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MINIMIZING MORTALITY OF MOOSE NEONATES FROM CAPTURE-INDUCED ABANDONMENT

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ABSTRACT: Neonatal moose (*Alces alces*) may be prone to maternal abandonment induced by capture activities. We observed unexpectedly high levels of abandonment during the first year of our study of calf survival and cause-specific mortality in northeastern Minnesota. In response, we crafted a capture-induced abandonment contingency plan to reduce calf deaths caused by such abandonment. Locations and movements of dams relative to calves were used to gauge whether abandonment was occurring and to trigger retrieval of live calves. The Minnesota Zoo and a private facility accepted abandoned calves in viable condition. As undesirable as it is to remove calves from the population and landscape, we found it preferable to leaving them to succumb to starvation, hypothermia, or predation. We believe variations of this plan may be used in other study areas to mitigate neonate mortality due to capture-induced abandonment.

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Capture-induced abandonment of ungulate neonates is a little-understood phenomenon in which mothers permanently reject offspring ostensibly in response to the disturbance of capture, marking of the neonate, or some combination of factors (Livezey 1990, Swenson et al. 1999). It is defined as "the permanent separation of mother and young causing death of the young," occurring ≤1 day after marking (Livezy 1990:193). The estimated rate of capture-induced abandonment of moose (*Alces alces*) neonates varies widely from 4.6 to 41.7% (Ballard et al. 1981, Keech et al. 2011, Patterson et al. 2013). In our recent study of moose calf survival and cause-specific mortality in northeastern Minnesota, Global Positioning System (GPS) collars fit to neonates of GPS-collared dams revealed that both exhibited complex behaviors before ultimate abandonment over ≥ 48 h post-capture (DelGiudice et al. 2015). This supports Livezey's (1990) contention that studies using very high frequency (VHF) collars or infrequent direct observation may not always recognize capture-induced abandonment.

Minimizing undue stress and mortality of study subjects during capture is an animal welfare issue, and we are bound by the ethics of our profession to ameliorate adverse effects of capture as much as possible (Sikes et al. 2011). Because the northwestern Minnesota moose population declined from 4,000 to <100 animals from the mid-1980s to 2007 (Murray et al. 2006, Lenarz et al. 2009), and the northeastern population by ~55% from 2006 to 2016 (DelGiudice 2016), public interest in the current moose research has been particularly keen (Khouri 2012, Marcotty 2013, Associated Press 2015).

Because losses associated with capture occurred in the current study, we responded with measures in an attempt to minimize such mortality (Butler et al. 2013, Carstensen et al. 2014, 2015; DelGiudice et al. 2014, 2015; Severud et al. 2015).

Due to an unexpected and unacceptable level of capture-induced abandonment early in the calf study (2013), our objective was to develop and employ a formal contingency plan for recovering affected neonates. This plan relied on our increased understanding of dam and calf movement behavior indicative of captured-induced abandonment, made possible from our hourly monitoring of GPS-collared dams and neonates during the 2013 calving season. During our 2014 capture operations, we implemented this plan and successfully mitigated mortality of abandoned, newly collared neonates. We further refined our plan for use in 2015, but those revisions remain untested due to the implementation of Executive Order 15-10 (28 April 2015) through which the Governor of Minnesota prohibited additional capture and collaring of moose in the state.

STUDY AREA

We conducted this study in a 6,068-km² area of northeastern Minnesota, USA, located between 47° 00′ N and 47° 56′ N, 89° 57′ W and 92° 17′ W. The area was characterized as Northern Superior Uplands (Minnesota Department of Natural Resources [MNDNR] 2015) and was interspersed with lakes, wetlands, logging roads, and low-density human settlements. Stands of northern white cedar (*Thuja occidentalis*), black spruce (*Picea mariana*), and tamarack (*Larix laricina*) predominated in the lowlands, and balsam fir (*Abies balsamea*), jack (*Pinus banksiana*), eastern white (*P. strobus*), and red pine (*P. resinosa*) were prevalent on the uplands, where mixed stands of trembling aspen (*Populus tremuloides*) and white birch (*Betula papyrifera*) also occurred. Open areas included deciduous shrub and sedge (*Carex* spp.) meadows (MNDNR 2015). White-tailed deer (*Odocoileus virginianus*) populations occurred at pre-fawning density of ≤4 deer/km² (Grund 2014). Predators of moose in the area included gray wolves (*Canis lupus;* 3 wolves/100 km², Erb and Sampson 2013) and black bears (*Ursus americanus*; 23 bears/100 km², Garshelis and Noyce 2011). Moose harvests last occurred in 2012 (DelGiudice 2012).

