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Research Article

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Chronic wasting disease effects on a breeding season behavior in White-tailed Deer (*Odocoileus virginianus*)

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Abstract

Wildlife disease outbreaks can lead to population declines, which are usually attributed to increased direct or indirect mortality. Alternatively, behavior associated with sickness can lead to social isolation, potentially decreasing fitness of affected individuals. A useful case study to examine this dynamic is chronic wasting disease (CWD), a neurological disease of cervids, known to affect behavior and movement. In this study, we monitored scraping, a White-tailed Deer (*Odocoileus virginianus*; WTD) breeding season behavior, in an area of high CWD prevalence to determine if this reproductive behavior is affected by CWD. At 107 scrape sites, we detected 3,063 scrape interactions and 218 unique bucks. Bucks engaged with scrapes most often, performing 73% of interactions—compared to 23% by does, and 4% by fawns. Twenty-one bucks captured on camera traps at scrape sites were harvested through recreational hunting, 13 testing CWD-positive and 8 CWD not-detected. We found no significant effect of CWD status on specific scraping behaviors. There may, however, have been population-level effects, with shifts toward greater proportions of scraping by yearling bucks and during daylight hours compared to findings from past studies.

Key words: behavior, breeding, chronic wasting disease, disease ecology, scraping, White-tailed Deer.

When disease is introduced to a wildlife population, population numbers may decline (Wobeser 2005). This is often attributed to increased mortality, but the ecology could be more complicated since population dynamics are governed by both death and birth rate (Jolles et al. 2005; Perez-Heydrich et al. 2012). Birth rate could be reduced if breeding success declines due to sickness-related behavior causing animals to socially isolate or conserve resources by limiting movement and other physical exertions (Hetem et al. 2008; Hart 2010; Hamilton et al. 2020).

Chronic wasting disease (CWD) in cervids is a useful case study for exploring potential drivers of population decline due to wildlife disease because, as a neurodegenerative disease, it changes deer behavior substantially as it progresses (Williams 2005). These changes vary seasonally (Edmunds et al. 2018) and the significance of behavior also changes throughout the year. Specifically, birth rate can be affected by changes that happen during the breeding season of White-tailed Deer (*Odocoileus virginianus*; WTD), which occurs during autumn in North America (DeYoung and Miller 2011). WTD bucks infected with CWD move less than their CWD-negative counterparts during the breeding season, which could indicate less time spent engaged in reproduction behaviors, such as finding and breeding with mates (Edmunds et al. 2018).

It can be difficult to monitor wildlife behavior, but scraping is one aspect of WTD breeding season behavior that can be clearly observed using camera traps. Scraping is a herd-wide breeding season display. Scrape sites are easily identifiable, consisting of a patch of bare ground created by WTD beneath an overhanging limb (Hirth 1977). Scrapes are used to communicate the presence and social status of individuals, most commonly by mature males who may defend the scrape (DeYoung and Miller 2011). Scraping is one of several examples of male WTD behavior that could contribute to their increased CWD prevalence compared to female WTD (Rogers et al. 2022). At scrape sites, individuals perform a distinct set of scraping behaviors, which consist of branch interactions, scraping soil, and rub-urinating (Moore and Marchinton 1971).

Branch interactions include contact with the mouth, preorbital gland, and antlers (Pruitt 1954; Kinsell 2010). The oral contact may serve to transfer scent to the branch from WTD mouths after licking their tarsal glands (Moore and Marchinton 1971). Scraping soil involves pawing at the ground to create or enlarge the patch

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of bare soil and may include scent deposition from interdigital glands (DeYoung and Miller 2011). Lastly, rub-urinating consists of WTD urinating over their tarsal glands to increase the scent left behind at the scrape and to leave a scent trail to allow potential mates to follow as the individual departs (Moore and Marchinton 1971).

WTD use scrapes to find mates during the breeding season, so monitoring changes in scraping behavior of individuals infected with CWD may provide insight into effects of disease on reproductive success. Previous studies on effects of CWD on doe reproductive success have been inconsistent, with an increased likelihood in CWD-positive WTD to have offspring (Blanchong et al. 2012) and no meaningful effect in Mule Deer (*Odocoileus hemionus*; Dulberger et al. 2010; Edmunds et al. 2016).

