Evaluating the Use of GPS-Collars to Determine Moose Calving and Calf Mortalities in Northeastern Minnesota

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EVALUATING THE USE OF GPS-COLLARS TO DETERMINE MOOSE CALVING AND CALF MORTALITIES IN NORTHEASTERN MINNESOTA

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SUMMARY OF FINDINGS

Adult survival is an important driver of large herbivore population dynamics; however, low and variable recruitment also can have a strong influence on population trajectory. The northeastern Minnesota moose (*Alces alces*) population has been exhibiting a downward trend since 2005. Neonate and seasonal survival rates and specific causes of mortality (e.g., predation, undernutrition, disease) of calves are largely unknown. Our research is investigating survival rates and specific causes of mortality. We monitored 73 adult female moose fitted with global positioning system (GPS) collars (50 confirmed pregnant at capture by progesterone concentrations, 6 unknown, 17 not pregnant) beginning 1 May 2013, looking for long-distance pre-calving movements followed by localization. We confirmed the presence of calves with a helicopter capture crew for 31 of 38 cows suspected of calving. Of these 31 dams, 28 were confirmed pregnant by progesterone levels during winter adult capture, and 3 did not have blood drawn and were of unknown pregnancy status. Forty-nine neonates from 31 dams (58% twinning rate) were fitted with expandable GPS collars during May 2013 and are being tracked intensely throughout their first year. We are retrieving collars from calf mortalities and estimating proximate causes of mortality on site. Mean elapsed time between estimated time of death and mortality investigation ranges from 34 to 60 hours, dependent upon accessibility and functioning of individual collars. Thirty mortalities have occurred (with 4 slipped collars) during 8 May-2 July 2013, leaving 15 calves “on air” to date. After censoring 4 slipped collars, 9 capture-related abandonments, and 2 capture-related mortalities, 19 of 34 calves have died (56%). Natural abandonment (n = 2), abandonment of unknown cause (1), drowning (1), black bear (*Ursus americanus*)-kills (4), and wolf (*Canis lupus)*- or possible wolf-kills (11) are preliminary causes of death. Identifying specific causes of calf mortality and understanding their relations to various landscape and other extrinsic factors should yield insight into mechanisms contributing to the declining moose population in northeastern Minnesota and serve as a basis for an ecologically-sound management response.

INTRODUCTION

The moose (*Alces alces*) is an iconic species of northern Minnesota, which has afforded valuable hunting and viewing opportunities (Minnesota Department of Natural Resources 2012 [MNDNR]). In its most recent draft of proposed revisions to Minnesota’s List of Endangered, Threatened and Special Concern Species, the MNDNR proposed moose for listing as a Species of Special Concern (http://files.dnr.state.mn.us/input/rules/ets/SONAR_all_species.pdf). Recently, the northwestern population declined precipitously to less than 100 moose due to a variety of natural factors (Murray et al. 2006). The northeastern moose population is in decline and is experiencing adult mortality rates similar to those of the northwestern population as it decreased (Lenarz et al. 2009, 2010).

Large herbivore population growth (λ) is most sensitive to variation in adult survival (Gaillard et al. 1998, 2000; Lenarz et al. 2010). Juvenile survival has less of an impact on overall population growth, but differences in temporal variation of juvenile survival may be important in accounting for between-year variation in λ (Gaillard et al. 2000). Fecundity and calf survival ultimately determine recruitment rates which are important to more fully understanding population dynamics (Van Ballenberghe and Ballard 2007). When viable populations of predators are present, predation can be a primary cause of mortality of temperate ungulate neonates (Linnell et al. 1995). Less is known about other specific ultimate or proximate sources of moose calf mortality or factors which may be contributing to predation

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and other sources of mortality. It also is unclear when predation is compensatory or additive to other sources of mortality (Franzmann et al. 1980, Linnell et al. 1995), although a recent study documented additive effects of predation in Alaska (Keech et al. 2011). The degree of predation's impact on calf survival depends on the extant predator guild and relative densities of predator and prey (Eriksen et al. 2011, Patterson et al. 2013).

