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# En riskanalys av älg nära väg

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Keywords: Alces alces, moose, traffic, collision, GIS, GPS, movement, migration, prevention methods

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## Abstract

For many decades the increase in traffic volume, expansion of highways and infrastructure has lead to an increase of wildlife vehicle collisions which are unfortunately very common in many countries today. They cause great deal of material damage and even kill humans or wildlife. Measures in the form of warning signs, under- and overpasses and fencing have been implemented for a long time with the help of observation by hunters and collisions sites. However this study focuses on the moose's perspective and the variables that, both spatially and temporally, could have an effect on why and when moose are close to certain types of roads. By equipping 50 moose *(Alces alces)* with GPS (global position system) collars and then analyze the positions in GIS (geographic information system) it was possible to create models that could predict where and when moose are closer to roads.

The results revealed no evidence that moose are closer to smaller roads, instead an increase of moose close to railroads appeared and also avoidance of larger roads such as major highways, highways and county roads. No evidence was found that moose are close to roads at any specific times during the day, but over the year the moose density close to roads increases for an inland population from December to May and for a coastal population July to November.

With more exact information on moose natural movements in a given area authorities can take earlier preventative measures before collisions occur such as seasonal warning signs, growing non-preferred vegetation close to road, higher embankments in certain areas and planning for under- and overpasses at the right location before new roads are being built.

## Sammanfattning

I dagens samhälle ökar biltätheten i samma takt som nya vägar och bostadsområden byggs upp. Allt fler viltolyckor sker med stora materiella kostnader och där liv offras, både människors och djurs. Åtgärder i form av varningskyltar, viltpassager och stängsel är mycket vanliga och har satts på plats där observationer av vilt har funnits eller där olyckor har skett. Denna studie görs utifrån älgars perspektiv och vilka variabler, både i tid och rum, som påverkar när och varför en älg väljer att vara nära en viss typ av väg. Genom att utrusta 50 älgar med GPS (globalt positioneringssystem) försedda halsband och analysera positionerna i GIS (geografiska informationssystem)är det möjligt att ta fram modeller som kan säga vart det finns större risk för älgar nära väg.

I min studie fann jag inga bevis för att älgar väljer att vara nära små vägar, däremot fann jag att älgtätheten ökade nära järnväg. Studien visade även att älgen undvek de större vägarna.

Jag fann inget som kunde styrka att älgtätheten nära väg skulle öka mellan gryning och skymning. Dock fanns en tydlig skillnad att det vissa månader var en högre älgtäthet närmare väg. I de två populationerna som undersöktes visade inlandspopulationen en ökning av älg nära väg under månaderna december till maj, medans kustpopulationen hade sin ökning under juli till november.

Genom att man med denna nya teknik få tillgång till en mer exakt information av älgens naturliga rörelsemönster i specifika områden kan myndigheter vidta åtgärder tidigare, före en olycka sker. Som exempel kan man sätta upp varningsskyltar med hastighetsbegränsning under säsonger med ökad risk, odla oätbar vegetation närmast väg, göra högre vägvallar och planera in viltpassager innan vägar har byggts.

## Table of contents

# Introduction

Today it is well known that collisions between wildlife, especially ungulates, and vehicles are an increasing problem worldwide (Rea 2003). As infrastructure grows the expansion of highway networks increase followed by a higher traffic volume and speed (Malo et al. 2004; Pynn & Pynn 2004). This leads to an increases in the number of collisions between wildlife and vehicles particularly in areas where migratory patterns cross roads (Groot Bruinderink & Hazebroek 1996; Malo et al. 2004; Pynn & Pynn 2004). Ungulate collisions are a major problem in many countries, especially developed countries such as those in Europe, the United States and Japan and are also of special concern in Fennoscandia (Groot Bruinderink & Hazebroek 1996; Rodgers & Robins 2006). Today there is increasing interest in roads and road location when looking at the reasons for and factors surrounding road kills, because of their influence on the environment around them (Litvaitis & Tash 2008).

When building roads the environment is strongly affected (Malo et al. 2004). Road construction changes the dynamics of the ecosystem in the area and destroys habitats (Malo et al. 2004; Litvaitis & Tash 2008). The expansion of urban areas reduces access to spatial and temporal refuges for wildlife which in turn leads to scattered home ranges and populations (Groot Bruinderink & Hazebroek 1996; Neumann 2006). The changes may increase the risk of wildlife vehicle collisions becoming more frequent due to changes and restrictions in movement patterns (Groot Bruinderink & Hazebroek 1996; Alexander & Waters 2000; Malo et al. 2004; Pynn & Pynn 2004; Krisp & Durot 2007).

Vehicle collisions with ungulates are just a minor part of the annual loss and even though the ungulate population numbers are not threatened by traffic, collisions may still be a major problem with conservation of wildlife resources (Groot Bruinderink & Hazebroek 1996). Changes such as new infrastructure may affect moose in many ways such as activity patterns, use of space, reproduction and survival rates (Neumann 2006). In the long run vehicle collisions impact the ungulate populations negatively and could be considered as a threat in certain areas (Rea 2003).

As previously stated, wildlife vehicle collisions (WVCs) are an increasing hazard, affecting traffic safety, wildlife conservation and last but not least the socio-economic issues such as human injuries and material damages that result from a collision (Groot Bruinderink & Hazebroek 1996; Finder et al. 1999; Rea 2003; Krisp & Durot 2007). The total loss increase by the number of collisions and the economic cost involves all from material, human injuries, police/wildlife officials' time, change in hunting opportunities and the cost of transportation (Groot Bruinderink & Hazebroek 1996; Rodgers & Robins 2006). Due to the high cost, both in lives and in material terms, it is important to find measures that could prevent collisions with wildlife (Joyce & Mahoney 2001).

By definition WVC are a result of a motor vehicle either hitting an animal or hitting another object in an attempt to avoid hitting the animal (Pynn & Pynn 2004). According to the Council for Wildlife Vehicle Collisions (2004) there were over 34,000 reported WVCs in Sweden during 2004 and almost 5,000 of them involved moose. Just in the last 30 to 40 years a tenfold increase has occurred among moose killed by trains and cars (Groot Bruinderink & Hazebroek 1996).

Västerbotten County had 323 collisions with moose reported during 2004 which constituted more than half of the wildlife collisions reported in the area (Council for Wildlife Vehicle Collisions 2004). More alarming is that collisions with moose increased by over 150 collisions between the years 2004 and 2006 in Västerbotten County (Council for Wildlife Vehicle Collisions 2006). From a study in 2001 it showed that in 2 out of 3 collisions with ungulates, moose were involved, and that 4 of 5 collisions with ungulates resulting in a death involve hitting a moose (Matstroms 2003).

