INVESTIGATION OF MOVEMENT DYNAMICS OF WILD DEER IN SOUTHEASTERN MINNESOTA TO UNDERSTAND POTENTIAL SPREAD OF CHRONIC WASTING DISEASE

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SUMMARY OF FINDINGS

Now in its second year, the Minnesota Department of Natural Resources (MNDNR) is continuing a study to investigate the movement dynamics of wild white-tailed deer (*Odocoileus virginianus*) in southeastern Minnesota. The detection of chronic wasting disease (CWD) in fall 2016 in Fillmore County motivated this project to 1) understand potential pathways of CWD spread on the landscape by movement of wild deer, and 2) increase our likelihood of managing the outbreak in this and other areas of Minnesota. In February 2019, we captured and fitted GPS collars to 64 white-tailed deer (39 female fawns and 25 male fawns) in our study area centered around the CWD Management Zone. A total of 173 deer have been collared since the study began in March 2018, but as of 3 August 2019, only 66 animals remain available for tracking. There have been 45 known mortalities due to hunter-harvest (n=14), poor health (n=6), vehicle collision (n=5), agency culling (n=4), unknown cause (n=4), and capture-related issues (n=12). A significant number of collars from the 2018 release cohort failed (n=80) due to either hardware malfunction or collar expansion failure; however, only one collar from the 2019 release cohort has failed. We considered movements during the fall, excursions, or temporary movements outside of an established adult home range. During fall 2018, females (n=6/11) had a slightly higher rate of excursions than males (n=6/26) at 55% versus 23%, respectively. The median excursion distance traveled by females and males was 4 km and 7 km, respectively. We estimated average natal (1 March 2019 -14 April 2019) home range size for fawns as 1.84 km^2 and 2.65 km^2 for female and male deer, respectively. Preliminary assessment of spring dispersal (15 April 2019 - 15 July 2019) suggests that dispersal probability of females (44%, n=34) was nearly equal to males (45%, n=22). Median dispersal distance travelled was also nearly equal between sexes at 10 km (n=15) and 11 km (n=10) for females and males, respectively. These dispersal rates and distances traveled are comparable with those estimated from 2018. These valuable data are informative for understanding potential CWD spread in wild deer in southeastern Minnesota and enable MNDNR to adjust surveillance and management activities more effectively to counter CWD spread in Minnesota.

INTRODUCTION

Chronic wasting disease (CWD) is a fatal infectious disease first characterized in the late 1960s in Colorado that affects elk *(Cervus canadensis)*, mule deer *(O. hemionus)*, white-tailed deer, reindeer (*Rangifer tarandus*), and moose *(Alces alces)*. It has been detected in wild and captive cervids in 26 states and 3 Canadian provinces in North America, as well as Finland, Norway, Sweden, and South Korea. Recent work has demonstrated that CWD can cause population declines in white-tailed deer and mule deer in the western US, particularly when high prevalence levels occur in a population (Edmunds et al .2016, DeVivo et al. 2017). In the upper Midwestern US, an ongoing study of CWD in white-tailed deer in Wisconsin has shown that CWD-infected deer die at 3x the rate of uninfected deer (Wisconsin DNR 2018). In the same

CWD system, research has shown that deer regularly die from CWD in the wild, although they typically go undetected by people (Samuel and Storm 2016).

It has been nearly 3 years since CWD was discovered during the 2016 regular hunting season in Fillmore County, Minnesota, and through 3 August 2019, the MNDNR has detected 52 CWD-positive wild deer in Minnesota (including 1 from Olmsted County in 2010). Just in the last year alone, of 8,040 deer tested across the state, 34 new positive cases were detected in Fillmore, Winona, Houston, and Crow Wing Counties. With the exception of the recent Crow Wing and Winona County cases, which are likely sourced to CWD-positive captive cervid farms, the distribution of new cases suggests spatial spread of disease radiating from the core area in DPA 603 (Figure 1). While it is not clear how CWD was introduced into Fillmore County, potential routes of introduction include movement of infectious deer from neighboring states (e.g., Wisconsin, Iowa, or Illinois), contact between wild deer and prior CWD-positive captive cervid facilities, or contamination of the environment with infectious cervid carcass material facilitated by out-of-state hunters disposing of butchering remains on their Minnesota property. This study aims to better understand natural deer movement ecology and in particular detect seasonal corridors of movement that may inform our management of CWD spatial spread in southeastern Minnesota.

As infected and non-infected deer interact and move across the landscape, they transmit infectious prions through direct contact with other deer or indirectly through environmental deposition (Almberg et al. 2011). Limited information exists about deer contact rates and their relationship to transmission rates. The presumed main driver of spatial spread among wild deer are natural movements, which vary as a function of season, sex, age, habitat, underlying deer density, and other variables (Nixon et al. 2007, Long et al. 2008, Long et. al. 2010, Lutz et al. 2015, Peterson et al. 2017). Besides this current effort, there is only one published source of information (Simon 1986) that informs the extent to which deer may move across the landscape and interact with each other in southeastern Minnesota. However, the Wisconsin Department of Natural Resources has an ongoing study in its third year designed to understand the impacts of CWD on survivorship and movements of deer in Wisconsin, which will be very helpful to compare our study results with.

