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# No mitigating effects of roadside vegetation clearing on ungulate-vehicle collisions in Nord-Trøndelag

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# ABSTRACT

The number of ungulate-vehicle collisions has increased substantially over the last few decades. To reduce the number of accidents several mitigation measures have been implemented, but there is in many cases no evaluation of their collision preventive effect. By analysing moose *(Alces alces)* and roe deer *(Capreolus capreolus)* collision data from 2009 – 2015, I evaluated the effect of roadside vegetation clearing conducted in 2011 and 2012 in Nord-Trøndelag in central Norway. In the cleared areas I expected a substantial decrease in collision probability in the year after a clearing, followed by a slow increase as the vegetation re-emerged. I found that for both species the probability of a collision was substantially higher in cleared compared to the uncleared areas, indicating that the areas with high risk of collisions are targeted for vegetation clearing. However, the results revealed no reduction in the number of roe deer and moose collisions following clearing, indicating that vegetation clearing has no collision preventive effect. For moose, I found the number of collisions on cleared and uncleared stretches to be synchronised among years, and that the annual growth in collision numbers and snow depth were positively correlated. This suggests that snow depth is an important factor influencing the number of moose-vehicle collisions in Nord-Trøndelag.

# SAMMENDRAG

I løpet av de siste tiårene har antall hjorteviltulykker økt betraktelig. For å redusere antall ulykker har en rekke avbøtende tiltak blitt iverksatt, men det er i mange tilfeller mangelfull validering av tiltakenes effekt. Ved å analysere kollisjonsdata fra 2009 – 2015 for elg- *(Alces alces)* og rådyrulykker *(Capreolus capreolus)* i Nord-Trøndelag i Norge evaluerte jeg effekten av vegetasjonsrydding som ble utført i 2011 og 2012. Det var forventet en betydelig reduksjon i antall ulykker i året etter rydding, etterfulgt av en gradvis økning som følge av at vegetasjonen kom tilbake. For begge artene var sannsynligheten for en kollisjon høyere i ryddede enn i uryddede områder, noe som tyder på at det er de mest risikoutsatte områdene som blir ryddet. Jeg fant derimot ingen reduksjon i verken elg- eller rådyrulykker etter vegetasjonsrydding, hvilket indikerer at tiltaket ikke har noen kollisjonsforebyggende effekt. For elg fant jeg at antall kollisjoner på strekninger rydda i 2011 og 2012 og strekninger som aldri har blitt rydda samvarierte, og at antall kollisjoner og snødybde var korrelert. Dette indikerer at snødybde er av stor betydning for antall elgulykker i Nord-Trøndelag.

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# INTRODUCTION

The last decades we have seen a tremendous development in the European transport sector; there has been a doubling in passenger transport, the number of cars have increased by one and a half and there has been a tripling in the length of motorways (Akerman et al., 2000). This is a development seen worldwide, and it is projected that by 2030 there will be over 2 billion vehicles in the world, 2.5 times more than in 2002 (Dargay and Gately, 1999, Dargay et al., 2007). The increasing traffic volume and development of the road network have great ecological consequences, as indicated in several reviews (Andrews, 1990, Forman and Alexander, 1998, Spellerberg, 1998, Trombulak and Frissell, 2000, Seiler, 2001). Seiler (2001) distinguishes between five categories of primary ecological effects of transport infrastructure on wildlife: habitat loss, disturbance, corridors, traffic mortality and barriers. Fragmentation can potentially have large detrimental impact on nature, as roads can act as barriers for many species and create fragmented landscapes (see for example Andrews 1990). This is for example seen in Norway, where roads and power lines act as barriers for reindeer (Vistnes et al., 2004).

The most obvious consequence of roads and traffic is the death of animals when colliding with vehicles, and for some vulnerable species traffic collisions can be a threat to population viability (Carsignol, 1989). For instance, in the Florida panther *(Felis concolor coryi)*, 50 % of the mortality is caused by traffic collisions (Foster and Humphrey, 1995). For most species, however, traffic collisions are not a threat to the viability of the species. Many species experience a large number of casualties due to collisions, but this is often because the species is abundant, rather than being particularly vulnerable to traffic mortality (Seiler, 2001). Bruinderink and Hazebroek (1996) for example, studied ungulates in large parts of Europe and since the traffic losses were low compared to the annual harvest, all populations were considered viable.

Nevertheless, during the last decades there has been a substantial increase in traffic collisions involving wild animals in both Europe and North America (Bruinderink and Hazebroek, 1996, Lehnert et al., 1996, Romin and Bissonette, 1996). Collisions are causing the death of millions of animals while many humans are killed and injured. In addition there are severe material costs, and ungulate-vehicle collisions (UVCs) are consequently a major road-safety issue. Lalo (1987) estimated that one million vertebrates are killed in the US every day. In Europe alone (without Russia) Bruinderink and Hazebroek (1996) estimated that 500 000 ungulates were killed yearly in traffic accidents, resulting in 300 humans killed, 30 000 humans injured, and material damage for over one billion Euros. For the U.S., Conover et al. (1995) estimated that the number of deer-vehicle collisions exceeds 1 million annually, causing approximately 29 000 human injuries and 200 fatalities.

