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# Relationship between moose (*Alces alces*) home range size and crossing wildlife fences

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Examensarbete i biologi, 15 hp, G2E

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## Relationen mellan hemområdesstorlek hos älg och möjligheten att passera viltstängsel

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Keywords: Home range, wildlife fence, moose (*Alces alces*), movement, Sweden

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## Abstract

Wildlife fences are today commonly used along highways to reduce the risk of vehicle collisions with wildlife. Since traffic and roads have expanded over the years, wildlife behaviour has become more interesting not only for the prevention of vehicle collisions but also to understand how human activities impact their natural habitats. Moose is one of those animals that have increased in interest in such studies. In this study, I tested if the probability to cross wildlife fences of moose would increase with increasing home range sizes, and also at what time of the year they cross. The study area is situated in Nordmaling municipality, located in Northern Sweden in the County of Västerbotten. Data from 2004/2005 with GPS positions of every hour from 18 moose individuals were used in this study. A normal 95% kernel utilization distribution (UD) was used to identify home range area of each individual and a general linear model (GLM) was used in analysis of home range area against response variable of crossings. To estimate which time crossings occurred over the year, a generalized linear mixed model (GLMM) was used. The results showed no effect of different home range sizes on the probability of crossing the fence. A difference over time and year was detected, with a more even distribution throughout the day in January compared to i.e. April and May which had a two sided distribution with most crossings in the morning and evening. I recommend future research to use more data and investigate how other factors like planned crossing areas passes affects the movement behaviour of moose.



## Sammanfattning

Viltstängsel är idag vanligt längs med vägar för att minska risken för viltolyckor. Eftersom trafikmängd och vägar har ökat med åren, har även intresset för djurs beteendemönster ökat och inte bara för att förebygga viltolyckor utan också för att förstå hur människan påverkar deras naturliga miljö. Ett av dem djur som har ökat i intresse inom naturvetenskapliga undersökningar är älgen. I den här studien testades älgars hemområdesstorlek för att se om möjligheten att passera viltstängsel ökar med en ökad hemområdesstorlek. Området för studien ligger i Nordmalings kommun, vilket ligger i norra Sverige i Västerbottens län. Data från 2004/2005 med GPS positioner av varje timme från 18 älgindivider användes i denna studie. En vanlig 95 % kernelUD (utilization distribution) användes för att identifiera hemområdets area för varje individ och en general linear model (GLM) användes för att testa hemområdens area mot individer som passerat respektive inte passerat viltstängslet. För att beräkna vilken tid passagerna inträffade över året, användes en generalized linear mixed model (GLMM). Resultaten visar att det inte finns någon skillnad i hemområdesstorlek för dem som passerar viltstängslet, men älgar verkar passera mer regelbundet under januari oavsett vilken tid det är på dygnet, i jämförelse mot april och maj då dem passerar mer under morgon och kväll.

Med mer data kan resultatet bli annorlunda och det skulle vara intressant att se hur andra faktorer som till exempel hur insatta viltövergångar påverkar rörelsebeteendet hos älgen.

# Introduction

## Background

The understanding for wildlife and their natural habitats and how human activities impact their natural behaviours have become more essential with the years. Roads and railways have steadily increased in the last century, and while road communication has expanded over the years, it has also created a much higher vehicle collision rate with wildlife (Brunderink and Hazebroek, 1996). For Sweden the total length of road networks with including private and forestry roads, is about 415,000 km (Trafikverket, 2013), and it has become more common to use wildlife fences along railways and roads (Olsson and Widen, 2008). However, this action has also affected wildlife behaviour negatively, making a barrier to movement and creating limited accessibility to resources (Breton et al., 2008; Olson and Widen, 2008). By using fences along traffic roadways it reduces the risk of vehicle collisions and also affects movement behaviour by moose (*Alces alces*; Clevenger et al., 2001).