Deer behavior and movements vary by sex, season, and landscape features, along with deer population demographics and social structure. Three types of movement likely facilitate disease spread across the landscape including dispersal events, recurrent seasonal movements, and temporary excursion events. The most substantial long-distance movements involve dispersal from natal to adult ranges, most likely to occur in 1-year-old deer during spring, although males may also disperse in fall. We define dispersal in this context as an asymmetric movement from the natal home range to a distinct and non-overlapping adult range. While dispersal usually occurs once, there are cases of 2-stage dispersals when a deer makes a second asymmetric movement to a second adult home range, but this is rare. Recurrent seasonal movements can include migratory behavior and movements between summer and winter ranges. Excursions (or synonymously forays) are temporary transient movements out of an established home range that typically occur in fall. Because deer densities and movement behavior can be altered by management actions, a better understanding of both deer density and movement activities related to density will enhance our ability to effectively manage disease risk in the Minnesota deer population. The importance of this research is underscored by the unabated spread of CWD both between and within states, and the need to find management solutions to suppress the spread of disease arising from natural deer movements.

METHODS

Study Area

The study area, approximately 7,250 km^2, is centered on DPA 603, also referred to as the CWD management zone, in Fillmore County, Minnesota (Figure 2). The study area limits are flexible and have been established as approximately a 20-mile buffer outside of and including DPA 603. We included extensive areas around DPA 603 to capture and release GPS-collared deer, so that our collared sample is representative of the deer population inside and surrounding the CWD management zone. Given the increase in number of cases detected within DPA 603 in 2017-18, and our expanded harvest efforts in response (both hunter-harvest and agency culling), we chose to limit capture of animals in the second year (2019) to areas outside of DPA 603. This choice increased the likelihood that collared animals would not be pre-maturely harvested during late season hunts and agency culling efforts before significant information regarding their movements could be obtained.

The study area is composed of a matrix of agricultural lands interspersed with deciduous forest upon a landscape of rolling hills and in some cases very steep ridges and valleys. There is considerable heterogeneity in landscape topography and land use, particularly as one moves from east to west. The eastern part of the study area is composed of forested blufflands and steep ridges and moving west and south, the landscape transitions to be flat and dominated by agriculture. More than 90% of the landscape is held in private ownership, and there is significant heterogeneity in deer density due to both habitat heterogeneity and localized refugia (i.e., parcels with viable deer habitat where hunter harvest is not permitted).

Since most of the region is in private ownership, our pre-capture efforts were heavily focused on securing permission to access private property in the study area. We secured permissions to use 115,259 acres, consisting of private (72,398 ac) and public (42,861 ac) properties, for search and capture of white-tailed deer in southeastern Minnesota (Figure 3). This amount reflects an additional 10,000 acres secured for access compared to the first year of the study. We could not have achieved our sampling goals without the enormous outpouring of support from private landowners in the study area (about 224). Public properties included state-owned wildlife management areas, forests, and natural areas. For future deer captures, we hope to add to our permission list and increase available properties for capture efforts. Increasing the size of contiguous blocks of property access increases the probability that we can capture deer there. We focused on securing permission to access properties that are forested (where deer may be flushed) with adjacent open fields (where deer may be captured and a helicopter may safely land).

Sampling Design and Data Collection

Given the breadth of the study area, we divided it into 10 quadrants (Figure 3) from which we established a baseline target goal of capturing 3-4 fawns (≈ 7-9 months old) of each sex per quadrant for 2019. Our goal was to capture and collar 64 deer; 32 male fawns and 32 female fawns.

We contracted with Quicksilver Air Inc. (Peyton, CO) to capture deer by net-gunning from a Robinson R44 Raven 2 helicopter. A highly experienced capture crew of 3 personnel from the company performed all deer handling procedures including deer capture, collar placement, ear tag placement, collection of auxiliary measurements (body temperature, age class, sex, and body condition), and an ear punch for genetic analysis. Helicopter pursuit time of animals did not exceed 3.5 minutes, and the crew was instructed to abort chase of an animal if pursuit time exceeded 5 minutes. Average handling time per animal was approximately the same at 3 minutes.

We programmed GPS collars for males (Iridium TL330 with expandable collar, Lotek Wireless Inc, Newmarket, Canada) and females (Iridium 420, Lotek Wireless Inc, Newmarket, Canada) to collect location coordinates every day at an increased rate during spring dispersal and fall rut periods. The rate of GPS location fixes was programmed to occur once every 85 minutes (approximately once per hour) between 15 April through 15 July and 1 September through 15 December. During all other time periods, collars were scheduled to collect positional data every 3 hours and 45 minutes or approximately 6 locations per day. We chose these periods in part based on seasonal movements recorded from yearling males in Wisconsin. To ensure that location data were collected across the entire 24-hour day distribution, we included a 15 minute offset from an hour (e.g., 1 hr 15 min, 3 hr 45 min) so programmed GPS fixes occurred on a staggered schedule that changed every day.

