

Home range size of female moose without calves was larger than females with calves, and this was most pronounced during the calving season. van Beest et al. (2011) also showed that females with calves reduce seasonal home range sizes compared to alone females during the summer. In contrast, other studies found no difference in home range sizes respective of reproduction status (Cederlund & Okarma 1988) or show that females with calves have significantly larger home ranges during the autumn (Cederlund & Sand 1994). Concerning changes in home range size between seasons, the estimation method was important, since the two methods yielded slightly different results. According to both estimations, the smallest seasonal home ranges were observed during pre-calving season and this is also shown in other studies (Phillips et al. 1973, Cederlund & Okarma 1988, van Beest et al. 2011). The 95% Kernel home range estimates indicated that seasonal home range size was largest during winter for both reproductive categories. I did not find evidence that this was described earlier, although Phillips et al. (1973) reported restricted movements of moose cows during the rut, followed by an increase in movement rates and also larger home range size during late fall and early winter (September to December), compared to late winter (January- April). The 100% MCP method showed that home ranges were the largest during the post calving season and smaller in the winter, which was similar to what was described by Stenhouse et al. (1995) and Cederlund & Sand (1994) although only for females with calves. In older studies, VHF transmitters are used for tracking the movement of moose, therefore minor differences in results of later studies applying GPS technology are not surprising and may be due to the increased precision and accuracy provided by these innovative devices (Cagnacci et al. 2010, Kie et al. 2010). Additionally, differences in home range size estimated with the 95% Kernel and the 100% MCP methods may come from the different principals of the two approaches. The Kernel method is based on the intensity of area utilization, allowing to identify multiple centers of activity and excluding unused areas from the estimation (Worton 1989, Hemson et al. 2005), while the MCP method includes all locations, connecting the outermost ones and not differentiating between how intensively different areas are used by the animal (Kenward 1987, Lawson & Rodgers 1997).

Travel speed

For travel speed, factors that represented the effect of wolves were not included in the best model, indicating that other external factors were generally more important for moose travel speed than the re-establishment of wolves. Nonetheless, I found that female moose had lower travel speed inside than outside the wolf territory, which may indicate that moose suppressed their movements in areas with wolf presence. Such a reduction of activity levels if predators are present in the area can be a beneficial anti-predator behavior, given that a moving animal can be detected by a predator more easily than an inactive animal (Lima and Dill 1990). On the other hand exposure to wolves showed increased travel speed with the amount of wolf locations in the individual moose home ranges. Increased movement rates could also be an advantageous behavior in order to escape predators

(Mitchell & Lima 2002). Comparing speed between the years with and without wolf presence revealed that the three female moose reduced their travel speed after the inclusion into the wolf territory. These findings provided basis for the assumption that moose females generally reduced their travel speed in relation to establishment of wolves, but showed elevated mobility in areas with a high exposure to wolves, i.e. with increased probability of encounters with wolves. Generally lower travel speed inside the wolf territory can be due to increased vigilance (Berger 1999, White and Berger 2001) and suppressed mobility (Lima and Dill 1990) when predators are present in the area. Increased travel speed in areas with higher level of wolf presence can be due disturbance and close encounters with wolves (Gude et al. 2006).

Travel speed was most affected by seasonal changes and reproductive status. I found that travel speed of females was highest during the calving season and the post calving season, while it was reduced during the pre- calving and the winter season. The analysis of travel speed before and after the establishment of wolves also showed a significant seasonal variation, although these three females had the highest mobility during the post calving and the lowest during winter. This can be explained by only minor differences found in travel speed between calving and post calving or between winter and pre calving seasons and possibly by high individual variation in movement responses to the changing of seasons (Vander Wal & Rodgers 2009). Findings of former studies also report that variation in movement rates follow seasonal changes because activity patterns are highly correlated with food quality and availability (Reisenhoover 1986, Cederlund et al. 1989). As more and higher quality forage is available in the spring, moose move more and utilize as much of it as possible, while in the autumn, the decrease in availability and quality of food results in reduced movement rates and gradual switching to less nutritious diet (Renecker & Hudson 1986, Cederlund 1989). Previous studies indicate that movement rates peak in May (Cederlund 1989, Eriksen et al. 2011) or June-July (Vander Wal & Rodgers 2009) and again in August and September (Eriksen et al. 2011, Cederlund 1989). Movements are gradually reduced from October-November (Eriksen et al. 2011) and are lowest around February (Cederlund 1989). In my study, I included May, June and July in the calving season therefore the observed increase in travel speed during calving season was consistent with findings of former studies. Season designations used in the cited studies differ from each other and also from my study, which made it difficult to compare between studies but may explain some of the differences seen in results.