The aim of this study was to document scraping behaviors in an area of high CWD prevalence and compare behavior at scrape sites between bucks that were CWD-positive to those in which CWD was not detected. We anticipated that CWD positivity would negatively affect WTD scraping behavior since CWD is a neurodegenerative disease known to affect behavior as the disease progresses (Williams and Young 1980; Williams 2005), with evidence of decreased activity in CWD-positive, WTD bucks during the breeding season (Edmunds et al. 2018).

We first considered the relationship between scraping and CWD on an individual level. If we assume that the goal of scraping for WTD is to communicate with as many potential mates as possible while continuing to survive, then the most successful deer will interact with many scrapes and visit at hours with the lowest risk. Therefore, we hypothesized that CWD-positive deer would visit fewer scrapes and be more likely to visit scrapes during daylight hours, when predation risk is greater.

We expected that population-level trends in scraping activity would differ between our study population in an area of high CWD prevalence and past studies where CWD was not present in the population. We hypothesized that presence of CWD would result in changes in scraping behavior and use since the disease alters WTD behavior (Edmunds et al. 2018) and affects demographic groups differently (Miller and Conner 2005; Grear et al. 2006).

Materials and methods.

Study area.

We conducted this study at Ames Research and Education Center, a University of Tennessee facility. Ames spans 74 km^2 in southwestern Tennessee within the Grenada–Loring–Memphis soil region (Longwell et al. 1963). Two-thirds of the landscape is upland/bottomland hardwood forests and Loblolly pine plantations. The remaining third is agricultural fields with soybeans, grain sorghum, corn, cotton, and wheat, along with fescue pastures to support cattle and horses. CWD was first detected on the property in 2018 (Turner et al. 2022) and during the 2021 to 2022 hunting season CWD apparent prevalence was 52% in mature WTD (Huang et al. 2024).

WTD breeding season in southwestern Tennessee peaks in the first 1 to 2 weeks of December (Houston A, University of Tennessee, Knoxville, Tennessee, USA, personal communication, February 2022) and scraping activity tends to peak 2 to 3 weeks prior to peak breeding season (Ozoga 1989; DeYoung and Miller 2011). We began searching for scrapes at the end of September, focusing on areas where scrapes had been observed in the past and along field edges, ridgelines, and forest paths because scrapes tend to be along deer travel corridors (Kile and Marchinton 1977).

Deer behavior and disease status.

We monitored scrapes using camera traps (Exodus Lift II, Exodus Outdoor Gear, Warren, Ohio) set to take 3 photo bursts with a 5-s delay between captures. Cameras were set 2 to 3 m from the scrape so that both the ground and licking branch were visible in photos. We monitored camera traps at scrapes between September 2021 and January 2022. If a scrape was determined to be inactive (i.e., no scraping behaviors performed for at least 7 days), the camera trap was moved to an active scrape site. From each photo, we extracted data on the demographics of visiting deer, visit time and length, and what scraping behaviors were performed. Visits were sorted into 2-week periods relative to breeding season: October 4 to 18 = Pre-Rut 1; October 19 to November 1 = Pre-Rut 2; November 2 to 15 = Pre-Rut 3; November 16 to 29 = Early Rut; November 30 to December 13 = Peak Rut; December 14 to 27 = Late Rut; and December 28 to January 9 = Post-Rut. Recorded behaviors included standing in the scrape, pawing at the ground, interacting with licking branches, and urinating (Moore and Marchinton 1971; DeYoung and Miller 2011).

We uniquely identified bucks using physical characteristics such as antler conformation, injuries, and coat coloration to track individuals across different scrapes and over time. Three deer biologists assigned these uniquely identified bucks into 1 of 3 age classes: yearling; 2.5 to 3.5; and 4.5+ years old based on physical characteristics (Murphy et al. 2001; Demarais et al. 2022). All harvested WTD from the property were sexed, aged using tooth replacement and wear, and tested for CWD using enzyme-linked immunosorbent assays (ELISAs; TeSeE Short Assay Protocol Combi Kit, Bio-Rad, Hercules, California). Additionally, optical density (OD) values were measured from ELISAs as an estimate of CWD progression in harvested deer (Hibler et al. 2003; Holz et al. 2022).

Statistical analysis.

