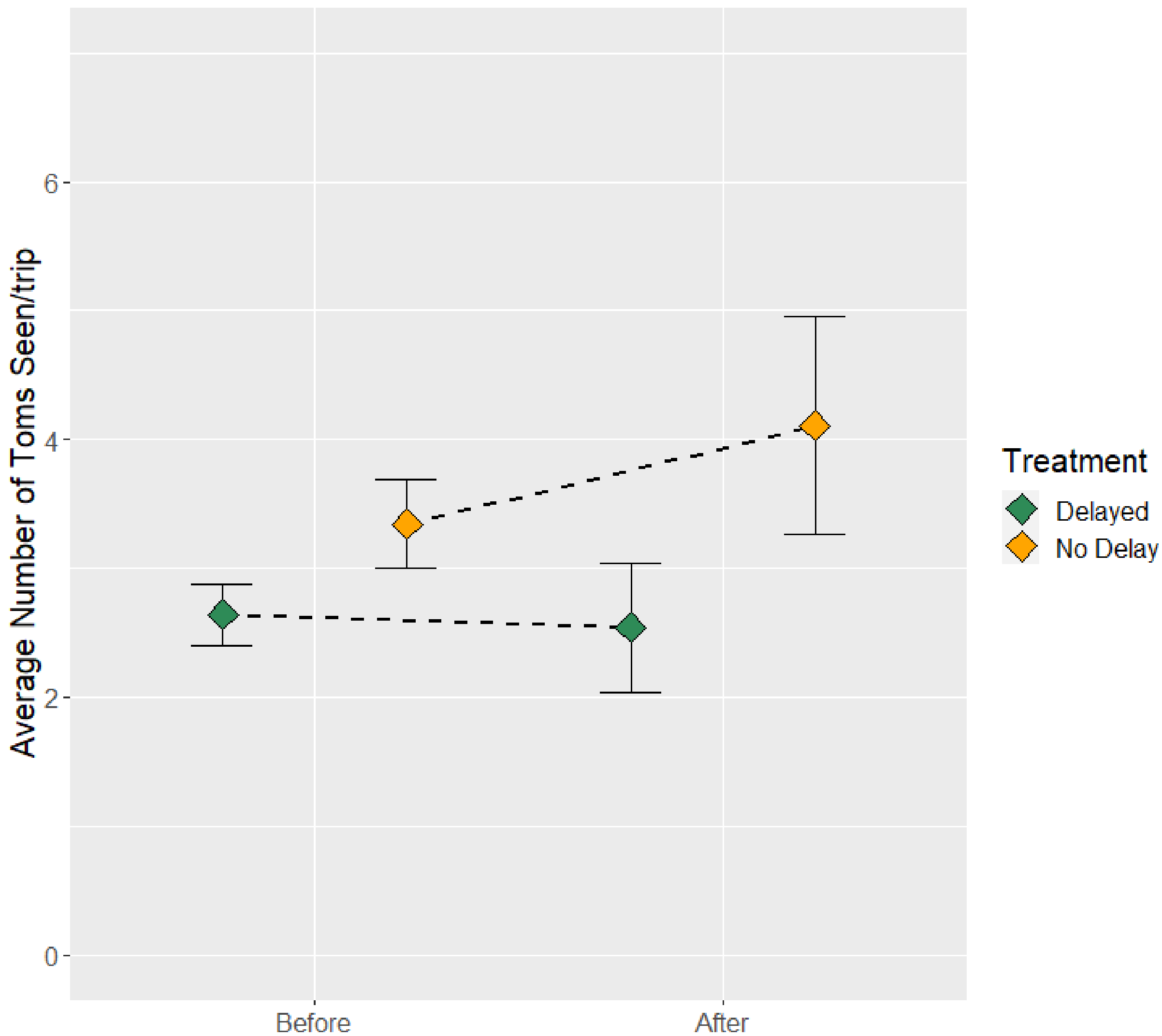

Figure 3.5. Average number of toms seen per trip by spring wild turkey hunters in south-middle Tennessee, USA from 2017–2022 with 95% confidence intervals of each. The number of toms seen per trip was calculated for each treatment group, delayed counties (Before: *n* = 833, After: *n* = 186) and no-delay counties (Before: *n* = 455, After: *n* = 107).

