USING ADULT FEMALE MOOSE BEHAVIOR TO ESTIMATE CALVING AND MORTALITY OF CALVES

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SUMMARY OF FINDINGS

Continuing research on cause-specific mortality and annual survival of moose (*Alces alces)* calves in northeastern Minnesota is critical to understanding the long-term trajectory of the population. Thirty-five global positioning system (GPS)-collared adult females were computer-monitored beginning in late-April 2016 for calving movements, or a long distance movement followed by intense localization. We observed 28 of 35 (80.0%) make a calving movement, and along with additional visual observations of calves, determined 31 of the 35 (88.6%) cows were pregnant. Mean birth-date was 12 May 2016 (median = 11 May 2016, 24 Apr–10 June [range]). Following confirmation of calf presence (e.g., calf pellets, tracks, afterbirth), cows were monitored for a rapid, long-distance movement ("flee") followed by a return to the origin of the flee, indicating a possible predator attack. We observed evidence of 15 mortalities with a mean age at death of 30.6 days (± 15.5 [standard error], 2.5–243, *n* = 15). Specific causes of mortality included 9 wolf-kills (*Canis lupus*), 3 bear-kills (*Ursus americanus)*, 1 unknown predator-kill, and 2 deaths following vehicle collisions. Eight of 12 cows returned to the mortality site a mean 2.6 (± 0.5) times. Calf survival to 30 days of age was 66.7% (± 8%). Survival declined to 32.6% (± 8%) at 1 year of age, and the calf:cow ratio was 0.35. Understanding movement behaviors of cows can yield important insight into mechanisms driving the decline of the population in northeastern Minnesota and aid in future management decisions.

INTRODUCTION

The near disappearance of moose (*Alces alces)* in northwestern Minnesota since the mid-1980s and a dramatic decline of northeastern Minnesota's population since 2006 (Murray et al. 2006; Lenarz et al. 2009, 2010; DelGiudice 2016) prompted aggressive studies of survival and cause-specific mortality of adults and calves in 2013 in northeastern Minnesota (Figure 1) using cutting-edge global positioning system (GPS) collar technology (Carstensen et al. 2014, Severud et al. 2015*a*). Earlier work (2002–2008) in northeastern Minnesota focused on moose survival and employed very high frequency (VHF) telemetry (Lenarz et al. 2009, 2010). Current studies changed to GPS collars to facilitate more expeditious investigations of adult and calf mortalities (Butler et al. 2013, Severud et al. 2015*a*).

Adult survival and reproduction are the primary drivers of ungulate population performance (Gaillard et al. 2000, Raithel et al. 2007). Several studies have reported that low and highly

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variable juvenile survival contribute to population declines (Hatter and Janz 1994, Cooley et al. 2008, Forrester and Wittmer 2013). Ungulate calves are particularly vulnerable to predation within the first few months of life (Franzmann et al. 1980, Keech et al. 2011, Patterson et al. 2013). In the most recent study of cause-specific mortality of moose calves in northeastern Minnesota, 50% of the collared individuals died within 50 days of birth (Severud et al. 2015*a*). The majority of calves were killed by wolves (*Canis lupus*), and a smaller proportion by black bears (*Ursus americanus*). Other studies have reported similar findings (Ballard et al. 1981, Osborne et al. 1991, Keech et al. 2011, Patterson et al. 2013). Wolves may prey on calves throughout the entire year, whereas bears have their greatest impact closer to parturition when the calves are less mobile (DelGiudice et al. 2009, Basille et al. 2015).

A primary objective of 1 of the studies initiated by the Minnesota Department of Natural Resources (MNDNR) in 2013 has been to assess annual variation of cause-specific mortality of calves. Unique challenges to the study's protocol for capturing and handling neonates in 2013 and 2014 (e.g., capture-induced abandonment, DelGiudice et al. 2015) and adults in 2015 (e.g., capture-related mortality, Carstensen et al. 2015) resulted in a Governor's executive order that captures be discontinued. Consequently, since 2015, research has continued without the benefit of neonates fitted with GPS collars (Severud et al. 2015*b*, Obermoller et al. 2017). In 2015, we monitored 60 cows with functioning GPS collars for calving activity (i.e., calving movement), and subsequently for a "mortality movement" relative to a potential calf mortality. A mortality movement was described as a cow making a sudden long-distance movement ("flee"), followed by a return to the origin of the flee, often multiple times (Figure 2; Obermoller et al. 2017).