In Sweden around 750 people are injured every year after collisions with moose and of those 80 die or are seriously injured (Groot Bruinderink & Hazebroek 1996; Matstroms 2003). For the ungulate involved it is almost always fatal. Ninety-two percent of moose and 98% of roe deer die (Seiler 2004). During the 1990s up to 5,000 moose and 25,000 roe deer were involved yearly in collisions that were reported to the police or SNRA (Swedish National Road Administration) which accounted for over 60% of all road collisions reported to the police (Seiler 2005). Although the numbers may be up to 50% higher since not all the collisions are being reported (Seiler 2005). The estimated costs of collisions with ungulates in Sweden are about 100 million Euros per year (Seiler 2004).

**Moose ecology**

Moose is the largest member of the deer family and is a coarse herbivore (compared to other ruminants such as roe deer) that during different seasons consumes different types of forage to get the optimized nutrient intake (Cederlund 1989; Nordengren 1997). Moose choose habitats by comparing food availability, predation risk and cost of locomotion (Dussault et al. 2005). In winter they feed on twigs of conifer-and deciduous species, especially young pine, and during summer the main food resources are tree leaves and herbs (Nordengren 1997; Dahlgren 2000). The presences of lakes within the habitats are important to moose, since aquatic habitats can produce food with a high concentration of minerals (Nordengren 1997). Moose eat Scots pine (*Pinus sylvestris*) and Lodge pole pine (*Pinus contorta*) during winter, and pines that grows in more fertile soils containing more nitrogen, phosphorus, potassium and less lignin which are good for the maximum intake of energy (Martinsson et al. 1983; Niemelä et al. 1988; Danell et al. 1991; Shipley et al. 1998)

As there is little non-human predation on moose in Sweden, the nutritional value of different habitats may be an important factor for a moose when it choose which habitat to browse in (Cederlund 1989; Mattson 1990; Ericsson 1999; Dussault et al. 2005). Compared to other animals moose tend to be found in higher densities in areas closer to town and human settlements (Maier et al. 2005). This is due to disturbed vegetation providing high quality food and also predators such as wolves and bears being more intolerant of human settlement (Maier et al. 2005).

Seasonal migrations of moose in northern areas has long been known and are described as the biannual movement along frequently used migrations routes between summer and winter range (Sweanor & Sandegren 1988; Ballard et al. 1991). In Sweden moose populations are said to be partial migrants, especially north of 60°N, as not all the moose migrate, each individual weighing the cost and benefit of migrating to a new habitat (Sweanor & Sandegren 1988). A moose probably chooses to migrate to find the best habitat, both in spatial and temporal terms, even if it means that the moose itself needs to adapt to a changed habitat (Sweanor & Sandegren 1988; Lundmark & Ball 2008). Therefore the migration can occur in any directions and depend on if the areas has good feeding habitat (higher proportion of pine), less snow or that the quality of snow are good so the moose does not sink through (Sweanor & Sandegren 1988; Nordengren 1997; Ball et al. 2001)

**When and where**

Animal distributions reflect the distribution of essential requirements such as food, water and reproduction (Litvaitis & Tash 2008). In searching for these they may use routes that involve ridges, powerline corridors, railroads, river and riparian corridors (Forman &

Deblinger 2000; Litvaitis & Tash 2008). As a result animals may concentrate their activities near roadsides or be forced to move close to roads in some areas, thus creating road kill hot spots (Litvaitis & Tash 2008). For example moose choose to stay close to roads to feed on clear-cuts that stimulate nutritious regrowth or use the road as a travel corridor during winters with deep snow or simply to lick salt and avoid flies (Dahlgren 2000; Rea 2003; Pynn & Pynn 2004). The vegetation of collision sites is often associated with forest areas, low crop cover, high habitat diversity and low presence of buildings, especially where dense forest meet open habitat (Malo et al. 2004).

Studies have been done on spatial aggregation of WVCs before (Malo et al. 2004) but all collisions may be affected by both spatial and temporal patterns (Seiler 2005). Temporal variables include mating, breeding, dispersal, food availability, migration, temperature, rain and snow, while spatial variables include animal abundance, location of foraging habitat, human settlement, landscape topography, fence locations and last but not least road alignment and traffic (Clevenger et al. 2001; Seiler 2005).

Compared to other animals, ungulates such as roe deer and moose are more often involved in collisions due to their camouflaging fur, size, and long-limbed body (Pynn & Pynn 2004). Because of its size and weight it is much more dangerous to collide with a moose than other deer (Krisp & Durot 2007). The dark fur of the moose is not reflective and their size and the fact that the moose tends not to look straight into headlights makes it harder for light to reflect in their eyes (Garrett & Conway 1999). Compared to smaller wildlife, moose tend to be less agile and defensive and having more unpredictable movement which could cause a greater risk of being involved in collisions (Pynn & Pynn 2004).

Ungulate road kills are in many cases associated with the higher activity rate that occurs during night, the breeding season and dispersal (Pynn & Pynn 2004). Around 70% of WVCs occur during summer and autumn (June to October) which often corresponds to the mating season (Groot Bruinderink & Hazebroek 1996; Joyce &Mahoney 2001; Pynn & Pynn 2004).

Peaks in WVCs are not random in space and time and differ between regions (Groot Bruinderink & Hazebroek 1996). For example southern Sweden has a peak in WVCs during calving in spring and rutting in fall, while northern Sweden peaks during winter when snowfall triggers to migration to lower areas or roads (Groot Bruinderink & Hazebroek 1996; Joyce & Mahoney 2001).

There is evidence that there were more calves involved in collisions from August to October when the cows becomes more mobile and the mating season starts, with the driver hitting the calf when trying to avoid the cow (Joyce and Mahoney 2001). During June to July there is a peak in WVCs among yearlings that are abandoned by the cows and in July to August more adult moose were involved in collisions (Joyce and Mahoney 2001).

The diurnal pattern of moose is that they are more active during hours closest to sunset, night and sunrise when the darkness gives protection and their foraging activities increases (Joyce & Mahoney 2001; Rea 2003). Seventy-five percent of WVCs occur between dusk and dawn when it is dark and during good driving conditions when a driver’s attention is likely to be decreased (Joyce & Mahoney 2001; Pynn & Pynn 2004). Only 22% of collisions occur during fog and rain and 5% during snow (Joyce & Mahoney 2001). At night time it is much harder for the driver to distinguish moose from the surrounding environment and it is more difficult to estimate the distance to the moose, especially if the moose is in silhouette (Joyce & Mahoney 2001). This gives the driver less time to react when a moose crosses a road (Joyce & Mahoney 2001). The driver may also be blinded by oncoming headlight from another vehicle or the animal may respond differently to headlights depending if it is day or night (Joyce & Mahoney 2001; Litvaitis & Tash 2008).

The Rodgers & Robins study from 2006 showed that most moose-vehicle collisions (MVCs) occurred during evenings from 6 pm to 2 am on two lane highways with increased speed limits and traffic volumes and with limited visibility due to vegetation. Seiler (2005) also concluded that MVCs were most likely to occur on unfenced roads and in hunting areas that gave good moose harvest. Matstroms (2003) supports Seilers theory that there is a higher risk of collisions on unfenced, public roads with a speed limit of 90km/h than on highways with cleared side vegetation and better sight. Matstroms (2003) also report that 2 out of 3 MVCs reported to the police occurred on 90 km/h road sections and that 9 out of 10 collisions with people who seriously injured or died occurred on roads with speed limits of 90 km/h or higher.