Mean daily minimum temperature at Ely in May 1991–2012 was 5 °C, and mean maximum was 18 °C. The mean minimum on 1 May was 1 °C and rose to 7 °C by the end of the month. Mean daily maximum was 14 to 20 °C (https://weatherspark.com/averages/30172/5/Ely-Minnesota-United-States). The mean daily minimum temperature at Grand Marais in May 1997–2012 was 5 °C, and the mean maximum was 15 °C. The mean minimum on 1 May was 1 °C and increased to 6 °C by the end of the month. Mean daily maximum was 12 to 17 °C (https://weatherspark.com/averages/29912/5/Grand-Marais-Minnesota-United-States).

METHODS

Neonate Capture, Handling, and Abandonment Considerations

2013. — We computer-monitored preparturient GPS-collared female moose beginning 1 May 2013 to identify a calving movement followed by localization (Severud et al. 2015). We allowed ≥36 hours before attempting to capture and handle calves of localized dams. A capture crew (Quicksilver Air, Inc., Fairbanks, Alaska, USA) located the calf(ves) via helicopter, fit a GPS collar (Vectronic Aerospace GmbH, Berlin, Germany), drew a blood sample, and measured several morphometrics and rectal temperature; search time for the dam via helicopter was not recorded. If twins were observed, both calves were handled and released together. At this age, neonates likely had received colostrum and milk from their dams. Suckling and brown adipose tissue stores are necessary for thermoregulation and maintaining body temperature (Schoonderwoerd et al. 1986). Captive moose neonates typically nurse an average 8 times/day (±1.5) for 130 sec/bout and consume 375 g milk/bout (Reese and Robbins 1994). Assuming that nursing occurred regularly over a 24-h cycle, this translates to 1 nursing bout every 3 h (2.2–4.8). We estimated the number of feedings missed, as it relates to potential abandonment, and the number of hours without food based on the dam's time away from the calf, assuming the calf last nursed 3 h prior to capture and will nurse immediately upon reuniting. All captures and handling methods were approved by the University of Minnesota's Institutional Animal Care and Use Committee (IACUC; Protocol 1302-30328A) and were consistent with guidelines recommended by the American Society of Mammalogists (Sikes et al. 2011). Additional details can be found in Severud et al. (2015).

Based on other studies using similar calf-handling methods (Keech et al. 2011, Patterson et al. 2013), we anticipated a low rate of capture-induced abandonment and did not have a formal contingency plan in place. Prior to capture operations, however, our staff veterinarian contacted several Canadian zoos that agreed to accept abandoned female calves, and the Minnesota Zoo agreed to accept 2 female calves. Since no location would accept males, we initially considered euthanizing abandoned males as a more humane alternative to allowing them to succumb to exposure, starvation, or predation.

2014. — Beginning 1 May 2014, we again remotely monitored cows for calving activity. We modified our capture and handling methods in 2014 in response to high levels of abandonment in 2013 (DelGiudice et al. 2014). Based on our analyses of capture-induced abandonment data from 2013 (DelGiudice et al. 2015), we initially retained all 2013 handling methods, but conducted all captures with a ground crew of 3–4 people (5 once) without the use of helicopter assistance. Search times were not recorded, but captures generally involved handlers briskly approaching the calving site coordinates with little time spent searching for calves. We only approached 1 dam/day and waited until she was reunited with her calf(ves) before approaching another eligible dam the following day. We used the mean distance (256 m) of non-abandoning dams from their calves (2013) during the first 48 h post-capture as a threshold distance to indicate that mothers and calves had reunited (DelGiudice et al. 2015).