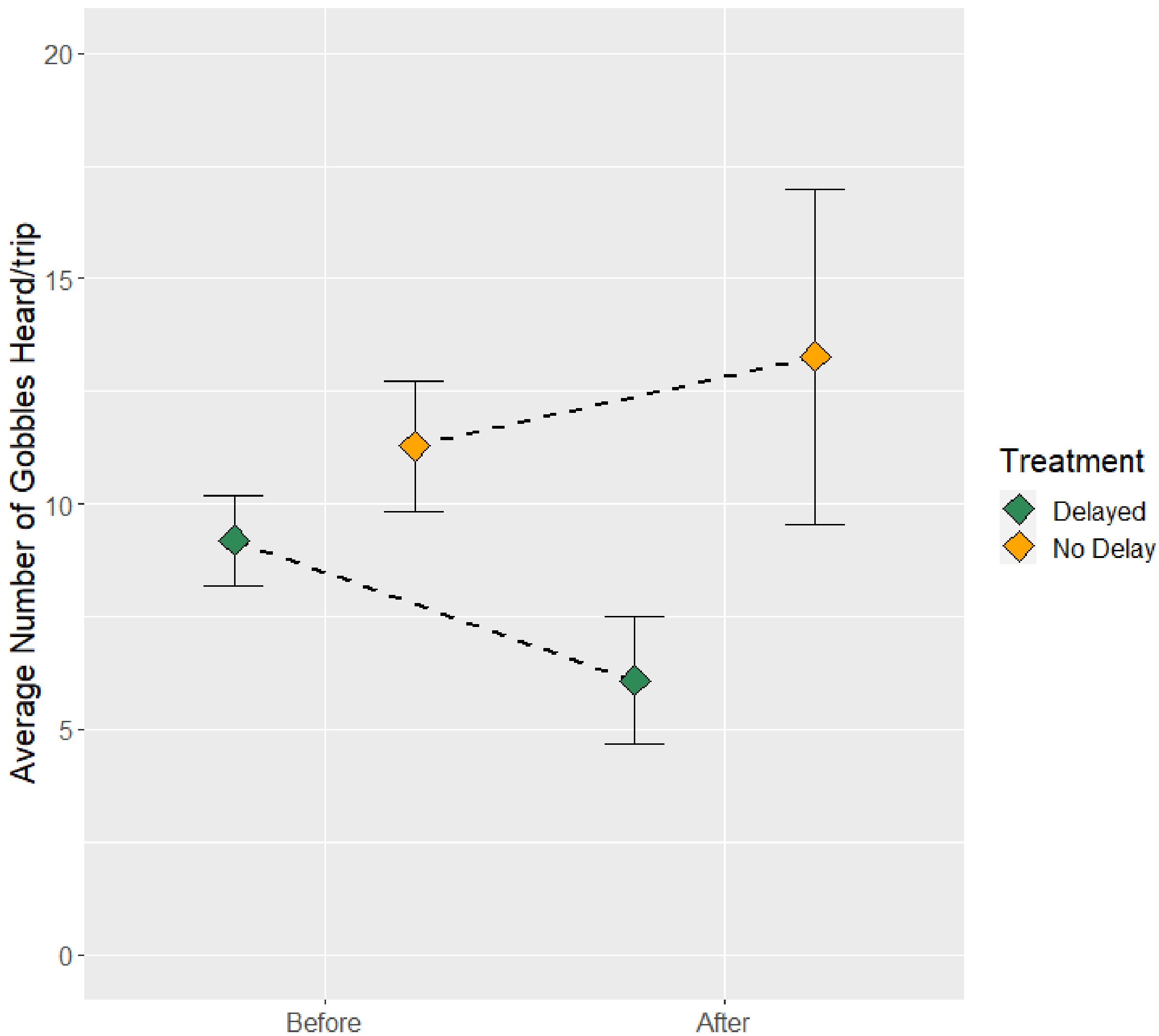

Figure 3.6. Average number of gobbles heard per trip by spring wild turkey hunters in south-middle Tennessee, USA from 2017–2022 with 95% confidence intervals of each. Gobbles heard per trip was calculated for each treatment group, delayed counties (Before: *n* = 833, After: *n* = 186) and no-delay counties (Before: *n* = 455, After: *n* = 107).