Particularly after the calves' first summer, wolves (*Canis lupus*) can have a range of impacts on their survival (Patterson et al. 2013). Wolves are more adept at killing calves in deep snow (DelGiudice et al. 2009, Sand et al. 2012, Sivertsen et al. 2012), but wolves in an Alaskan study also were responsible for calf mortalities in fall (Keech et al. 2011). Typically, bear-caused (*Ursus* spp.) mortality of calves is greatest closer to parturition, more immediately following emergence from winter dens (Bastille-Rousseau et al. 2011). Once bears enter dens, their impact on calf mortality decreases dramatically (Garneau et al. 2008, Bastille-Rousseau et al. 2011). Cows in poor nutritional condition may defend calves less vigorously (Patterson et al. 2013). Further, risk of predation is not independent of maternal care and experience (Ozoga and Verme 1986, Gaillard et al. 2000). The importance of natural non-predatory causes of calf mortality likely vary during different times of the year, such as malnutrition and exposure in spring, or malnutrition and tick-related deaths in winter (Patterson et al. 2013). The extent to which diseases drive calf mortality is not well understood, although diseases have led to poor recruitment in moose (O'Hara et al. 2001, Murray et al. 2006). Juvenile animals are more predisposed to parasites than adults, and pathology related to parasite infection may be an important source of mortality for moose calves (Jenkins et al. 2001, Murray et al. 2006). Further, small calves may not be tall enough to efficiently nurse, leading to malnutrition (Murray et al. 2006). Drowning and climate have been known to affect moose calves more than predation in some regions (Crête and Courtois 2009). In winter, temperature and snow depth can be more important causes of mortality than predation (Keech et al. 2011).

Pregnant cow moose tend to move long distances (mean = 6 km) prior to localizing to give birth (McGraw et al., in review). These distances are typically much longer than movements between foraging and bedding sites. Following a long movement, calving localizations as measured by global positioning system (GPS) collars, resemble mortality localizations. A cow and calves may stay within a 1.2-ha area for up to 4 days.

Expandable GPS collars have until now not been fitted to moose neonates, and have only recently been used on other ungulate neonates (white-tailed deer [*Odocoileus virginianus*], Long et al. 2010; fallow deer [*Dama dama*], Kjellander et al. 2012). Observable fine-scale movement patterns and habitat use of moose calves, made possible by GPS collars, will enable us to examine landscape factors important for calf survival, and to closely track calves and their dams so we can quickly investigate mortality events to assign proximate causes and gather evidence for ultimate causes and contributing factors. Having dam and calf(ves) fitted with GPS collars also allows us to study the importance of proximity of dam and offspring to juvenile survival.

OBJECTIVES

1. Evaluate monitoring of movement behavior of GPS-collared adult female moose to determine timing and location of calving; and
2. Evaluate remote tracking of GPS-collared calves and dams to determine and investigate calf mortalities and to assign cause.

METHODS

Our study area is the same as that of the Environmental and Natural Resources Trust Fund (ENRTF)-supported study focused on survival and cause-specific mortality of adult moose in northeastern Minnesota (see Figure 1, research summary of DelGiudice, Severud, and Wright). As part of the companion adult moose mortality study, 111 adult moose (84 females, 27 males) were captured and fitted with Iridium GPS collars (Vectronic Aerospace, Berlin, Germany) during January 2013 (Butler et al. 2011). Blood was collected and tested for pregnancy; ≥2.0 ng/mL was the progesterone concentration threshold indicative of pregnancy. We monitored cow movements during pre-parturition and calving, with particular attention afforded to pregnant cows. We looked for movement patterns indicative of calving, including a long-distance movement followed by localization (Bowyer et al. 1999; McGraw et al., in review).

