WINTER SURVIVAL AND CAUSE-SPECIFIC MORTALITY OF WHITE-TAILED DEER IN NORTHERN MINNESOTA: UPDATING WITH GPS COLLARS

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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) collar, 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 (survival and reproduction) 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 female deer residing on study sites in northcentral (Inguadona Lake) and northeastern (Elephant Lake) Minnesota. Specifically, 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. Mortalities of 6 of 20 GPS collared adult, female deer occurred from 10 April to 28 May on the 2 sites, 3 at Elephant Lake and 3 at Inguadona Lake. Wolf predation was the proximate cause of all of these mortalities, and most of these deer were in poor condition when they were killed. Overall, the survival rate decreased to 0.68 (95% confidence interval 0.50−0.93) by 28 May. Wolves preyed on a fourth deer in poor condition at Inguadona Lake, but it occurred within 2 days of being captured, so we excluded it from analyses as a capture-related mortality. Typically, adult female deer enter winter in the best physical condition compared to fawns and adult males, and thus have the highest probability of surviving winter. This at least suggests that overall mortality rates across sex and age classes during this past winter could have been even higher than indicated by our preliminary adult female data. Ongoing federal protection of wolves in Minnesota limits the Minnesota Department of Natural Resources' (MNDNR) management options, and consequently, 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 is warranted in interpreting our preliminary findings, but they do

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highlight the need for multi-year follow-up study to better understand whether deer-habitat-wolf predation relationships have been changing since completion of the MNDNR's previous long-term study.

INTRODUCTION

Studies that have examined the influences of extrinsic (e.g., location, season, 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 population performance and dynamics of white-tailed deer (*Odocoileus virginianus*) and other ungulates in northern Minnesota and elsewhere (Nelson and Mech 1986*a*,*b*; Fuller 1990; Bartmann et al. 1992; DelGiudice 1998; Gaillard et al. 2000; DelGiudice 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 (i.e., indicated by a w**inter severity index [WSI]; DelGiudice et al. 2002, 2006) in northcentral Minnesota. 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) compared to the mildest winter (1990−1991). That study also documented that the relative risk of death 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 adult deer mortality by wolves increases sharply 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). The evaluation report focused on improving population estimates and acknowledged throughout that improved habitat management would have to be the other key component of this plan to establish and meet population goals. More detailed information and a greater understanding of winter habitat requirements of deer in northern Minnesota has been an ongoing need of wildlife managers and foresters to enhance their ability to plan, integrate, and implement long-term forest and habitat management strategies and associated activities. Relative to population and habitat management, 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. Using cutting-edge global positioning system (GPS) collars and remote sensing and geographic information system (GIS) technologies, this recently-launched study will increase understanding of habitat requirements and methods to evaluate demographics required by managers to prescribe forest manipulations that best support population goals (DelGiudice et al. 2017).

Fieldwork for this study was initiated during winter 2017−2018. A critical overall objective of this first year is to establish the technical feasibility of making fine-scale measurements of habitat use by white-tailed deer (see companion research summary by Smith et al. 2018) and to monitor winter survival and cause-specific mortality as a means of assessing habitat quality (DelGiudice et al. 1989*a*,*b*) and updating 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 discussed above and in a companion research summary in this issue (Smith et al. 2018), the study included 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 WSI throughout the state by accumulating 1 point for each day with an ambient temperature ≤−17.7^o 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 and Elephant Lake at the end of winter 2017−2018 was 61 and 122, respectively. 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. (2018).

METHODS

During 10−11 March 2018, 19 adult (>1.5 years 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 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. 2018). All deer were fitted with a Globalstar Recon GPS collar (Model IGW-4660-4; Telonics, Inc., Mesa, Arizona). We programmed all collars to collect 1 location-fix every 2 hours during December−June and 1 location-fix 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. This also 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 14 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 through the end of May (~80 days) to 0.68 (95% confidence interval 0.50–0.93) and was similar at Inguadona and Elephant Lakes (Figure 1). Natural mortality during late winter 2017−2018 was notably higher than expected. Overall, the late winter mortality rate was 35% (7 of 20 deer). The first mortality occurred at Inguadona Lake on 13 March within 2 days of capture; consequently, we assessed it as capture-related, but the proximate cause was wolf predation. Furthermore, ocular assessment of the collected long bone marrow (i.e., red) indicated near exhaustion of fat in this depot, thus this individual was in poor condition when it was killed (Mech and DelGiudice 1985). Laboratory analyses of marrow fat content of all collected bone specimens are pending. Importantly, because this captured animal was physically restrained for only 5 minutes, and not chemically immobilized, there was no risk of residual drug-effects and limited potential influence of the brief handling on its vulnerability to subsequent predation.