Based on our findings from 2013 (see Results and Discussion, and DelGiudice et al. 2015), we developed a formal capture-induced abandonment contingency plan to retrieve rejected calves that were alive and in "good condition" (Fig. 1). In cooperation with the Minnesota Zoo, we contacted several zoos in the USA that agreed to accept and maintain calves; the Minnesota Zoo agreed to function as a staging area and eventually a receiving site for multiple calves. Additionally, private captive facilities were interested in accepting abandoned calves (males and females). Because dams may repeat calf abandonment in multiple years (Patterson et al. 2013), cows abandoning in 2013 were not approached in 2014.

RESULTS

General Capture Results

In 2013, the total time that handlers were on the ground (from drop from the helicopter to pick up) was not consistently recorded, but averaged 30.5 min (range = 18–56 min) for 10 captures. The average handling time was 9.1 min (range = 3–18 min; see Severud et al. 2015 for additional results), and neonates averaged 2.2 days old (see DelGiudice

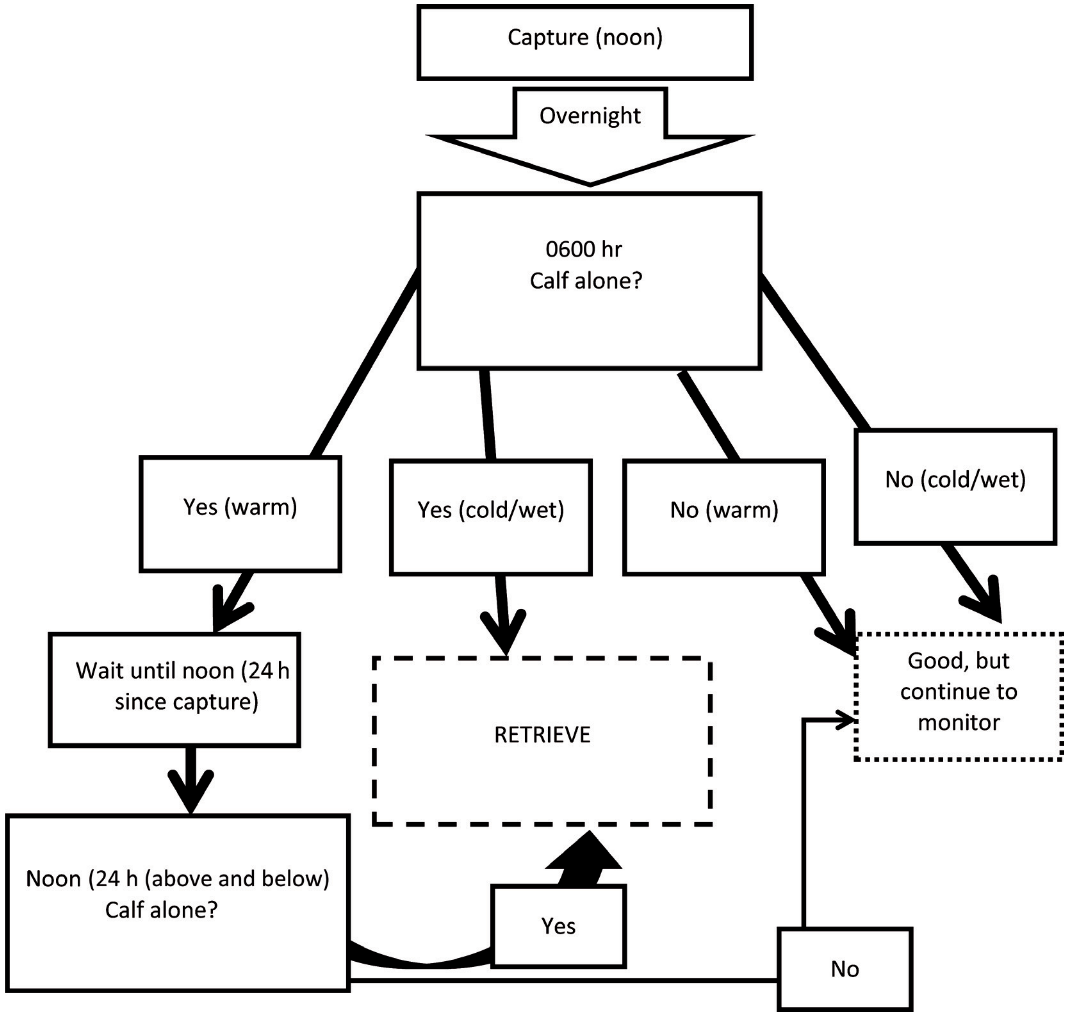

Fig. 1. The original protocol used in handling and collaring neonatal moose calves in northeastern Minnesota, May 2014. 'Warm' indicates that the daily minimum temperature is <9 °C below the mean minimum temperature in May. 'Cold' indicates that the daily minimum temperature is ≥9 °C below the mean minimum temperature in May. 'Wet' indicates any measureable precipitation.

et al. 2015 and Severud et al. 2015 for additional results). The average rectal temperature of 43 neonates at capture was 38.7 °C. We observed no difference between neonates abandoned versus those not, and viewed this as evidence that calves had likely nursed.

In 2014, average handling time was 7.5 min (range = 5.0 – 10.4, n = 8) and calf age was 1.7 days (range = 0.5 – 2.7, n = 12). When dams exhibited similar or higher levels of abandonment than in 2013, we further modified our methods by reducing our capture team to 2 people and limited handling to fitting a GPS-collar and sex determination. Mean handling time was reduced to 0.7 min (range = 0.2 – 2.2, n = 13) and calf age was 2.5 days (range = 1.7 – 4.1, n = 13).

Mortality from Capture-Induced Abandonment