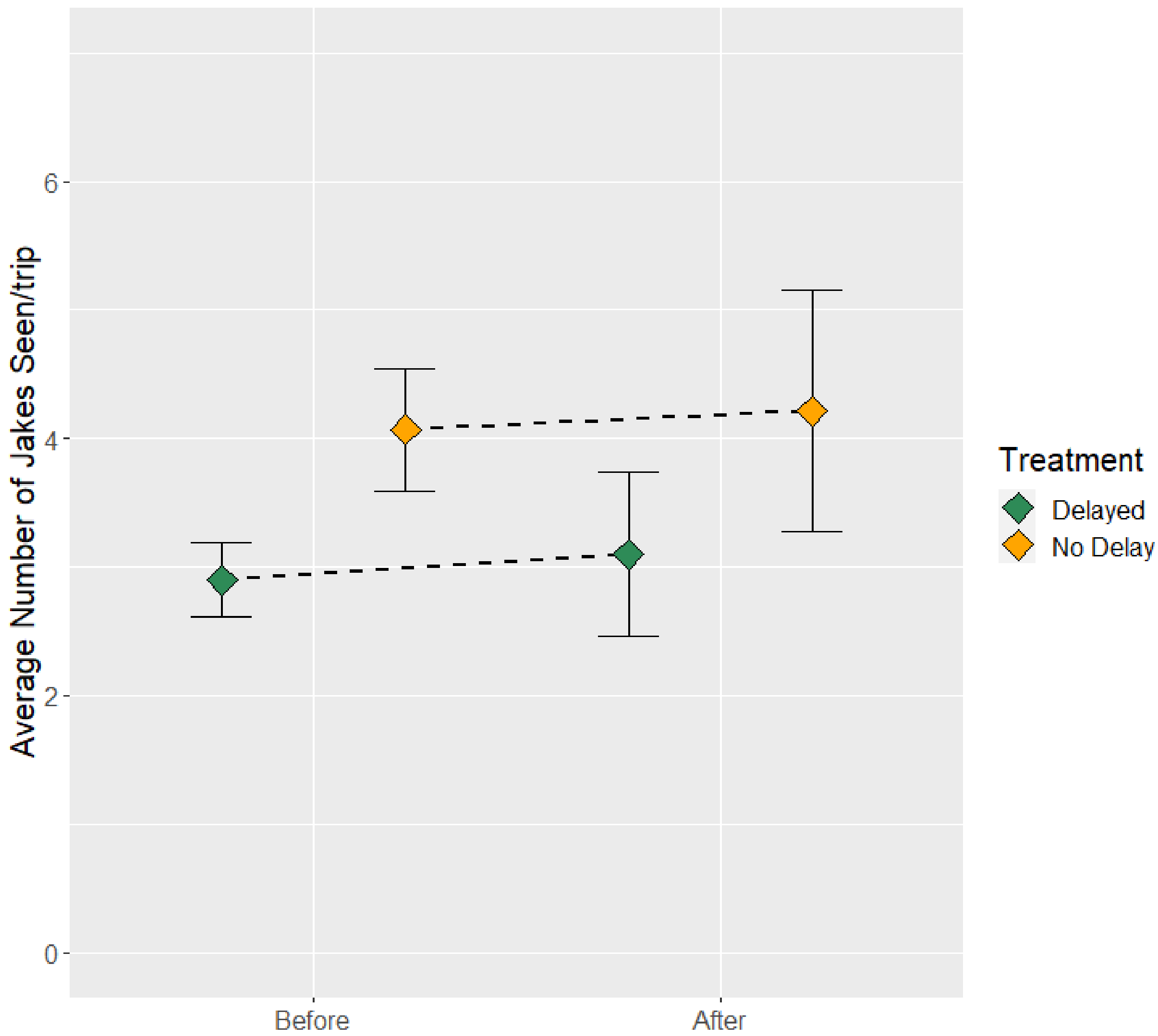

Figure 3.7. Average number of jakes seen per trip by wild turkey hunters in south-middle Tennessee, USA from 2017–2022 with 95% confidence intervals of each. The number of jakes seen was calculated for each treatment group, delayed counties (Before: n = 833, After: n = 186) and no-delay counties (Before: n = 455, After: n = 107).