The collars included timed-release drop-off mechanisms, which after 130 weeks (2.5 years) will cause the collars to detach and can be retrieved and potentially re-furbished. In addition, for male collars only, we included a line-of-sight mechanism that permits the collars to be detached remotely in line of sight to the animal (within 200m). We added this feature on male collars because male necks expand and contract with season, and during the rut when their necks are largest in diameter, there is a risk that collars could be too tight if the expansion mechanism fails. If hunters are in the field and may come across collared deer with suspected tight collar issues and then report them to us, we can make efforts to locate and remotely release these collars.

Due to hardware failures from our first release cohort of 115 GPS collars in March 2018, the manufacturer (Lotek) warrantied 73 failed collars (63%) and provided us with replacements at no cost. As of 3 August 2019 seven additional GPS collars from the 2018 release cohort have gone off the air for unknown reasons (although these were not under warranty). The manufacturer made modifications to on-board software, corrected quality-control issues with production of the collars, and modified the expansion design of male collars (by our direction and input) to improve performance of the equipment.

Data Analysis

We define dispersal as having occurred if an individual displayed a permanent, asymmetric movement from a natal range to a distinct adult range (Kenward et al. 2001, 2002), such that pre-dispersal locations do not overlap post-dispersal locations (Long et al. 2005, Lutz et al. 2015). All recorded spatial locations were vetted before incorporated into any analysis because the accuracy of a location is influenced by the number of satellites available in the sky that communicate with a collar and how a deer is juxtaposed in the landscape (i.e., influence of physical barriers). The vetting process involved omitting any spatial location from further consideration if less than 3 satellites were used to derive a location. These 2-dimensional location coordinates resulted in highly biased altitude above sea level estimates (around 0) and high Dilution of Precision values (> 4) indicative of inaccurate locations (generally on the order of > 500m based on controlled tests). We estimated natal and adult home ranges using minimum convex polygons (MCP) (Mohr 1947). We assumed that we captured fawns on their natal range during the initial capture period in February 2019. We calculated dispersal distance as the straight-line distance between adult home range and natal home range centroids (Kenward et al. 2002). We performed all spatial data analysis and characterization using R software (R Core Team 2017), R package adehabitatHR (Calenge 2006), and ArcMap 10.6 (Environmental Systems Research Institute, Redlands, CA, USA).

We classified a movement as an excursion (or foray event) if it was a temporary movement clearly outside the boundary of a home range, with subsequent return to the respective home range.

We estimated the distance of an excursion as the straight-line distance between the farthest excursion location outside of the home range and the centroid of the home range. We examined seasonal differences in dispersal and excursion distances.

Collars were programmed to transmit a mortality text and email message if inactive for 12 hours. Mortality events were investigated within 48 hours of mortality notification whenever possible. Sometimes a triggered mortality event was the result of a slipped or broken collar, in which case responding staff simply retrieved the collar from the field. In cases of true mortalities, responding staff routinely collected medial retropharyngeal lymph nodes for CWD testing, a muscle sample for potential genetic testing, and a front incisor tooth for age confirmation. Upon inspection of carcasses, staff were instructed to collect additional samples if any tissues or organs appeared abnormal, and these were submitted for additional diagnostic testing at the University of Minnesota Veterinary Diagnostic Laboratory. If an animal died within the first 2 to 3 weeks following capture, every effort was made to retrieve the entire carcass and submit it to the University of Minnesota Veterinary Diagnostic Laboratory to determine cause of death. In these cases, we were particularly interested in determining whether an animal died due to capture myopathy, which results from extensive muscle damage due to extreme exertion, struggle, or stress of capture. Capture myopathy is an unfortunate reality when handling wildlife, and we make every effort to avoid excessive animal handling during capture. Outside of an approximate 3-week window following capture when capture myopathy is most likely to occur, staff performed field investigations to determine likely cause of death. Using all evidence available from a carcass (e.g., broken bones, bite marks, body condition) and the area surrounding a death site (e.g., evidence of struggle), staff assigned probabilities of cause of death including hunter harvest, agency culling, vehicle collision, starvation, health-related, capture-related, predation, or uncertain.

Collared deer were not protected from legal harvest during hunting seasons, and we encouraged hunters to select animals for harvest based on their personal preference regardless of whether the hunter noticed a collar on the deer. Hunters who harvested a collared deer were asked to contact MNDNR and return the collar.