We began monitoring 73 collared adult female moose (50 confirmed pregnant at capture by progesterone concentrations, 6 unknown, 17 not pregnant) on 1 May 2013. Cow collars were programmed to collect hourly locations during May and transmit these locations 3-4 times per day. An automated R program (J. D. Forester, University of Minnesota, Twin Cities, unpublished data) generated emailed reports 6 times daily (0400, 0800, 1200, 1600, 2000, 2400 hr), which contained a document (pdf format) displaying various movement and location metrics for each collared cow, and table (csv format) and map (kml format) files with all recent locations of each animal. The .pdf reports contained a rough map of northeastern Minnesota with all cows displayed and a summary table of all animal locations and distances moved in the last 24 and 48 hours. The metrics for each cow included the date and time of the last location, movement path of the last 5 days, movement path of the last 24 hours overlaid on Google Earth imagery, a plot showing 3-hour average distances moved, and each cow's data on a single page (Figure 1). The distance plot showed peaks in movements that we then monitored for possible dampening of movements. If the cow moved <100 m over 36 hours after making a long-distance movement (dam-calf bonding time), the program flagged that cow as "localized," and that cow was put on the eligible list for visitation by the helicopter capture crew. When a cow was eligible for capture, we also checked her movement path on the Vectronic website (https://www.vectronic-wildlife.com; Figure 2). As a third way to check that the cow's movements were restricted, we plotted distances between fixes using data directly from the satellite base station using Excel (see Figure 2 in research summary of DelGiudice, Severud, and Wright). After capture, dams and calves were paired for the automated reports, and an additional plot was included (proximity between dam and calf, Figure 3). This plot was monitored for possible abandonments. Calves also were added to the report and had a page similar to that of the cows displaying their location and movement metrics.

Once a cow was identified at a calving site, a capture crew (Quicksilver, Inc., Fairbanks, AK) searched for the pregnant cow and calf(ves) by helicopter (see research summary of DelGiudice, Severud, and Wright). Each captured calf was fitted with an expandable Globalstar GPS collar (440 g; Vectronic Aerospace, Berlin, Germany) and 2 ear-tags, and was weighed (kg). Collars were programmed to take a fix hourly. Twins each received a collar and ear-tags. As feasible relative to the dam's behavior, the crew also made morphometric measurements (neck circumference, girth, total body length, hind leg length), collected blood, and measured a rectal temperature. All captures and handling protocols followed requirements of the Institutional Animal Care and Use Committee for the University of Minnesota (Protocol 1302-30328A) and were consistent with guidelines recommended by the American Society of Mammalogists (Gannon et al. 2007).

We will monitor each collared calf daily until mortality or until its collar drops off (designed to be about 400 days). We relied upon the collars to send mortality alert notification to cell phones via text message (i.e., SMS) when mortalities occurred, but after several mortalities went unnoticed (see below), we began using the Vectronic website and GPS Plus X software to check if calf collars were far from dam collars or in mortality mode. Each morning all dam and calf groups are checked and monitored closely throughout the day if separated by >100 m.

When we receive a mortality alert or determine a mortality may have occurred, we dispatch a necropsy team to collect the collar and carcass remains and to determine the cause of death (Ballard et al. 1979). To avoid possible investigation-induced abandonment, investigations are delayed if the dam is still in the area, especially if she is with a twin. Our primary field objective is to recover the entire carcass and deliver it to the University of Minnesota's Veterinary Diagnostics Laboratory (VDL) for necropsy. If the carcass cannot be extracted and transported, we perform a detailed field necropsy. If scavenged, fresh organ and tissue samples are collected and shipped to the VDL as feasible (Butler et al. 2011). Care is taken to haze off predators and scavengers when approaching the mortality site; bear repellent spray and firearms are available as a last resort for protection, but their use is not necessarily anticipated (Smith et al. 2008, 2012). We postpone the investigation when predators are sighted on the carcass; return is dependent on the age and size of the carcass as an indication of how long the predator or scavenger may feed.

Once we begin a thorough investigation of the site, we are careful not to disturb potential evidence. We photograph tracks and scat and collect scat when identification is uncertain. We note the presence of puncture wounds on the neck, skull, or hind quarters and claw marks across the body and take photographs of all wounds. When the hide is present, we note if it is inverted, which may indicate a bear was feeding on the carcass. We document the consumption of viscera, the rumen, or its contents. Wolves may chew on ribs and ends of long bones, whereas bears are more likely to cache pieces of the carcass. To determine if the calf was alive or dead when consumed, we look for subdermal hemorrhaging or sprays of blood on the collar or on broken or matted vegetation. We take note of the position of the carcass (lateral or sternal), and the distribution of body parts (scattered or near the carcass). An odor of decomposition or many fecal pellets in the area may indicate scavenging versus predation.