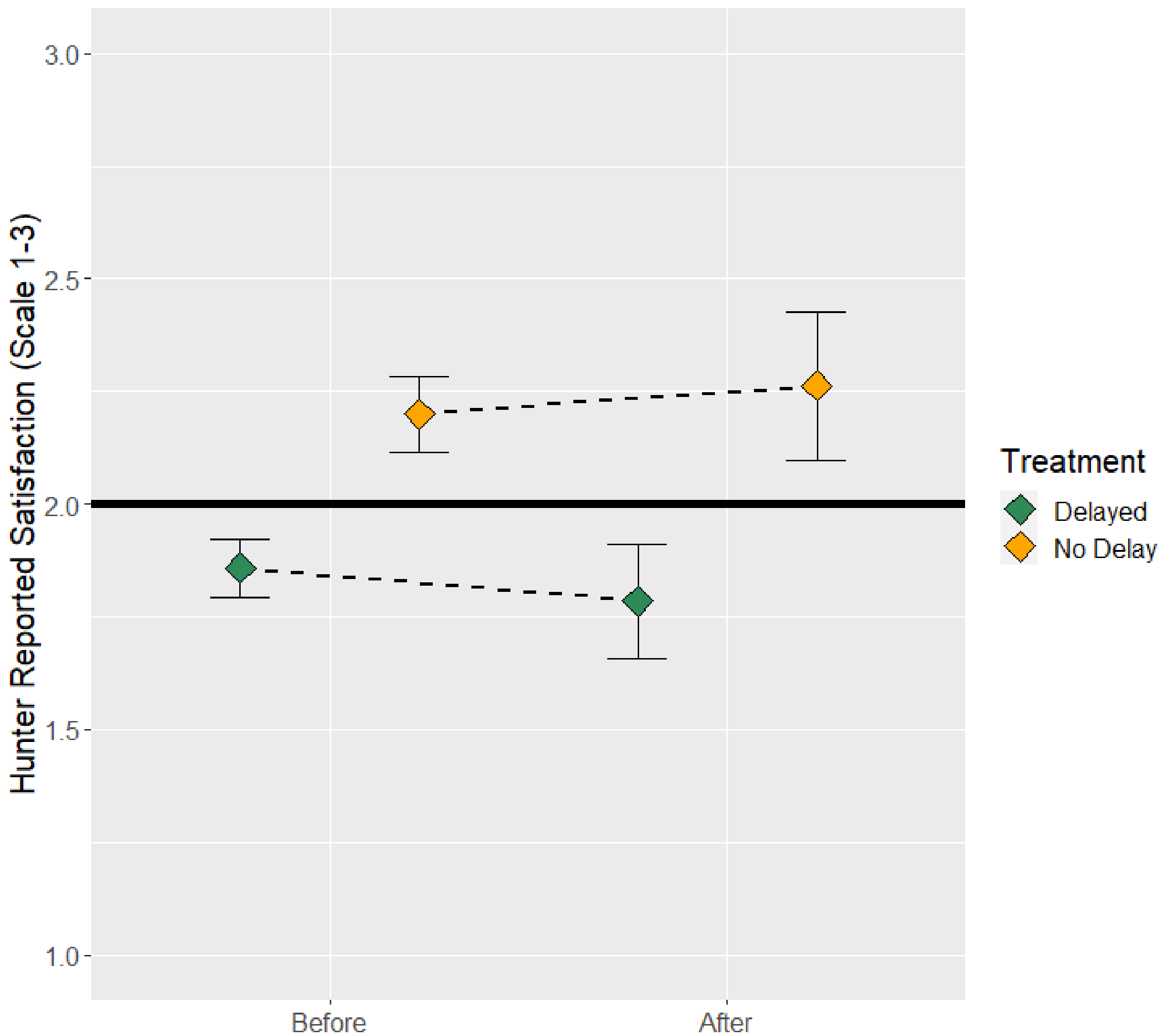

Figure 3.8. Hunter satisfaction (1: unsatisfied, 2: neutral, 3: satisfied) of spring wild turkey hunters in south-middle Tennessee, USA from 2017–2022 with 95% confidence intervals of each. Hunter satisfaction was calculated for each treatment group, delayed counties (Before: n = 833, After: n = 186) and no-delay counties (Before: n = 455, After: n = 107) and the thick black line represents a neutral response.

