WINTER SURVIVAL AND CAUSE-SPECIFIC MORTALITY OF WHITE-TAILED DEER IN NORTHERN MINNESOTA: WINTER 2020 UPDATE

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SUMMARY OF FINDINGS

Ongoing studies that examine the influences of environmental, intrinsic, and demographic factors on survival and cause-specific mortality rates of white-tailed deer (*Odocoileus virginianus*) have been critical to enhancing our understanding of population performance and to improving management. A recent evaluation report from the Office of the Legislative Auditor recommended that the "…DNR should conduct field research to collect and utilize more information about Minnesota's deer… and inform the department's vital rate estimates of deer births and deaths, and better reflect deer population dynamics" to improve our understanding of demographics and habitat requirements. Using cutting-edge global positioning system (GPS) collars, and remote sensing and geographic information system (GIS) technologies, we recently launched a study that will inform a level of understanding of habitat requirements and drivers of population performance required by managers to prescribe forest manipulations that best support population goals. Herein, our objectives are to compare winter survival rates and cause-specific mortality (and influential factors) of adult (≥1.5 yr) female deer residing on study sites in northcentral (Inguadona Lake) and northeastern (Elephant Lake) Minnesota. We predicted that survival, percent winter mortality, and the impact of wolf (*Canis lupus*) predation would be influenced by winter severity in a way that is consistent with our understanding of this relationship garnered from a previous long-term (1991−2005) study in northcentral Minnesota. The *natural* mortality rate during the first winter (2017−2018) was high; 6 of 19 (31.6%) GPS-collared deer (3 at each site) were killed by wolves during 10 April to 31 May 2018. Overall survival had decreased to 0.68 (95% confidence interval [CI] 0.50−0.93) by the end of May. Since this was a *pilot year*, the survival estimate was limited by small sample sizes (10 collared deer per site) and represented only the late–winter season (12 March to 28 May 2018) due to delayed capture operations. However, during the second and third winters (2018−2019 and 2019−2020), with more than twice the sample size (*n*=51 and *n*=42), the *natural* mortality rate was also high (38.7% and 24.4%); 18 of 49 deer were preyed upon by wolves and 1 by bobcat (*Felis rufus*) between 1 November 2018 and 31 May 2019, and 10 of 41 deer were preyed upon by wolves between 1 November 2019 and 31 May 2020. The overall survival rate was 0.60 (95% CI=0.48−0.75) and 0.73 (95% CI=0.62−0.88) for winters 2018−2019 and 2019−2020, respectively. Wolf predation rates during the 3 winters (31.6%, 36.7%, and 24.4%) notably exceeded what we expected based on the documented relationship of the previous long-term study. Typically, adult female deer enter winter in better physical condition than fawns and adult males, and thus have the highest probability of surviving winter. Our findings at least suggest that during the 3 winters overall mortality rates at the population level, across sex and age classes, were likely higher than indicated by our adult female data. Ongoing federal protection

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of wolves in Minnesota limits the Minnesota Department of Natural Resources (MNDNR) management options and has at least contributed to the estimated wolf population almost doubling from winter 1988−1989 (1,521 wolves) to the present (~2,900 wolves). Caution may be warranted in interpreting our preliminary findings, but they highlight the need for continuation of this study to better understand whether deer-habitat-wolf predation relationships have been changing since completion of the MNDNR's previous long-term study, a potentially significant consideration relative to implementation of the state's recently developed deer management plan.

INTRODUCTION

Studies that have examined the influences of extrinsic (e.g., habitat, predation, and human activities), intrinsic (e.g., age, sex, condition), and demographic (e.g., density) factors on survival and cause-specific mortality rates have enhanced our understanding of the dynamics of white-tailed deer (*Odocoileus virginianus*) and other ungulate populations in northern Minnesota and elsewhere (Nelson and Mech 1986*a*,*b*; Fuller 1990; Bartmann et al. 1992; DelGiudice 1998; Gaillard et al. 2000; DelGiudice et al. 2002, 2006). A long-term (1991−2005) study of female deer, the reproductive component of populations, reported that the relative risk of mortality was strongly related to the severity of winter conditions in northcentral Minnesota (DelGiudice et al. 2002, 2006). Indeed, the risk of death increased as winters progressed, and by the end of winter was at least 10 times greater during the most severe winter (1995−1996, hereafter 1996) compared to the mildest winter (1991). That study also documented that the relative risk of death of female deer by natural causes was consistently greater than by all other causes of mortality (e.g., hunting), and that wolf (*Canis lupus*) predation, directly related to snow depth, was the primary cause of mortality. Furthermore, the risk of mortality by wolves increases sharply for adults after 6 years of age.