If we found a GPS collar without a carcass or other evidence of predation, we backtracked to the last known locations of the calf and its dam to examine a larger area in an expanded search. The Iridium collars are more accurate than the calf collars, so we use the cow's locations from the approximate time of death of the calf to look for a kill-site or evidence of the cause of mortality. We determined a collar to be slipped rather than a possible mortality if the breakaway section was frayed and/or the bolts holding the breakaway section were loose, coupled with both an absence of blood on the collar and lack of evidence within a 30-m radius of the collar.

RESULTS

We deployed 49 expandable GPS collars on the first neonates observed and captured from 31 dams (58% twinning rate) during 8-17 May 2013 (Figure 4; see research summary of DelGiudice, Severud, and Wright for additional details). Of the 31 dams, 28 were confirmed pregnant by progesterone, and 3 were unknown. Once we deployed 49 collars, we ceased capture operations, so it is not known whether the remaining cows calved or not. We visited 7 cows (4 pregnant, 3 not pregnant) which exhibited movement patterns indicative of calving, yet no calf was observed. We visited 4 dams more than once because no calf was observed during the first visit, yet the dam was behaving as if a calf was near, or she remained localized following the first visit. During a subsequent visit the helicopter crew observed and captured a calf or twins with each of these 4 dams.

As of 2 July 2013, we have documented 30 mortalities (Figure 5) and 4 slipped collars; 15 collared calves remain "on air." Capture-related activities accounted for 11 mortalities (see research summary of DelGiudice, Severud, and Wright). Of the remaining 19 mortalities, there were 2 natural abandonment (dam and calf were together after capture activities for 2-3 days before abandonment), 1 abandonment of unknown cause, 1 drowning, 4 bear-kills, and 11 wolf- or possible wolf-kills. Histological and disease-screening results from the VDL are pending. After censoring the capture-related mortalities and slipped collars, 19 of 34 calves have died (56%) as of 2 July 2013, with 15 of those preyed upon by wolves or bears.

Of the 28 mortalities we have investigated on site, 11 of the collars failed to send a mortality alert text message. Three of these collars were buried and never transmitted a mortality message to the satellite base station (and stopped sending GPS fixes); 1 was on a drowned animal in slightly flowing water (causing collar movement); 5 sent mortality transmissions to the base station, but the base station did not send an email or text alert; and 2 simply did not send a mortality transmission to the base station. It is unknown whether the collars that never sent a mortality transmission to the base station were in VHF mortality mode, because this was not checked in the field in these instances.

Mean elapsed time between estimated time of death and mortality investigation was 59 hours (range = 0-577 hr, n = 34). A collar that was inaccessible for 24 days (located on an island with the surviving twin and dam) was an extreme outlier at 577 hours. With this outlier excluded the mean time to investigation was 44 hours. The mean response-time was 60 hours (range = 10-577 hr, *n* = 20) when we received a mortality alert text message. With the island collar omitted, the mean was 34 hours (range = 10-80, *n* = 19).

DISCUSSION

Tracking GPS-collared cow movements was a highly reliable way to estimate whether or not a cow had calved. Of the 38 dams suspected of calving and subsequently visited, 31 were with a calf (82% success rate). We do not know for certain whether the 7 dams observed without calves had given birth. The calves may have been stillborn, abandoned, or preyed upon before we visited. Our study objective was to fit GPS collars to 50 newborns. We decided to track cows during May to look for movement patterns indicative of *calving* rather than fit vaginal implant transmitters (VITs) to pregnant cows for several reasons. Fitting VITs would have required determining pregnancy status during winter captures, which would have added significant expense and time to the handling of the adult females. Monitoring pregnant cows (determined later in the lab by serum progesterone concentration) for a "calving move" did not limit us to only those 50 pregnant females which would have been fitted with a VIT; the latter also would have required the expense of monitoring from a fixed-wing aircraft. Finally, twinning, unknown at adult capture, would mean that ultimately we would not be collaring neonates from all 50 cows fitted with a VIT. Indeed, this year's high twinning rate (58%) meant that newborns of only 31 dams were captured and collared; so the expense, time, and effort of fitting and monitoring VITs in 19 of the dams would have been wasted relative to calf capture operations. Monitoring calving movements will be invaluable next year as we plan to capture calves from collared cows that we will not need to recapture during winter to determine pregnancy.