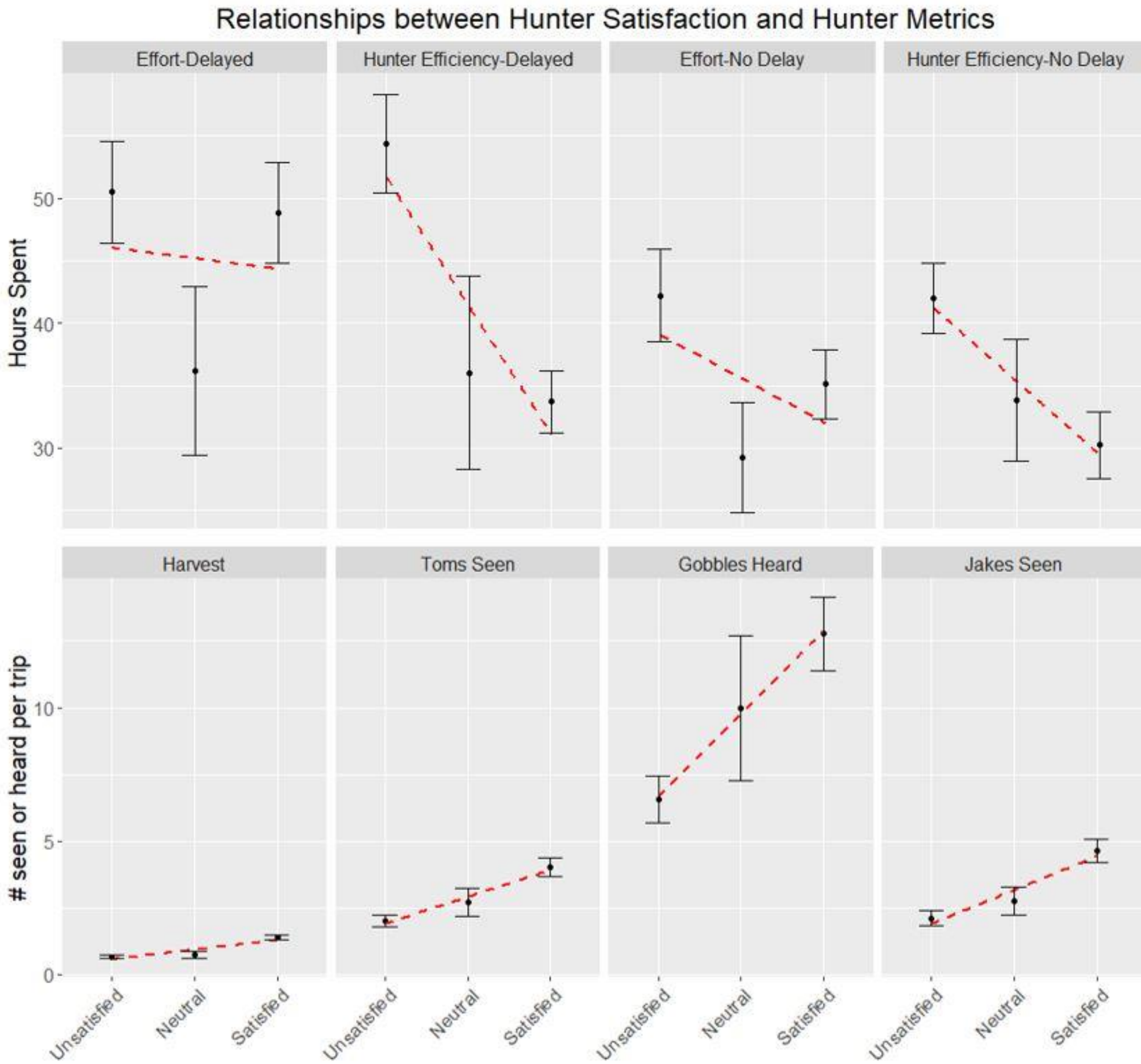

Figure 3.9. The averages of each hunter metric of hunters in south-middle Tennessee, USA from 2017–2022, separated by hunter satisfaction scores (unsatisfied, neutral, and satisfied). The red dashed line represents the line of best fit based on the averages for each satisfaction group.