Moose is one of those ungulates who have become of much interest in nature studies, not only for its natural behaviour but also because of its high risk of vehicle collisions (Seiler 2005; Breton et al., 2008; Bunnefeld et al., 2012). Vehicle collisions with wildlife have increased and back in 2006 the number of vehicle collisions with moose where up to about 6,000 (Vägverket, 2007). By constructing new roads and maintaining the old ones, it creates environmental factors for animals and their movement behaviour, but while roads are expected to be avoided by animals, they also appear to facilitate animal movements (i.e. by roadside vegetation and movement paths along roadsides et cetera; Forman and Alexander, 1998; Rea et al., 2010). Forman and Alexander (1998) explain in their ecological study that predators and vertebrates uses roadsides in search of road kill and plants. While road networks, amount of traffic and moose populations are growing, vehicle collision with moose is likely to increase.

Moose are today located in northern Europe, Asia and North America and are considered to be the largest species of the Cervidae family (Broders et al., 1999). Since 1940, the moose population has steadily increased in Sweden due to new forestry management methods that were introduced in the last decades (Hörnberg, 2001). Especially in the 1960s to the 1980s, the moose densities extensively increased which involved an increase in forest damage (Hörnberg, 2001).

Today there are studies who investigate individual moose behaviour and one of those are made by Dussault et al. (2005), in were they investigate them most significant causes of moose space use in environmental scales. Forage availability influence space use by moose, and movement rates are low in habitats with high forage availability. This was especially the case for the winter period (Dussault et al., 2005).

Börger et al. (2008) explains home ranges as “the spatial expression of behaviour animal performs to survive and reproduce”, and home range sizes are shown to have a relationship with the amount of energy and nutrient resources and shelter against predators (Andersson et al., 2005).

Earlier studies (Ball et al. 2001; Rivrund et al. 2011) suggest that home range sizes of moose differ between individuals depending on where they are in Sweden and in what environmental conditions they live. The two basic factors that influence migration are the condition of snow and accessibility to food supply (Ball et al., 2001). There is a tendency that with decreasing resources required surviving of ungulates, home range size and movement rate increase (Andersson et al., 2005).

With increasing road density it creates higher cross-over activity for moose, and especially for summer periods (Beyer et al., 2013). Leurian et al. (2008) reported that highways and forest-road crossings by moose occurred most during May-July and also with a peak in October, in which most of the crossings occurred at night. Compared with Neumann et al. (2012) in which they showed almost the same result in their study, with a peak between May-June and November-January of road-crossings throughout the day.

Still, no studies have been found to show if different home range sizes of moose individuals could affect their fence crossing behaviour.

## Aim of the Research

Today, overpasses- and underpasses are scattered introduced along roadways to facilitate cross-way movement of moose, and it is been reported that moose could cross fences anyway without over- and underpasses (Ericsson. et al., 2005). Moose movement rate and their home range sizes are affected by the amount of nutrient rich food supply, snow conditions, daylight and useful environmental habitats acting as shelter against predators (Ball et al., 2001; Andersson et al., 2005; Rivrund et al., 2011; Neumann et al., 2012). This leads me to the questions 1) if there are any differences in fence crossing-over activity between different moose individuals with different home range sizes, and also 2) at what time during the day and year they prefer to pass the roadway fences. Based on prior studies (Ball et al., 2001; Andersson et al., 2005; Ericsson et al., 2005; Leurian et al. 2008; Neumann et al. 2012) my prediction is that moose with a larger home range size will have a higher moving rate activity than moose with a smaller home range size. Because a large home range size is likely to be the result of low possibilities to resources creating a much higher moving rate and therefor the cross over activity over the wildlife fence is predicted to be high for large home range areas. Also it would be predicted that moose movement will be at a minimum during winter when conditions like snow depth will no longer be a barrier to look for more high-nutrient and high quality food resources as the vegetation period begins, and also that female moose seem to have a higher moving rate in connection of calving season (Bunnefeld et al., 2011).

Based on the study by Leurian et al. (2008) where it was reported that moose crossings occurred most at night, it would be predicted that I would get the same result. This seems to be a result from factors as when high traffic rates and noise from vehicles during day, creating higher accessibility to crossing road at night when the rates are low (Forman and Alexander, 1998).