Both reproductive categories of female moose showed elevated travel speed during the summer and autumn whereas females without calves had a more pronounced increase during the calving season. It is expected that females with calves move less intensively during calving season due to the restricted mobility of the calves (van Beest et al. 2011). In this study, females with calves increased their travel speed more moderately during the calving season, compared to females without calves. Inter-seasonal change of travel speed was more pronounced than the differences due to reproductive status, with the exception of the calving season. Season alone explained most of the variation in travel speed, but the

distinct differences observed between females with and without calves during the calving season also showed that movement patterns are affected by reproductive status.

Linearity of movement

I found that the directionality of female moose movement did not differ in relation to the presence of the wolves or between before and after the establishment of wolves. Although research in North America showed that as a response to wolf presence, female moose with calves are likely to reduce their foraging in order to increase vigilance (Berger 1999, Berger et al. 2001), behavioral adaptations that can affect linearity of movement have not been observed in Scandinavia (Eriksen et al. 2011).

I found that female moose changed between concentrated and directional movements mostly according to seasons and reproductive status. Female moose accompanied by calves moved less directional. This difference in linearity was most pronounced during the calving season and explained most of the seasonal variation, considering that no such reduction was seen in females without calves. Females without calves generally travelled more directional in all seasons with a lower variance in this movement pattern. Foraging movements are generally characterized by an increased variety of turning angles and shorter steps in the movement path, while if not foraging, animals move in a more direct manner (Fryxell 2008). If this is linked to resource availability, more concentrated movement can be expected when a lot of food is available and longer, more directional movements as resources get scarcer (Fryxell 2008). The fact that this reduction of linearity was only seen in females with calves, indicated that this was a result due to the limited movement abilities of their young (Eriksen et al. 2011), and increased vigilance (Berger 1999, White and Berger 2001). Eriksen et al. (2011), also observed minimal variation in linearity of female moose between seasons, except for a reduction in June which they explained as restricted movements due to taking care of their young.

Conclusions

My results showed that the re-establishment of wolves in Sweden may to some extent affect the movement patterns of female moose. In conclusion, I found that differences in seasonal home range size of female moose in the study area correlated with exposure to wolves and that travel speed and linearity of movement was mostly affected by seasonal changes and differences in reproductive status. By applying the method of model selection (Burnham & Anderson 2002), I discovered that the generally suppressed travel speed and the more elevated mobility observed in certain, more intensively used areas was related to presence of wolves. Overall, my results supported that mobility of females was more strongly influenced by external factors and their reproductive status, than the return of their long absent natural predators.

Former studies investigating the possible effect of the re-establishment of wolves on Scandinavian moose found that moose do not adapt to this predator (Berger et al. 2001, Sand et al. 2005, 2006, Wikenros 2011, Eriksen et al. 2009, 2011). Overseas, prey species e.g. elk (*Cervus elaphus*), bison