RESULTS AND DISCUSSION

From 18-21 February 2019, we captured and outfitted 64 deer with Iridium GPS collars: 39 female fawns and 25 male fawns (Figure 4). During the capture period, 3 male fawns and 1 female fawn were able to kick off their collars just after initial collar fitting, and we were able to retrieve these collars to redeploy them on other animals. One female fawn accidentally broke its neck upon capture, and we were able to donate the meat from this animal to the Share the Harvest donation program (for details on the program, see https://www.dnr.state.mn.us/cwd/share-harvest.html). One male was able to kick its collar off within about a month of capture. Seven deer (6 females, 1 male) have died since capture (Table 1). Two animals are suspected to have died due to capture myopathy based on examination at the UMN Veterinary Diagnostic Lab, 1 female was killed by vehicle collision on US Hwy 63 just south of Stewartville, MN, and it is unclear what caused the death of the remaining four individuals. There has only been 1 collar failure to date (2%) from the second release cohort of 64 GPS collars, which so far suggests that the modifications made to improve collar performance have been successful. As of 3 August 2019, we have 66 deer actively being monitored including 38 females and 28 males.

We have amassed over 450,000 records of deer location data from 23 March 2018 through 1

September 2019. By September 2018, most of the fawns from the March 2018 release cohort were expected to have established an adult home range. We used data from September through December 2018 to examine fall movements, particularly excursions or temporary movements outside the home range. From the deer available in the study at that time (n=37), we found that 55% of females (n=6/11) and 23% (n=6/26) of males underwent excursions or temporary movements outside of their established adult home range (Table 2). The median distance traveled for females and males was about 4.3 km and 7.3 km, respectively, (Table 2) in the fall. So, although females had a higher likelihood of making excursions from their home range, they tended to travel a shorter distance compared with males.

Prior to the spring dispersal period between April and July 2019, the average winter home range size of deer from the 2019 release cohort were similar at 1.84 km^2 for female fawns and 2.65 km^2 for male fawns (Table 3). These winter home range estimates align with our expectations of deer home range at this time of year, and were similar to 2018 estimates. During the spring dispersal period of 2019 (approximately 15 April through 15 July), female deer had a higher than expected apparent dispersal probability (44%, n=15/34), although it was comparable with males (46%, n=10/22). These proportions were not appreciably different than estimates from 2018. The median dispersal distance travelled was 10.1 km (n=15) and 11.2 km (n=10) for females and males, respectively (Table 3). These estimates align almost exactly with estimates from 2018 when females and males traveled a median distance of 12 km and 12.5 km, respectively. Given our small sample sizes, we choose the median (as opposed to mean) as a measure of central tendency because of the non-normal distribution of distances that deer traveled. Such non-normality causes extreme outliers (which we have) to skew distance distributions, artificially inflating the mean.

From the 2019 release cohort, we found that 2 males and 1 female have apparently dispersed to Iowa, although it is not clear yet if they have established an adult range in that state. We saw similar movements from animals in the 2018 release cohort that appeared to be seasonal movements between winter and summer ranges. The majority of mortalities arose from harvest – either by hunters (n=14) or agency personnel (n=4) (Table 1). Capture related issues (n=12), poor health (n=6), vehicle collision (n=5), and unknown causes (n=4) made up the remaining causes of death (Table 1). The total number of deer mortalities we were able to document are likely an underestimate because of the failure of 73% of our 2018 release cohort collars, which precluded us from determining their fates.

While male dispersal is typically regarded as the primary force driving potential disease spread (CWD) on the landscape (Grear et al 2006, Oyer et al. 2007), evidence suggests that females orphaned at a young age (Etter et al. 1995) or high underlying deer density (Lutz et al. 2015) can drive females to disperse. Given the relatively high rate and extent of female dispersal and high pre-fawn deer densities in the farmland-forest transition zone of our study area at around 22 deer/mi^2 (Norton and Giudice 2017), we hypothesize that this phenomenon may be occurring in southeastern Minnesota. This highly productive landscape favors high deer survival and fecundity, given extensive food resources, winter cover, and relatively mild winters. Additional years of collaring female and male fawns representative of southeastern Minnesota will further inform our understanding of dispersal and movement activities as it relates to potential spread of CWD prions on the Minnesota landscape.

We have provided outreach materials both for landowners that have provided us with permission to use their properties for deer capture and for the general public. We continue to inform participating landowners twice per year with deer movement updates and maps of the collared deer in the study, and provide a summary of study findings and expectations for future work. Similarly, we continue to update a dedicated website to this research project at https://www.dnr.state.mn.us/cwd/deer-movement-study.html. This site provides information about the purposes of the study, periodic updated findings, and information about how readers can assist and contribute to our efforts. We encourage the public to provide us with trail camera photos of collared deer they may encounter, and with their permission, we make these pictures available on our website. There have also been almost two dozen popular press articles covering this study in various media outlets. Overall, we strive to continually improve how we communicate science to the public, and provide transparency in all of the work that we conduct.

Future Capture and GPS-Collaring Efforts

Between January and February 2020, we plan to capture and GPS-collar between 80 and 90 white-tailed deer fawns in the study area to maintain a sample size of about 100 deer for location monitoring at any given time. We will aim to collect equal sample sizes between sex, but this depends in large part on chance as there is no way to verify sex until the capture crew captures and processes a deer in the field. Like previous years, we hope to capture approximately 4-5 deer of each sex in each of 10 quadrants around the study area.