## Materials and methods

### Study area

The study area (800 km$^2$) is situated in Nordmaling municipality (N 63°34’30”, E 19°30’36”), located in Northern Sweden in the County of Västerbotten. Nordmaling is close to the coastline, and the locations of the moose positions are in both sides of the European highway 4 (E4), which goes in north-south direction through the Nordmaling municipality (Figure 1). Along the European highway, wildlife fence was present for the actual year when the moose data was collected.

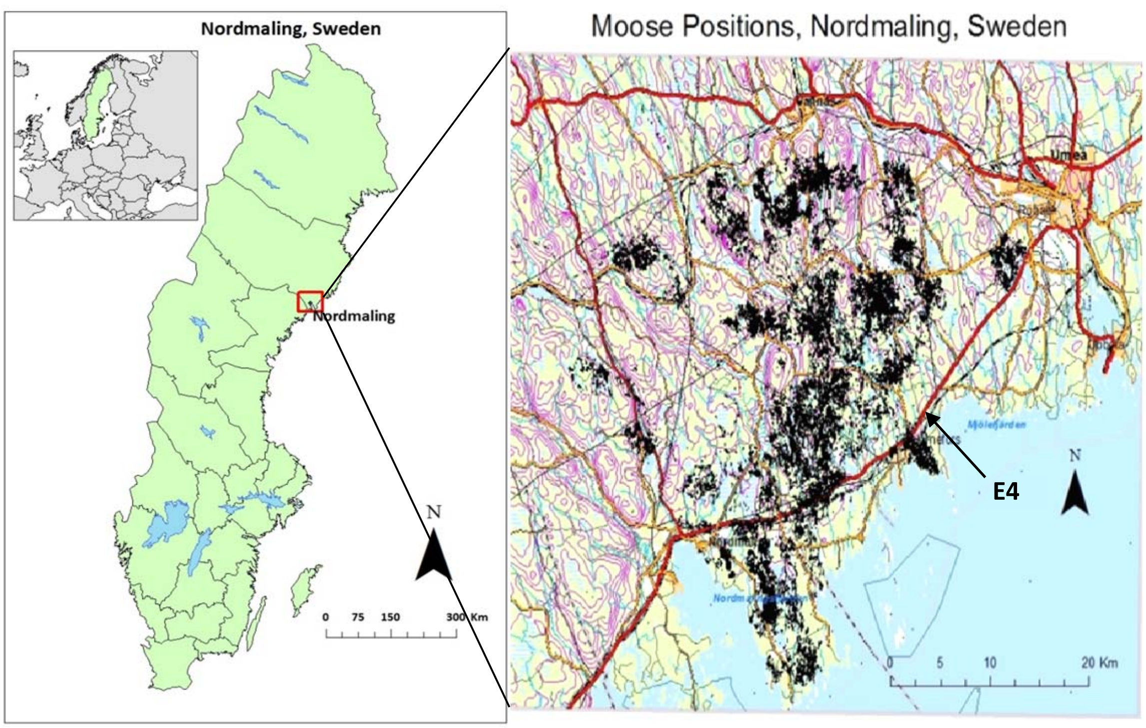



Figure 1.Map of moose positions in Nordmaling located in the counties of Västerbotten, Sweden (WRAM, 2013).

### Moose data

Collected data of the year 2004/2005 from the Nordmaling report (2005) was used for this study. 18 female moose with GPS transmitters were followed over a year from end of

February 2004 until start of March 2005, and their GPS positions were given every full hour (Dettki et al., 2013). This resulted in a total of 154,500 GPS positions for all the moose individuals. Most of the individuals had their respective home ranges for winter and summer located on both sides of a highway road (E4) containing fences on each side of it and only a few individuals had both of their seasonal ranges on the same side (Ericsson et al., 2005). Even though the European highway contained wildlife fence, the moose individuals were able to cross-over it. The data was provided from the Department of Wildlife, Fish, and Environmental Studies at the Swedish University of Agricultural Sciences (SLU), in Umeå, Sweden (WRAM, 2013).