Dams with young calves display reduced movements (Testa et al. 2000), which allowed us to differentiate between cows with and without calves. The calves' limited mobility at an early age makes them particularly vulnerable to wolf and bear predation. Once dams lose their calf or calves, their movements may increase by approximately 12% within 48 hours (Testa et al. 2000). DeMars et al. (2013) applied a movement threshold (using a 3-day average) to caribou (*Rangifer tarandus*) dams. When the dam's movements exceeded 186.5 m/hour, the calf was assumed to be dead. "Normal movements" of females then resumed, because they were no longer limited by the mobility of a calf. These authors successfully detected calf survival up to 4 weeks of age using this threshold. We attempted to improve our understanding of the temporal and spatial aspects of maternal movement patterns relative to calf mortalities using 2013 and 2014 movement data of GPS-collared moose dams relative to known mortalities of their GPS-collared calves. We then applied that understanding to support detection and investigation of mortality events of calves born in spring 2016.

OBJECTIVES

1. Determine the pregnancy rate of GPS-collared adult females by intense computer-monitoring of movements associated with calving activity and field confirmation
2. Increase our understanding of dam movements relative to cause-specific mortality of calves
3. Identify, locate, and assign cause of mortality to moose calves with field confirmation
4. Determine seasonal and annual survival rates of moose calves

METHODS

Adult moose (128 females, 51 males) were captured and fitted with GPS collars (Vectronic Aerospace GmbH, Berlin, Germany) in winters 2013–2015 as part of a companion study examining survival and cause-specific mortality in northeastern Minnesota (Butler et al. 2013, Carstensen et al. 2015). Due to natural mortalities, malfunctioning GPS collars, and battery expiration, 35 adult females with functioning GPS collars were available for intense computer-monitoring during the 2016 calving season. Twenty-three cow collars were programmed to take locations every 4 hours and transmit these locations to our base station after 6 successful fixes. The remaining 12 cow collars were locked in "mortality mode," programmed to take locations every hour, and transmit these locations after 11 successful fixes. We monitored 20 cows with functioning GPS collars for calving in May−June 2017: 12 collars took a location every 4 hours, while the remaining 8 recorded a location every hour. In early-May of each year, all cows were monitored for a calving movement, which is a long-distance movement followed by intense localization (McGraw et al. 2014, Severud et al. 2015*a*). Automated reports highlighting calving movements were generated twice daily based on a 4-hour fix rate for each cow (Severud et al. 2015*a*, Obermoller et al. 2017*;* J. D. Forester, University of Minnesota, unpublished data). In spring 2016, we verified calving by examining the calving site for calf presence (e.g., tracks, pellets, hair) or evidence of birth (e.g., scrape in the earth, afterbirth) after the cow left the area to avoid disturbing her or her calf. In a few cases, we confirmed the presence of a calf by a public-reported visual, camera traps, or by searching a subsequent localization. Following verification of a calf by 1 of these methods, we monitored each cow's locations daily for a mortality movement (as previously described). All monitoring in 2017 was completed remotely, and calving was not verified by the aforementioned methods.

In 2013 and 2014, we captured and fitted 74 neonates with GPS collars (with mortality accelerometers) to monitor them for survival and mortality events (Severud et al. 2015*a*,*b*). We analyzed movement patterns of GPS-collared dams of GPS-collared calves that died of known causes in 2013 and 2014 to determine characteristics indicative of specific causes of mortality (e.g., wolf or bear predation, abandonment). Specifically, we used temporal and spatial analyses of mortalities of 2013 and 2014 to aid in identifying calf mortality events in 2015 and 2016. In 2015, a 50% success rate of detecting mortalities associated with a mortality movement was documented until moose neonates were approximately 3 weeks of age, after which, identifying mortality sites became increasingly difficult, because of increased movement rates of the cow-calf pairs (Severud et al. 2015*b*).