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We extend warm thanks to all of the participating landowners in southeastern Minnesota that gave us permission to access and conduct capture operations on their properties. We thank all the MNDNR Wildlife and Enforcement staff, who assisted in contacting landowners and fielding questions about the study to the public including Don Ramsden, Mike Tenney, and Mitch Boyum. Special thanks to Julie Hines and Bob Wright for their great work assisting us with our GIS mapping needs; Chris Scharenbroich and Pete Takash for their efforts with helping us update the webpage dedicated to this project on the DNR website; Rushford Municipal Airport (Airport Manager Mike Thurn) and Fillmore County Airport (Airport Manager Isaac Deters) in Preston, Minnesota for use of their facilities. Without the support of these and many more people behind the scenes, this project would not be possible. We also thank the Legislative-Citizen Commission on Minnesota Resources (LCCMR), the Environment and Natural Resource Trust Fund (ENRTF) - Emerging Issues account (M.L. 2015, Chp. 76, Sec. 2, Subd. 10) that we received grant funding from provided the needed funds to get this project off the ground. Additional funding was provided in part by the Wildlife Restoration (Pittman-Robertson) Program.

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Table 1. As of 3 August 2019 there have been 45 known mortalities from both release cohorts of deer in 2018 (n=109) and 2019 (n=64) in southeastern Minnesota. Given the hardware and electronic failure of 80 collared deer from the 2018 cohort and 1 collared deer from the 2019 cohort, we can only detect if one of these animals died by reports provided by hunters or the public that might have harvested them or come across their carcasses in the field. Thus, the observed mortalities provided below are likely an underestimate of total collared deer deaths.

Cohort-Sex	Capture-related	Hunter-harvest	Agency-culled	Poor condition/ health	Vehicle collision	Unknown
2018-Female	3	3	0	1	1	1
2018-Male	6	11	4	2	3	2
2019-Female	2	0	0	3	1	1
2019-Male	1	0	0	0	0	0
TOTAL	12	14	4	6	5	4

Table 2. Mean proportion (and 95% confidence interval) of available white-tailed deer in southeastern Minnesota collared in March 2018 undergoing excursions during fall (Sept through December 2018) or temporary movements from their adult home range, and the median distance (Distance – km) traveled during excursions. The distance estimates do not account for non-linear pathways traveled, forward and backwards movements along pathways, and only describe straight-line distances.

Cohort	n-total	% Excursions (95% C.I.)	n-Excursion	Distance (min, max)
Females	11	54.5 (24.6, 81.9)	6	4.3 (3.8, 7.0)
Males	26	23.1 (9.8, 44.1)	6	7.3 (2.3, 35.0)
TOTAL	37		12	

Table 3. Mean estimate (and 95% confidence interval) of winter home range (HR - km^2), apparent spring dispersal probability (Pr. Dispersal), and median apparent spring dispersal distance (Distance – km) of white-tailed in southeastern Minnesota collared in March 2019. The distance estimates do not account for non-linear pathways traveled, forward and backwards movements along pathways, and only describe straight-line distances.

Cohort	n-HR	HR (95% C.I.)	n-Dispersal	Pr. Dispersal (95% C.I.)	Distance (min, max)
Female fawns	34	1.84 (1.46, 2.19)	34	0.44 (0.28, 0.62)	10.1 (4.8, 47.1)
Male fawns	22	2.65 (1.69, 3.45)	22	0.46 (0.25, 0.67)	11.2 (4.0, 86.9)
TOTAL	56		56		