**Data analysis**

In GIS a moose road-crossing was classified either as 1 and 0 if the movement path segment between point locations intersected with the wildlife fence or not. By using the extension geospatial modeling environment from Beyer (2010), the movement paths were calculated between all the moose positions. Even though some moose crossed the wildlife fence several times, both the moose positions between the movement paths that intersected with the fence were classified as a cross (1). With a data set containing attributes of X, Y coordinates, time and date of GPS positions in Greenwich mean time (GMT), object id and if the moose did cross the fence or not I further completed the analysis in the statistical program R (Crawley, 2007).

To estimate the home range size for each moose individual over the whole year a normal 95% kernelUD (utilization distribution) estimation with the least squares cross validation smoothing parameter (LSCV) was used (R Package *adehabitatHR;* Celange, 2011). Meaning, first the utilization distribution gives the probability density to relocate the animal at any place according to their coordinates and through the kernel the home range is estimated with 95 % probability to relocate the animal. Because of the limited time for this project, the data set for home range analysis was decreased by calculating one random position per moose and day. A few moose in my study were observed to be migratory and the probability to influence the result with location errors was possible. Because of this a coarser resolution through a grid of 200 (200x200 m) was used to reduce the risk of false extreme home range area values. With a general linear model (GLM) the home range area was tested against the response variable of cross (yes=1, no=0; Crawley, 2007). For the analysis of temporal cross-over activity in relation to month and hour, a generalized linear mixed model (GLMM) was used separately for month and hour on the individuals from the data frame that did cross the wildlife fence (R Package *lme4* 0.999375-42; Crawley, 2007). The date and time in Greenwich Mean Time (GMT) of GPS positions were recalculated in to Swedish time (GMT+1) because the positions were located in Sweden.

Graphs showing the distribution of crossings in relation to hour for every month were made in MS Excel 2007. For all analyses in GIS the software ArcGIS 10.1 was used and the statistical analyses were made in R 2.15.1.

## Results

The result is divided in two parts, with home range area activity between different moose individuals and the spatiotemporal activity for those individuals that did cross the wildlife fence in relation to hour and month of the year.

### Home range

Of the 18 moose that were followed, 5 (n=5) did not cross the wildlife fence and 13 (n=13) did cross the wildlife fence (Table 1). It was no difference between home range sizes of the individuals that crossed the wildlife fence and to those that did not cross, and the mean value was almost the same (no cross=4,002, cross=4,009; Figure 2). Also, there was no tendency of higher cross-over activity between the different home range sizes, and through the generalized linear model (GLM) the result was not significant (α=0.05, p=0.995).

Table 1. Summary statistics for home range sizes in hectares of moose individuals that did cross respective not cross the wildlife fence.

| Home range size (ha) | | | | | |
|---|---|---|---|---|---|
| Fence cross | N | Mean | S.E. | Minimum | Maximum |
| No Cross | 5 | 4,002 | 445 | 2,772 | 5,222 |
| Did Cross | 13 | 4,009 | 671 | 1,341 | 9,008 |