The accident trend has been the same in Norway as seen in Europe and North America. In total about 6000 ungulates are killed annually on Norwegian roads and railways (Statisitics Norway, 2015), but since these statistics only include accidents with fatal outcomes, the number of collisions are significantly higher (Vegdirektoratet et al., 2014). On average 2-5 humans are killed per year as a result of ungulate traffic collisions, while 5-20 are severely injured, and the societal costs are estimated to about 900 million kroner per year (Vegdirektoratet et al., 2014).

Between 1970 and 2007, the number of moose *(Alces alces)* killed in traffic in Norway (cars and trains) increased from about 200 to 2100 (Solberg et al., 2009), and for the last 15 years the number of moose killed in traffic has fluctuated between 1500 and 2000 (Statisitics Norway, 2015), where the majority (about 65 %) occurs on roads (Solberg et al., 2009). The number of roe deer *(Capreolus capreolus)* killed in traffic is about twice as high, with about 4000 individuals killed yearly, which in turn has increased substantially from 1970, when 200 individuals were killed (Solberg et al., 2009). About 90 % of these roe deer collisions happen on roads (Solberg et al., 2009).

Many factors can affect the number of UVCs, of which population density and traffic intensity (as a measure of the number of vehicles per time unit) seem to be particularly important (Lavsund et al., 2003, Seiler, 2004, Solberg et al., 2009, Rolandsen et al., 2011). The increase in moose and roe deer related accidents in Norway during the last 40 years is closely related to an increase in ungulate population densities and traffic intensity in the same period (Solberg et al., 2009). In addition, the vehicle speed seems to be an important factor influencing the risk of moose-vehicle collisions (MVCs) in

Sweden (Seiler (2005). This effect was not linear as the highest risks were found at intermediate traffic intensities, above which traffic seems to have a deterrent effect (Seiler, 2005). Speed limit has also been shown to be an important factor influencing deer collisions in Canada (Ng et al., 2008).

In seasonal environments, light conditions and climatic factors also influence the number of accidents (Gundersen and Andreassen, 1998, Haikonen and Summala, 2001, Joyce and Mahoney, 2001, Rolandsen et al., 2011, Sullivan, 2011). In Norway, most UVCs happen during winter when days are short and snow is restricting locomotion and access to food for most wild ungulates (Solberg et al., 2009). More accidents are typically recorded in snow rich and cold winters, particularly in municipalities with on average deep snow (Solberg et al., 2009). This is probably because moose and deer tend to move to lower altitudes during winter, where there is less snow, and where the density of roads is higher (Gundersen et al., 1998, Solberg et al., 2009). Moreover, as ungulates are most active during dusk and dawn (Haikonen and Summala, 2001), this period coincides with high traffic intensity during winter, increasing the probability of accidents (Rolandsen, 2010, Huseby, 2013)

To decrease the socioeconomic costs related to ungulate vehicle collisions, several mitigation actions have been implemented (Andreassen et al., 2005, Huijser et al., 2009). Warning signs are probably most widely used (Romin and Bissonette, 1996, Putman, 1997, Sivertsen, 2010), but also vegetation clearing, scent marking, wildlife reflectors, intercept feeding, and wildlife fences are regularly used to prevent wildlife collisions (Huijser et al., 2009, Sivertsen, 2010). However, the mitigating effects of these actions have been evaluated far too seldom. An important step forward is therefore to quantify the accident-reducing effect of the various measures, and to determine what measures are providing the most cost-effective results.

Vegetation clearing is a widely used mitigating measure in Norway in order to reduce UVCs. Similar measures are also implemented in other parts of the world, but there are few studies evaluating their effect. In Norway, the procedure involves removing trees, shrubs and other vegetation in a distance of 6-25 meters from the road (Iuell, 2005). The assumption is that ungulates will be less likely to reside in cleared areas and therefore spend less time next to the road and cross roads more seldom. Vegetation clearing along the road edges will also make ungulates crossing roads more easily detected, and thus give car drivers more time to react and avoid collisions. This can prevent accidents from happening or reduce the severity of the accidents if they occur (Antonson et al., 2015, Iuell, 2005). However, emerging new vegetation (as a consequence of vegetation clearing) has also been shown to attract ungulates to roadsides, for example white tailed deer (*Odocoileus virginianus)* (Waring et al., 1991) and moose (Child et al., 1991). A prerequisite for success is therefore that cleared areas are regularly maintained to avoid new vegetation to emerge and create attractive foraging habitat (Iuell, 2005).