When we observed a presumed mortality movement we deployed a team to the site for an investigation. At the site, we searched in the immediate area for any sign of calf mortality. If no evidence was immediately found, we expanded our search to more efficiently and thoroughly cover the surrounding area. We conducted the search as a 3- to 4-person team; 1 person carried a handheld GPS and hiked in each cardinal direction, and the other team members spread out to the right of the first person in 10-m intervals. We hiked in this manner for about 200 m, returned to the origin, and repeated this process in the remaining cardinal directions. Due to various factors (e.g., calf age, habitat type, topographical limitations, and lack of cow or calf sign), we adjusted our search area as needed. We searched for carcass remains, sign of a specific predator, and other site evidence (e.g., broken vegetation, blood sprays) to lead us to a cause of death. Evidence indicative of a bear-kill included cached body parts, peeled or inverted hide, selective feeding on viscera or sensory organs, and claw marks across the body, whereas a wolf-kill would be indicated by long bones chewed on the ends, presence of the rumen and its contents, scattered remains over a large area, and puncture wounds on the head, neck, or hindquarters when present (Ballard et al. 1981, Severud et al. 2015*a*,*b*). The aforementioned information was used to assign specific causes of mortality. Following a mortality or unusual movements, we performed survival investigations to determine whether the cow had lost her calf or calves or had a remaining twin alive. We executed survival investigations by heading to localized areas previously occupied by the cow. Opportunistically, we placed camera traps in areas the cow frequently occupied to attempt to capture evidence of a calf.

We conducted surveys using a Bell Jet Ranger (OH-58) helicopter to locate all cows with functioning GPS collars and determine 8-month and near-annual calf survival (recruitment). We also determined which cows still had surviving calves to evaluate the success of our mortality and survival investigations from the previous summer. To calculate success, we had a predetermined expectation of whether each cow would have a calf or not based on their movements post-calving. We monitored the status of the cows via calf survival checks, mortality investigations, and movement rates. In cases where the cow was not located, we searched for a maximum 15 minutes before moving to the next animal.

We calculated Kaplan-Meier survival using the *KMsurv* package in Program R. A calf was assumed to be dead if not observed with its dam during survey flights; we assigned the mortality date at the median of the birth date and flight date. Cows not seen during the flights were censored from the analysis (Figure 4).

RESULTS

Thirty-one of 35 (88.6%) cows monitored in 2016 were determined to be pregnant via calving movement and site confirmation or by visual observation of a calf or calves. We observed 28 of the 35 (80.0%) cows, or 90.3% (28 of 31) of the pregnant cows make a calving movement. Mean duration of the calving movement was 24.5 hours (± 2.5 [standard error], 3.2–63.8 [range], n = 28), and mean total path length over this period was 5.3 km (± 0.8, 0.1–18.3, n = 28). Mean displacement from the start of the calving movement to the birth location was 2.3 km (± 0.6, 0.1–15.2, n = 28). Of the 3 remaining cows that were not observed making a calving movement, one came back "on air" during the calving season and a calf was confirmed via camera trap, another did not make a calving movement, but was seen with a calf by the public, and the remaining cow was killed by wolves with a calf *in utero* (Carstensen et al., unpublished data).

We confirmed evidence of a calf for 27 of 31 of our cows via calf pellets, tracks, afterbirth, or visualization of the calf (e.g., camera trap or seen by public). In the 4 remaining cases we were only able to confirm the presence of a calving bed, but subsequent evidence of reduced movements by the cow further increased our confidence a calf was still present. The mean birth-date was 12 May 2016 (median = 11 May, 24 Apr–10 Jun), with 75.0% of the localizations occurring during 4–14 May 2016 (Table 1).