The Office of the Legislative Auditor (OLA) recently issued an evaluation report of the Minnesota Department of Natural Resources' (MNDNR) management of the state's deer population (OLA 2016). This document focused on improving population estimates, but emphasized that improved habitat management should be a key component of a new statewide deer management plan to establish and meet population goals. The OLA report recommends that the "…DNR should conduct field research to collect and utilize more information about Minnesota's deer… and inform the department's vital rate estimates of deer births and deaths, and better reflect deer population dynamics" to improve our understanding of demographics and habitat requirements. Partially in response to the OLA report, we recently launched a study using cutting-edge global positioning system (GPS)-collars, and remote sensing and geographic information system (GIS) technologies, that will provide a level of understanding of habitat requirements and drivers of population performance (survival and reproduction) required by managers to prescribe forest manipulations that best support population goals (DelGiudice et al. 2017, 2019).

Fieldwork for this study was initiated during winter 2018. In addition to an overall objective of establishing the technical feasibility of making fine-scale measurements of habitat use by deer at the forest stand level (see Smith et al. 2019), we monitored winter survival and cause-specific mortality as a means of assessing habitat quality (DelGiudice et al. 1989*a*,*b*) and to update input for state modeling of northern deer populations. We predicted that the influence of winter severity on crude winter mortality and the wolf predation rate of adult female deer would be consistent with findings from our previous long-term study (DelGiudice et al. 2002, 2006).

OBJECTIVES

1. To compare winter survival rates of adult female deer residing on the Inguadona Lake and Elephant Lake sites, located in northcentral and northeastern Minnesota, respectively, where there are differences in winter severity, habitat composition, and deer density.
2. To determine specific causes of mortality and contributing factors.

STUDY AREA

As mentioned above and in a previous research summary (Smith et al. 2019), this study includes 2 deer winter range sites, Inguadona Lake (46 km^2) in northcentral and Elephant Lake (76 km^2) in northeastern Minnesota. These sites allow natural comparisons of potential influences of differences in winter severity, habitat composition, and deer density on habitat use and requirements and associated vital estimates. D'Angelo and Giudice (2015) reported pre-fawning deer densities of 7−9 and 3−5 deer/km^2 in the vicinity of the Inguadona Lake and Elephant Lake sites, respectively. The MNDNR calculates a winter severity index (WSI) throughout the state by accumulating 1 point for each day with an ambient temperature ≤−17.7° C and an additional point for each day when snow depth is ≥38 cm during 1 November−31 May. Generally, winters with maximum WSI values (by 31 May) <100, 100−180, and >180 are assessed as mild, moderately severe, and severe, respectively, relative to impacts on deer survival; however, multiple factors may influence this interpretation annually and geographically (DelGiudice et al. 2006). Maximum WSI at Inguadona Lake at the end of winter was 60, 113, and 63 during 2018, 2019, and 2020, respectively. The maximum WSI values at Elephant Lake were 130, 121, and 117. Additional details addressing site boundaries, location, topography, forest composition, long-term weather, and wolf and black bear (*Ursus americanus*) densities are provided in Smith et al. (2019).

METHODS

During 10−11 March 2018, 19 adult (≥1.5 yr old), female white-tailed deer were captured by net-gunning from helicopter (Hells Canyon Helicopters, Clarkston, Washington), 9 and 10 on the Inguadona Lake and Elephant Lake sites, respectively. A tenth deer was captured on 25 February 2018 by Clover trap at Inguadona (Clover 1956). Except for this deer (which was immobilized with xylazine and ketamine, and reversed with yohimbine), all deer were physically restrained for handling (Smith et al. 2019). Similarly, 20 adult female deer were captured on each site by net-gunning from helicopter (Quicksilver Air, Inc., Fairbanks, Alaska) during 5−8 February 2019 and 13 more deer, 8 and 5 on the Inguadona Lake and Elephant Lake sites, respectively, were captured on 6 February 2020 (Helicopter Wildlife Services, Austin, Texas), and handled following the same protocol. All deer were fitted with a Globalstar Recon GPS collar (Model IGW-4660-4; Telonics, Inc., Mesa, Arizona). We programmed all collars deployed in 2018 and 2019 to collect 1 location-fix every 2 hours during December−June and 1 location-fix every 4 hours during July−November. Collars deployed in 2020 were set to 1 location-fix every hour during December–June and every 4 hours during July–November. The collar's mortality sensor relies on a 3-axis accelerometer. The unit samples this accelerometer every second. "Active" is recorded when the reading of any of the 3 axes changes by more than 0.3 g (gravitational force) since the last active second. Less than 5 accumulated seconds of activity during the previous 8-hours causes the unit to detect mortality, which triggers the collar to send a mortality notification through the Globalstar satellites, followed by sending an email to our team. This launches our field investigation and increases the VHF pulse rate to notify researchers in the field. Our field investigations included a thorough search for site and carcass evidence to determine the specific cause of mortality. When available, we collected a mandible (to extract a fourth incisor) and femur (or other long bone as necessary) to age the deer to the year and assess body condition (Gilbert 1966, Mech and DelGiudice 1985). We conservatively assigned ultimate cause of death as "capture-related" when the mortality occurred within 7 days of capture, regardless of the proximate cause (e.g., wolf-kill; DelGiudice et al. 2002, 2006) or handling method (i.e., physically or chemically immobilized).

