PRE-PARTURITION MOVEMENT PATTERNS AND BIRTH SITE CHARACTERISTICS OF MOOSE IN NORTHEAST MINNESOTA

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ABSTRACT: Habitat used immediately after parturition is important to survival of moose calves, though different habitat types may be functionally similar and thus contribute to the variability in habitat use reported in the literature. Neonates are relatively immobile, which restricts movement of the cow-calf pair and makes both vulnerable to predation. The cow also requires adequate access to forage during the period when calf mobility is limited. We used fine-scale movement data to determine linear distance traveled to the birth site as well as habitat use by cow-calf pairs in northeast Minnesota. All cows made long distance movements ($\bar{x}$ = 6 km) to the birth site where they localized in 1.72 ± 0.48 ha (95% kernel polygon) for approximately 7 ± 0.7 days. A mosaic of cover types that reflected availability across the landscape were used by the cow prior to localization at the birth site. Birth site areas consisted of one cover type rather than the mosaic used before birth, and varied among cows, though bogs were used most often (40%). The small birth site area and use of bog habitat were likely a consequence of low calf mobility post-parturition. Upon exiting the birth site, cow-calf pairs shifted toward use of mixed and young/regenerating forest which likely reflects the need and use for highly nutritious browse to meet the high energetic cost of lactation.

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The time around parturition is critical to survival of offspring. The mother should select habitats that increase the survival of offspring and express behavior that reduces exposure of her and offspring to higher mortality risk. For species such as moose (*Alces alces*), choices may be further restricted because the calf has limited mobility during the first weeks of life (Altmann 1958, 1963).

Most moose give birth during a 19-day period in the month of May (Sigouin et al. 1997). Searches for calving sites typically take place after peak calving. Opportunistic ground searches (Addison et al. 1990, Wilton and Garner 1991), ground searches using VHF telemetry (Bowyer et al. 1999, Langley and Pletscher 1994, Leptich and Gilbert 1986, Scarpitti et al. 2007), and searches from aircraft for VHF collared cow-calf pairs (Bailey and Bangs 1980, McGraw et al. 2011) have all been used to locate calving sites. Cows will make a longer distance move followed by localization at calving, indicating that monitoring of daily locations can help identify when calving occurs (Testa et al. 2000).

For logistical reasons, most descriptions of pre-parturition movement patterns and birth site characterization have relied on relatively few locations in each parturition event. Single daily locations are typically obtained in VHF telemetry studies to determine if a cow has localized or given birth (Testa et al. 2000). Ground searches for maternal beds accurately describe birth locations, but do not fully delineate the entire area used around the birth location during the post-parturition period when cow-calf movements are limited. Aerial and ground VHF searches more accurately describe portions of the post-parturition area used by calf-cow pairs than the actual birth site.

The limitations of single or few observations of cow-calf pairs during parturition may contribute to the high variation in vegetative cover and vegetation density, visibility, and proximity to water that has made describing generalized calving site characteristics difficult (Addison et al. 1990, Poole et al. 2007). Variability of calving habitats across regions is probably also a function of available habitat types within a study area. Moose are reported to birth on hill tops in Quebec and Ontario (Addison et al. 1990, Wilton and Garner 1991, Chekchak et al. 1998), and some swim to islands where available (Addison et al. 1993). Undisturbed lowland areas dominated by cedar and near water were important for calving in Maine (Leptich and Gilbert 1986), and in New Hampshire moose used mature, mixed, and coniferous forests, perhaps because open water and islands were rare (Scarpitti et al. 2007). Post-parturition areas had a higher than expected bog component in Minnesota, though results were variable among cows (McGraw et al. 2011).

Some cow moose select birth sites that provide hiding cover but do not necessarily have the highest quality or quantity of forage available (Leptich and Gilbert 1986, Langley and Pletscher 1994, Bowyer et al. 1999). This is often interpreted as a trade-off between avoiding predators and meeting nutritional requirements (Bowyer et al. 1999), and may be important to consider as a factor influencing calving site selection in Minnesota where black bear (*Ursus americanus*) and wolves (*Canis lupus*) occur. Some cows in British Columbia calved in areas with lower forage availability that also had lower predation risk, while others calved in areas with higher forage availability and presumably higher predation risk (Poole et al. 2007).