The calving movement occurred over a mean 26.4 hours (± 6.0, 2.1–75.4, n = 16) in 2017. Subsequently, the cows localized for 6.4 days (± 0.9, 2.5–13.9, n = 15). Sixteen of 20 (80%) cows this spring (2017) made a calving movement. The mean birth-date was 11 May 2017 (median = 11 May, 1 May–17 May), with 81.3% of the localizations occurring during 7–13 May 2017 (Table 1).

We documented 15 calf mortalities from 28 mortality investigations, providing a 53.6% overall success rate. We observed mortalities at 12 of 21 (57.1%) investigations where a cow made a mortality movement. Following a mortality we checked and confirmed evidence (e.g., tracks, pellets, hair) of a surviving twin for 5 cows. The remaining cows were checked and had no confirmed evidence or had increased movement rates indicating a calf was not present. Based on the preponderance of evidence at each mortality site, we recorded 9 (60.0%) wolf-kills, 3 (20.0%) bear-kills, 1 (6.7%) unknown predator-kill, and 2 (13.3%) deaths following a possible vehicle collision (Figure 3). Accounting for both calf mortalities and confirmation of calf presence (e.g., calf pellets, tracks, afterbirth, or observation of calf), 30-day calf survival was 66.7% (± 8.0%, Figure 4). Calves died at a mean of 30.6 days (± 15.5, 2.5–243.3, n = 15) of age. We also had 5 cases where a cow made a mortality movement, but no evidence of a calf mortality was found. The cows' behaviors (increased movements) following the mortality movement suggested a calf or calves had been lost; we believe the mortalities simply were not found within the searched area or the mortality occurred beyond this area. Winter survey flights confirmed these calves had been lost. Furthermore, during the flights we noted 4 calves had been lost, but no mortality movement had been observed.

The annual survival rate was 32.6% in 2016 (Figure 4). The mean distance cows fled following a mortality was 1,633.5 m (± 444, 126–5,805, n = 12). Cows that made return trips to the mortality site returned a mean of 2.6 times (± 0.5, 1–5, n = 8). Return trips were a mean of 106 m (± 25.9, 33.8–230, n = 7) from the mortality site.

On 17−18 January, we observed 14 moose calves from 25 of the original 35 cows monitored at calving. There were 10 moose not located during the winter survey (3 mortalities, 7 with non-functioning GPS collars). During the spring survey (19 Apr 2017), we located 6 moose calves from 17 cows; 8 additional moose were not located (3 cows were not found, 2 collars were remotely removed, 3 collars were non-functioning). The recruitment rate for the 2016 cohort was 20%, with 29.2% (7 of 24) of the cows giving birth to twins. Our calf:cow ratio from the spring survey (19 April 2017) was 0.35 (6 of 17).

DISCUSSION

Identifying parturition via the calving movement continued to be a reliable tool for estimating pregnancy rates. We had only 1 case where a cow did not make the calving movement and was subsequently seen with a calf. With this tool, recapturing GPS-collared cows to fit vaginal implant transmitters (VITs) each year is unnecessary, and it reduces cost and stress to the animals. Total path length and displacement associated with calving movements in 2016 were similar to movements of 2012 to 2015 (McGraw et al. 2014, Severud et al. 2015*a*,*b*). We noted that 80% of monitored cows (90% of our pregnant cows) made a calving movement; similarly, 82% of cows were observed making a calving movement in 2015. Our mean birth-date was 12 May, very similar to what was reported in 2013 and 2015 in northeastern Minnesota (Severud et al. 2015*a*,*b*). The mean birth-date of 19 May 2014 was much later and may have resulted from a severe and prolonged winter (Severud et al. 2015*a*). Normal birth-dates, as in 2013 and 2015–2017, may indicate relatively good health of adult females during the calving period and during the previous rut. Interestingly, the 2017 peak calving period was much shorter than in previous years, and so far, the range of birth dates follows a similar pattern (Table 1).