We observed and handled many sets of twins at the beginning of calving, but over half of our singletons were handled the last 2 days of captures. To more accurately represent the northeastern population next year we will attempt to spread out capture efforts throughout the calving season. In northeastern Minnesota, mean calving date was 14 May (range 3-27 May), with 70% of births happening 9-20 May (McGraw et al, in review). We will need to balance attempting to catch later-born calves with loss of visibility due to leaf-out (see research summary of DelGiudice, Severud, and Wright).

To date we have had 4 collars slip off. In each instance the breakaway section of the collar was frayed and bolts were loose. There was no tearing or blood on the collars or sign of a struggle at the collar location. This may be a design flaw that will need to be addressed before next year's captures.

When collars did not send mortality alert text notifications, our response-time increased from 35 to 45 hours. Some collars were not sending text messages after calf release, consequently, we began to closely monitor cow and calf(ves) proximities and GPS Plus X software to alert us to possible mortalities rather than relying only on text messages. Bears caching collars or calves drowning and remaining in flowing water may either keep the collars from transmitting or keep the collars in normal mode due to movement. Similarly, predators or scavengers may "play" with the collar and keep it in normal mode long after mortality has occurred. These all will be considerations next year for how we monitor the calves and their dams from the beginning of capture operations.

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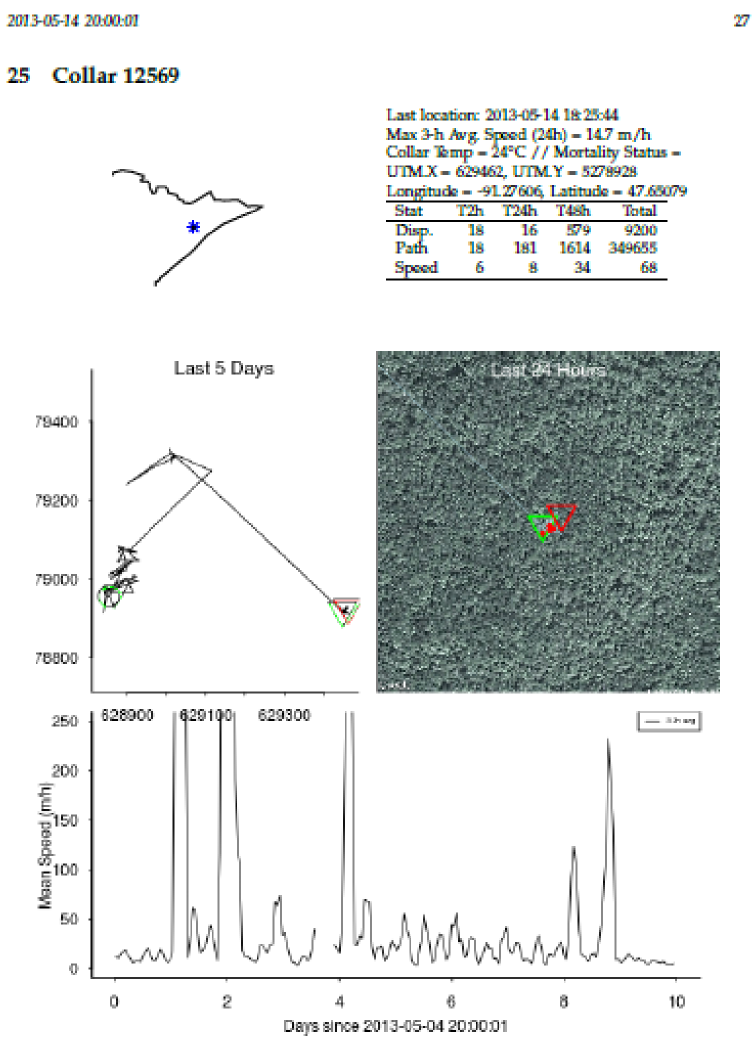