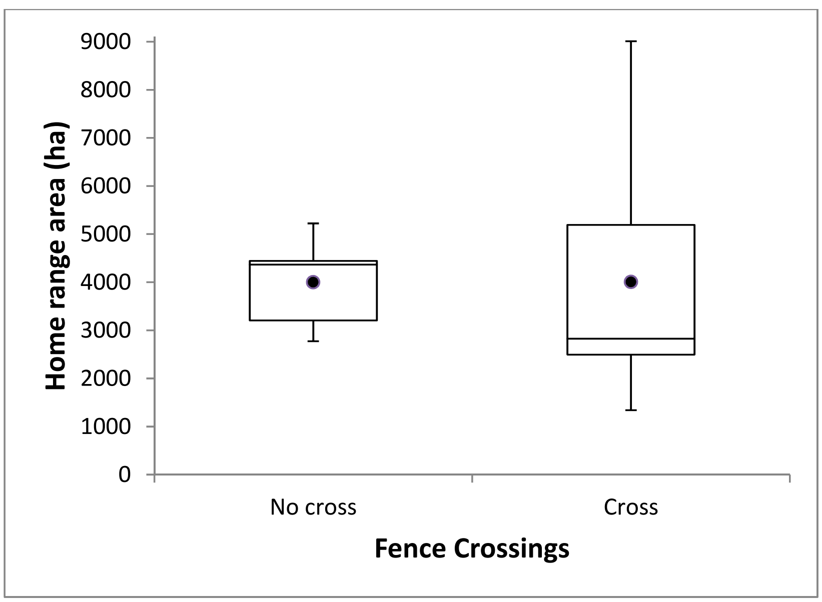



Figure 2. Home range sizes in hectare (ha) for moose individuals that cross (13) respective not Cross (5) the wildlife fence. Black dots show the mean value of home range area for each group (no cross=4,002, cross=4,009) and the median are shown as a line.

**Spatiotemporal fence-crossings**

A total of 367 moose crossings were detected of those 13 (n=13) individuals that did cross the fence (Figure 3). The crossings only occured in the months of Januray, February, March, April, May, November and December, with a spatiotemporal differency of activity with the highest amount of crossings by one individual in January (cross=110, $\alpha$=0.05, p<0.001; Table 2). There was also only one individual with 65 crossings in December, which gave a smaller difference between the months of January and December (estimate=-0.5; Table 2).

By the generalized linear mixed model (GLMM) with random selection for the individuals, all the months did significant differ against January with a extremely low p-value for all ($\alpha$=0.05, p<0.001). For the amount of crossings in relation to time of the day, all the crossings in allmost every month, except for January, had a tendency for a two-sided distribution with activity before and after lunchtime which is clearely displayed in April and May (Table 3; Figure 4), and through the generalized linear mixed model (GLMM) the result was significant for hour 11.00 ($\alpha$=0.05, p=0.014), 12.00 ($\alpha$=0.05, p=0.028) and 18.00 ($\alpha$=0.05, p=0.025).

Table 2. Summary statistics for all crossings divided between the months.

| Total of crossings | Nr. Of Individuals (N) | | |
|---|---|---|---|
| 367 | 13 | | |
| Cross | Month | Estimate | S.E |
| 110 | January | (4.5) | 0.38 |
| 19 | February | (-2.3) | 0.29 |
| 42 | March | (-3.5) | 0.38 |
| 62 | April | (-2.0) | 0.44 |
| 67 | May | (-2.1) | 0.39 |
| 2 | November | (-3.0) | 0.87 |
| 65 | December | (-0.5) | 0.16 |

Table 3. Summary statistics for all the crossings divided between samples of hours over the whole year.

| Distribution of 367 crossings. | | | | | |
|---|---|---|---|---|---|
| Time (GMT+1) | Crossings | Mean | S.E | Minimum | Maximum |
| 00.00-03.00 | 93 | 23.3 | 1.6 | 20 | 26 |
| 04.00-08.00 | 79 | 15.8 | 2.4 | 11 | 24 |
| 09.00-13.00 | 34 | 6.8 | 0.9 | 4 | 9 |
| 14.00–18.00 | 64 | 12.8 | 2.4 | 5 | 20 |
| 19.00–23.00 | 97 | 19.4 | 2.6 | 10 | 24 |