2013. — Due to changing concerns over chronic wasting disease, recovered moose calves ultimately could not be transported to Canadian zoos that had previously agreed to accept them. However, because abandonment by moose and other ungulates was so poorly understood at the time, we were unable to apply strict guidelines or thresholds (e.g., distance between dam and neonate, time away) for recognizing capture-induced abandonment. This also made us reticent to revisit dam-calf pairs after collaring, concerned that further disturbance might induce abandonment. In general, dams did not defend their calves when handlers approached to capture neonates (DelGiudice et al. 2015).

We attempted to recover the first of 9 abandoned calves of 49 captured and handled. This calf was female from a mixed set of twins that were 65 h old at capture. They were captured on 8 May, and we retrieved the abandoned calf on 10 May at ~1000 hr. The dam made one return visit without the male twin (9 May at 0435 hr) before she ultimately abandoned the female. The female calf was hypothermic upon retrieval and our staff veterinarian administered 50–70 cc of lactated Ringer's solution subcutaneously and attempted to slowly warm the calf. A thermometer was not immediately available upon retrieval, but after ~3 h of warming, its rectal temperature was 33.6 °C, and the calf was warmed to 37.8 °C in the next 2 h; however, it died shortly thereafter, en route to the zoo. The second abandoned calf was male and euthanized. Subsequently, due to the uncertainty of interpreting dam behavior relative to abandonment, a decision was made to leave all apparently abandoned calves in the field hoping that dams might reunite with them.

In 2013, 7 dams abandoned at least 1 calf, and made 0–2 return trips to their calf (ves) within the 48-h post-capture period before ultimately abandoning (DelGiudice et al. 2015). Of the 24 non-abandoning dams, 19 returned directly to their calves after the capture process, and stayed with the calf until the calf died of natural cause or was abandoned naturally (DelGiudice et al. 2015). The other 5 dams made 1–3 short return trips before reuniting with their calves until we removed the collars in February 2014. The non-abandoning dams stayed away an average of 4.7 h and most return-trips occurred within 1–12 h post-capture. One dam (12605) abandoned a calf, but we successfully re-united them and the other twin via helicopter; another (12559) seemed to be moving between her twins (13080 and 13097) before all rejoined. Dam 12488 abandoned her calf, but this was assigned "abandonment of unknown cause" since the pair was together for 15 h post-capture, after which the dam left without returning. The general pattern exhibited by 19 of the 24 non-abandoning dams was to initially flee at capture, but upon return, remain with the calf (DelGiudice et al. 2015).