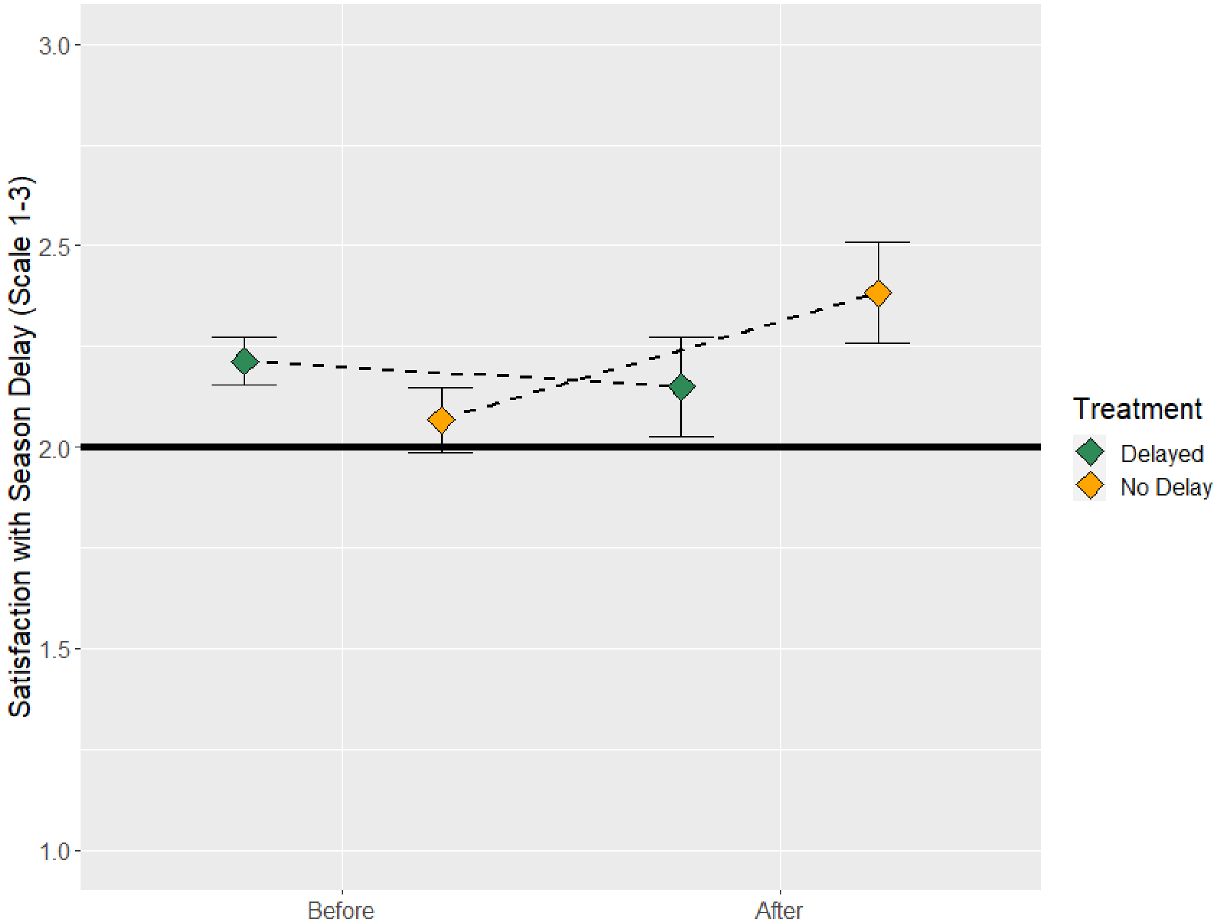

Figure 3.10. Satisfaction with the season delay (1: unsatisfied, 2: neutral, 3: satisfied) of spring wild turkey hunters in south-middle Tennessee, USA from 2017–2022 with 95% confidence intervals of each. Satisfaction was calculated for each treatment group, delayed counties (Before: n = 854, After: n = 201) and no-delay counties (Before: n = 477, After: n = 102) and the thick black line represents a neutral response.