Statistical analyses were conducted using RStudio version 4.1.1 (R Core Team 2021). We compared day and night visitation among demographic groups (fawns, does, and bucks sorted by age-class category) using a chi-square test. We used Wilcoxon rank-sum tests using the "stats" package to check for differences between WTD with and without CWD detected (susceptibility to harvest and scraping behaviors). Although values for the untested bucks are included for context, these were not statistically compared to values for positive and not-detected bucks because of their unknown disease status. We used Kruskal–Wallis tests using the "stats" package to compare scrape behaviors among age classes of bucks. Finally, we modeled ELISA OD values against buck scraping activity (duration of time spent at scrapes, number of scrape interactions, number of times scraping soil, number of urinations at scrapes, and number of branch interactions) using simple linear regressions. These univariate models allowed us to examine the relationship between CWD progression and buck behavior. Given the small available sample size of CWD-positive (n = 13) and CWD not-detected (n = 8) deer that were both harvested and detected on camera traps, we conducted a post hoc power test to evaluate the strength of our data (Faul et al. 2007).

Results

Over 4 months, we monitored 107 scrapes for 7,385 camera trapping days, allowing us to document 3,063 scrape interactions within the population. Bucks engaged with scrapes most often, performing 73% of interactions (n = 2,223), compared to 23% by does (n = 702) and 4% by fawns (n = 138). The most common behavior by bucks, does, and fawns while scraping was interacting with the licking branch (Table 1). We did not observe any rub-urination during the 702 interactions by does. Scrape interactions occurred at night 67% of the time, but this trend differed significantly across sex and age groups ($\chi^2 = 115$, $P < 0.001$). Fawns had the highest percentage of day visits (46%) and bucks ≥ 4.5 years old had the lowest percentage (16%; Fig. 1). Scrape interactions peaked in the first half of November, just prior to the start of rut (mid-November) and decreased as rut progressed (Fig. 2).

We identified 218 unique bucks from camera trap data using antlers and other physical traits. These unique bucks were comprised of 72 yearlings (33% of bucks), 126 bucks that were 2.5 to 3.5 years old (58%), and 20 bucks that were ≥4.5 years old (9%). Of the 2,223 interactions by bucks, most interactions were performed by 2.5- to 3.5-year-olds (59%) with 1.5-year-olds and 4.5+-year-olds interacting less frequently (32% and 9%, respectively).

Bucks visited a median of 4.5 different, monitored scrapes (range = 1 to 23 scrapes), with no effect of buck age class ($P = 0.78$; Table 2). Over the study period, bucks performed a median of 7 scrape interactions (range = 1 to 42 interactions) and visited monitored scrapes for a median of 10 total minutes (range: 1 to 81 min). The maximum number of times a buck revisited a scrape was 11, but most buck-scrape pairings involved only a single visit (median = 1; Fig. 3).

Since deer that are harvested earlier in the season have fewer opportunities to interact with scrapes, we checked to see if CWD status affected susceptibility to harvest for the 98 harvested WTD. There was no difference in the average number of days between the opening weekend of hunting season and the day each WTD was harvested between CWD-positive (median = 62 days, $n = 47$) and not-detected deer (median = 58, $n = 51$, $P = 0.82$).

Twenty-one of the 30 bucks (≥1.5 years old) harvested on the study site were matched to bucks detected at monitored scrapes. Scraping behavior metrics, as documented from camera trap photos, were not influenced by disease status (Table 3). Duration at scrapes was similar for CWD-positive (median = 8 min) and CWD not-detected bucks (median = 8.5, $P = 0.85$; Table 3). The number of scrape interactions was likewise similar for CWD-positive (median = 4) and CWD not-detected bucks (median = 5, $P = 0.77$; Table 3). A post hoc power test of the data on number of scrape interactions found the power to be 0.16. Univariate regression models of scrape behaviors did not show any relationships between ELISA OD values and any measure of scrape interaction ($P > 0.37$).

Discussion

Individual scraping behavior results suggest no significant effect of CWD on these particular WTD breeding-related behaviors. This

Table 1. Number of scrape interactions and occurrence of scraping behaviors by White-tailed Deer in total and by bucks, does, and fawns at scrapes at Ames Research and Education Center in southwestern Tennessee. Scrapes were monitored by camera trap from September 2021 to January 2022. Each scrape interaction included a combination of behaviors including standing in the scrape, interacting with the licking branch, scraping the soil, rub-urinating, and urinating. Branch interactions included any kind of physical contact between the branch and the individual (e.g., oral, antler, preorbital gland). Percentages show how often each behavior was performed during a scrape interaction, which at a minimum involved standing in or sniffing the scrape.