Six additional mortalities occurred from 10 April to 28 May on the 2 sites, 3 at Elephant Lake and 3 at Inguadona Lake. Wolf predation was the proximate cause of all of these mortalities as well. Four of these deer were in only fair to poor condition, whereas 2 could not be assessed due to insufficient evidence (e.g., no long bone recovered). Excluding the capture-related mortality from our calculations reduced the natural mortality rate to 33% at Inguadona; it was 30% at Elephant Lake and 32% overall. Given the low to moderate, end-of-the-season, maximum WSI values for Inguadona (66) and Elephant Lake (122), 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, attributable to deepening snow increasingly impeding deer mobility and escape (deer have a heavier weight-load-on-track) and to its steady compromising effect on 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 or 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, as indicated by maximum WSI values, this prompts consideration of the role of winter habitat deficiencies compromising the ability of deer to adequately fulfill their biological requirements as the season progressed. Indeed, it is additionally noteworthy that winter survival and wolf predation rates were similar on both sites, despite the maximum WSI at Inguadona Lake being half that at Elephant Lake. 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 deer research that enhances the MNDNR's understanding of vital estimates and associated population performance and dynamics for improved management be continued (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 this past winter could have been even higher than indicated by our preliminary adult female data, which also did not include winter mortality that occurred before collar deployment on 10 March. 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 1988−1989 (1,521 wolves), just as the previous deer study was initiated (winter 1990−1991), to the present (~2,900 wolves, Erb and DonCarlos 2009, Erb et al. 2017). Caution is warranted in interpreting our preliminary findings, but they appear to critically highlight the need for multi-year follow-up 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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LITERATURE CITED

Bartmann, R. M., G. C. White, and L. H. Carpenter. 1992. Compensatory mortality in a Colorado mule deer population. Wildlife Monographs121.

Clover, M. R. 1956. Single-gate deer trap. California Fish and Game 42:199−201.

D'Angelo, G. J., and J. H. Giudice. 2015. Monitoring population trends of white-tailed deer in Minnesota - 2015. Section of Wildlife, Minnesota Department of Natural Resources, St. Paul, Minnesota, USA.

files.dnr.state.mn.us/wildlife/ deer/reports /harvest/popmodel_2015.pdf – 2015-09-09.

DelGiudice, G. D. 1998. Surplus killing of white-tailed deer by wolves in northcentral Minnesota. Journal of Mammalogy 79:227–235.

DelGiudice, G. D., J. Fieberg, M. R. Riggs, M. Carstensen Powell, and W. Pan. 2006. A long-term age-specific survival analysis of female white-tailed deer. Journal Wildlife Management 70: 1556–1568.

DelGiudice, G. D., J. R. Fieberg, and B. A. Sampson. 2013*a*. A long-term assessment of the variability in winter use of dense conifer cover by female white-tailed deer. PLoS ONE 8(6): e65368. Doi: 10.1371/journal.pone.0065368

DelGiudice, G. D., M. S. Lenarz, and M. Carstensen Powell. 2007. Age-specific fertility and fecundity in northern free-ranging white-tailed deer: evidence for reproductive senescence? Journal of Mammalogy 88:427−435.

DelGiudice, G. D., L. D. Mech, and U. S. Seal. 1989*a*. Physiological assessment of deer populations by analysis of urine in snow. Journal of Wildlife Management 53:284−291.

DelGiudice, G. D., L. D. Mech, and U. S. Seal. 1989*b*. Browse diversity and the physiological status of white-tailed deer during winter. Transactions of the North American Wildlife and Natural Resources Conference 54:134−145.