Compared to 2015, in 2016 we increased our success rate of locating mortalities using the mortality movement by 21% (Severud et al. 2015*b*). We also located 5 mortalities where the calf was ≥30 days of age at mortality; none were located past 21 days of age in 2015. This was likely most attributable to our addition of conducting formal searches (patterns versus casual searches) for mortality evidence and to more rigorous monitoring.

Our percentage of predator-kills was similar to those of the first 3 years of this study (2013–2015), increasing our confidence that predators, especially wolves, are the leading cause of calf mortality in northeastern Minnesota. Furthermore, as during 2013−2015, calf survival to 30 days in 2016 was low (66.7%), and less than half that (32.6%) by 1 year (recruitment), which highlights the contribution of poor reproductive success to the sluggish performance of the northeastern moose population (Gaillard et al. 2000, Raithel et al. 2007).

A wealth of valuable calf production (must assume twinning rates), survival, and cause-specific mortality data and information are missed when biologists must forego capturing and GPS-collaring moose neonates. However, identifying calf mortalities via the movements of GPS-collared dams provides researchers with an option for continuing, with limitations, assessments of the impacts of calf survival and cause-specific mortality on population performance.

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Table 1. Calving date summary for GPS-collared cow moose in northeastern Minnesota, 2013–2017. Calving activity was concluded based on observation of a calving movement.

Year	Mean	Median	Earliest	Latest	"Peak" calving	% of calves during peak	WSI[a]
2013	14 May	14 May	2 May	2 June	6–17 May	73%	120–139
2014	19 May	18 May	5 May	16 June	11–22 May	75%	180+
2015	11 May	10 May	29 April	14 June	3–15 May	76%	100–119
2016	12 May	12 May	24 April	10 June	4–14 May	75%	67–105
2017[b]	11 May	11 May	1 May	17 May	7–13 May	81%	60–119

[a]Winter severity index (WSI) was calculated by accumulating a point for each day ambient temperature was ≤0° Fahrenheit (−17.8° Celsius) and an additional point for each day snow depth was ≥15 inches (38.1 cm)
[b]2017 calving season not completed, values may change.