Other, more human, reasons for WVCs to occur include drink driving, talking to passengers, not wearing seatbelts (which increases the risk of death by 8 times), driving at night, traveling frequently on roads with known high wildlife usage or driving on straight roads which give good visibility and the resultant increased speed decreasing reaction time if an ungulates crosses the road (Joyce & Mahoney 2001; Pynn & Pynn 2004).

**Roads**

Roads affect many species, forming a barrier that creates habitat fragmentation, leading to potential habitat loss or alienation, road mortality and later possibly to local extinction (Clevenger & Waltho 2000; Dyer et al. 2002). The fragmentation and the physical barrier that roads create are considered to be highly threatening when it comes to maintain species diversity (Clevenger & Waltho 2000). Roads and other transportation corridors are often built in areas that follow the natural land contours and therefore often cross habitat and routes that are frequently used by ungulates for travel and migration (Rea 2003). Dussault et al. (2007) showed that moose often cross highways in areas with valleys, good feeding habitat and few lakes and rivers.

Compared to other ungulates that avoid roads moose take advantage of the road during winter as a travel corridor when the snow is deep, but mainly they use the roadside open habitat for feeding on deciduous shrubs or to find sodium in pools provided by snow accumulation (Rea 2003; Dussault et al. 2007). Rea (2003) also showed a peak of moose movement in corridors during spring with early plant growth and in autumn with late senescing forages.

Due to the high population of moose, fences are built along roads to increase road safety and avoid collisions (Dahlgren 2000). As previously stated fences or the road itself can act as a partial barrier for the moose migrating between summer and winter ranges and also during winter when the moose may congregate close to roads and cause damage to the forest, especially on regenerating pine clear-cuts, which are the main source of food for the moose (Dahlgren 2000; Jonsson 2001). Studies have shown an increased browsing pressure within 3 km of the highway (Ball & Dahlgren 2002).

Collisions rates are low in areas where the roads have high embankments (>2m) and good crossing points such as under- and overpasses for animals but higher in areas where the roads are at the same level as the landscape (Malo et al. 2004). Malo et al. (2004) also showed that there is a higher risk of collisions in areas with no building and high habitat diversity such as high forest cover and low crop cover. They also found that most collisions occurred on smaller roads with no fencing and only two lanes (Malo et al. 2004). The width of the road could also play a part if a moose choose to cross the road since moose often use forest edges as cover at a crossing smaller corridors contain more forest compared to larger roads (Rea 2003). Unfortunately these are the roads that get the least money spent on them for mitigation measures (Malo et al. 2004). The road barrier effect can differ a lot. A higher traffic volume could lead to a stronger barrier, but at low traffic intensity more species try crossing the roads more often which could lead to a higher road mortality rate (Krisp & Durot 2007).

**Moose in Sweden**

Sweden has one of the highest moose densities in the world with 0.7-0.9 moose/km$^2$ in Västerbotten (Hörnberg 1995; Ball et al. 2001). This is due to intense forestry and regenerating of the clear-cuts that create good moose habitat but also the lack of natural predators and good management by humans (Lavsund 1989). Moose are well adapted to the northern boreal climate and are found throughout Sweden (except Gotland). The population is up to 200,000 – 300,000 individuals during wintertime (Cederlund 1989; Jonsson 2001).The populations grew fast during the 1970s due to restrictions on hunting, an increased proportion of young pine and mild winter with little snow which led to low mortality and consequently a high percentages of calves (Cederlund & Markgren 1987).

The largest predation on moose is human hunting with 81-91%, second is the European brown bear (*Ursus arctos*) that account for 1% of adult moose deaths and 30% of calf mortality and the third is the wolf (*Canis lupis*),which kills about 4% of the population (Ericsson & Wallin 2001; Neumann 2006). Ungulates, such as moose, play an important role in the ecosystems, both in human society and in the food supply (Jonsson 2001). Here in Sweden the moose population is primarily regulated by hunting (250,000 people participate in the annual hunt) and therefore is of great economic importance to Swedish society (Mattsson 1990; Ericsson 1999).

**Aim**

The most common factors to determine WVC risks have been traffic volume, vehicle speed, occurrence of fencing, distance to the forest, moose abundance and the density of moose (Seiler 2005). With the advent of the new technique of GPS (global position system) and GIS (geographic information system) moose movement can be recorded in close intervals and it is possible to investigate how moose move and why and when they choose to be close to certain roads. By gaining knowledge of the factors that influence animal movement on to or across roads (Finder et al. 1999) and analyzing the different variables alone and together it should be possible to predict the location of animal crossings and create models that could predict collision sites. With help of the models, preventative measures for road safety and wildlife survival could be created (Malo et al. 2004). Therefore this study will focus on three major predictions:

1. Moose prefer to stay closer to smaller roads.
2. Moose are closest to roads between dusk to dawn.
3. The local density of the population of moose close to roads will differ over they year.

# Material and methods

**Study area**

The study was carried out in Västerbotten County in the north of Sweden (Fig.1). It is one of the largest counties covering one-eighth (55 432 $km^2$) of the total area of Sweden. Västerbotten lies within the middle boreal zone (Ahti et al. 1968) and can, due to both coast and mountains, have a large variance in climate and vegetation. The climate average temperature range in July is between 6 and 16ºC and in January between -6 and -15ºC. The summers are short between 1 June and 10th September and snow is typically present from November to April (SNA 2003). In coastal areas snow covers the ground 160 days a year with a median of 40 cm depth on 31 January, inland there is snow cover for 160-180 days and 50-60 cm depth (Ball et al. 2001). Daylight varies a lot during the year with only a few hours of daylight during winter to almost 24 hours a day during summer. The length of the growing season is about 150 days, starting in mid-May.

The composition of the county is mostly forest (53%) which is dominated by coniferous forest but also bog and alpine heath are very common vegetation types in the area. The most common tree species are Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), Lodgepole pine (*P.controrta*) birch (*Betula pendula*) and (*Betula. pubescens*) (Jonsson 2001). On the ground the dominating species are blueberry (*Vaccinium myrtillus*), lingonberry (*Vaccinium vitis-idea*) and heather (*Calluna vulgaris*) (McGuire 2000). In bogs the dominant species are willow (*Salix sp*.), dwarf birch (*Betula nana*), sedge (*Carex ssp.*) and grasses order *Poacea* (Ball et al. 2001). The area also represents clear-cuts and agricultural fields (Ball et al. 2001).

The roads in the county are divided into four different categories depending on their size: major highways, highways, county roads and secondary roads. According to SIKA (Swedish Institute for Transport and Communications analysis) 2004/05 over 180,000 vehicles were on the roads in the county and the car density was 461 cars per 1000 people in year 2004/05.