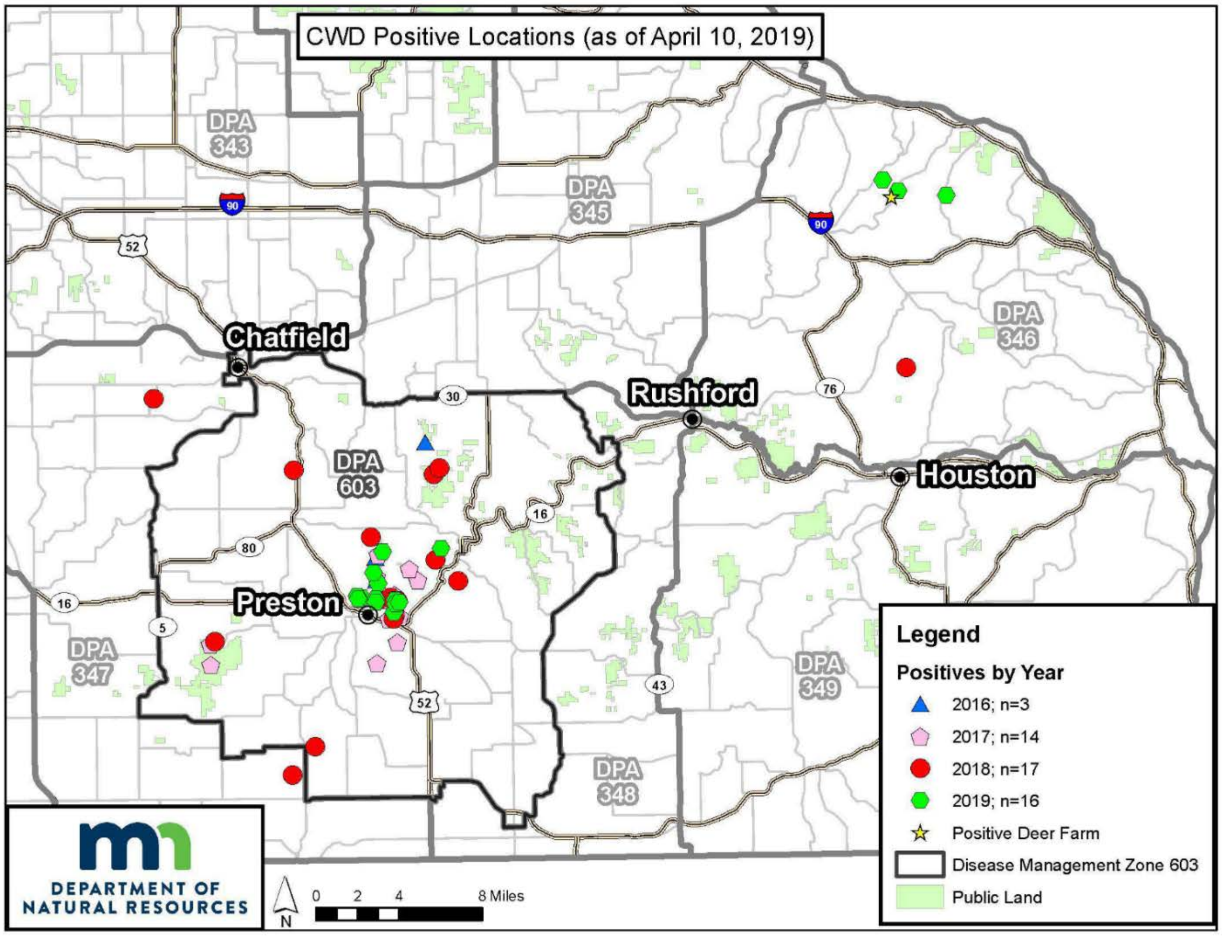

Figure 1. Spatial distribution of wild white-tailed deer confirmed with CWD infection in southeastern Minnesota as of 03 August 2019. There have been 50 wild white-tailed deer confirmed positive with CWD in southeastern Minnesota since fall 2016. The grey-labelled areas represent deer permit areas (DPA), which have recently been re-designated in the 600 series representing disease management zones. DPA 603 is outlined in black and is to be phased out completely (used here as a visual reference).