Figure 1. Example report for adult female moose number 12569 from 20:00 hours, 14 May 2013, northeastern Minnesota, showing movement paths for the last 5 days and 24 hours, and 3-hour average hourly distances moved. Green circle represents the start of the 5-day period, green triangle the start of the 24-hour period, and red triangle the most recent location. Red dots indicate location when the collar was “localized.” We visited this cow at 7 days since 4 May (12 May), but she had not yet calved. She made a “calving move” ~9 days after 4 May 2013 (14 May) and then localized. She was visited on 15 May and her twins were collared.

Figure 2. Vectronic website (https://www.vectronic-wildlife.com) map interface showing the path of adult female moose number 12569, 12–14 May 2013, northeastern Minnesota. The green square represents the start of the interval, and the red square depicts the end of the interval. The cow's movement pattern in the southwestern corner of the map indicates typical bedding and foraging, whereas the cluster in the southeastern corner of the map indicates a tight localization which followed a long-distance movement. This cluster is likely the calving ground.

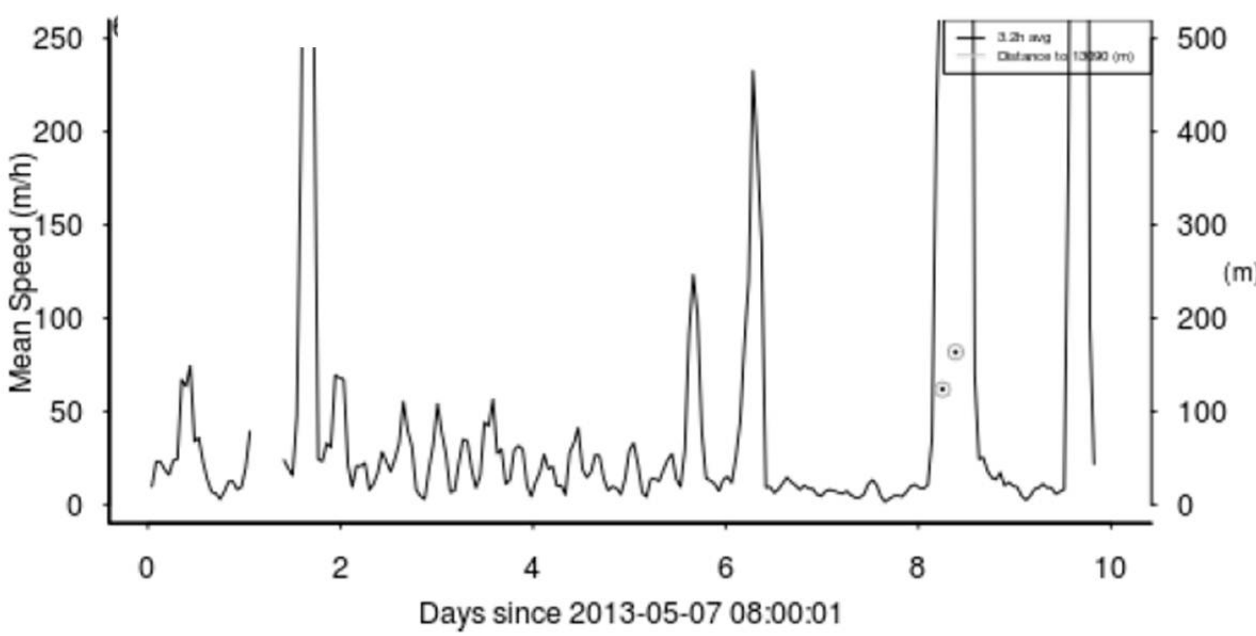

Figure 3. Distance plot displaying both 3-hour average distance moved and proximity of adult female moose number 12569 to calf number 13090, northeastern Minnesota. Line displays the distance the dam has moved; dots with circles represent the distance between the dam and calf collar.