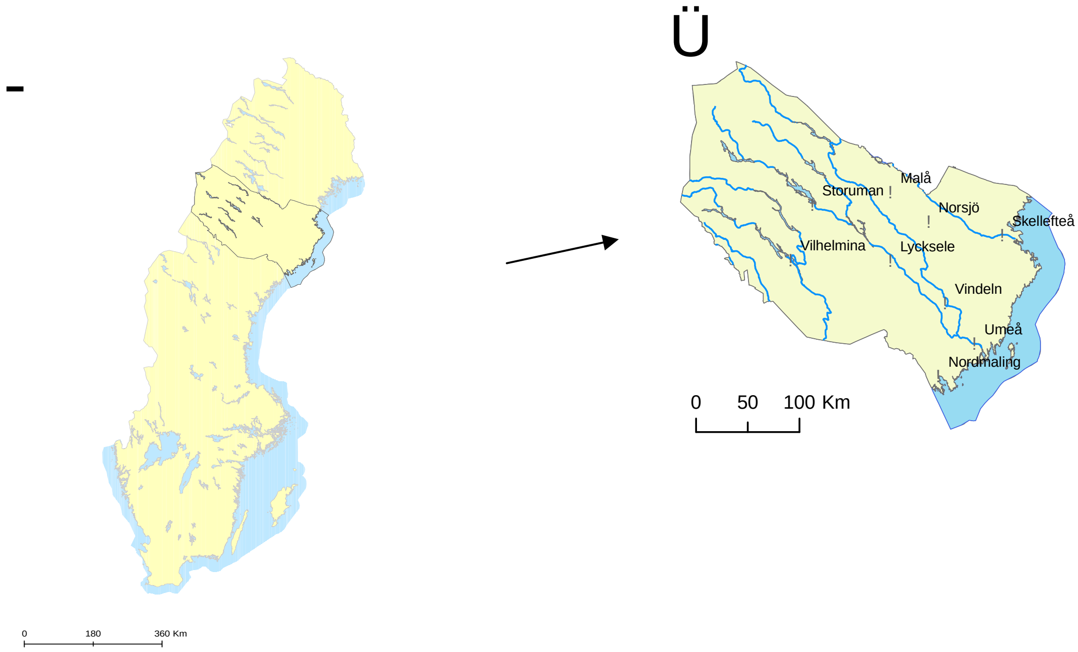


Fig. 1. The study area Västerbotten County, Sweden.

**Field methods**

Two moose populations were studied during 2004 and 2005 using GPS techniques. The coastal population (*Nordmaling*) with 23 individuals had data from 2004-02-28 to 2005-03-03 and the inland population (*Mittskandia*) with 27 individuals, had data from 2004-11-07 to 2005-10-31. As a part of an ongoing larger project *Älg i Mittskandia,* moose were equipped with a GPS telemetry collar and positional data was, with help of a GSM (Global System for Mobile Communications) mobile, transferred to a database. The collars were programmed to record the positions as coordinates in the Swedish grid system RT 90 every half hour. By using GPS telemetry collars for marking the positions in field a large dataset could be stored and a more detailed analysis per individual could be carried out (Dettki & Ericsson 2006).

**Data analysis**

The data analysis was started by using the GIS technology and the program ArcGIS 9.1 ArcGIS is the tool that was used to create maps of Västerbotten County and to plot GPS positions from the moose-track data. The method showed where there were higher moose densities, but to reduce the large dataset it was decided to create buffer zones around each road in Västerbotten. The buffer zones were equally independent of the road size, but for further analyses the roads were separated into four sizes: major highways, highways, county roads and secondary roads. To decide on a buffer that fitted the theory of moose close to roads, several articles were reviewed and decisions based on these.

The surrounding vegetation can both influence the driver's visibility and also the moose's movement. A moose can move up to 60 km/h and within 15 seconds it can move 250 m (Swedish hunting society). The average speed is 270 m/minute (Litvaitis & Tash 2008). Moose have different escape behavior, for example they might run to a safe distance but still be able to observe human activities (Baskin et al. 2004). As a driver one has different detection distances depending on speed, vegetation and light levels, Roger & Robins (2006) found in their study that a mean detection distance for all vehicle types was 105 m. Assuming a driver is on a road driving 90 km/h and spots a moose 50 m ahead, with the reaction and braking time the collision speed will still be 70 km/h (Moose accidents association) and cause great damage. With these facts the decision was made to set two buffers: 0-50 m from the road and 51-250 m from the road (Fig. 2). In further data analysis only the moose with positions within 250 m from road were included. The results were then exported to Microsoft Access where more necessary information was added on each moose and its position (Appendix 1).

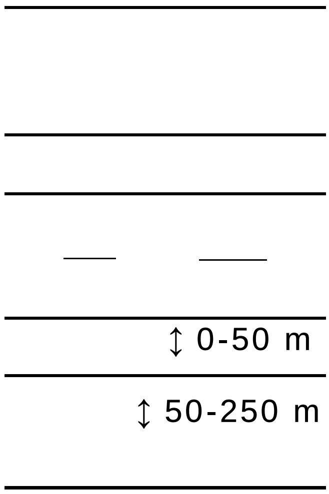


Fig. 2. Example of the buffer system.

Completing the database in Microsoft Access provided several different variables to work with and analyze that could indicate the factors that influenced the moose's choice to stay closer to roads. The variables fell into three categories (Table 1). If a moose were positioned or fulfilled the criteria of a certain variable, a number 1 was recorded otherwise it was set to zero or missing value, i.e. a binary classification. For example, a moose over 4 years equals a number 1, otherwise 0 (Appendix 1).

Table 1. Time-, road- and other variables in the database.

| **Road variable** | **Time variable** | **Other variable** |
|---|---|---|
| Major highway | Night | Coast population |
| Highway | Sunrise | Sex |
| County road | Sunset | Age |
| Secondary road | PM | Calf |

The first two predictions, that moose stay closer to smaller roads and that moose stay closer to roads during dusk to dawn, were analyzed statistically using JMP 7.0.1 (SAS Institute Inc 2007) with a generalized linear model with settings for binominal and logit function. The model was to test the relationship of a variable and closeness to roads. The variable tested could only have a 1 or 0 answer. Night (1) or not night (0).

The 50 m buffer was the response variable (y) in all cases and explanatory variable (x) was the variable containing road type, time and others (Table 1). Each variable was tested alone with a simple regression test.

Finally, a full model was created involving several variables that could give an exact prediction of the moose proximity to roads. For that a stepwise logistic regression test was used. The stepwise approach has the advantage of preventing problems of co-linearity among independent variables (Dussault et al. 2005).

For the third prediction, that moose density close to roads will differ over the year, a chi square test was used on both populations to see if there was a normal distribution or not.

## Results

A total numbers of records for the inland population were 201,837 GPS positions and for coastal population 351,259 GPS positions but by creating the buffer zones, the large dataset could be reduced from 553,096 GPS positions to 62,993 GPS positions.