DelGiudice, G. D., A. Norton, J. F. Knight. 2017. Informing winter habitat management prescriptions and population vital rate estimates for white-tailed deer in northcentral and northeastern Minnesota. Phase I research proposal. Minnesota Department of Natural Resources Section of Wildlife, St. Paul, Minnesota, USA.

DelGiudice, G. D., M. R. Riggs, P. Joly, and W. Pan. 2002. Winter severity, survival and cause-specific mortality of female white-tailed deer in north central Minnesota. Journal of Wildlife Management 66:698–717.

DelGiudice, G. D., B. A. Sampson, and J. H. Giudice. 2013*b*. A long-term assessment of the effect of winter severity on the food habits of white-tailed deer. Journal of Wildlife Management. 77:1664−1675.

Erb, J., and M. DonCarlos. 2009. An overview of the legal history and population status of wolves in Minnesota. Pages 49-64 *in* A. P. Wydeven, T. R. Van Deelen, and E. J. Heske, editors. Recovery of gray wolves in the Great Lakes Region of the United States: an endangered species success story. Springer. New York, New York, USA.

Erb, J., C. Humpal, and B. Sampson. 2017. Minnesota wolf population update 2017. Minnesota Department of Natural Resources Section of Wildlife, St. Paul, Minnesota, USA.

Fuller, T. K. 1990. Dynamics of a declining white-tailed deer population in north central Minnesota. Wildlife Monographs 110.

Gaillard, J. –M., M. Festa-Bianchet, N. G. Yoccoz, A. Loison, and C. Toigo. 2000. Temporal variation in fitness components and population dynamics of large herbivores. Annual Review of Ecology and Systematics 31:367−393.

Gilbert, F. F. 1966. Aging white-tailed deer by annuli in the cementum of the first incisor. Journal of Wildlife Management 30:200−202.

Mautz, W. W. 1978. Nutrition and carrying capacity. Pages 321–348 *in* J. L. Schmidt and D. L. Gilbert, editors. Big game of North America: ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Mech, L. D., and G. D. DelGiudice. 1985. Limitations of the marrow-fat technique as an indicator of body condition. Wildlife Society Bulletin 13:204−206.

Moen, A. N. 1976. Energy conservation by white-tailed deer in the winter. Ecology 57:192−198.

Nelson, M. E., and L. D. Mech. 1986*a*. Mortality of white-tailed deer in northeastern Minnesota. Journal of Wildlife Management 50:691–698.

Nelson, M. E., and L. D. Mech. 1986*b*. Relationship between snow depth and gray wolf predation on white-tailed deer. Journal of Wildlife Management 50:471−474.

Office of Legislative Auditor (OLA). 2016. Evaluation report, Department of Natural Resources: Deer population management. Program Evaluation Division, St. Paul, Minnesota, USA.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Robbins, C. T. 1993. Wildlife feeding and nutrition. Academic Press, New York, New York, USA.

Smith, B. D., G. D. DelGiudice, and W. J. Severud. 2018. Establishing the feasibility of making fine-scale measurements of habitat use by white-tailed deer in northern Minnesota, winter 2017–2018. *In* L. Cornicelli, M. Carstensen, B. Davis, N. Davros, and M. A. Larson, editors. Summaries of Wildlife Research Findings 2017. Minnesota Department of Natural Resources, St. Paul, Minnesota, USA. *In prep*.