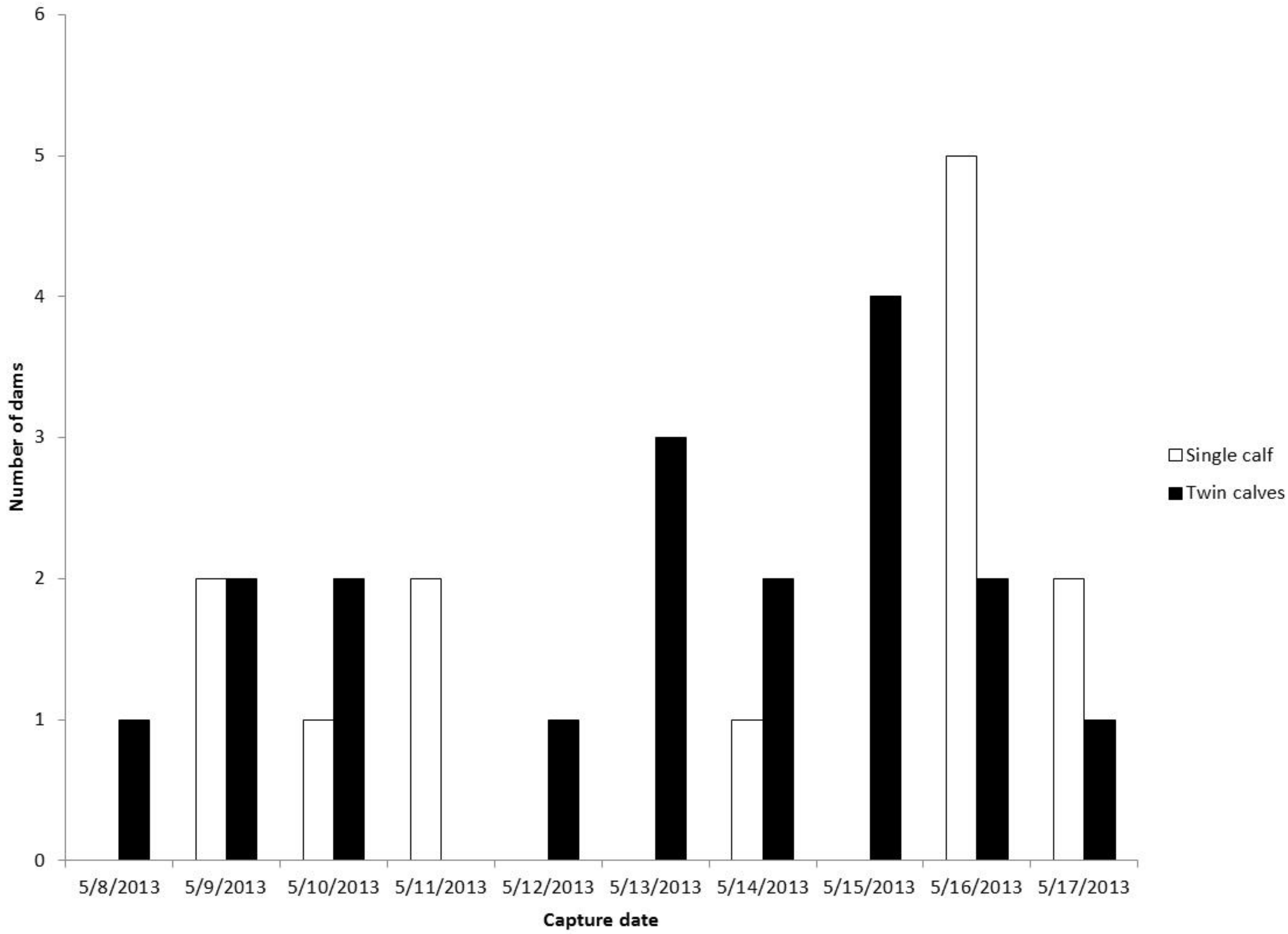

Figure 4. Number of moose dams with single and twin calves captured and handled, 8-17 May 2013, northeastern MN.\