The first prediction that moose choose to stay closer to smaller roads (secondary roads) was rejected with a p-value of 0.1096 (sig level 0.05). The three other road types all showed a significant result, but with a negative estimate, meaning it would be more likely that the number of moose decreases close to major highways, highways and county roads (Table 2). Only Railroads showed a significance p-value of 0.0001 with a positive estimate.

The second prediction that moose stay closer to roads during dusk to dawn was rejected (Table 2). Only the variable sunset (p= 0.0003) but with a negative estimate, which as mentioned previously shows a decrease of moose close to roads.

Apart from testing to see if road type and time could affect moose proximity to roads other variables were tested such as population, sex, age and calving. The results showed that all four variables may affect moose proximity to roads, but age was the only variable that had a negative estimate (Table 2).

Table 2. Estimate values (JMP 7.0.1, generalized linear model with binominal and logit function) for interaction between variables and 50 m buffer.

| **Variable** | **Estimate** | **P-value** |
|---|---|---|
| Major highway | -0.080 | 0.0012 |
| Highway | -1.635 | 0.0381 |
| County road | -0.698 | 0.0001 |
| Secondary road | 0.037 | 0.1096 |
| Railroad | 0.651 | 0.0001 |
| | | |
| Coast population | 0.182 | 0.0001 |
| Sex | 0.184 | 0.0006 |
| Age | -0.098 | 0.0002 |
| Calf | 0.435 | 0.0001 |
| | | |
| Night | -0.036 | 0.0698 |
| Sunrise | 0.014 | 0.7045 |
| Sunset | -0.139 | 0.0003 |
| PM | -0.035 | 0.0833 |

With the stepwise logistic regression test a full model that best could predict moose proximity to roads was created that included the variables county road, railroad, calving, population, sunset and age.

The third prediction, that the local density of the moose populations differ over the year could be confirmed with a Chi square test for normal distribution that got rejected. The amount of GPS positions within buffer for each population was plotted (Fig. 3a-b).

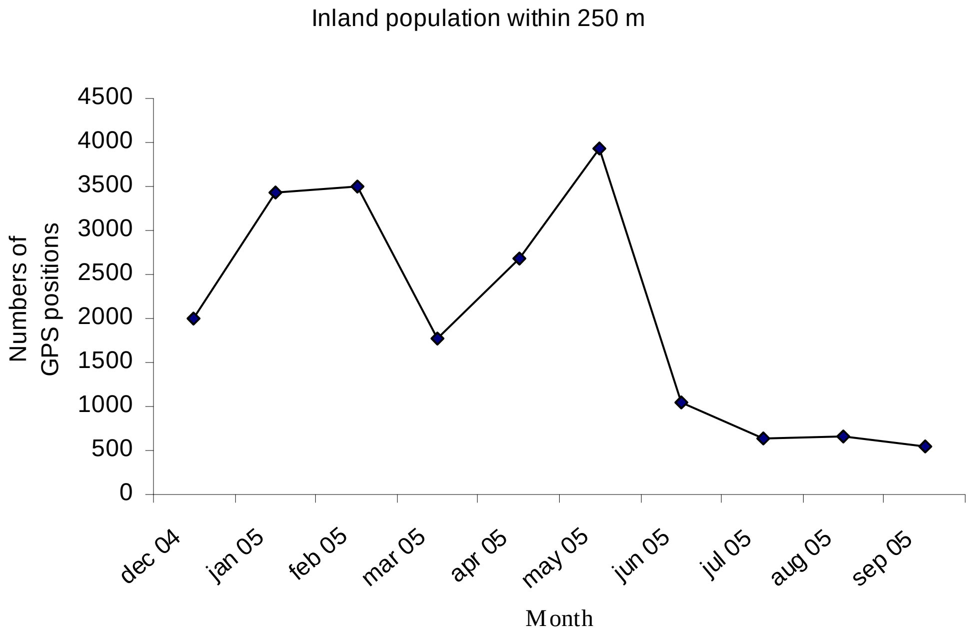


Fig. 3a. Numbers of GPS positions within the 250 m from road in inland population

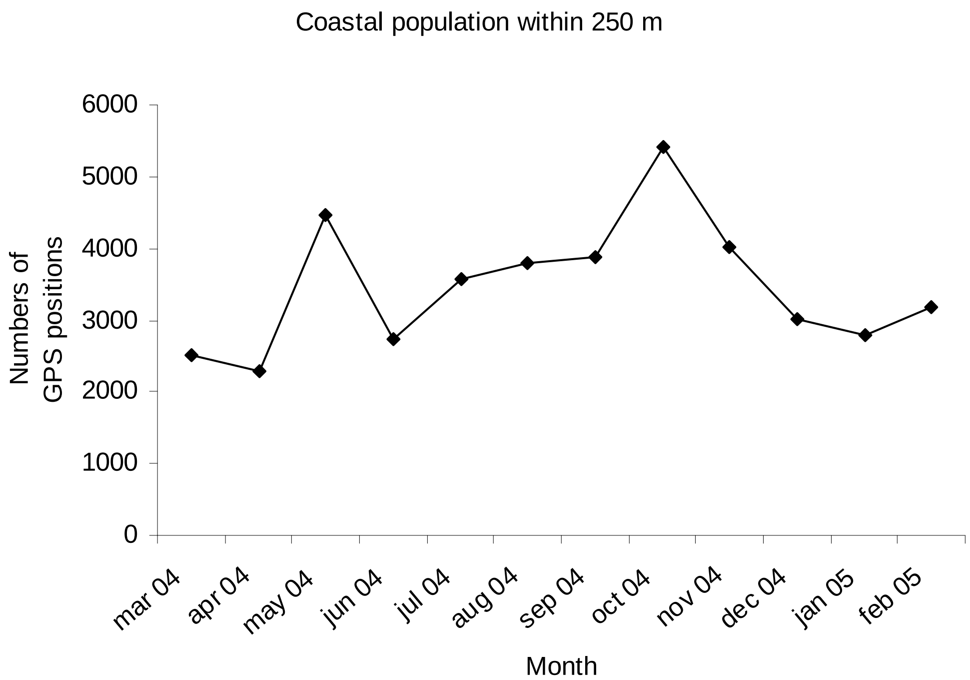


Fig. 3b. Numbers of GPS positions within the 250 m from road in coastal population.

To be able to compare which month had a higher density of moose within the buffer compared with the total amount of GPS positions, I created figures to show the results in percent, one for each population (Fig 4a-b). Clear differences are shown. For inland population an increase are shown in January to February and April to May. The coastal population show peaks in distribution in July to November but also a peak in May.