	Total interactions	Branch interaction	Scrape soil	Rub-urinate	Urinate
Bucks	2,223	1,381 (62.1%)	321 (14.4%)	169 (7.6%)	81 (3.6%)
Does	702	255 (36.3%)	22 (3.1%)	0 (0%)	12 (1.7%)
Fawns	138	67 (48.6%)	8 (5.8%)	1 (0.7%)	1 (0.7%)
Total	3,063	1,703 (47.3%)	351 (11.4%)	170 (5.6%)	94 (3.1%)

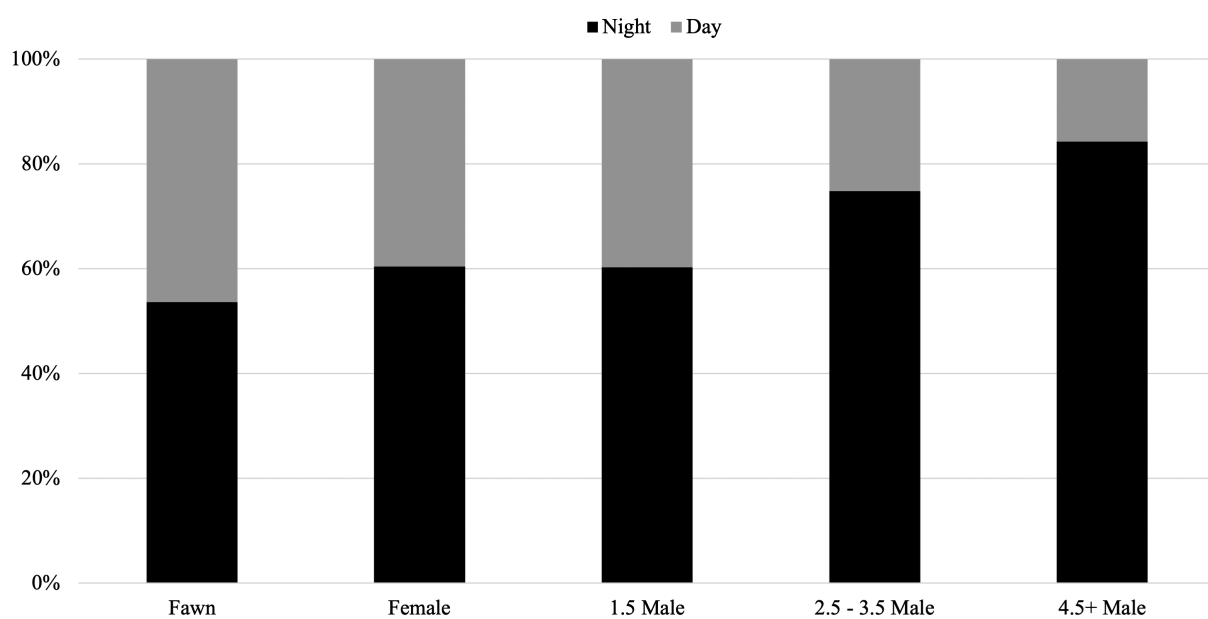

Fig. 1. Proportion of scrape visits at day and at night by sex and age class of White-tailed Deer in southwestern Tennessee monitored by camera traps from September 2021 to January 2022. Bucks are divided into 1.5-year-old, 2.5- to 3.5-year-olds, and 4.5+-year-olds. The observed ratios among these demographic groups differed significantly from expected ($\chi^2 = 115$, $P < 0.001$).