Understanding habitat and space use behavior during parturition may be especially important in northeast Minnesota because the moose population is declining and recruitment rates in recent years are the lowest on record (DelGiudice 2013). Characteristics of the birth site and post-parturition areas have not been studied in detail in Minnesota, in large part because post-parturition locations have been obtained from VHF telemetry flights that occur after peak calving, and provide only one location within 2–4 weeks of calving (McGraw et al. 2011).

GPS-collared moose can be used to locate calving sites by identifying a longer movement followed by localization (Poole et al. 2007). Our objective was to identify movement patterns indicative of calving by using location data recorded at 20 min intervals from GPS-collared moose. We then evaluated fine-scale movements and habitat use of the cow while the calf had limited mobility. Additional objectives were to characterize size, cover type composition, and length of time spent at the birth site by cow-calf pairs. The fine-scale GPS locations allowed us to re-examine our previous data from VHF-collared moose (McGraw et al. 2011) and compare past results with a more precise and robust dataset that can more accurately describe habitat use and movement patterns of moose during parturition.

STUDY AREA

Both the VHF- and GPS-collared moose studies occurred in approximately the same 3,700 km^2 area of northeast Minnesota (47°30′N, 91°20′W; Fig. 1). Land ownership is mostly public (~82%) and includes portions of the Superior National Forest as well as state, county, and tribal lands. A significant portion of private ownership exists as blocks of industrial forest land.

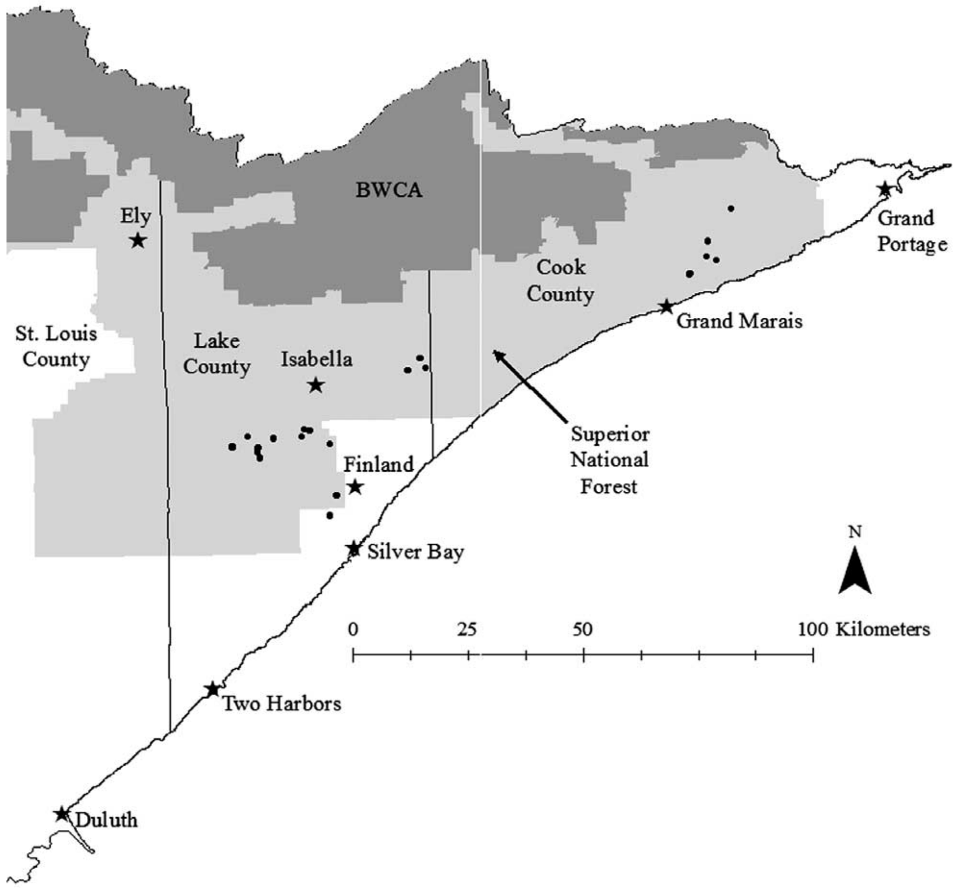

Fig. 1. Study area in northeast Minnesota where black dots indicate birth sites (n = 20) of GPS collared moose, 2012.