Abandoned calves died an average of 56 h post-capture (DelGiudice et al. 2015) and 32 h after the last visit by their dam ("visit" defined as located ≤ 256 m from calf; DelGiudice et al. 2015). Overall, non-abandoning dams began returning to calves at 13–18 h post-capture. We documented one collared calf that died following natural abandonment - the dam and calf had reunited for 80 h (Severud et al. 2015).

2014. — Two mortalities following abandonment were a singleton male and a female from a set of twins. The singleton's dam made 3 return trips to the vicinity (within an average 256 m), but we resisted retrieving this calf to not further disturb the dam. When it became apparent she was not returning, we initiated a retrieval response but the calf was dead; it died 68.5 h post-capture, and 25 h after the third return visit.

The second mortality resulted from abandonment of a set of female twins. Because the dam's collar was not transmitting locations, we were unsure of her location post-capture; upon transmission it was clear that she had abandoned the twins and we initiated retrieval. This dam made 2 return trips within an average 86 m from the twins prior to their recovery when we found a dead and a viable calf. The dead calf died 98 h post-capture and 63 h after the dam last returned within 256 m.

In 2014, 6 of 19 dams abandoned 9 of 25 calves (3 singletons and 3 sets of twins; DelGiudice et al. 2014); however, following modification of our capture protocol, the abandonment rate fell from 5 of 9 dams abandoning 7 of 12 calves, to 1 of 10 abandoning 2 of 13 calves. Of the 9 abandoned calves, 7 were retrieved in viable condition and brought into captivity. They nursed vigorously on formula (Milk Matrix 30/52, Zoologic, Hampshire, Illinois, USA), although we limited consumption to about 1, 12-oz bottle every ~4 h to prevent diarrhea from overfeeding (Schwartz 1992). Rectal temperatures were all within normal range. In a few cases where a skin test indicated dehydration, we administered saline subcutaneously. The 7 calves were retrieved 50.9 ± 11.7 h post-capture and all survived in captivity up to 18 months of age (at publication).

One collared calf (from a set of twins) died following natural abandonment and had an umbilicus infection. It was initially abandoned but we reunited it with its dam, after which she made several trips between this calf and its healthy twin before abandoning (Severud et al. 2014). As in 2013, dams in 2014 did not tend to vigorously defend their calves when handlers approached neonates.

In 2013 and 2014, dams (n = 35) not abandoning their calves were within 256 m of their calves for 19.1 (95% Confidence Interval [CI] 17.19–21.1) and 41.5 hourly fixes (95% CI 38.5–44.6) within 24 and 48 h post-capture, respectively. In stark contrast, abandoning dams (n = 13) were within 256 m of their calves for only 3.8 (95% CI 2.1–5.4) and 6.2 hourly fixes (95% CI 3.5–8.8) within 24 and 48 h post-capture, respectively (DelGiudice et al., unpublished data).

DISCUSSION

The establishment and refinement of an abandonment contingency plan enabled our team to retrieve viable calves that had ostensibly been abandoned by their dams due to handling or collaring. When we initiated collaring in 2013, we did not know what movement patterns, distances between dams and their calves, or times apart could readily be used to identify abandonment. Natural abandonment of neonatal ungulates has been anecdotally reported in the literature, but the level and causes of naturally occurring abandonment of moose neonates are unknown. Based on our assumptions of behavior and movement, we observed a single case each in 2013 and 2014.

Our plan was intended to be flexible and adaptable to circumstances in the field, such as location of the dam, number of calves (twins or singleton), return-visits made by the dam, timing and duration of return-visits, current proximity of dam and calf, sign of compromised condition of the calf at capture (e.g., small size, injury, deformity or anomaly), fresh predator sign in the vicinity, or adult collar malfunctioning (failure to transmit GPS locations, VHF can be used to check for gross proximity). Many of these instances would have triggered a quicker response to retrieve calves.