Southeast Deer Movement Study Area

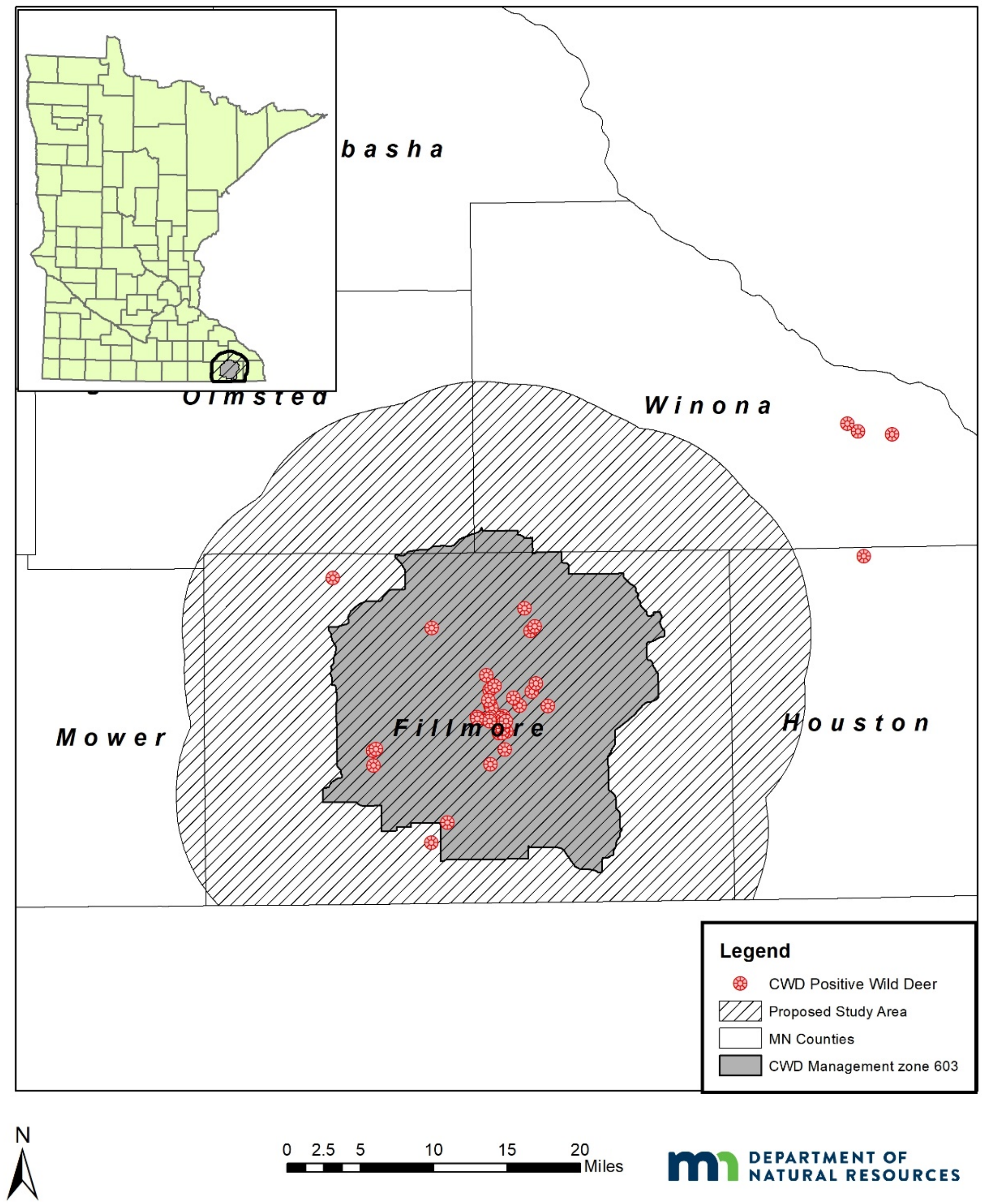

Figure 2. Approximate study area boundaries in and around the chronic wasting disease management zone (Deer Permit Area 603). Also shown are locations of CWD positive wild deer (n=50) from 2016 through September 2019 in southeastern Minnesota. This area is largely private land, so the final disposition of sampling locations for GPS collaring deer will depend on permissions we receive from cooperating landowners, weather patterns, and local scale landscape characteristics that facilitate helicopter capture of wild white-tailed deer.