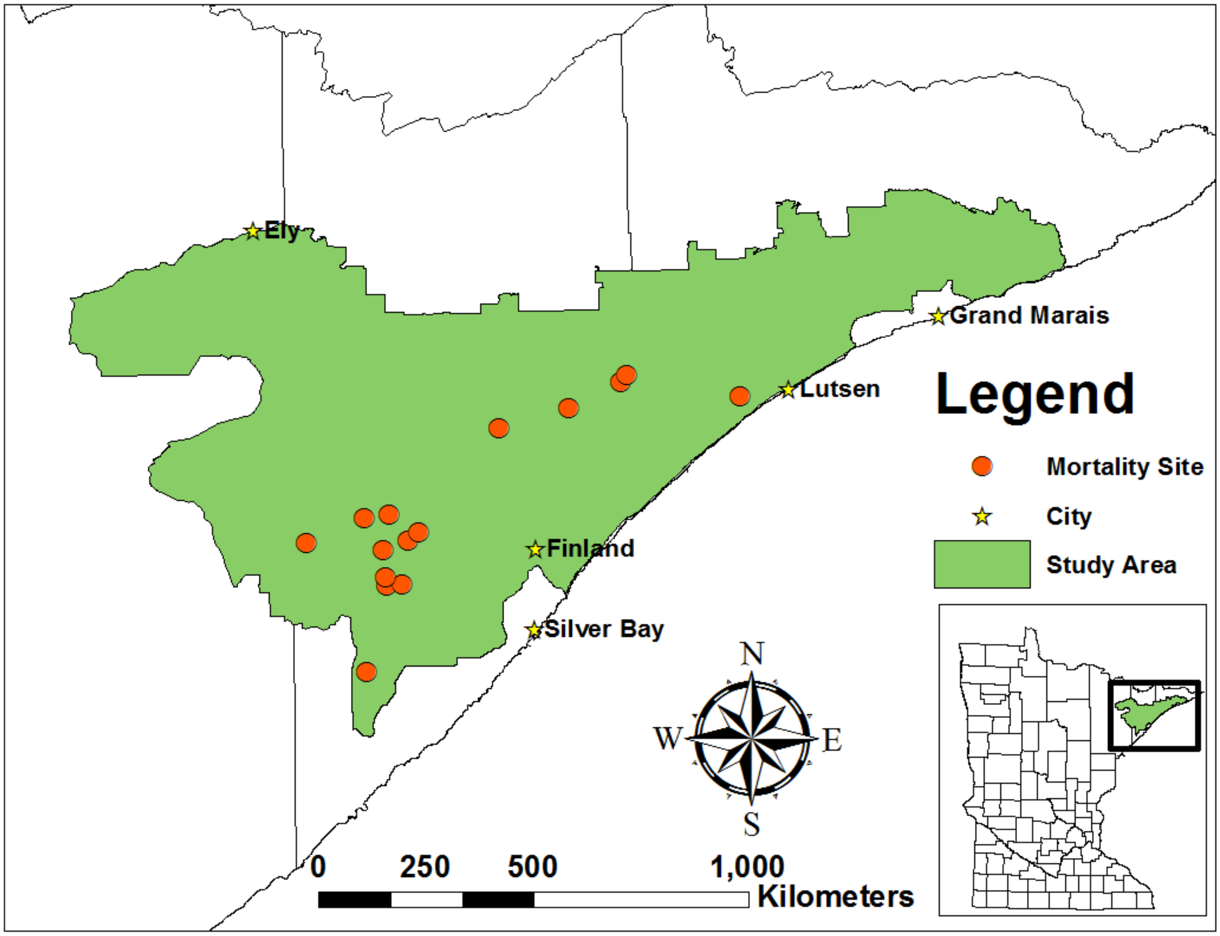

Figure 1. Moose calf study area (6,068 km^2) for examining survival and cause-specific mortality in northeastern Minnesota, 2016–2017. Solid orange circles depict mortality sites (n =15) of moose calves during May 2016–January 2017.