A boreal forest mix is the matrix from which moose in northeast Minnesota choose a calving location. The region is part of the Northern Superior Uplands (Minnesota Department of Natural Resources [MNDNR] 2010) and is transitional from northern hardwoods in the south to Canadian boreal forests in the north (Pastor and Mladenoff 1992). Important habitat types in the home ranges of moose are young mixed conifer and deciduous forests, including aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), and balsam fir (*Abies balsamea*). Early successional forests (11–30 years post-disturbance) are used because forage is within reach of moose (Kelsall et al. 1977). Summer ranges consist largely of black spruce (*Picea mariana*) lowlands as well as uplands and cut over areas dominated by paper birch, aspen, and balsam fir (Peek et al. 1976). In early summer, moose generally use upland, lowland, and plantation areas in proportion to their occurrence (Peek et al. 1976). Northeast Minnesota has a continental climate with severe winters and warm summers. Precipitation usually occurs as snow from December–March.

METHODS

Adult cow moose were darted from helicopters and fitted with GPS collars (Lotek

Wireless, Inc., Newmarket, Ontario, Canada) in January and February 2011 (McCann et al. 2014). Blood samples were taken and blood progesterone levels were used as an indication of pregnancy at capture. GPS collars recorded locations every 20 min for 2 years. Locations, movement, and habitat use of collared females were analyzed for patterns indicative of parturition beginning 1 May as previously defined in a VHF study (Lenarz et al. 2011, McGraw et al. 2011).

The area occupied by the cow following its initial localization in May was considered the birth site because cows birth shortly after the initial localization (Testa et al. 2000, Poole et al. 2007). Some cows remained in the immediate vicinity of the birth site, and others moved a short distance from the birth site and localized again (i.e., a secondary localization event). The area and time spent at both sites, as well as the total post-parturition area were calculated.

Pre-parturition movement patterns

We monitored pre-parturition movements using 20-min GPS location data for each cow (n = 52) during the month of May. The short time scale between GPS locations allowed us to calculate the distance moved each day throughout parturition. The length and duration of the movement was recorded from the last location in a cluster of foraging paths and bed sites to the initial localization at the birth site following the linear path. Straight-line distances from the last feeding bout to the birth site were also calculated for comparison with past VHF studies. Initial localizations at birth sites were identified by cows occupying smaller areas for longer durations and with less variation in location than foraging or bedding locations. In 2012 births were verified using helicopter searches to visually observe cow-calf pairs at the birth site shortly after parturition.

VHF Flight Simulations

We used calving dates and locations from GPS-collared moose to better describe the VHF data set used previously to describe post-parturition habitat in Minnesota (McGraw et al. 2011). We simulated post-parturition locations using GPS data to estimate the distance that cow-calf pairs in the VHF data set were from the birth site based on calving dates from GPS-collared moose in 2012. This was necessary because calves located in the VHF data set could have been up to 4 weeks old. We also compared habitat characteristics at birth sites of GPS-collared moose to the habitat characteristics of the simulated VHF data set, and to habitat characteristics of the actual VHF data set. All 12 flight dates from the 2004–2008 VHF study (McGraw et al. 2011) were randomly assigned to each cow in the current study to simulate the location of the cow at 1200 hr using Excel 2010 (Microsoft Corporation, Redmond, Washington, USA). The random assignment of flight dates was repeated to estimate the distance from the actual birth site to the simulated VHF post-parturition location. We then calculated the straight line distances from the GPS birth site to the simulated VHF post-parturition site.

Birth Site and Post-Parturition Area

Birth sites (n = 20) were identified by viewing location data in GoogleEarth (Google Inc. 2013 (Version 7.1.1.1888, Mountain View, California, USA) to locate clusters of points following long movements in May. Dates and times of entry into and exit from the birth sites were identified visually. Entrance into the birth site was defined as the first point in a cluster. The cow was still considered to be in the birth site when making short movements and re-localizing. The cow left the birth site when she moved and did not localize again or made a large movement from the last cluster of points at the