(*Bison bison*), and moose show strong behavioral adaptation towards the re-establishment of wolves with changes in habitat selection (Stephens & Peterson 1984), increased vigilance (Berger 1999, White and Berger 2001, Berger et al. 2001, Laundré et al. 2001), shift in feeding and birthing sites (Berger et al. 2001) or aggressive behavior (Mech & Botiani 2003). These anti-predator behavioral responses have not yet been found in Scandinavian moose (Berger et al. 2001, Sand et al. 2005, 2006, Wikenros 2011, Eriksen et al. 2009, 2011) and it remains an interesting question if they ever will be. There are major differences between the two continents regarding predator-prey history. In Scandinavia, predators were absent for a much longer period than in North America (Sand et al. 2006a), and during most of this time the moose population was intensively harvested by humans (Lavsund & Sandegren 1989), in contrast to no or a very low hunting pressure overseas (Orians et al. 1977, Peterson et al. 1984). In Scandinavia, human harvest have completely replaced predation and even remained the main mortality factor after the re-establishment of wolves (Wikenros 2011). With increased density of wolves, prey species may invest more in anti-predator adaptations, balancing the cost with reducing predation risk (Creel et al. 2005). A combination of factors such as larger wolf territories (Fritts & Mech 1981, Hayes & Harestad 2000), lower densities of wolves, high moose:wolf ratios (Pedersen et al. 2005), intense current and past hunting harvest (Lavsund & Sandegren 1989, Cederlund & Sand 1991, Wikenros 2011) and a more homogenous landscape (Cederlund & Okarma 1988, van Beest et al. 2010 Olsson et al. 2010) may alone or in combination contribute to wolves using individual moose home ranges less intensively in Scandinavia and may possibly explain why behavioral adaptations of moose to wolves are not as uniform and extensive as found in North America.

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REFERENCES

- Alexandersson , H., Andersson , T. (1995). Nederbörd och åska [Precipitation and thunderstorms] . In Raab, B., Vedin, H. *Klimat, sjöar och vattendrag* [Climate, lakes and rivers] SNA, pp.76-90. Höganäs, Sweden : Bokförlaget Bra böcker . (In Swedish)
- Alfredéen, A.-C. (2006). Denning behaviour and movement pattern during summer of wolves *Canis lupus* on the Scandinavian Peninsula. *M.Sc. thesis*, Swedish University of Agricultural Sciences, Uppsala.
- Baskin, L., Ball, J.P., Danell, K. (2004). Moose escape behaviour in areas of high hunting pressure. *Alces* 40, 123–131.
- Berger, J. (1999). Anthropogenic extinction of top carnivores and interspecific animal behaviour: implications of the rapid decoupling of a web involving wolves, bears, moose and ravens. *Proc Biol Sci* 266, 2261–2267.
- Berger, J., Swenson, J.E., Persson, I.-L. (2001). Recolonizing carnivores and naïve prey: conservation lessons from pleistocene extinctions. *Science* 291, 1036–1039.
- Björkhem , U., Lundmark , J. E. (1975). Mapping of soil conditions in Grimsö Wildlife Research Area (Report No. 23). Departments of Forest Ecology and Forest Soils, Royal College of Forestry, Stockholm. (In Swedish with English summary.)
- Bjørneraas, K., Van Moorter, B., Rolandsen, C.M., Herfindal, I. (2010). Screening global positioning system location data for errors using animal movement characteristics. *Journal of Wildlife Management* 74, 1361–1366.
- Bunnefeld, N., Börger, L., van Moorter, B., Rolandsen, C.M., Dettki, H., Solberg, E.J., Ericsson, G. (2011). A model-driven approach to quantify migration patterns: individual, regional and yearly differences. *Journal of Animal Ecology* 80, 466–476.
- Burnham, K.P., Anderson, D. (2002). Model selection and multi-model inference, 2nd ed. Springer.
- Burt, W.H. (1943). Territoriality and home range concepts as applied to mammals. *Journal of Mammalogy* 24, 346–352.
- Cagnacci, F., Boitani, L., Powell, R.A., Boyce, M.S. (2010). Animal ecology meets GPS-based radiotelemetry: a perfect storm of opportunities and challenges. *Philosophical Transactions of the Royal Society B: Biological Sciences* 365, 2157–2162.
- Calenge, C. (2006). The package “adehabitat” for the R software: A tool for the analysis of space and habitat use by animals. *Ecological Modelling* 197, 516–519.
- Cederlund, G. (1989). Activity patterns in moose and roe deer in a north boreal forest. *Holarctic Ecology* 12, 39–45.
- Cederlund, G., Bergström, R., Sandegren, F. (1989). Winter activity patterns of females in two moose populations. *Canadian Journal of Zoology* 67, 1516–1522.