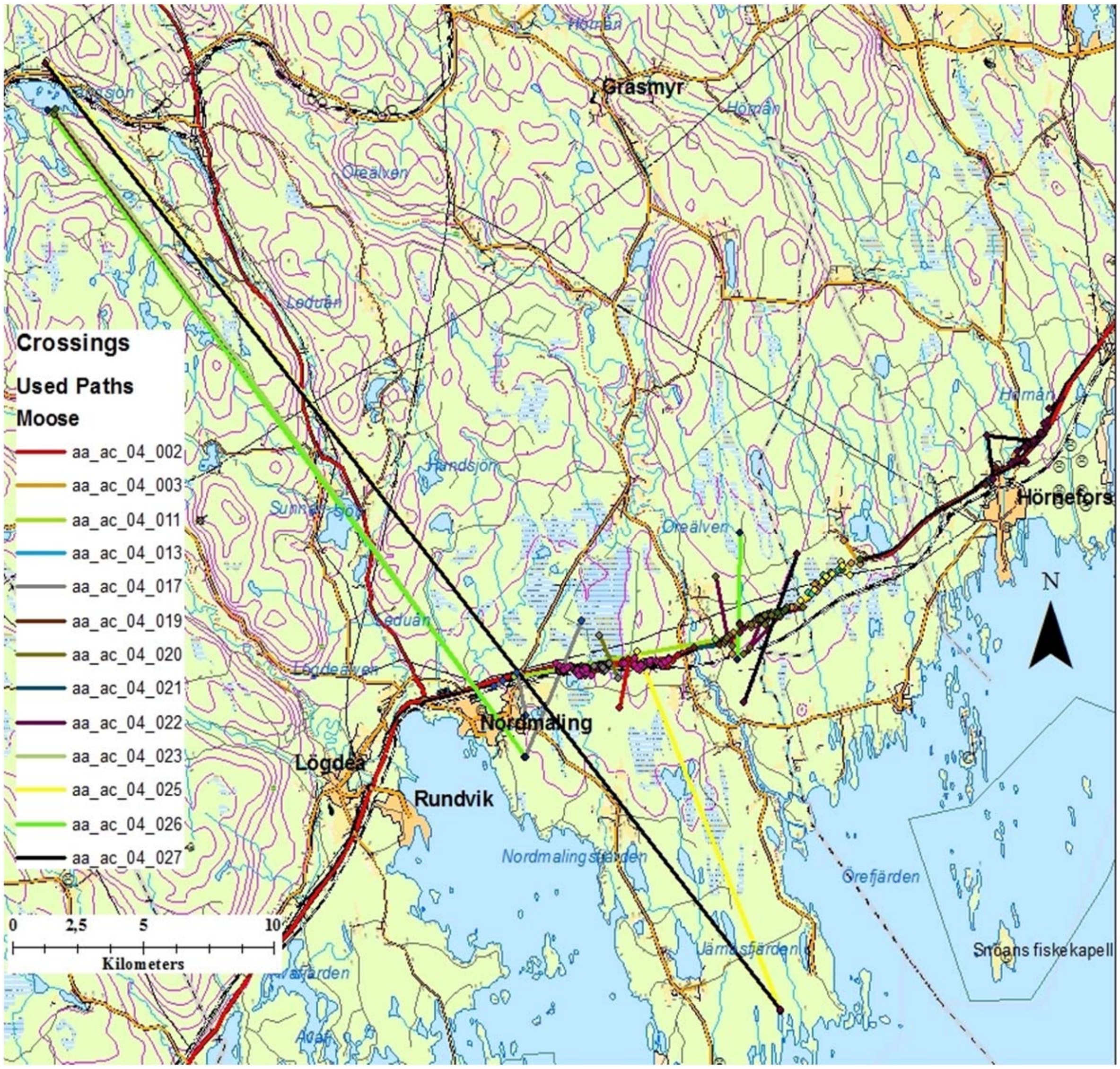
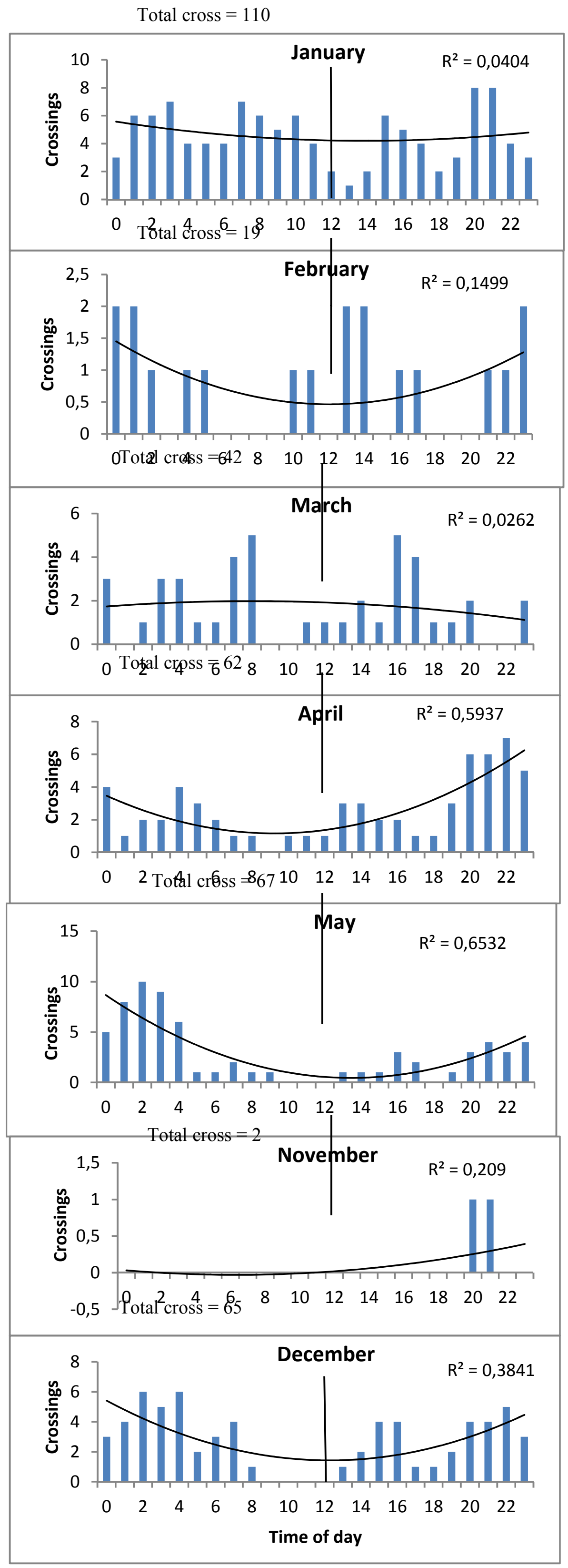