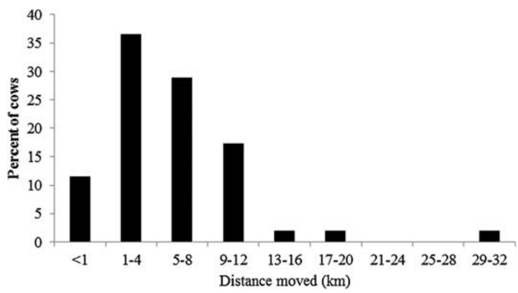

Fig. 2. Distance moved by cows (n = 52) before localization at parturition. Distances were measured as a linear path from locations collected every 20 min by GPS-collared moose.

birth site. Birth site areas were calculated as 50% and 95% kernel polygons using all locations occurring between birth site entry and exit dates (Fig. 2). We calculated 50% and 95% kernel polygons in the Geospatial Modelling Environment (Beyer 2012) using the plug-in estimator and a 10 m output cell size.

We used the Land Use Land Cover (LULC) habitat classification system to determine cover type composition of birth sites (McGraw et al. 2011). The LULC raster data set was derived from LANDSAT Thematic Mapper (TM) images at a 30 m resolution (MNDNR 2007). Source imagery dates ranged from June 1995 to June 1996. The LULC classification system defined 16 cover types in northeast Minnesota with >95% accuracy. More than 90% of the study area consisted of 6 terrestrial cover types: mixed, coniferous and deciduous forests, wet bog, marshes and fens, and regenerating forests (Moen et al. 2011).

We calculated cover type composition within 50% and 95% kernel birth site polygons using ArcMap 10.1 (ESRI, Redlands, California). Cover type composition in these polygons was compared to cover type outputs of post-parturition areas identified during the VHF study (McGraw et al. 2011) with ANOVA. We used Statistix (version 9.0; Analytical Software, Boca Raton, Florida) and Excel 2010. Significance level for all tests was set at $P = 0.05$. Unless otherwise noted, means are presented throughout as $\overline{X} \pm SE$.

RESULTS

All GPS-collared cows with high progesterone levels (4.98 ± 0.3 ng/mL) at capture showed localization behavior indicative of calving in May. Most cows that localized (46 of 52) made a long distance movement of 6 km ± 0.8 km (range = 1–33 km; Fig. 2) over 17 ± 1.7 h (range = 2–57 h) before stopping at the birth site (Fig. 2). Linear path distances calculated using 20 min GPS locations were twice as long as straight line distances from the beginning of the long distance movement to the birth site. The straight-line distance from the start of the long-distance movement to the calving site was 3 ± 0.5 km (range = 0.3–23 km). Cows with low progesterone levels (0.33 ± 0.2 ng/mL) were not pregnant. All cows with low progesterone levels did not make a long distance movement and did not localize.

Cows remained localized at the birth site for 4 ± 0.4 days (range = 1–15 days). Of the 52 cows that initially localized, 32 moved 133 ± 17.9 m (mode = 80 m; range = 30–460 m) before localizing again for an additional 3 ± 0.6 days (range = 0–16 days). The remaining 20 cows did not move away from the site where they first localized. In total, cow-calf pairs spent 7 ± 0.7 days (range = 1–18 days) in the post-parturition area. The 50% kernel areas for 20 cows were 0.42 ± 0.06 ha and the 95% kernels were 1.72 ± 0.48 ha in the post-parturition period (Fig. 3).

The cover type trends indicating selection by cows were consistent, though not statistically different from post-parturition areas calculated in the previous VHF study (Fig. 4). The proportion of bog cover type continued to increase as polygon size around birth sites

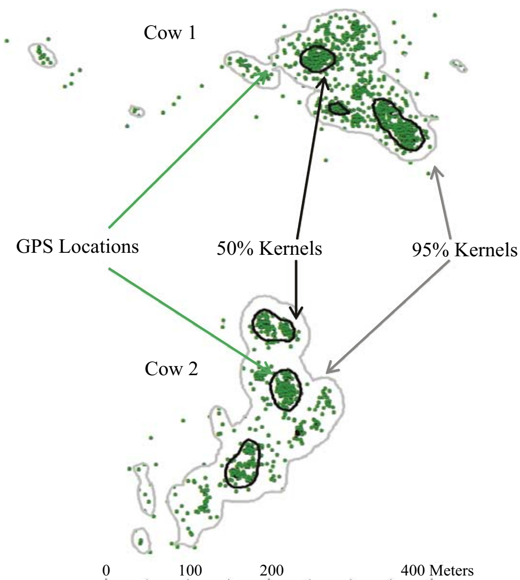

Fig. 3. Example of birth site areas as defined by 50% (black lines) and 95% (gray lines) kernel polygons for 2 cows. Each point indicates the location of each cow at the birth site at 20 min intervals.