- Cederlund, G., Sand, H. (1991). Population dynamics and yield of a moose population without predators. *Alces* 27, 40.
- Cederlund, G., Sand, H. (1994). Home-range size in relation to age and sex in moose. *Journal of Mammalogy* 75, 1005–1012.
- Cederlund, G., Sandegren, F., Larsson, K. (1987). Summer movements of female moose and dispersal of their offspring. *The Journal of Wildlife Management* 51, 342–352.
- Cederlund, G.N., Okarma, H. (1988). Home range and habitat use of adult female moose. *The Journal of Wildlife Management* 52, 336–343.
- Cederlund, G.N., Sand, H.K.G. (1992). Dispersal of subadult moose (*Alces alces*) in a nonmigratory population. *Canadian Journal of Zoology* 70, 1309–1314.
- Creel, S., Winnie, J., Maxwell, B., Hamlin, K., Creel, M. (2005). Elk alter habitat selection as an antipredator response to wolves. *Ecology* 86, 3387–3397.
- Eriksen, A., Wabakken, P., Zimmermann, B., Andreassen, H.P., Arnemo, J.M., Gundersen, H., Liberg, O., Linnell, J., Milner, J.M., Pedersen, H.C., Sand, H., Solberg, E.J., Storaas, T. (2011). Activity patterns of predator and prey: a simultaneous study of GPS-collared wolves and moose. *Animal Behaviour* 81, 423–431.
- Eriksen, A., Wabakken, P., Zimmermann, B., Andreassen, H.P., Arnemo, J.M., Gundersen, H., Milner, J.M., Liberg, O., Linnell, J., Pedersen, H.C., Sand, H., Solberg, E.J., Storaas, T. (2008). Encounter frequencies between GPS-collared wolves (*Canis lupus*) and moose (*Alces alces*) in a Scandinavian wolf territory. *Ecological Research* 24, 547–557.
- Fortin, D., Beyer, H.L., Boyce, M.S., Smith, D.W., Duchesne, T., Mao, J.S. (2005). Wolves influence elk movements: behaviour shapes a trophic cascade in Yellowstone National Park. *Ecology* 86, 1320–1330.
- Fraker, M.E., Luttbeg, B. (2012). Effects of perceptual and movement ranges on joint predator–prey distributions. *Oikos* no–no.
- Fritts, S.H., Mech, L.D. (1981). Dynamics, movements, and feeding ecology of a newly protected wolf population in northwestern Minnesota. *Wildlife Monographs* 3–79.
- Fryxell, J.M., Hazell, M., Börger, L., Dalziel, B.D., Haydon, D.T., Morales, J.M., McIntosh, T., Rosatte, R.C. (2008). Multiple movement modes by large herbivores at multiple spatiotemporal scales. *Proc Natl Acad Sci U S A* 105, 19114–19119.
- Gilliam, J.F., Fraser, D.F. (2001). Movement in corridors: enhancement by predation threat, disturbance, and habitat structure. *Ecology* 82, 258–273.
- Gude, J.A., Garrott, R.A., Borkowski, J.J., King, F. (2006). Prey risk allocation in a grazing ecosystem. *Ecological Applications* 16, 285–298.
- Hayes, R.D., Harestad, A.S. (2000). Demography of a recovering wolf population in the Yukon. *Canadian Journal of Zoology* 78, 36–48.