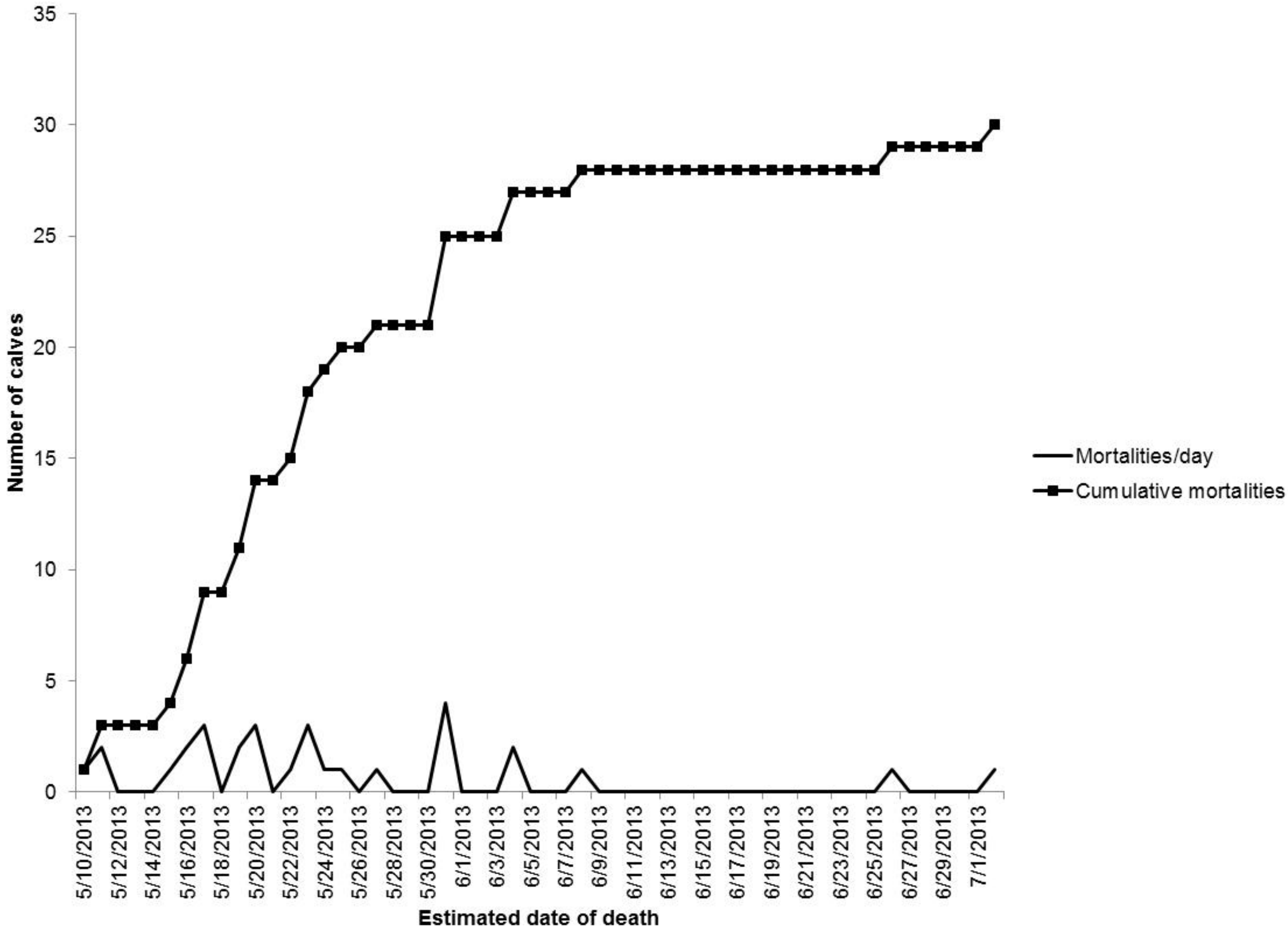

Figure 5. Number of moose calf mortalities by day and cumulative mortality by day, 10 May – 2 July 2013, northeastern MN.