We calculated Kaplan-Meier survival estimates using the R package *KMsurv* (R Core Team 2017). We examined relationships between the WSI and percent winter mortality by simple linear regression analyses in Excel (Version 14.0.7153.5000, Microsoft Corporation 2010).

RESULTS AND DISCUSSION

Overall survival of our GPS-collared adult female deer decreased markedly to 0.68 (95% confidence interval [CI] 0.50–0.93), 0.60 (95% CI 0.48−0.75), and 0.73 (95% CI 0.62−0.88) during winters 2017–2018 (2018), 2018−2019 (2019), and 2019−2020 (2020), respectively, and was consistently similar at Inguadona Lake and Elephant Lake (Figure 1). The overall crude natural mortality rate (reported for consistency with the estimate from the previous study, but not to replace use of the aforementioned survival rates) was 31.6% (6 of 19 deer), 38.7% (19 of 49 deer), and 24.4% (10 of 41 deer) during winters 2018, 2019, and 2020, respectively (Figure 2). These rates exclude 1 capture-related mortality during each of the first and second winters and an unrecovered hunter-harvested deer during each of the second and third years. Wolf predation rates were 31.6% (6 of 19), 36.7% (18 of 49), and 24.4% (10 of 41) during the 3 winters (Figure 2). Wolf predation accounted for all of the natural mortality during winter 2018 and 2020, and all but 1 of the mortalities during 2019, which was a deer killed by a bobcat (*Felis rufus*). Many of the wolf-killed deer were in poor condition as indicated by a mean marrow fat content of 71.8% (± 5.3 [SE], range = 3−91%, *n*=22; Watkins et al. 1991).

Given the low to moderate maximum WSI values during winters 2018, 2019, and 2020 at Inguadona Lake (60, 113, and 63) and Elephant Lake (130, 121, and 117), reflecting mild to moderately severe conditions, these female mortality rates, overall and due to wolf predation specifically, were extraordinarily high (Figure 2). Winter wolf predation on northern deer is directly related to snow depth. Deepening snow increasingly impedes deer mobility and escape (deer have a heavier weight-load-on-track than wolves) and steadily compromises their energy balance and endurance (Moen 1976, Nelson and Mech 1986*b*, DelGiudice 1998, DelGiudice et al. 2002). Consequently, most winter mortalities, both in our previous long-term and present studies, occurred during March−May, when snow cover is deepest and body condition is poorest.

The preponderance of evidence in this study suggests that poor condition was a noteworthy contributing factor to the high mortality rates by wolf predation. Given that winter conditions were not particularly severe at either site in any of the 3 years, as indicated by maximum WSI values, prompts consideration of the role of winter habitat deficiencies compromising the ability of deer to adequately fulfill their biological requirements and avoid wolf predation as the season progresses. Indeed, it is additionally noteworthy that winter survival and wolf predation rates were similarly low and high, respectively, on both sites during all 3 winters. Increasing concerns about the limited quantity and quality of habitat (e.g., dense conifer cover) on deer winter range in northern Minnesota, in large part, prompted the need for the present study (T. Rusch, L. Petersen, and P. Backman, MNDNR, Section of Wildlife, personal communication), as did OLA's evaluation report strongly recommending continued deer research that enhances the MNDNR's understanding of vital estimates and associated population dynamics for improved management (OLA 2016). Typically, adult female deer enter winter in the best physical condition (i.e., most replete fat reserves), and thus have the lowest hazard risk or highest probability of surviving winter compared to fawns and adult males (Mautz 1984, Robbins 1993, DelGiudice et al. 2002). This at least suggests that overall winter mortality rates during these 3 years could have been even higher than indicated by our adult female data. Ongoing federal protection of wolves in Minnesota limits the MNDNR's management options, and consequently, has at least contributed to the estimated population almost doubling from winter 1989 (1,521 wolves), just as the previous deer study was initiated (winter 1991), to the present (~2,900 wolves, Erb and DonCarlos 2009, Erb et al. 2017). Accumulating evidence critically highlights the need for multi-year continuation of this study to better understand whether these complex deer-habitat-wolf predation relationships have been changing since completion of the previous long-term study (DelGiudice et al. 2002, 2006, 2007, 2013*a*, *b*).