- Hemson, G., Johnson, P., South, A., Kenward, R., Ripley, R., Macdonald, D. (2005). Are kernels the mustard? Data from global positioning system (GPS) collars suggests problems for kernel home-range analyses with least-squares cross-validation. *Journal of Animal Ecology* 74, 455–463.
- Jenny, D., Zuberbühler, K. (2005). Hunting behaviour in West African forest leopards. *African Journal of Ecology* 43, 197–200.
- Johnson, C.J., Parker, K.L., Heard, D.C., Gillingham, M.P. (2002). Movement parameters of ungulates and scale-specific responses to the environment. *Journal of Animal Ecology* 71, 225–235.
- Jonsen, I.D., Myers, R.A., Flemming, J.M. (2003). Meta-analysis of animal movement using state-space models. *Ecology* 84, 3055–3063.
- Kenward, R. (1987). Wildlife radio tagging: equipment, field techniques and data analysis. Academic Press.
- Kie, J.G., Matthiopoulos, J., Fieberg, J., Powell, R.A., Cagnacci, F., Mitchell, M.S., Gaillard, J.-M., Moorcroft, P.R. (2010). The home-range concept: Are traditional estimators still relevant with modern telemetry technology? *Phil. Trans. R. Soc. B* 365, 2221–2231.
- Laundré, J.W., Hernández, L., Altendorf, K.B. (2001). Wolves, elk, and bison: reestablishing the “landscape of fear” in Yellowstone National Park, U.S.A. *Canadian Journal of Zoology* 79, 1401–1409.
- Lavsund, S., Sandegren, F. (1989). Swedish moose management and harvest during the period 1964–1989. *Alces* 25, 58–62.
- Lawson, E.J.G., Rodgers, A.R. (1997). Differences in Home-Range Size Computed in Commonly Used Software Programs. *Wildlife Society Bulletin* 25, 721–729.
- Lima, S.L., Dill, L.M. (1990). Behavioral decisions made under the risk of predation: a review and prospectus. *Canadian Journal of Zoology* 68, 619–640.
- Main, K.L. (1987). Predator avoidance in seagrass meadows: prey behavior, microhabitat selection, and cryptic coloration. *Ecology* 68, 170–180.
- Månsson, J., Andrén, H., Pehrson, Å., Bergström, R. (2007). Moose browsing and forage availability: a scale-dependent relationship? *Canadian Journal of Zoology* 85, 372–380.
- Mech, L.D., Boitani, L. (2003). Wolves: behavior, ecology, and conservation. University of Chicago Press.
- Mitchell, W.A., Lima, S.L. (2002). Predator-prey shell games: large-scale movement and its implications for decision-making by prey. *Oikos* 99, 249–259.
- Mohr, C.O. (1947). Table of equivalent populations of north American small mammals. *American Midland Naturalist* 37, 223–249.
- Moorcroft, P., Lewis, M.A., (2006). Mechanistic home range analysis. Princeton University Press.
- Neumann, W., Ericsson, G., Dettki, H., Arnemo, J.M. (2011). Effect of immobilizations on the activity and space use of female moose (*Alces alces*). *Canadian Journal of Zoology* 89, 1013–1018.