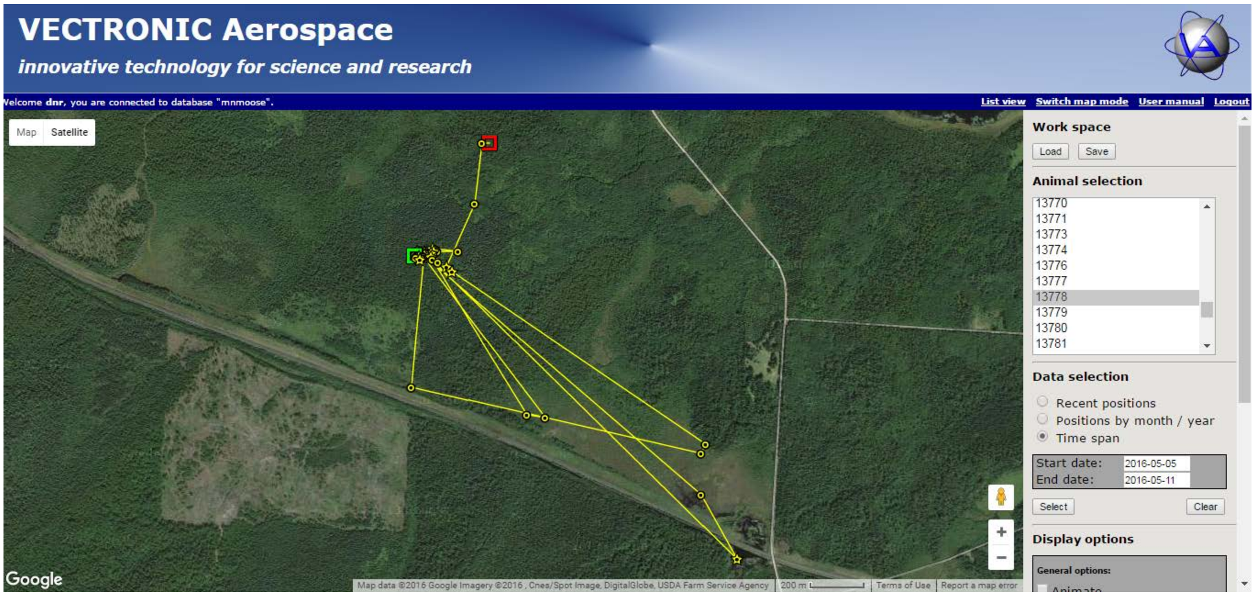

Figure 2. Vectronic Aerospace website (https://www.vectronic-wildlife.com) displaying the path of adult female moose 13778 in northeastern Minnesota, 5–11 May 2016. The green and red squares represent the beginning and end of the interval, respectively. The cow's movements show flees and return-visits to the green square; a mortality occurred on 5 May 2016. This cow made 3 return-visits before leaving the area. We found 3 wolf scats at the mortality site, which consisted of calf hair, teeth, vertebrae and other bone fragments. The estimated age at mortality was 2.7 days.