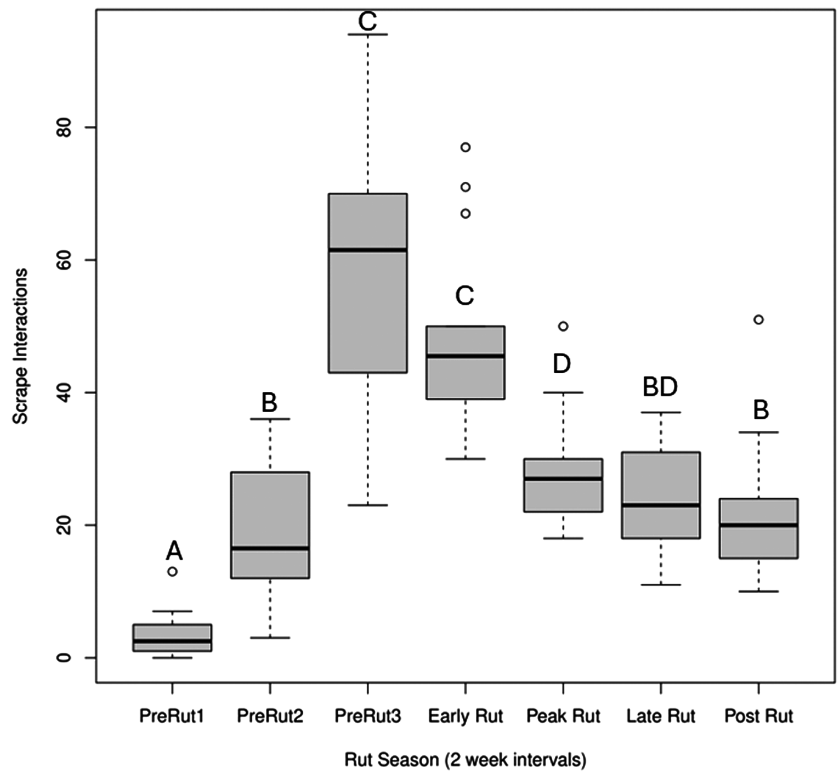

Fig. 2. Number of scrape interactions occurring during 2-week periods relative to rut by White-tailed Deer in southwestern Tennessee. Scrapes were monitored September 2021 to January 2022. Letters indicate significance. Fortnights with the same letter were not significantly different from each other in terms of number of scrape interactions occurring during that period. Two-week periods were defined as: Pre-Rut 1 = October 4 to 18; Pre-Rut 2 = October 19 to November 1; Pre-Rut 3 = November 2 to 15; Early Rut = November 16 to 29; Peak Rut = November 30 to December 13; Late Rut = December 14 to 27; and Post-Rut = December 28 to January 9.

Table 2. Scrape behavior statistics for unique White-tailed Deer bucks by age class monitored from September 2021 to January 2022 in southwestern Tennessee. There was no significant difference between age classes for number of unique scrapes visited or total scrape interactions performed. Age classes were compared statistically using Kruskal–Wallis tests.

	1.5-year-old bucks (n = 72)	2.5- to 3.5-year-old bucks (n = 126)	4.5+-year-old bucks (n = 20)
Unique scrapes visited			
Mean ± SD	6.2 ± 5.3	5.8 ± 4.4	5.0 ± 3.8
Median	4	5	5
Range	1 to 23	1 to 20	1 to 13
P-value		0.78	
Total scrape interactions			
Mean ± SD	9.2 ± 8.8	9.8 ± 8.8	9.2 ± 8.7
Median	5	7	7
Range	1 to 39	1 to 42	1 to 34
P-value		0.56	

contrasts with previous results showing WTD bucks that were CWD-positive were less active during the rut than CWD-negative bucks (Edmunds et al. 2018). However, Blanchong et al. (2012) did not find an effect of CWD status on their measure of WTD reproduction: likelihood of a buck siring fawns. In our data set, there was a consistent trend across variables toward decreased scraping activity by CWD-positive deer that suggests the sample size of 13 positive and 8 not-detected bucks may not have been sufficient to capture effects of CWD on these particular reproductive behaviors. This is supported by a post hoc power test that showed power only at 0.16 for the Wilcoxon rank-sum test comparing the number of scrape interactions between CWD-positive and not-detected bucks.

Breeding season effects can also be considered on a population level. Though only 21 bucks had known disease status, CWD prevalence of 52% in mature, harvested WTD on the study site (Huang et al. 2024) suggests that many other WTD observed at scrapes were also infected with CWD. Some inferences can be made about the effect of CWD on scraping behavior by comparing our results—that yearlings performed 32% of all scrape interactions by bucks—to previous studies that occurred prior to the introduction of CWD, e.g., that yearling bucks did not scrape (Miller et al. 1987) or scraped only 15% as much as older bucks (Ozoga and Verme 1985). The similarity in our data set between the proportion of bucks per age class and the proportion of scraping activity by bucks performed by each age class suggests that no single age class dominated scrapes in this population, unlike in past studies (Ozaoga and Verme 1985; Miller et al. 1987).