- Olsson, M., Cox, J.J., Larkin, J.L., Widén, P., Olovsson, A. (2010). Space and habitat use of moose in southwestern Sweden. *European Journal of Wildlife Research* 57, 241–249.
- Orians, G. H. et al. (1997) Wolves, bears, and their prey in Alaska: biological and social challenges in wildlife management. Washington, DC: National Research Council.
- Pedersen HC, Wabakken P, Arnemo JM, Brainerd SM, Brřseth H, Gundersen H, Hjeljord O, Liberg O, Sand H, Solberg EJ, Storaas T, Strřmseth TH, Wam H, Zimmermann B (2005) Carnivores and Society (RoSa). The Scandinavian wolf research project SKANDULV. Activities carried out during 2000–2004. *NINA Report no. 117*. (In Norwegian with English summary)
- Peterson, R.O., Woolington, J.D., Bailey, T.N. (1984). Wolves of the Kenai Peninsula, Alaska. *Wildlife Monographs* 3–52.
- Phillips, R.L., Berg, W.E., Siniff, D.B. (1973). Moose movement patterns and range use in northwestern Minnesota. *The Journal of Wildlife Management* 37, 266–278.
- Renecker, L.A., Hudson, R.J. (1986). Seasonal foraging rates of free-ranging moose. *The Journal of Wildlife Management* 50, 143–147.
- Risenhoover, K.L. (1986). Winter activity patterns of moose in interior Alaska. *The Journal of Wildlife Management* 50, 727–734.
- Rřnnegård, L., Sand, H., Andrén, H., Månsson, J., Pehrson, Å. (2008). Evaluation of four methods used to estimate population density of moose (*Alces alces*). *Wildlife Biology* 14, 358–371.
- Sand, H., Wabakken, P., Zimmermann, B., Johansson, Ö., Pedersen, H., Liberg, O. (2008). Summer kill rates and predation pattern in a wolf–moose system: can we rely on winter estimates? *Oecologia* 156, 53–64.
- Sand, H., Wikenros, C., Wabakken, P., Liberg, O. (2006a). Cross-continental differences in patterns of predation: Will naive moose in Scandinavia ever learn? *Proc. R. Soc. B* 273, 1421–1427.
- Sand, H., Wikenros, C., Wabakken, P., Liberg, O. (2006b). Effects of hunting group size, snow depth and age on the success of wolves hunting moose. *Animal Behaviour* 72, 781–789.
- Sand, H., Zimmermann, B., Wabakken, P., Andrén, H., Pedersen, H.C. (2005). Using GPS technology and GIS cluster analyses to estimate kill rates in wolf–ungulate ecosystems. *Wildlife Society Bulletin* 33, 914–925.
- Stenhouse, G.B., Latour, P.B., Kutny, L., MacLean, N., Glover, G. (1995). Productivity, survival, and movements of female moose in a low-density population, northwest territories, Canada. *Arctic* 48, 57–62.
- Stephens, P.W., Peterson, R.O. (1984). Wolf-avoidance strategies of moose. *Holarctic Ecology* 7, 239–244.
- Turchin, P. (1998). Quantitative analysis of movement: measuring and modeling population redistribution in animals and plants. Sinauer.

- van Beest, F.M., Rivrud, I.M., Loe, L.E., Milner, J.M., Myrsterud, A. (2011). What determines variation in home range size across spatiotemporal scales in a large browsing herbivore? *Journal of Animal Ecology* 80, 771–785.
- Vander Wal, E., Rodgers, A.R. (2009). Designating seasonality using rate of movement. *Journal of Wildlife Management* 73, 1189–1196.
- Vedin, H. (1995). Lufttemperatur [Air temperature] In B. Raab & H. Vedin Klimat, sjöar och vattendrag [Climate, lakes and rivers] SNA (pp. 91 – 97). Höganäs, , Sweden : Bokförlaget Bra böcker . (In Swedish)
- Wabakken P., Sand H., Liberg O., Bjärvall A. (2001). The recovery, distribution, and population dynamics of wolves on the Scandinavian peninsula, 1978-1998. *Canadian Journal of Zoology* 79, 710–725.
- Wabakken, P., Aronson, Å., Sand, H., Strømseth, T.H. and Kojola, I. (2004). The wolf in Scandinavia: status report of the 2003-2004 winter. *Oppdragsrapport 5-2004*. Høgskolen i Hedmark, Elverum. (In Norwegian with English summary, figures and tables.)
- Wabakken, P., Aronson, Å., Strømseth, T.H., Sand, H., Maartman, E., Svensson, L., Flagstad, O., Hedmark, E., Liberg, O. and Kojola, I. (2010). The wolf in Scandinavia: status report of the 2009-2010 winter. *Oppdragsrapport 4-2010*. Høgskolen i Hedmark, Elverum. (In Norwegian with English summary, figures and tables.)
- Wabakken, P., Aronson, Å., Strømseth, T.H., Sand, H., Maartman, E., Svensson, L., Åkesson, M., Flagstad, O., Liberg, O. and Kojola, I. (2011). The wolf in Scandinavia: status report of the 2010-2011 winter. *Oppdragsrapport 1-2011*. Høgskolen i Hedmark, Elverum. (In Norwegian with English summary, figures and tables.)
- White, K.S., Berger, J. (2001). Antipredator strategies of Alaskan moose: are maternal trade-offs influenced by offspring activity? *Canadian Journal of Zoology* 79, 2055–2062.
- Wikenros, C. (2011). The return of the wolf – effects on prey, competitors and scavengers. *Doctoral thesis* no. 2011: 85. Department of Ecology, Swedish University of Agricultural Sciences, Uppsala.
- Worton, B.J. (1987). A review of models of home range for animal movement. *Ecological Modelling* 38, 277–298.
- Worton, B.J. (1989). Kernel Methods for Estimating the Utilization Distribution in Home-Range Studies. *Ecology* 70, 164–168.
- Zimmermann, B., Wabakken, P., Sand, H., Pedersen, H.C., Liberg, O. (2007). Wolf movement patterns: a key to estimation of kill rate? *Journal of Wildlife Management* 71, 1177–1182.