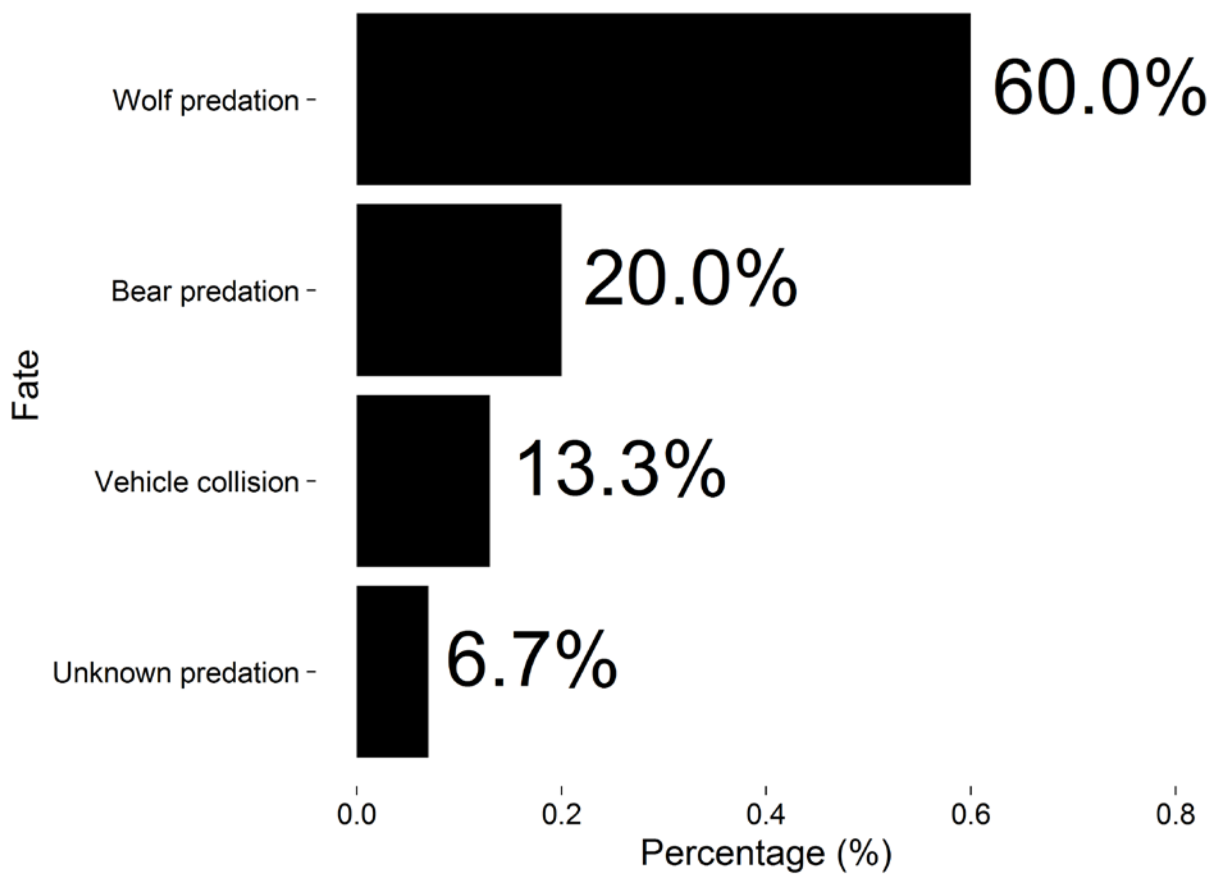

Figure 3. Cause-specific mortality of moose calves (*n* = 15) in northeastern Minnesota, May 2016–January 2017.

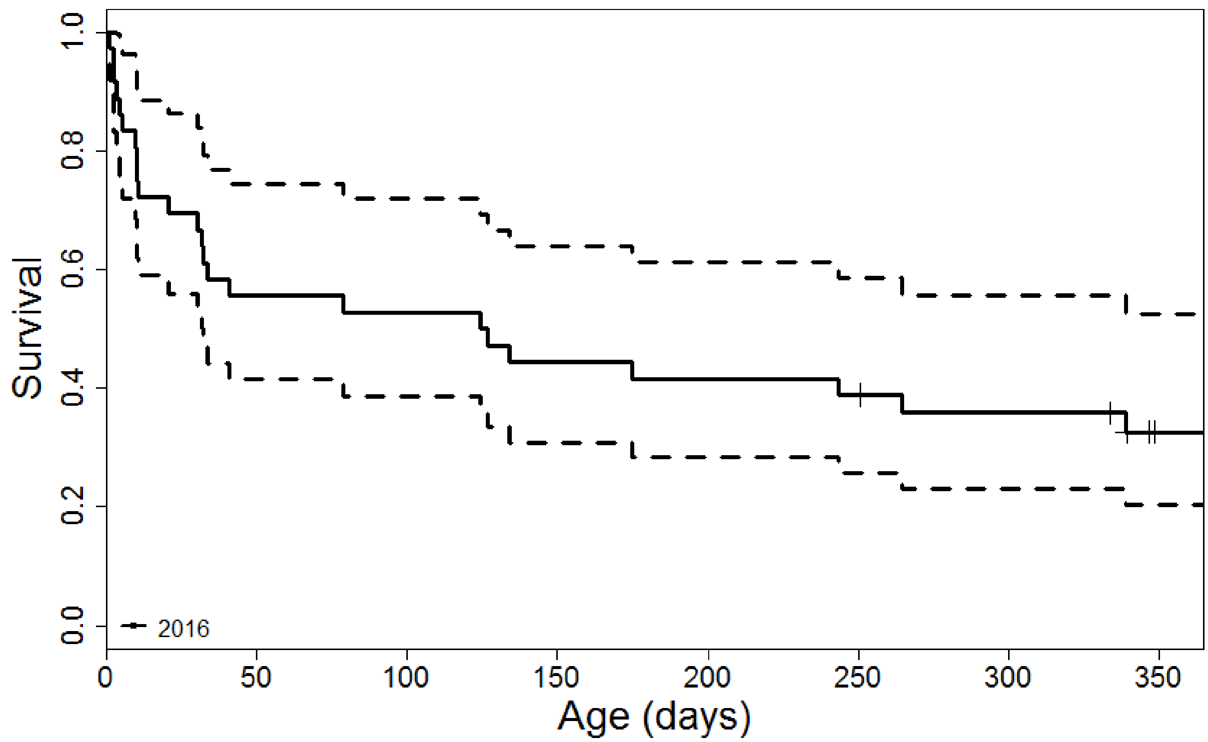

Figure 4. Kaplan-Meier annual survival (± 95% confidence intervals) of moose calves in northeastern Minnesota, 2016–2017.