Nine calves died following capture-induced abandonment in 2013, but in the process we gained an understanding of this behavior. Because of the population's rather rapid decline over the previous 7 years, we considered it important to initially attempt to obtain as much data at capture as reasonably possible. In 2014 we rescued viable calves using our abandonment contingency plan and further refined our capture methods to minimize capture-induced abandonment.

Considerations for revising the 2015 protocol. — Based on results from 2014 (DelGiudice et al. 2014), we further refined our contingency plan (Fig. 2) with addition of thresholds that would trigger cessation of captures and consideration to reunite abandoned calves with their dams, as done with one calf in 2013 and 2014. The thresholds for discontinuing capture operations were: 1) 3 capture-related mortalities (direct, e.g., trampled by dam; indirect, e.g., related to captured-induced abandonment); 2) availability at zoos for calves recovered in viable condition was exhausted, and not to exceed 6 capture-induced abandonments; 3) the proportion of capture-induced abandonments that would discontinue capture operations would have changed with the total number of calves collared (i.e., more liberal proportions when the sample size was smaller, more restrictive proportions as sample size increased).

We would continue operations until we reached 6 calves collared. When the sample size accumulated to 7–30 calves, we would proceed with caution if 15–20% of calves had been abandoned, and ceased operations if >20% were abandoned. When >30 calves had been captured, these levels would have changed to 5–10% and >10% of calves abandoned. Capture would discontinue only as the result of a new abandonment, not as a result of changing thresholds (e.g., when capturing the seventh or 31st calf). We also considered developing a plan to reunite individual abandoned calves with their dams. However, we considered this a risky option; many factors (e.g., current location of the dam, presence of a twin) were weighed before launching the attempts in 2013 and 2014. A formal plan was not created for 2015 due to the Governor's Executive Order.

Members of the media and the public were very concerned with the fates of individual animals, and capture-related mortality was essentially unacceptable at any level. As researchers studying a declining moose population, we were concerned with population-level processes such as overall birth and death rates, and understanding these demographic parameters was key to discovering the underlying mechanism of the population decline. An online petition that maintained focus on the deaths of individual animals convinced Minnesota's Governor to issue an Executive Order on 28 April 2015 which barred placement of any additional collars on moose by the state. Thus, we were not able to implement our revised protocol in 2015, but keep it in reserve should this Executive Order be rescinded.

Maternal rejection of offspring is an abnormal, little-understood behavior, although not uncommon across species (e.g., Beale and Smith 1970, Livezey 1990, Linnell et al. 2000). The manifestation of this behavior is a significant risk that researchers assume when designing a study that includes handling neonates. Without both dams and calves wearing GPS-collars, we would not have observed the patterns which allowed us to develop an effective plan to recover abandoned calves in viable condition (DelGiudice et al. 2015, unpublished data). VHF telemetry and direct observational studies may underestimate capture-induced abandonment because we identified some dams that reunited temporarily with their calf(ves), but eventually abandoned them. Mortalities may then be attributed erroneously to birth defects, predation, disease, or malnutrition (Livezey 1990), biasing estimates of neonatal survival and cause-specific mortality (Gilbert et al. 2014); albeit, natural abandonment is not well understood either.

Our study was annually reviewed by the University of Minnesota's IACUC, and our abandonment contingency plan represents a