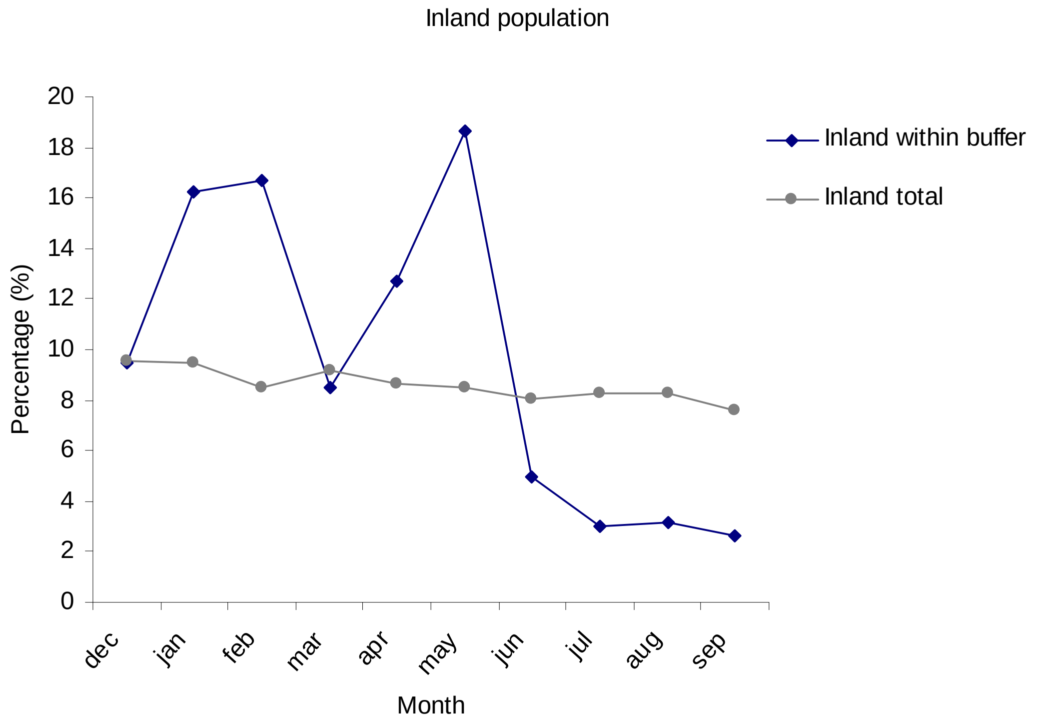


Fig. 4a. Show the distribution of GPS positions in percent in the inland population within 250 m from road compared with the total over the year.

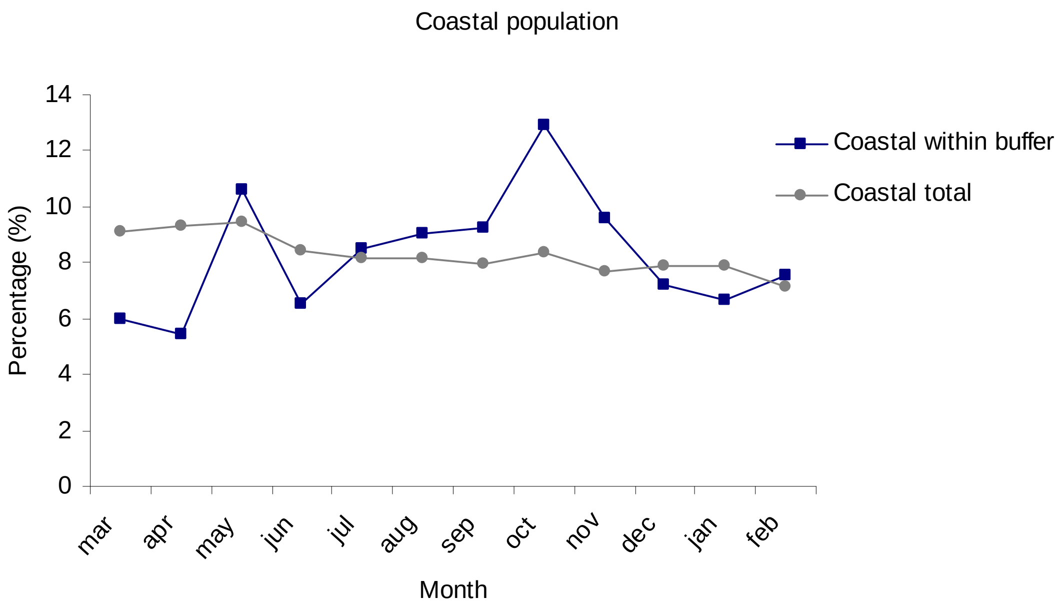


Fig. 4b. Show the distribution of GPS positions in percent in the coastal population within 250 m from road compared with the total over the year.

## Discussion

The focus and aim of this study was to determine which kind of road type and variable that either alone or together could have an impact on when and why moose are closer to roads. The results of the analysis showed that it is possible to predict the location of moose close to roads in two ways, both spatial and temporal, and therefore it should be possible in the future to predict sites with higher risk of collisions with moose.

The first prediction that a moose stays closer to secondary roads compared to larger roads was rejected and the results showed a significant correlation with the other roads (major highways, highways and county roads) but with a negative estimate, that is a probability that number of moose decreases closer to those roads. Only railroads showed significance with a positive estimate, an increase. It is documented that most wildlife collisions occur on smaller roads, especially within an unfenced moose home range with forest and hedges close by (Malo et al. 2004; Neumann 2006). Finder et al. (1999) also showed evidence that a greater distance to forest decreased the risk of wildlife collisions sites. The results from this study showed no significant correlation with smaller roads but it can be explained that moose do not need to spend a lot of time close to smaller roads and there is no obstacle for them to cross the road for a better feeding habitat, water resource or to follow the natural migrations path. However on smaller roads the speed limit can be high and cause a high impact collision between wildlife and human and this might be more serious on a small unlit, unfenced road surrounded by forest, without extra lanes and with nothing to give the driver warning of wildlife close to the road. This compares to larger fenced roads with clear-cuts or embankments that could help the driver see the animal in time and reduce speed. Unfortunately it is the smaller roads that do not attract investment (Malo et al. 2004) when it comes to preventative measures even though one single collision can cost an amount of money and potentially a loss of life.

Studies have shown that wildlife try to avoid areas of human settlement, larger roads and high traffic density (Dahlgren 2000), which could explain the negative trend found of moose close to major highways, highways and county roads. Although many species seems to have a high tolerance of roads, the number of collisions is determined by the way they react to traffic; some stand still and other run from or towards the road (Groot Bruinderink & Hazebroek 1996). Both Forman & Alexander (1998) and Burson (1999) saw a decrease of animals within 100 m from roads but Burson concluded that the moose were used to the traffic and did not show any changes in abundance, distribution or behaviour. However Dussault et al. (2007) showed that the moose movement rate increased before, during and after a highway crossing and that maybe this finding could be applied to the results of this study. After a crossing moose move beyond the buffer zone defined into a safer area, even Dussault et al. (2007) showed that distances within 500 m from roads were an unsuitable habitat for moose.