decreased (34 ± 11% of 50% kernel polygons), while the amounts of mixed forest (24 ± 9% of 50% kernel polygons) and regenerating young forests (6 ± 5% of 50% kernel polygons) declined. Primary and secondary localization sites for each cow, defined using 50% kernel polygons, were within a single cover type (Table 1). Bog habitats (35%) were used more than other available cover types by GPS-collared cows, followed by mixed forest (25%) and conifer (20%).

Composition of cover types used 5 days prior to the long distance movement to birth site was variable among cows, but included a higher diversity of cover types than after localizing at the birth site (Fig. 5). The trend in cover type use indicated a general movement away from variable use of mixed forests and young and regenerating stands to use of one cover type, more often bogs.

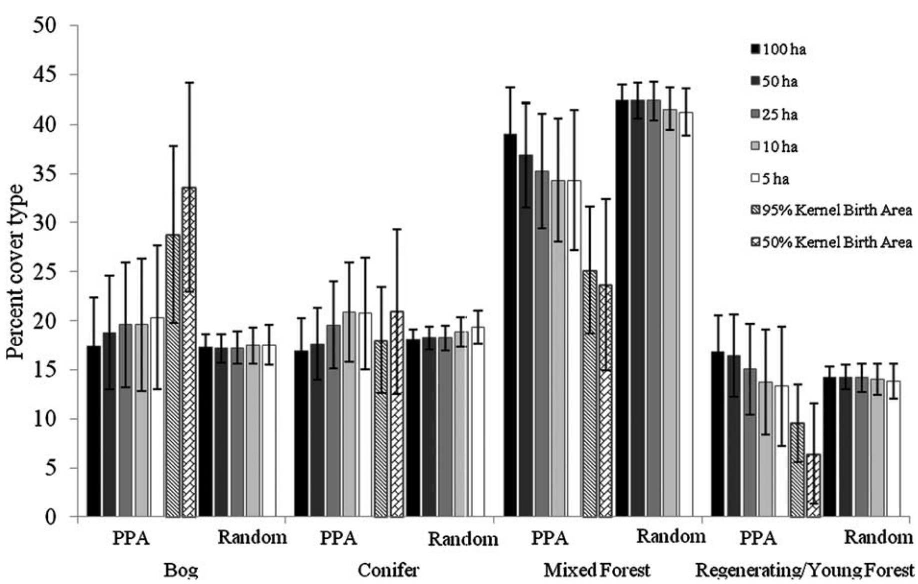

Fig. 4. Change in cover type composition as the area surrounding the known cow/calf locations (PPA) and random locations were incrementally reduced from 100 to 5 ha (McGraw et al. 2011), compared to composition of kernel birth site areas as defined using GPS collar location data collected at 20 min intervals throughout the calving period.

The average calving date during the GPS study was 14 May (mode = 17 May; range = 3–27 May), with 70% of births occurring between 9 and 20 May. Post-parturition locations from the VHF study were obtained by observing cow-calf pairs from helicopters after peak calving, between 21 May and 5 June each year (McGraw et al. 2011). Simulation based on calving dates of GPS-collared cows indicated that mean calf age was 12 days (95% CI: 9.9–13.4 days) when cow-calf pairs were located during the VHF study. Cow-calf locations for GPS-collared cows corresponding to the simulated locations from the VHF study were 2 km (95% CI: 0.2–3.8 km) from actual birth sites.

Table 1. Proportion of birth sites (n = 20) in each cover type, based on the area inside 50% kernel birth site polygons.