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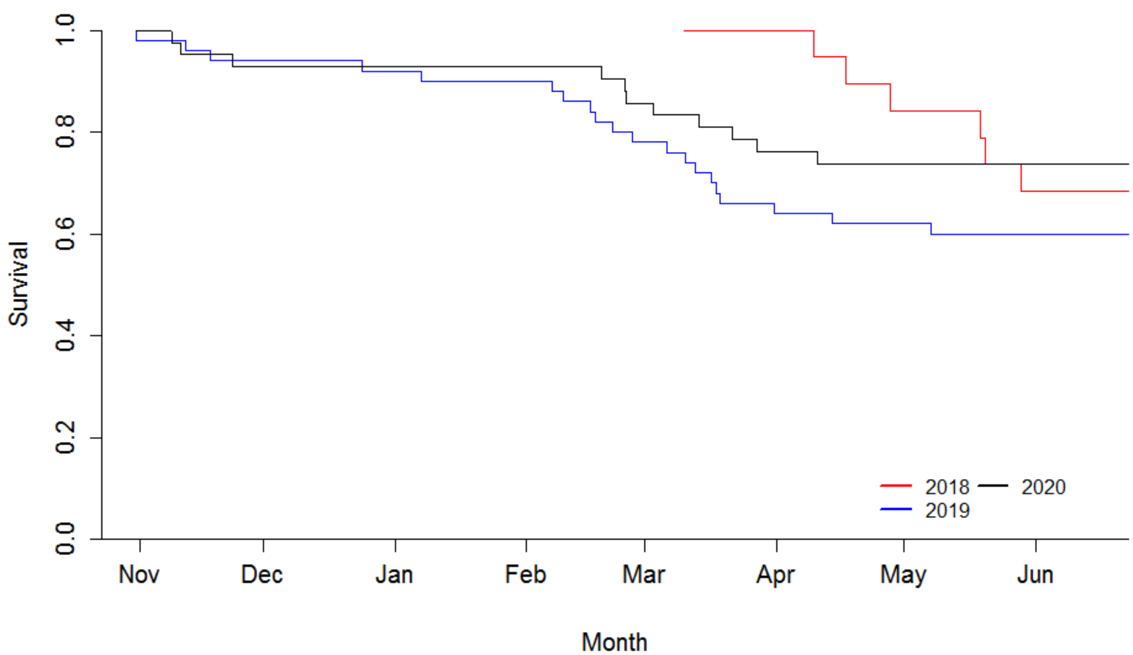
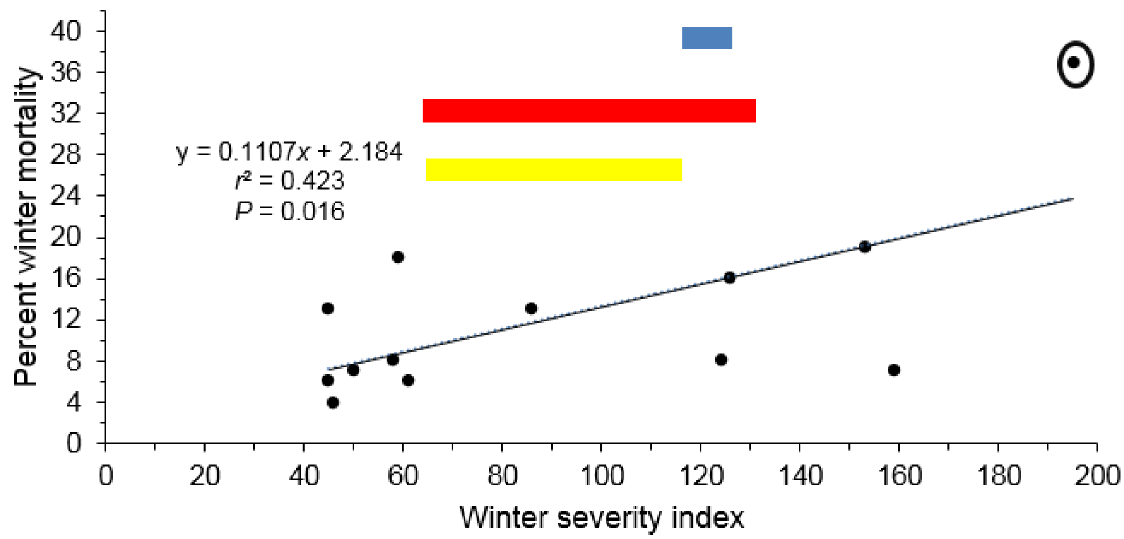