It is possible that on larger roads moose tend to run from traffic in time thus avoiding accidents rather than on smaller roads where more collisions may occur, because smaller road does not have the sound of high traffic intensity or wide open areas associated to larger roads. Krisp & Durot (2007) also stated that higher traffic flows give a larger barrier effect which might prevent wildlife crossing roads, but also that smaller roads give a smaller barrier effect that could cause more crossings of wildlife.

Only at railroads was there a tendency for a higher density of moose within the buffer zone. An explanation for this could be that moose may use the tracks as travelling corridors as they run straight through good feeding habitat or home ranges. Also areas close to railroads are often clear-cuts and good feeding habitat for moose.

Prediction number two, that moose stay closer to roads during dusk to dawn was rejected. Cederlund (1989) found that moose are active during the day, but most active close to sunrise and sunset and that the distribution of good feeding habitats influences the activity pattern and habitat use. Even studies from Groot Bruinderink & Hazebroek (1996) declare a higher risk of traffic collisions with ungulates during the hours of darkness. However this study's finding is that crossings during night are random rather than following a pattern and that the driver's visibility is reduced which could lead to unexpected and sudden encounters with moose or other wildlife. This is despite the fact that drivers should be more aware of the risk in areas known as good feeding habitats.

It is interesting to note that the coastal populations *Nordmaling* were found closer to roads than the inland population, *Mittskandia*. This implies that moose are at a higher risk in coastal regions than inland. A reason for this could be that many roads run close to the coast whereas they are more widely distributed inland. The sex of the moose also seemed to be a contributory factor, but with so few bulls included in the data that definitive conclusions cannot be drawn. If a moose had a calf a strong correlation was shown which can be explained as the cow may use roads as travel corridors for the new born but also they may spend a longer time close to roads due to slow movement. With age, proximity to roads decreased and it may be that moose learns by the year which roads and areas to avoid and they may create their own traditional walking routes.

The third prediction was that density of moose close to roads would be of normal distribution over the year. A chi square test of the two populations' distribution was rejected. *Mittskandia* had increased density from December to May, *Nordmaling* from July to November. Since moose in the north are said to be partially migratory, it is probably correct that the normal distribution would be rejected. Several studies have been carried out on snow and its effect on moose and other ungulates. For example Lundmark & Ball (2008) showed that both the snow's quality and quantity can be highly significant when it comes to migratory behaviour and the start of the movement from summer to winter ranges since it affects the food availability and the energy cost to walk. A snow depth greater than 70cm forces moose to travel on ploughed areas such as roads, and studies from Norway show that during winters with deep snow moose have their winter ranges close to railroads (Gundersen et al. 1998; Garret & Conway 1999). This may bring them closer to human settlements.

As moose are generalist herbivores they feed on different vegetation at different times of the year. This influences their habitat choice and their migratory behaviour and for example Ball et al (2001) found evidence that during winter moose prefer areas with pine 5-30 years of age and spruce which are over 70 years old. These would provide good food and also cover from deep snow (Ball et al 2001). During spring moose would move closer to roads and railroads for feeding since open areas lose their snow early leading to early growth of forage (Lundmark & Ball 2008). In agreement with Joyce and Mahoney (2001) this study found it important to look further into the habitat use and the seasonal movement of moose to reduce the number of MVCs and not just look at the moose densities.

Other factors that could influence moose movement close to roads at certain times of year are the predation risks of wolves and bears (Neumann 2006). At these times moose may choose to be closer to roads since they are more used to human settlement then the predators. During the hunting season moose may move further away from roads, seeking refuge from hunters (Neumann 2006).

**Preventative measures**
Many preventative measures have been tested over the years in an attempt to make roads safer for both human and wildlife, although few have been effective (Rea 2003). Measures such as fencing and the use of mirrors, road signs, over-and underpasses, road-level crossings and whistles have been used in order to try and reduce wildlife vehicle collisions. No measure has been found to work in isolation; rather combining several measures has been proven to be the most effective approach (Malo et al. 2004).

With help of GIS and GPS technology it is possible to understand the landscape structure and its effect on the moose movement patterns (Fahring & Merriam 1994). A GPS collar provides increased locational accuracy but it is a more expensive method then the standard telemetry equipment and one which can lead to pseudo-replication (Moen et al. 1996). In the follow section different preventative measures will be discussed and the positive and negative impact they could have assessed.

When building roads today it is important to focus on their construction both from a human and wildlife point of view. With the GIS and GPS technology, road contractors could establish where the highest risk of moose and other ungulates crossing could be and construct over - or underpasses or completely avoid such areas. For example topographic features, such as bends and slopes, which give reduced visibility and parts of home ranges that acts as breeding or calving ground are areas where there is a higher risk of collisions and these should be avoided (Groot Bruinderink & Hazebroek 1996).

Passages for wildlife were first constructed in the 1970s and are widely used as a preventative measure in many parts of the world today (Clevenger & Waltho 2000). It is less expensive to build the passages when planning to build a new road than to reconstruct an existing road (Groot Bruinderink & Hazebroek 1996). The passages' purpose is to increase the permeability and habitat connectivity across roads and it is important that the passage works for more then just one species (Clevenger & Waltho 2000). The design of overpasses should be of a wide visual angle and a short passage while the underpasses could have a more natural design combining with landscape and hydrological features (Groot Bruinderink & Hazebroek 1996). The number of passages needed in an area depends on the ungulates' migratory behaviour, their confidence in the passage, its structure and the presence of fences (Groot Bruinderink & Hazebroek 1996). Today many passages are combined with fencing and vegetation to direct the animal to the crossing (Forman & Alexander 1998).

The efficiency of fences from a traffic point of view has been studied in many part of the world and Clevenger & Waltho (2000) found that fencing could reduce collisions by 80% while a Krisp & Durot study from Finland in 2007 showed that out of 4719 collisions with moose 1239 (26%) occurred within sections where warning signs were and only 199 (4%) occurred within fenced roads. Seiler (2005) showed that fencing a 90 km/h road and clearing vegetation gave a 26% reduction of collisions risk and at 70 km/h it would give a 65% reduction.

Fencing is the most efficient preventative measure from a traffic point of view to reduce the number of WVCs although it is expensive, fragments habitats and affects the animals' movement patterns (Andreasen et al. 2005; Gundersen et al. 2005). Fences could interfere with the migration of moose between summer and winter ranges and could isolate populations, or the animals could get hurt or trapped inside the fenced corridor when trying to cross a road (Dahlgren 2000; Krisp & Durot 2007).

Animals are forced to move along the fences and the danger of collisions is moved towards the end of the fences (Krisp & Durot 2007). Clevenger & Waltho (2000) found that more wildlife collisions occurred at the end of fences and it is important that other preventative measures such as warning signs, increases lightning and lower speed limit are used in such areas.