Cover Type	Birth Site (%)	Home Range (95% fixed kernel)	Northeast Minnesota (%)
Deciduous Forest	10	5	9
Mixed Forest	25	39	40
Bogs	40	21	13
Coniferous Forest	20	17	23
Regenerating	5	16	7
Other	0	2	8

DISCUSSION

In the current study in which actual birth sites were identified (n = 20), the bog cover type was used in higher proportion than its availability. However, there was still considerable variability in cover type composition among birth sites, with mixed forest used less than expected if birth site selection was random, whereas coniferous and deciduous forests were used about in proportion to availability. In the 5 days before long distance movement to birth sites, cows used a wide variety of cover types. Upon movement to the birth site, cows tended to move to a specific cover type in which they localized to give birth and remained for 7 days. These data are consistent with past studies (Addison et al. 1990, Langley and Pletscher 1994, Chekchak et al. 1998, Bowyer et al. 1999, Scarpitti et al. 2007) demonstrating considerable variation in habitat types used

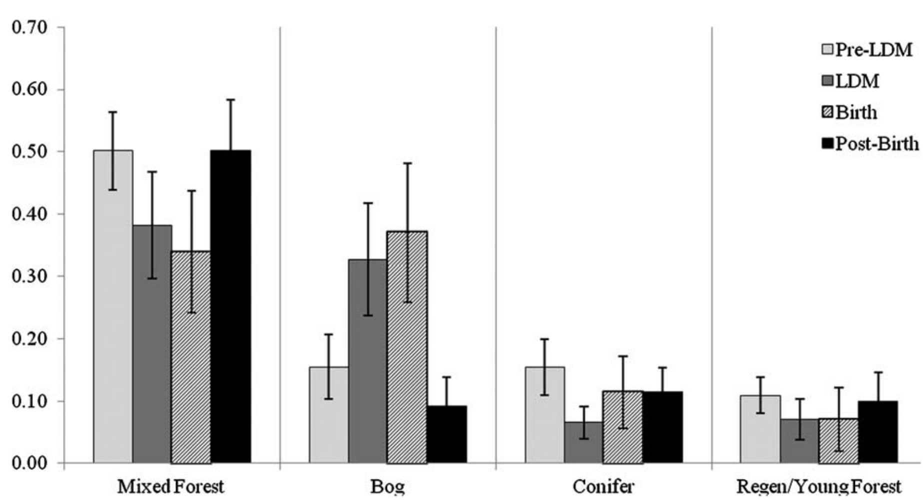

Fig. 5. Proportion of cover types used during periods beginning 5 days prior to the long distance movement (Pre-LDM), during the long distance movement (LDM), localization at the birth site (Birth), and 5 days post localization at the birth site (Post-Birth).

as calving sites. This implies that many habitat types are functionally similar in terms of what aspects are required to successfully rear calves. As a result, specific protective measures of calving sites would be difficult to implement given the wide variety of suitable habitat available.

While calves are relatively immobile after birth, bog cover types were used by nearly half of cows for birth sites in Minnesota. Bogs likely provide hiding cover for calves as well as some foraging opportunities and access to water for cows while their movements are restricted by the calf. As the cow-calf pairs moved away from the birth site, variability of cover type composition increased, with more time spent in mixed forests as well as young and regenerating forests. Movement to foraging habitat shortly after spring green up, when browse species have the highest nutritional content, likely allows cows to meet the energetic demands of lactation.

Despite the lag time between parturition and when cow-calf pairs were located during VHF telemetry flights, cover type composition was consistent with those observed with GPS data. While the cow-calf pair moves away from the birth site after about one week, some cover types may remain important and sought out 3–4 weeks post-parturition. As the post-parturition area surrounding VHF telemetry locations of cows with 12 day old calves was decreased, the proportion of bog cover type increased and mixed forest types decreased (McGraw et al. 2011).

Straight-line distances for cows were half as long (3 km) as the movement lengths measured by following the linear path (6 km). Using 20 min GPS location data allowed us to refine movement calculations, and as a result, we identified that a greater proportion of moose in this study (88%) made long distance pre-parturition movements than reported in the literature (20%; Bowyer et al. 1999). Previous studies have measured straight-line distances from 2 discrete observations. While long distance movements observed in northeast Minnesota are similar in length to those reported in central Alaska (7.3 ± 2.3 km; Bowyer et al. 1999), they are twice the length of those reported in south central Alaska (4 km; Testa et al. 2000). These differences are likely due to the method of measurement. In this study, duration and length of the pre-parturition movement were calculated by measuring the linear path of the cow with 20 min location data, whereas past VHF studies located cows once (Testa et al. 2000) or twice daily (Bowyer et al. 1999) during the calving period. More frequent locations will influence the measured distance moved per day during the long distance pre-parturition movement.