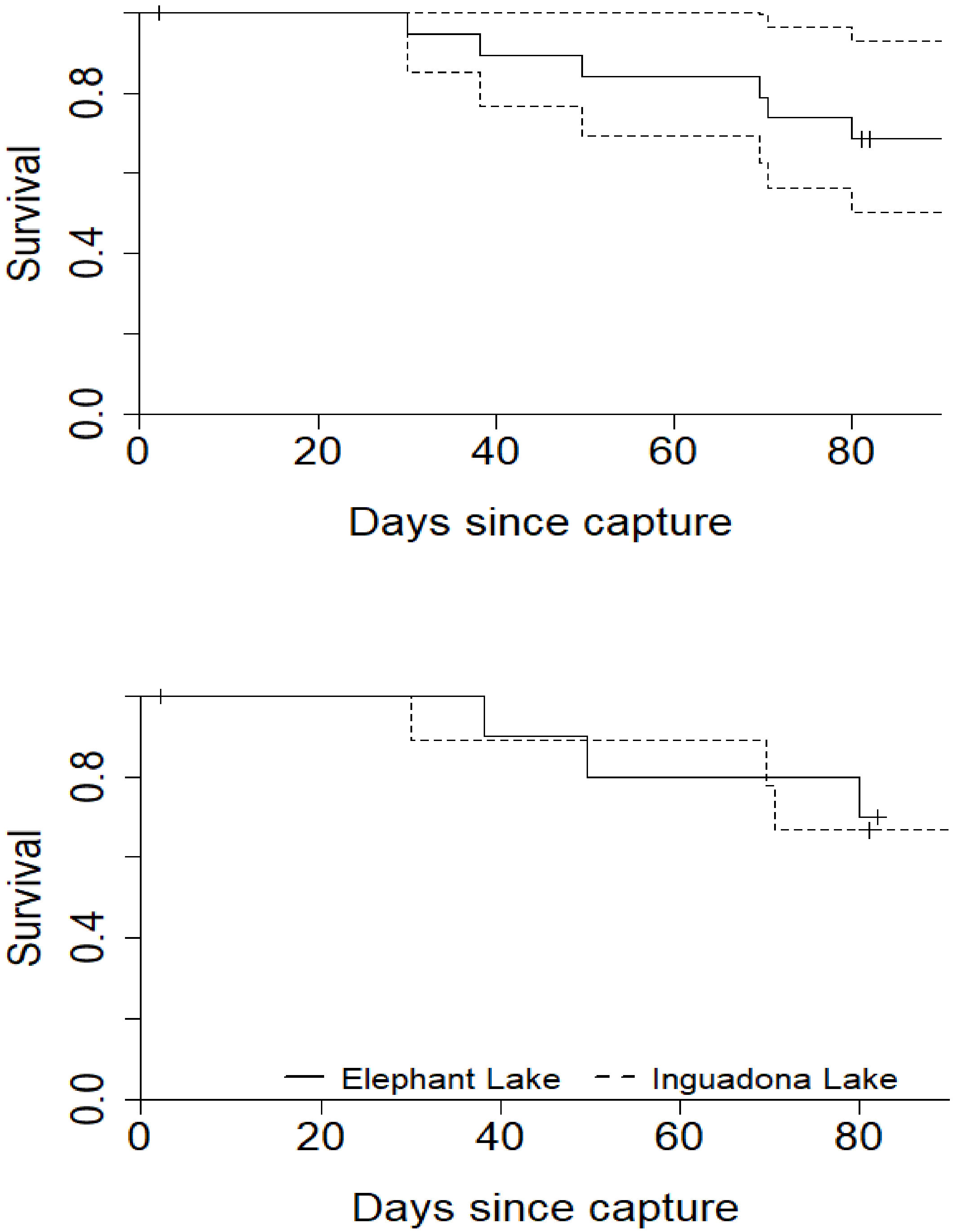

Figure 1. Kaplan-Meier survival for all 20 global positioning system-collared, adult (>1.5 years) female white-tailed deer (top, pooled) on the Inguadona Lake (northcentral) and Elephant Lake (northeastern) study sites and comparing survival for the 10 deer on each of the sites (bottom), Minnesota, 11 March−31 May 2018. The early single tick mark represents the deer censored due to capture-related mortality, and the double mark represents the last day post-capture included in the analysis. Dashed lines in the top graph represent 95% confidence intervals.