A road sign warning of wildlife is a common and inexpensive way of getting the driver's attention and raising their awareness of wildlife close to roads. Warning signs are often permanently placed following suggestions from hunting associations, local authorities or where collisions have previously occurred (Krisp & Durot 2007). However the drivers get accustomed to the signs which loose their impact and a study showed that only 40% of the drivers noticed signs and moose dummies (Groot Bruinderink & Hazebroek 1996; Krisp & Durot 2007). To get drivers' attention with warning signs it is important that the signs are seasonal and lit, preferably triggered by the ungulates, and that a reduced speed limit is introduced with the sign on the most dangerous road sections (Groot Bruinderink & Hazebroek 1996; Rodgers & Robins 2006). It is also important to site the sign in the correct location where there is a high risk of collisions as it has been proved not to be efficient if warning signs cover long stretches of roads because people tend to notice them less (Malo et al. 2004; Krisp & Durot 2007).

Removal of vegetation, such as trees and shrubs, is one way to increase the visibility of wildlife for drivers and hence improve road safety (Rea 2003). This approach might reduce the risk of moose staying close to road, but the removal could also allow new plants to grow and attract ungulates (Groot Bruinderink & Hazebroek 1996; Rea 2003). Today vegetation management uses methods such as the elimination of roadside vegetation, planting inedible and thorny cover plants and the creation of diversionary feeding (Groot Bruinderink & Hazebroek 1996; Rea 2003). Unfortunately this kind of measure has not proved very efficient or very cost-effective at a landscape level (Rea 2003). Rea (2003) points out the importance of cutting vegetation at the right time of year, early in the growing season. Cutting in the middle of a season leads to a regrowth of higher nutritional value then at other times of the year (Rea 2003). Forest clearing increases the visibility for both drivers and moose and although forest clearing is expensive initially it has a low maintenance cost and it is proven to be efficient since it prevents animals staying and browsing close to roads and railroads (Gundersen et al. 2005). Instead the animal moves across the clearing or avoids the area completely since some animals require cover to move safely (Gundersen et al. 2005). Studies show that vegetation removal 20-30 m from a railroad gave a 56% reduction of moose-train collisions (Groot Bruinderink & Hazebroek 1996). Openings in forested areas, due to forestry or agriculture, should be located far from roads (Groot Bruinderink & Hazebroek 1996) since ungulates prefer to feed in open areas instead of the forested ones (Malo et al. 2004). It is important to say that the focus of this study has been on the moose and the models created are only tested on moose. There can be a large variance of roads sections where wildlife collisions can occur with other animals because different animals prefer different kind of habitat and food (Malo et al. 2004).

As mentioned in the introduction, moose and other ungulates may use roads for many reasons, one of which would be to lick salt. Dussault et al. (2007) found that highway crossing sites were located closer to brackish pools with high sodium concentration and Groot Bruinderink & Hazebroek (1996) concluded that many collisions with deer occur because of the salt from snowmelt and the use of salt on roads. Their recommendation is to use Cam-acetate instead of NaCl which is more attractive to animals (Groot Bruinderink & Hazebroek 1996).

Finally, it is very important that more education is made available for the driver about wildlife and road safety because for drivers the best way to improve road safety is simply by reducing speed, staying alert while driving during dusk to dawn, and taking notice of warning signs (Joyce & Mahoney 2001; Pynn & Pynn 2004).

**Further studies**

Many studies have focused on the features of road sections that have high collision rates (Malo et al. 2004). In this study it was not known whether a certain road or area had a higher risk of collisions with or without fencing. The sole focus of the study was to examine whether moose choose to be close to smaller or larger roads and at which time and season this occurs. On the basis of the study further investigation could be done that focuses on specific roads or road sections with higher densities of moose within the buffer. Carrying out a complete inventory of the area and its landscape, looking at the types of vegetation growing, the number of moose in the area, the types of preventative methods for wildlife collisions used in the area, the number of road kills that has been reported and the impact of human influence on the area.

To create new more effective solutions to reduce wildlife collisions it is important to create complete models containing all the information that is available. The models should be based on road kills, traffic density, date, time, place, species, sex, age, calf, breeding and calving ground, weather conditions, geographical distribution and population size and trends (Groot Bruinderink & Hazebroek 1996). Additionally the models should include variables such as forestry, agriculture and human settlement. By identifying resources and features that could have a role in why and when wildlife vehicle collisions occur and combining them with GIS models could be created to predict high risk collision sites and where mitigation measures should be carried out (Groot Bruinderink & Hazebroek 1996; Litvaitis & Tash 2008).

# Conclusions

The analysis carried out in this study revealed no evidence that moose tend to be found closer to smaller roads, which could be due to smaller roads not having any fencing and a low car density. In such areas moose could move freely over habitats to better feeding grounds without any barrier effect. The results showed that moose avoided larger roads which is probably due to the study's narrow buffer zone of 250m. The larger the road, the stronger the barrier effect. At a larger road the higher traffic density, the fencing and the reduction of vegetation could hinder the moose from moving close to the road. Although an increase of moose close to railroads was found. Railroads often run straight through good feeding habitat and could be used as travel corridors for the moose during deep snow.

No evidence was found that moose are located within the buffer at specific times during the day but over the year it was found that the moose density close to roads increases for the inland population from January to May and for the coastal population from July to November.

The recommendation arising from the study for the future is to investigate this topic further and to establish models that could be used throughout the country and outside it. With the knowledge gained it would be possible to predict where and when moose are to be found close to roads and to apply this information when planning new roads, infrastructure and agriculture. Building and creating safer roads would be cost effective and would save lives, rather than suffering the consequences of misplaced warning signs and other inappropriately applied preventative measures or indeed not applying preventative measures at all.

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## Appendix 1.

| Classification | Description |
|---|---|
| Object_ID | A unique number for each moose in the project |
| Collar_ID | Can be the same for more then one moose, depending on what time they got the collar on |
| GMT_Date | Time |
| Sunrise | The time when the sun goes up |
| Sunset | The time when the sun goes down |
| Locale_N | GPS position |
| Locale_E | GPS position |
| Nordmaling | Coastal population |
| 50m buffer | If the moose is within 50m from road = 1 other= 0 |
| 250m buffer | If the moose is within 50-250m from a road = 1 other = 0 |
| Major highway | If the moose is on major highway = 1 other = 0 |
| Highway | If the moose is on highway = 1 other = 0 |
| Countyroad | If the moose is on countyroad =1 other = 0 |
| Secondary road | If the moose is on secondary road =1 other =0 |
| Railroad | If the moose is on railroad=1 other =0 |
| Age | If the moose is older then 4 years = 1 other = 0 |
| Sex | If the moose is a female =1 other = 0 |
| Night vs. Day | If the moose is close to within buffer between sunrise and sunset= 1 other = 0 |
| Sunrise vs. Other time | If the moose is close to road during dawn(1 hour before and after sunrise) = 1 other = 0 |
| Sunset vs. Other time | If the moose is close to road during dusk (1 hour before and after sunset) = 1 other= 0 |
| Sunrise and Sunset vs. Other time | If the moose is close to road during sunrise and sunset = 1 other = 0 |
| Calf | If the moose has been given birth to calf = 1 other =0 |