Appendix 1. GPS collar IDs, sex, birth year, as well as dates of captures and last locations acquired from GPS collared wolves.

| Collar ID | Sex | Territory | Birth year | Date of capture | Last GPS location |
|--------------------|--------|------------|--------------|-----------------|-------------------|
| M1347 | male | Uttersberg | 2001 | 2005/03/16 | 2006/02/07 |
| M1345 ¹ | male | Uttersberg | 2001 | 2007/03/09 | 2009/10/07 |
| F2159 | female | Uttersberg | 1999 | 2006/01/27 | 2008/07/05 |
| M7571 | male | Hedbyn | 2007 or 2008 | 2010/02/11 | 2010/04/13 |
| F7572 | female | Hedbyn | 2007 or 2008 | 2010/02/11 | 2011/02/15 |

¹same individual as M1347

Appendix 2. GPS collar IDs, sex, birth year, dates of captures and last locations acquired from GPS collared moose as well as the number of estimated seasonal home ranges. Females excluded from the analysis due to low number of locations are shown in *italics*. Females used in the analysis of movement variables before and after wolf establishment are shown in **bold**.

| Collar ID | Sex | Birth year | Date of capture | Last GPS location | Seasonal home ranges (n) |
|----------------------|---------------|-------------|-------------------|-------------------|--------------------------|
| F07001 | female | 1997 | 2007-03-05 | 2012-01-10 | 14 |
| F07002 | female | 2004 | 2007-03-05 | 2012-01-10 | 14 |
| F07003 | female | 2002 | 2007-03-06 | 2009-10-23 | 7 |
| F07004 | female | 2006 | 2007-03-08 | 2007-12-12 | 2 |
| F07005 | female | 2000 | 2007-03-08 | 2012-01-10 | 14 |
| F07006 | female | 2001 | 2007-03-08 | 2011-11-26 | 14 |
| F07008 | female | 1997 | 2007-03-09 | 2007-08-23 | 1 |
| F07009 | female | 2005 | 2007-03-09 | 2009-08-29 | 9 |
| F07010 | female | 2002 | 2007-03-09 | 2012-01-10 | 14 |
| F07011 | female | 2005 | 2007-03-09 | 2011-07-19 | 14 |
| F07014 | female | 2006 | 2007-03-10 | 2007-09-22 | 1 |
| F07014a ¹ | female | 2006 | 2010-03-31 | 2012-01-10 | 3 |
| F07015 | female | 2002 | 2007-03-10 | 2009-08-31 | 9 |
| F07017 | female | 1997 | 2007-03-10 | 2011-12-11 | 6 |
| F07018 | female | 1999 | 2007-03-11 | 2008-01-30 | 3 |
| F07019 | female | 2002 | 2007-03-11 | 2009-08-09 | 8 |
| F07020 | female | 1991 | 2007-03-11 | 2010-12-15 | 12 |
| F07021 | female | 2002 | 2007-03-11 | 2009-11-14 | 10 |
| F07022 | female | 2006 | 2007-03-11 | 2008-01-03 | 2 |
| <i>F07023</i> | <i>female</i> | <i>2006</i> | <i>2007-03-12</i> | <i>2007-07-11</i> | <i>0</i> |
| F07024 | female | 2003 | 2007-03-12 | 2009-07-03 | 8 |
| F10001 | female | 2008 | 2010-03-30 | 2010-11-18 | 2 |
| <i>F10002</i> | <i>female</i> | <i>2004</i> | <i>2010-03-30</i> | <i>2010-07-22</i> | <i>0</i> |
| F10004 | female | 2007 | 2010-03-30 | 2012-01-09 | 3 |
| F10008 | female | 2006 | 2010-03-31 | 2010-12-23 | 2 |
| F10009 | female | 2001 | 2010-03-31 | 2012-01-10 | 3 |
| <i>F10010</i> | <i>female</i> | <i>2007</i> | <i>2010-03-31</i> | <i>2010-06-30</i> | <i>0</i> |
| F10012 | female | 2006 | 2010-03-31 | 2010-09-29 | 1 |
| <i>F10013</i> | <i>female</i> | <i>2005</i> | <i>2010-03-31</i> | <i>2010-06-27</i> | <i>0</i> |
| F10014 | female | 1999 | 2010-03-31 | 2010-08-17 | 1 |
| F98015 | female | 1998 | 2010-03-31 | 2012-01-10 | 3 |