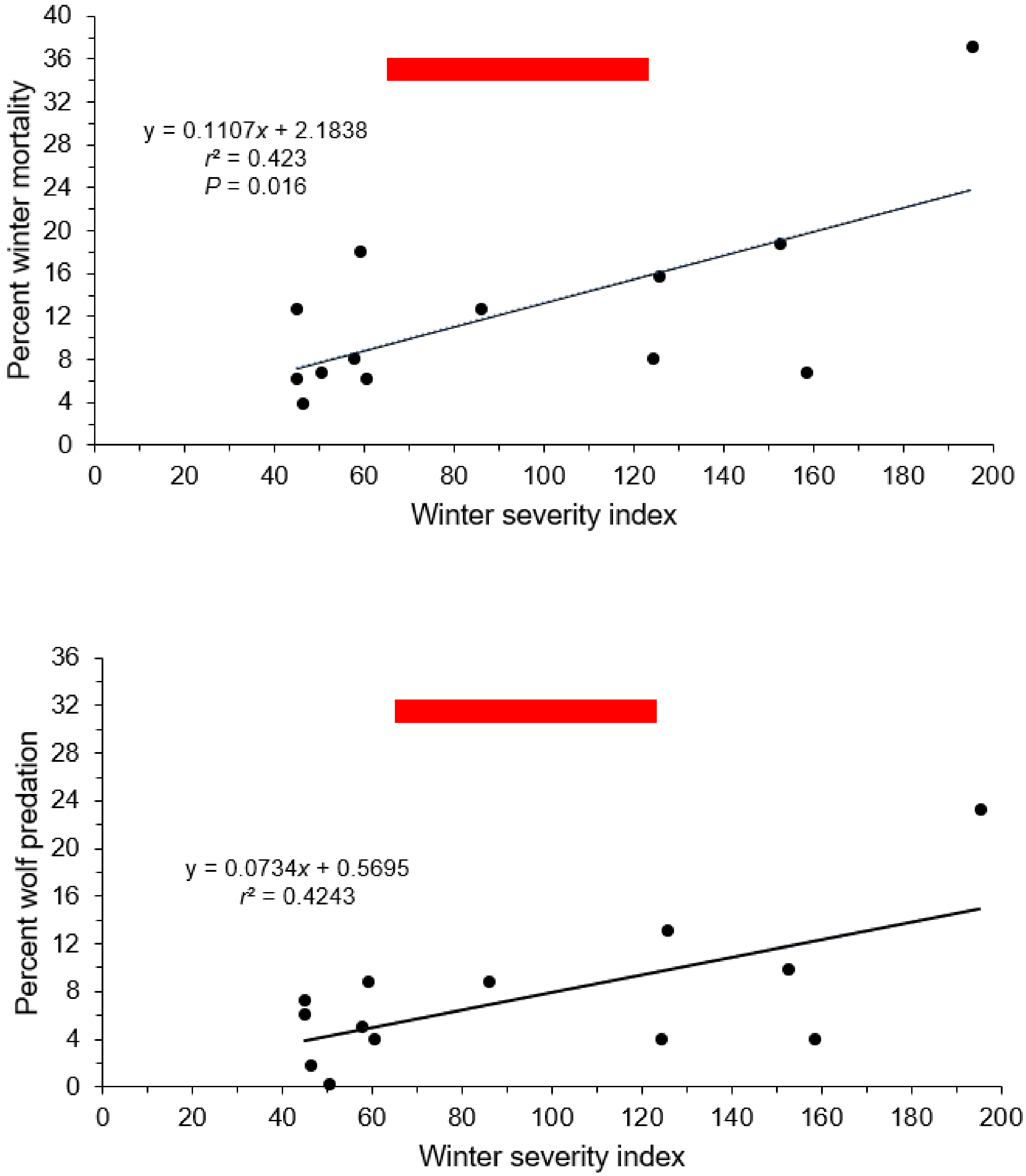

Figure 2. Comparison of pooled percent crude winter mortality (35%, top) and wolf predation rates (32%, bottom), depicted by the red bars, for 20 global positioning system-collared, adult (>1.5 years), female white-tailed deer from a study site in northcentral (Inguadona Lake) and northeastern (Elephant Lake) Minnesota during winter 2017−2018 to the long-term relationship of these rates for radiocollared adult, female deer to maximum winter severity index (WSI) in northcentral Minnesota, during winters 1990−1991 to 2002−2003 (DelGiudice et al. 2006). The red bar spans from a maximum WSI of 61 (Inguadona Lake) to 122 (Elephant Lake).