Figure 1. Kaplan-Meier survival curves of adult (≥1.5 yr), female white-tailed deer from date-of-capture, 10−11 March (*n*=19) to 31 May 2018, from 1 November 2018 to 31 May 2019 (*n*=50), and from 1 November 2019 to 31 May 2020 (*n*=42), at the Inguadona Lake and Elephant Lake study sites (pooled), northcentral and northeastern Minnesota. One capture-related mortality was excluded from the analysis for each of the first 2 winters.



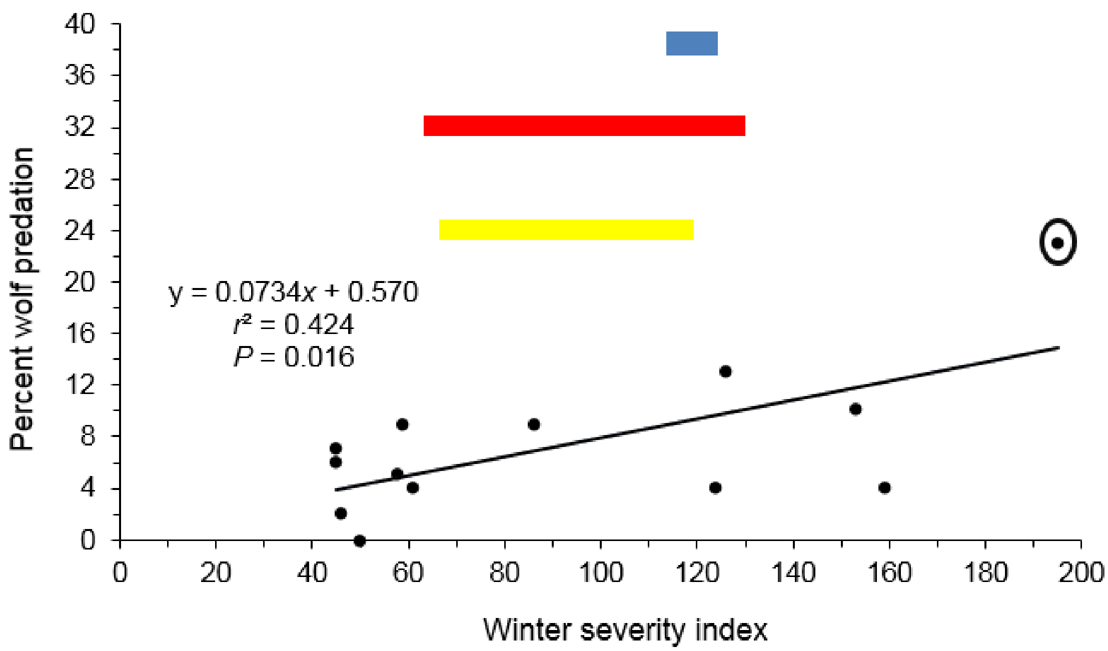


Figure 2. Comparison of pooled crude winter mortality (top) and wolf predation rates (bottom) of adult (≥1.5 yr), female white-tailed deer at the Inguadona and Elephant Lake sites, northcentral and northeastern Minnesota, respectively, during winters 2017−2018 (red, *n*=19 deer), 2018−2019 (blue, *n*=49−50), and 2019−2020 (yellow, *n*=41−42), to the long-term relationship of these rates for adult, female deer to the maximum winter severity index (WSI) in northcentral Minnesota, during winters 1990−1991 to 2002−2003 (DelGiudice et al. 2006). Maximum WSI values at the 2 sites spanned 60 to 130, 113 to 121, and 63 to 117 during the 3 recent winters, respectively. One capture-related mortality was excluded from each of the first 2 winters. The circled data point represents historically severe winter 1995−1996.