Calves are most vulnerable during the first weeks of life and affect cow movement until the calf is more mobile. Cows remain in visual or vocal distance during the initial post-parturition days when calves are less mobile (Cederlund et al. 1987, Van Ballenberghe and Ballard 2007). The duration of time spent in the birth area was ~7 days which is consistent with the amount of time female moose were protective of birth sites at a research facility in Russia (Bogomolova and Kurochkin 2002); however, it is shorter than the 3–4 weeks reported elsewhere (Altmann 1963, Bowyer 1999). This could be a result of the limitations of VHF technologies or reflect different definitions of the birth site area, ranging from the point of parturition to the larger area of restricted cow-calf movement in the weeks following birth.

The size of the birth site area used during the first post-partum week tended to be small and located in a single cover type; however, this is partly a function of the coverage resolution (30 × 30 m cell size). Variability among cows in terms of cover type selection for birth sites could also be an anti-predator strategy (Bowyer et al. 1999). Black bears (*Ursus americanus*) and wolves (*Canis lupus*) occur throughout moose habitat in northeast Minnesota and their possible effect on birth site selection strategy should be considered, as restriction of the birth site area could be a function of predator avoidance. A cow remaining localized in a small area while its calf is relatively immobile reduces the area in which a predator may encounter the pair (Bowyer et al. 1999). Eventual movement from the birth site after ~7 days may be a function of depleted forage and continued predator avoidance. Though the birth site area may be small, it stands to reason that the longer the pair remains at the birth site, the more likely they are to encounter a predator. Cow-calf pairs that moved short distances within a few days post-partum remained in the same cover type when they localized again. These short movements could also reflect low availability of forage or disturbance (Bowyer et al. 1999). The temporal scale at which we were able to monitor GPS-collared cows is much finer than was previously possible, enabling us to more accurately define the spatial extent of birth site areas. It is possible that past observations using ground searches and/or telemetry overlooked small movements to secondary birth sites, resulting in calculation of smaller birth site and post-parturition areas.

Aerial birth site searches should be interpreted with caution if they are flown only once or twice a year after peak calving. Simulated locations of cows that represented the 2004–2008 VHF flights occurred 12 days after localization of cows at the birth site, and after most cow-calf pairs would have left the area (McGraw et al. 2011). The identification of birth site characteristics from the simulated VHF flights would have been 2 km from the actual post-parturition habitat when the calf is more mobile.

The use of GPS collars to collect locations every 20 minutes vastly improved our ability to identify pre-parturition movement patterns and allowed us to more accurately define the spatial extent of calving areas. Future research using GPS technology to record fine scale movement patterns is needed to determine when cows with calves resume normal activity levels after parturition. Defining and identifying this will lead to more accurate description of post-parturition habitat use and cow-calf movements.

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REFERENCES

Addison, E. M., R. F. McLaughlin, D. J. H. Fraser, and M. E. Buss. 1993. Observations of pre- and post-partum behaviour of moose in central Ontario. Alces 29: 27–33.

———, J. D. Smith, R. F. McLaughlin, D. J. H. Fraser, and D. G. Joachim. 1990. Calving sites of moose in central Ontario. Alces 26: 142–153.

Altmann, M. 1958. Social integrations of the moose calf. Animal Behavior 6: 155–159.

———. 1963. Naturalistic studies of maternal care in moose and elk. Pages 233–253 *in* H. L. Rheingold, editor. Maternal Behavior in Mammals. Wiley & Sons, New York, New York, USA.

Bailey, T. N., and E. E. Bangs. 1980. Moose calving areas and use on the Kenai

National Moose Range, Alaska. Proceedings of the North American Moose Conference and Workshop 16: 289–313.

Beyer, H. L. 2012. Geospatial Modelling Environment (Version 0.7.2.1). (software). URL: <http://www.spatialecology.com/gme>.

Bogomolova, E. M., and Y. A. Kurochkin. 2002. Parturition activity of moose. Alces Supplement 2: 27–31.