This increased engagement of younger bucks at scrapes could have been a result of differences in the demographic composition of this deer herd compared to previously studied herds. Past studies also found a greater proportion of overall scrape visits occurring at night (75% to 85%, Alexy et al. 2001; Kinsell 2010) than our finding of 67%. This could be another indication of differing demographics since the proportion of day and night visits differed significantly among age classes. Alternatively, it could be a result of a lack of caution due to decreased awareness stemming from CWD (Williams and Young 1980; Williams 2005). Predation risk is lower during the night because hunting is not permitted following 30 min after sunset in Tennessee (TWRA 2023). Therefore, dominant males may

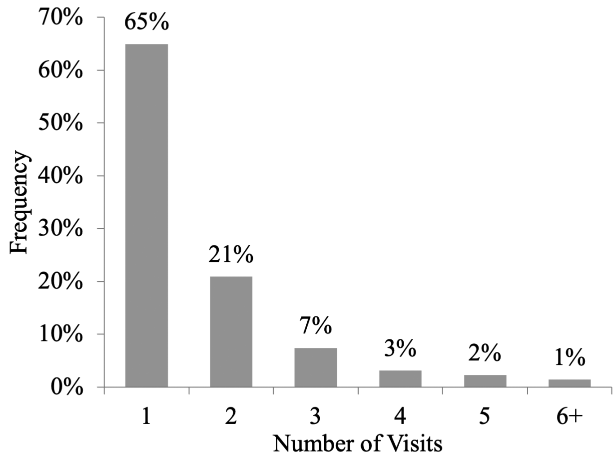

Fig. 3. Histogram of the number of visits by unique White-tailed Deer bucks to individual scrape sites. Unique buck (*n* = 218) visitation to scrape sites (*n* = 107) was monitored in southwestern Tennessee from September 2021 to January 2022. Most bucks visited a scrape a single time, while 21% of buck-scrape pairs involved 2 visits.

Table 3. Scrape behaviors in White-tailed Deer by known CWD-positive bucks, bucks that were harvested and did not have CWD detected, and bucks that were not harvested and therefore were not tested for CWD. Scrapes in southwestern Tennessee were monitored by camera traps from September 2021 to January 2022. Positive and not-detected bucks were compared using Wilcoxon rank-sum tests.

	Positive (*n* = 13)	Not detected (*n* = 8)	Not tested (*n* = 197)
Scrapes visited			
Mean ± SD	4.5 ± 1.8	5.8 ± 5.6	6.0 ± 4.8
Median	5	2.5	5
Range	2 to 7	1 to 15	1 to 23
P-value	0.66		—
Scrape interactions			
Mean ± SD	5.5 ± 3.4	7.0 ± 7.0	8.9 ± 9.6
Median	4	5	6
Range	2 to 12	1 to 22	0 to 50
P-value	0.77		—
Duration at scrapes (minutes)			
Mean ± SD	10.2 ± 7.8	11.6 ± 12.5	14.0 ± 13.3
Median	8	8.5	10
Range	3 to 29	1 to 38	1 to 81
P-value	0.83		—

exclude other individuals from visiting scrapes during the more advantageous, nighttime hours (DeYoung and Miller 2011).

We could not monitor all scrapes on Ames in this study. Past research found an average of 87.5 scrapes/km^2 (Kile and Marchinton 1977). If that holds true for our study site, there would have been nearly 4,400 scrapes on the property, and we would have had camera traps on <3% of them. Our goal was to monitor a representative sample of scrapes dispersed throughout the property. The fact that our camera traps documented 72% of harvested bucks suggests that our data captured a representative proportion of the scraping behavior that occurred in the area. Additionally, by capturing photos instead of videos, there was the potential to miss scraping behaviors, although we mitigated this a priori by using camera settings to collect 3 photo bursts with short intervals between activation.

There is still much to learn regarding how CWD may affect breeding behavior and population growth rates. Studying scrapes has the potential to improve understanding of this dynamic. More work is needed to expand the data set of scraping behavior in individuals with known disease status to determine how individuals differ in scraping behavior, how those tendencies change with maturity and CWD status, and the influence of other members of the herd on the actions of an individual. Additionally, future research can build upon this study by associating GPS locations from collared WTD with known scrape locations to build a social network (Hearst et al. 2021; Egan et al. 2023) that includes interactions at scrapes and other locations to better understand the significance of scrapes in breeding season social interactions and the comparative risk of disease spread.

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Author contributions

This study was conceived and funding was acquired by SD, BKS, AB, and KCV. MHJH, SD, BKS, and AB designed the methodology. Data were collected by MHJH, AH, and AB and analyzed by MHJH, SD, BKS, and AB. MHJH wrote the first draft, with contributions and critical revisions by all authors.

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Conflict of interest

None declared.

Data availability

Data can be accessed at https://scholarsjunction.msstate.edu/cfr-publications/25/ following a 1-year embargo (ending 15 November 2024).

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