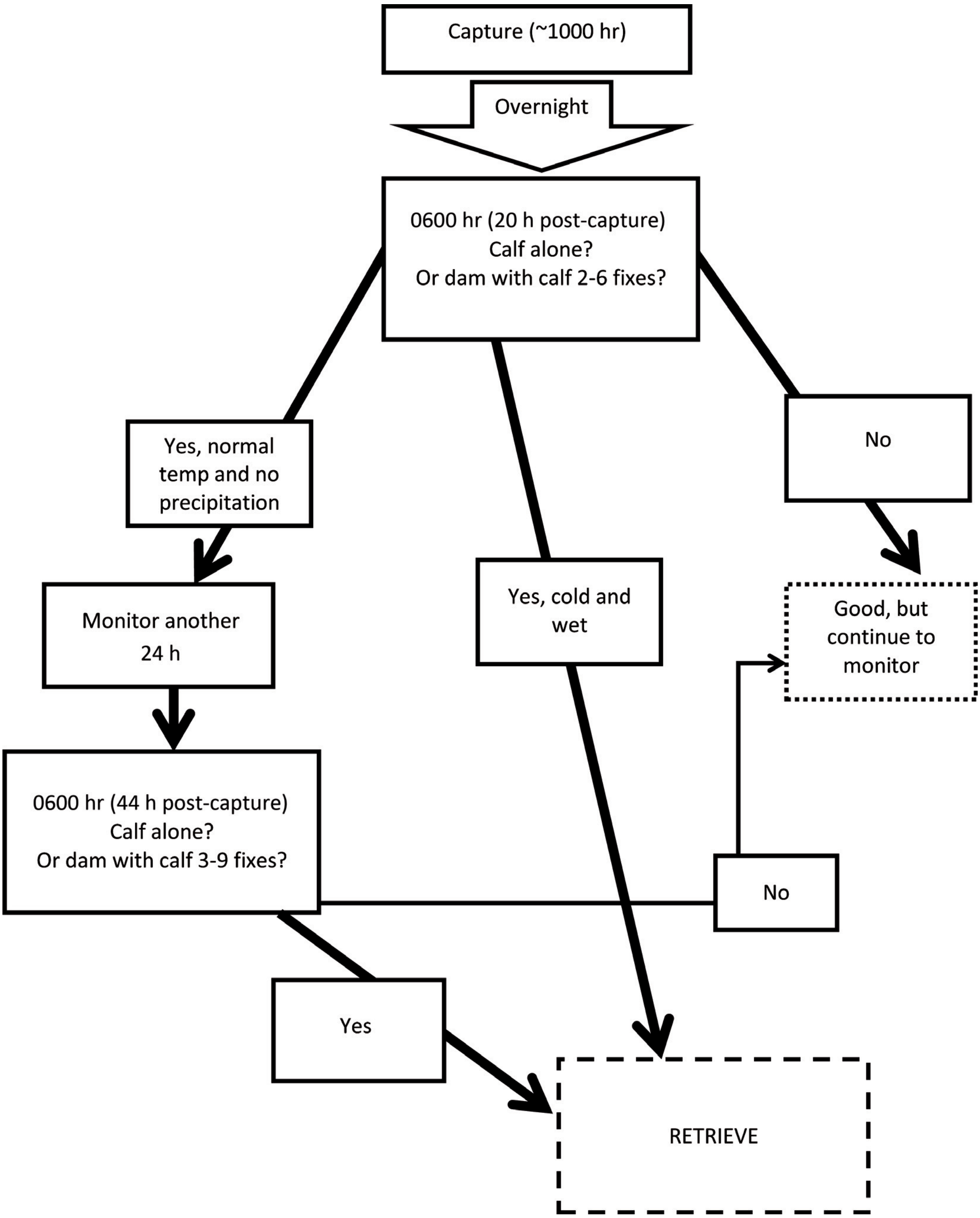

Fig. 2. A modified protocol developed from field experience in 2014 for handling and collaring neonatal moose calves in northeastern Minnesota. 'Warm' indicates that the daily minimum temperature is <18 °C below the mean minimum temperature in May. 'Cold' indicates that the daily minimum temperature is ≥18 °C below the mean minimum temperature in May. 'Wet' indicates any measureable precipitation.

refinement and improvement of our initial methods towards the advancement of animal welfare during field research (Sikes et al. 2011). Capture-induced mortality has significant cost with respect to animal welfare, budgets, time, personnel, data lost, and public relations. Our protocol proved effective in the recovery of abandoned neonates, and these neonates contribute to educational, zoo, and captive facility goals, including diversifying the gene pool of captive moose. We believe this protocol and the information therein will be useful in future studies to help recognize and mitigate losses associated with capture, handling, and marking neonatal moose.

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