Bowyer, R. T., V. Van Ballenberghe, J. G. Kie, and J. A. K. Maier. 1999. Birth-site selection by Alaskan moose: maternal strategies for coping with a risky environment. Journal of Mammalogy 80: 1070–1083.

Cederlund, G., F. Sandegren, and K. Larsson. 1987. Summer movements of female moose and dispersal of their offspring. Journal of Wildlife Management 51: 342–352.

Chekchak, T., R. Courtois, J-P. Ouellet, L. Breton, and S. St-Onge. 1998. Characteristics of moose (*Alces alces*) calving sites. Canadian Journal of Zoology 76: 1663–1670.

DelGiudice, G. D. 2013. 2013 Aerial Moose Survey. Minnesota Department of Natural Resources, St. Paul, Minnesota, USA. <http://files.dnr.state.mn.us/recreation/hunting/moose/moose_survey_2011.pdf> (accessed March 2013).

Kelsall, J. P., E. S. Telfer, and T. D. Wright. 1977. The effects of fire on the ecology of the boreal forest, with particular reference to the Canadian north: a review and selected bibliography. Occasional Paper #323. Canadian Wildlife Service, Ottawa, Canada.

Langley, M. A., and D. H. Pletscher. 1994. Calving areas of moose in northwestern Montana and southeastern British Columbia. Alces 30: 127–135.

Leptich, D. J., and J. R. Gilbert. 1986. Characteristics of moose calving sites in northern Maine as determined by multivariate analysis: a preliminary investigation. Alces 22: 69–81.

Lenarz, M. S. 2011. 2011 Aerial Moose Survey. Minnesota Department of Natural Resources, St. Paul, Minnesota, USA. <http://files.dnr.state.mn.us/recreation/hunting/moose/moose_survey_2011.pdf> (accessed March 2011).

McCann, N. P., R. A. Moen, and S. K. Windels. 2014. Identifying thermal refugia for a cold-adapted mammal facing climate change. Oecologia (in review).

McGraw, A. M., R. A. Moen, and M. Schrage. 2011. Characteristics of post-parturition areas of moose in northeast Minnesota. Alces 47: 113–124.

Minnesota Department of Natural Resources (MNDNR). 2007. Landsat Based Land Use-Land Cover. <http://deli.dnr.state.mn.us/metadata.html?id=L250000120604> (accessed April 2013).

———. 2010. Ecological Classification System: Laurentian Mixed Forest Province. <http://www.dnr.state.mn.us/ecs/212/index.html> (accessed February 2011).

Moen, R. A., M. E. Nelson, and A. Edwards. 2011. Radiotelemetry locations, home ranges, and aerial surveys in Minnesota. Alces 47: 101–112.

Pastor, J., and D. J. Mladenoff. 1992. The southern boreal-northern hardwood forest border. Pages 216–240 *in* H. H. Shugart, R. Leemans, and G. B. Bonan, editors. A Systems Analysis of the Global Boreal Forest. Cambridge University Press, Cambridge, United Kingdom.

Peek, J. M., D. L. Urich, and R. T. Mackie. 1976. Moose habitat selection and relationships to forest management in northeastern Minnesota. Wildlife Monographs 48: 3–65.

Poole, K. G., R. Serrouya, and K. Stuart-Smith. 2007. Moose calving strategies in interior montane ecosystems. Journal of Mammalogy 88: 139–150.

Scarpitti, D. L., P. J. Pekins, and A. R. Musante. 2007. Characteristics of neonatal moose habitat in northern New Hampshire. Alces 43: 29–38.

Sigouin, D., J-P. Ouellet, and R. Courtois. 1997. Geographical variation in the mating and calving periods of moose. Alces 33: 85–95.

Testa, J. W., E. F. Becker, and G. R. Lee. 2000. Movements of female moose in relation to birth and death of calves. Alces. 36: 155–162.

Van Ballenberghe, V., and W. B. Ballard. 2007. Population dynamics. Pages 223–246 *in* A. W. Franzmann and C. C. Schwartz, editors. Ecology and Management of the North American Moose, 2nd Edition. University Press of Colorado, Boulder, Colorado, USA.

Wilton, M. L., and D. L. Garner. 1991. Preliminary findings regarding elevation as a major factor in moose calving site selection in south central Ontario, Canada. Alces 27: 111–117.