Figure 3. Moose individuals with their GPS positions and movement crossings over used fence from 2004/2005, in Nordmaling (Beyer, 2010; WRAM, 2013).

The activity was more evenly distributed throughout the day in January ($R^2$=0.04) in compare to the other months like April ($R^2$=0.59) and May ($R^2$=0.65; Figure 4).

Figure 4. The graphs are showing the distribution of crossing in relation to hour for every month. The hour of 12.00 is marked with a line. Note that with increasing light (April and May) crossings occur earlier and later on the day.



## Discussions

The discussion begins with evaluation of the home range result in were I bring up the result and explain it in a different sight of view, and ends with interpretation of the crossing distribution over the day in each month of crossings occurrence.

### Home-range

Of 18 female moose in this study 13 crossed the fence and there was no variation in home range area between moose individuals that crossed the fence and to those that did not cross, and there was no significant difference between the two variables of crossings ($\alpha$=0.05, p=0.995) and therefore my prediction of a higher fence cross activity for moose with a larger home range area did not match the result.

Earlier studies show that wildlife home range have a correlation to availability of resources and environmental factors as snow condition and shelter against predators which creates a higher moving rate for larger home range areas (Ball et al., 2001; Andersson et al., 2005; Leurian et al. 2008; Rivrund et al., 2011; Neumann et al., 2012; Montgomery et al., 2013). Home range size is smaller in winter than in summer, with low browse accessibility which gives an expectation of a higher movement rate for wildlife in large home range areas independently for summer and winter (Andersson et al. 2005; Rivrund et al., 2011). According to my result, with seasonal ranges counted together making a total home range area per individual, this does not seem to be the case, because the crossings appeared independently of home range size over the year (Figure 2). The explanation for the difference of results between authors and mine appears to be the size of used data and different study areas with different environmental conditions. Factors like forest biomass, roadside vegetation, latitudinal gradients and amount of traffic rate in other studies have a tendency to be important in moose movement behaviour (Forman and Alexander, 1998; Andersson et al., 2005; Beyer et al., 2013) but were not considered in this study area due to lack of data.