Part IV: Conclusion

Spring Hunting Season Start Date

The indirect effects of the spring hunting season on wild turkey population dynamics are a knowledge gap within the field of wild turkey management (Isabelle et al. 2018, Londe et al. 2023). In the 1990's and early 2000's, it was believed that the hunting season should coincide with peak incubation to minimize the potential impact of hunting pressure, including illegal harvest on hens (Healy and Powell 1999). However, research has documented that peak nest incubation initiation does not coincide with peak gobbling activity (Chamberlain et al. 2018). State agencies attempt to balance the needs of the wild turkey and hunters to not negatively impact turkey population growth while still providing high-quality hunting opportunities for the hunter.

Recently, the rationale behind season start dates has begun to shift to favor later hunting seasons with increased seasonal productivity as justification. This change may have negative effects on hunter satisfaction as hunters may miss peak gobbling activity by hunting later in the year. In Tennessee, historically, the spring hunting season started prior to peak nest initiation, and in 2021 and 2022 the hunting season was delayed 14 days in select counties to more closely align with the later stages of egg laying and nest incubation initiation.

We documented no differences in nest incubation initiation (nesting rate, $P = 0.83$), nesting chronology ($P = 0.07$), clutch size ($P = 0.28$), hatchability ($P = 0.33$), nest success ($\beta = 0.225$, 95% CI: -0.276, 0.727, weight = 0.23), poult survival (ΔAICc = 10.16, weight = 0.004) or hen survival (ΔAICc = 6.945, weight = 0.021) in the delayed counties. Based on these results, we documented no biological support for the later start-date hypothesis in Tennessee. Hunting male wild turkeys in the early stages of egg laying or during peak incubation produced similar levels of reproductive output. Our results should not be interpreted as justification that earlier hunting seasons are better for productivity, but rather that starting the hunting season prior to peak nest initiation had no negative effects on wild turkey seasonal fecundity in Tennessee. We documented that hunters heard less gobbling than previous years in delayed counties ($P = 0.04$), but harvest/hunter success was unaffected ($P = 0.28$) in those counties. Hunter satisfaction in delayed counties did not change after the season delay ($P = 0.18$). The positive effect of increased hunter efficiency (hours spent/bird harvested; $\beta = -0.01$, $P = <0.0001$) and the negative effect of fewer gobbles heard on hunter satisfaction ($\beta = 0.03$, $P = <0.0001$) could have counteracted each other and explain why we did not see changes in hunter satisfaction. Hunter support for the two-week delay in Tennessee may decline, however, as hunters become aware that there is no reproductive benefit from the delay.

We propose state wildlife agencies consider both gobbling and nesting chronology when setting hunting season frameworks and how they both impact hunter satisfaction. Our data indicate hunting seasons starting earlier in the reproductive cycle (peak nest initiation vs. peak nest incubation) did not influence reproduction but did affect hunter experiences. Timing of gobbling and nesting activity, of course vary among states, and their spring hunting season start dates should reflect those differences. We encourage state wildlife agencies to conduct similar research to determine any effect of a delayed season on wild turkey productivity prior to making season-framework changes that could negatively affect hunter satisfaction.

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Vita

Joseph Quehl is from Mendota Heights, Minnesota and grew up hunting and fishing with his family in northern Minnesota. He obtained a Bachelor's of Science in Wildlife Ecology and Management from the University of Wisconsin-Stevens Point, in 2020. He was heavily involved in the student chapter of the Wildlife Society there and has worked on multiple research projects from ruffed grouse in the Northwoods of Wisconsin, pheasants in the great plains of Kansas, and waterfowl in the Prairie Pothole Region of Iowa. All of these positions, schooling, and upbringing helped develop a strong passion for game species management through habitat management or regulatory changes. He began his Master of Science degree at the University of Tennessee, Knoxville in 2021 where he studied eastern wild turkey reproductive ecology in relation to the start date of the spring hunting season.