¹same individual as F0714

Appendix 3. Parameter values of the models with the lowest AIC_C values (from Table 1.) for the response variables travel speed (m(h), linearity and seasonal home range size (km²). Models were tested on the ‘reduced’ dataset (n = 144).

| Model | Response variable | n | Fixed factors | β | SE | P | |
|--------------|---------------------------------|-----|---------------|--------------|----------------|----------------|----------------|
| A3 | Travel speed | 144 | intercept | 3.623 | 0.061 | < 0.001 | |
| | | | season | pre-calving | 0.063 | 0.061 | 0.300 |
| | | | | calving | 0.681 | 0.051 | < 0.001 |
| | | | | post-calving | 0.596 | 0.047 | < 0.001 |
| | | | | winter | 0 | 0 | |
| | | | reproduction | with calf | -0.153 | 0.039 | < 0.001 |
| without calf | 0 | 0 | | | | | |
| B3 | Linearity | 144 | intercept | 3.068 | 0.022 | < 0.001 | |
| | | | season | pre-calving | 0.003 | 0.023 | 0.911 |
| | | | | calving | -0.087 | 0.020 | < 0.001 |
| | | | | post-calving | 0.023 | 0.017 | 0.171 |
| | | | | winter | 0 | 0 | |
| | | | reproduction | with calf | -0.089 | 0.013 | < 0.001 |
| without calf | 0 | 0 | | | | | |
| C9 | Home range size (95% Kernel) | 144 | intercept | 985.933 | 128.734 | < 0.001 | |
| | | | season | pre-calving | -206.608 | 98.996 | 0.039 |
| | | | | calving | -9.761 | 71.254 | 0.891 |
| | | | | post-calving | -131.143 | 71.776 | 0.070 |
| | | | | winter | 0 | 0 | |
| | | | reproduction | with calf | -253.438 | 27.107 | < 0.001 |
| without calf | 0 | 0 | | | | | |
| D9 | Home range size (100% MCP) | 144 | intercept | 1093.183 | 144.527 | < 0.001 | |
| | | | season | pre-calving | -202.968 | 144.776 | 0.079 |
| | | | | calving | 82.344 | 99.545 | 0.410 |
| | | | | post-calving | 122.778 | 98.480 | 0.215 |
| | | | | winter | 0 | 0 | |
| | | | reproduction | with calf | -336.544 | 71.296 | < 0.001 |
| without calf | 0 | 0 | | | | | |
| | wolf exposure | | 71.124 | 12.105 | < 0.001 | | |