By increasing the number of observations and use all the positions instead of one random position per day and moose, the result could be better. The use of a grid size of 200 in the utilization distribution (UD) could also have affected the result, due to the consequence if moose with large home ranges have low resolution it increases the size of total area. Comparison of different grid sizes resulted in that a size of 200 gave the best result with low false home range area values. Because of the limiting time for this project, a normal 95% kernelUD estimation method (R Package *adehabitatHR;* Celange, 2011) was used instead of the Brownian bridge movement model (BBMM) which is a method for calculating movement behavior between two locations and use the information to better estimate the home range area and where the fence crossings do occur (Horne et .al. 2007). From BBMM a conclusion could be drawn if fence do or do not affect movement behavior by moose.

Regarding the total amount of 154,500 GPS positions, the expectation was to find a higher number of crossings then 367. An explaining reason could be that home range of summer and winter were not separately located on both sides of the E4 for all the individuals (Ericsson et al., 2005), which gave no required movement path over the fence.

Along highways and roads, fence have a positive effect on road crossings which causes avoidance of wildlife and reduces risk of vehicle collisions (Olsson and Widen, 2008) and this seem to be logic as another reason for low crossing occurrences in my study.

**Spatiotemporal fence-crossings**

Crossing occurrence did not happen in the months of June, July, August, September and October which was unpredicted regarding earlier studies from Leurian et al. (2008) that have a peak of crossings between May-July and also in October. Their study area is located in north of Quebec City, Quebec, Canada which has one of the highest total annual snowfall in the world with >550 cm in some areas and this could explain the difference between the results, as severe snow conditions creates movement difficulties for wildlife (Ball et al., 2001). Also, the amount of crossings in my study had only a small difference between May, April and December in relation to January (Table 2; Figure 4) which indicates low impact of snow depth against moving activity.

The distribution of crossings throughout the day over the year showed an avoidance of movement activity in April and May in contrast to January, which had a more even distribution throughout the day and this seem to be logic as time of daylight effect movement activity through a higher amount of traffic and noise from vehicles (Table 3; Figure 4; Laurian et al., 2008). This agrees with my prediction of a higher movement rate at night based on earlier studies from Leurian et al. (2008).

Most crossings in my study occurred in January, May and December (Table 2) and corresponded with the result from Neumann et al. (2012), thus with a difference as they have peak of crossings also in June and November. This difference may be due to a higher number of used individuals, as they use 102 compared to 18 for this study, making a higher cross-over activity possible.

No crossings occurred in the summer period which contradicts the expectation and wildlife fence and also roads seem to play a major role of crossing abundance. Wildlife fence makes it difficult for individuals to pass (Clevenger et al., 2001) and according to my data; no over- or underpasses were present to facilitate cross-way movement of wildlife the actual year data were collected. Therefore all crossings that occurred are considered to be jump overs. That is probably why no crossings occurred in the summer period with any snow which facilities moose to jump over the fence. Brownian bridge movement method should have been used to better calculating the exact time when and where the cross occurred. Meaning from my result, every moose position was reported every full hour, and therefore the time could not be so accurate and where actual crossings did occurred. One individual affected the result remarkably since it had a total of 110 crossings in January. By using the generalized linear mixed model (GLMM) with moose individuals as random effect, it was obviously a significant result against month of January. Still the main question was when and how often crossings occurred and not how many crossings per individual and therefore this was not taken in consideration.

## Conclusions

Regarding to my result, different home range sizes have no effect on the activity to over-cross wildlife fences. Thus, more observations and moose individuals are needed to confirm this result. Also it would be good to use more possible factors such as distance against fence, and with introduced passes available for individuals to cross the highway in the study area. This is to better understand reactions of moose movement behavior against wildlife fence. Even though it would be predicted with a higher activity in summer with no snow as barrier, it seems to be more difficult to over-cross fences in compare to winter.

The spatiotemporal crossing activity indicated a higher moving rate over highway fence when daylight is low. Activity have a negative correlation against daylight, which was clearly showed in April and May compared to January that had a more even distribution of crossings throughout the day. This knowledge could be used in further investigations and to better understand moose movement behavior and by that reduce risk of vehicle collisions.

Use more data and test home range and movement behavior over more than a year, a better result would be expected.

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