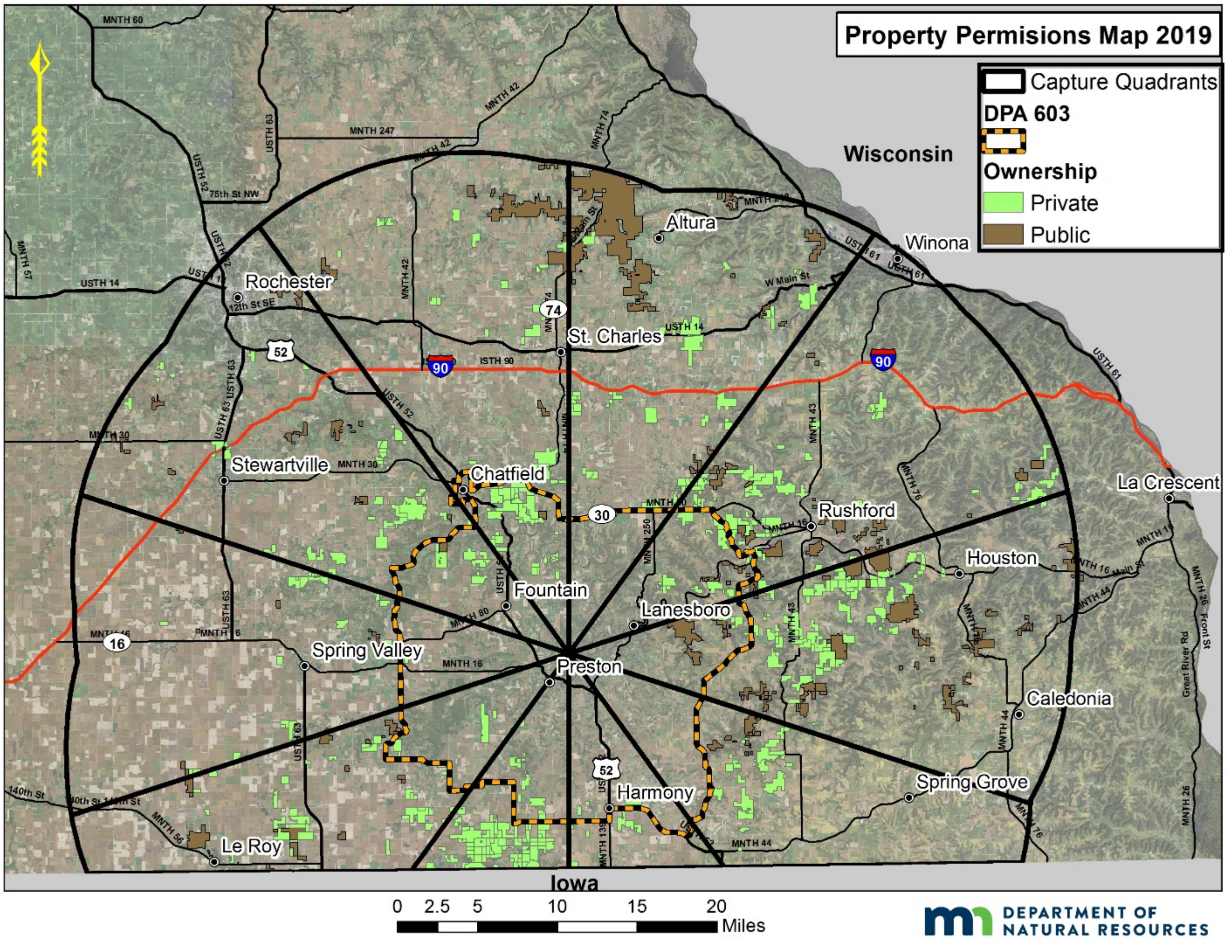

Figure 3. Spatial distribution of study area capture quadrants used as a basis for establishing the February 2019 deer capture goals in southeastern Minnesota. The target optimal capture distribution was established as 3-4 male and 3-4 female white-tailed deer fawns captured per quadrant. We secured permissions to access 115,259 acres of property, consisting of private (72,398 ac) and public (42,861ac) lands – over 180 mi^2.

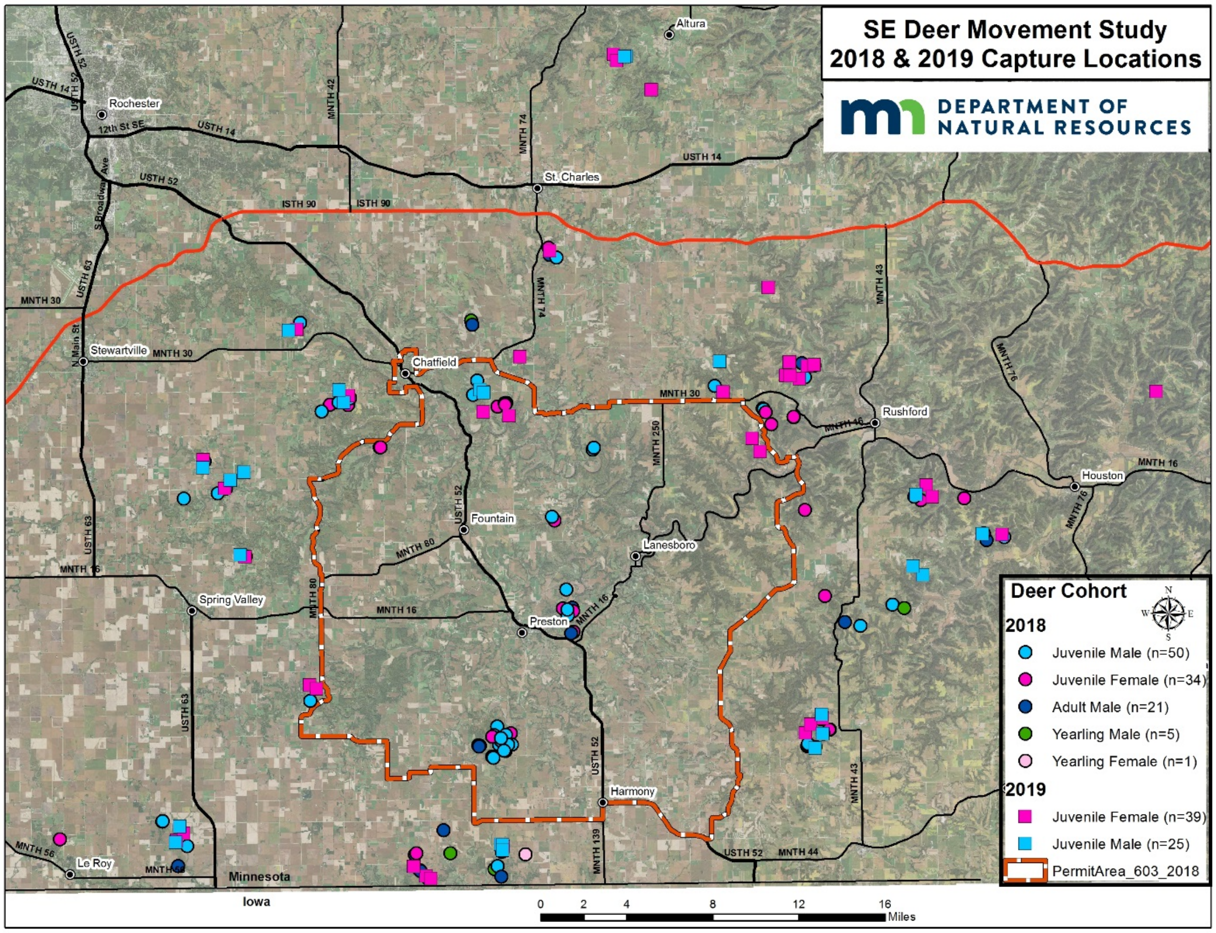

Figure 4. Spatial distribution of all deer captured and GPS-collared in southeastern Minnesota during March 2018 (n=109) and February 2019 (n=64). Points represent the locations where white-tailed deer were captured, collared with GPS units, and released in the study area centered on CWD management zone 603 in Fillmore County, Minnesota.