Studies that have examined the effect of vegetation clearing have found mixed results (e.g. Jaren et al., 1991, Sivertsen, 2010, Meisingset et al., 2014, Rolandsen et al., 2015, Eriksson, 2014): Sivertsen (2010) showed that vegetation clearing can cause both a decrease and an increase in number of accidents, and discussed if the absence of effect (or even negative effects) might have been the result of poor maintenance of the clearing zone, making the vegetation clearing inefficient or counterproductive due to regrowth. Lavsund and Sandegren (1991) found that vegetation clearing resulted in a 20 % decrease in moose-vehicle accidents in Sweden, while Jaren et al. (1991) found that vegetation clearing resulted in a 50 % reduction in the moose accident rate on railways. In much of the same area, Rolandsen et al. (2015) found some support for a decrease in moose-train accidents in the years following vegetation clearing, but the results were associated with a high level of uncertainty. Eriksson (2014) found no collision preventive effect of tree removal along railways in Sweden. In a driving simulator study focusing on moose encounters, Antonson et al. (2015) found no effect of the vegetation on driving speed, speed variability, or visual scanning of road sides in general when comparing open and forested landscapes. However, when a moose was present, drivers reduced speed more when vegetation was sparse along roads than when the vegetation was dense. The latter supports the hypothesis that vegetation clearing will reduce the number of UVCs because drivers reduce speed and consequently may avoid accidents more often.

The main aim of this thesis was to investigate the effect of vegetation clearing as a mitigation measure on UVCs (moose and roe deer) in Nord-Trøndelag County in central

Norway. In this county, the use of vegetation clearing has been conducted along several road stretches during the last three decades, but like in other parts of Norway, both the extent of clearing and the maintenance frequency were only partly known (Sivertsen, 2010). During the last decade, better databases and tools to report and store both ungulate-vehicle collisions (e.g. www.hjorteviltregisteret.no) and the location of stretches cleared of roadside vegetation (e.g. www.gint.no), have been developed. Hence, in this study I restricted my dataset to the period covering the last seven years (2009-2015) when most municipalities in the county reported vegetation clearing data to the County Council, and recorded georeferenced UVCs. During the study period extensive vegetation clearing was conducted on parts of the road network in 2011 and 2012. This made it possible to examine whether the accident rate changed after clearing as compared to the conditions prior to clearing and on stretches that were not previously cleared.

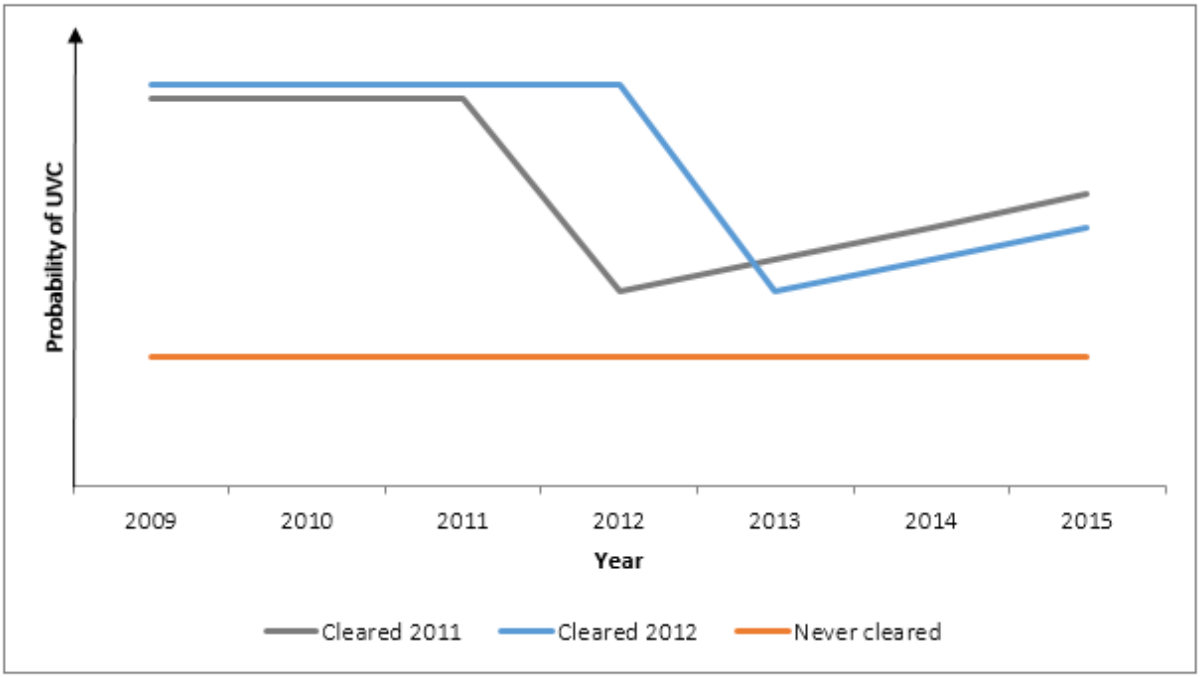



Figure 1. A conceptual illustration of the predicted responses in probability of UVC following clearing of roadside vegetation in Nord-Trøndelag County in 2011 or 2012, given that density and environmental effects are constant.

Based on the hypothesis that vegetation clearing has a preventive effect on the probability of traffic accidents with moose and roe deer, I predicted a significant decrease in the probability of UVCs on cleared stretches as compared to the conditions prior to clearing and on stretches that were not previously cleared (Fig. 1). Indeed, because the cleared stretches were relatively evenly distributed on the road network

(Fig. 2), I expected the UVCs in cleared and uncleared areas to be similarly affected by other temporal effects, such as population density and environmental conditions (e.g. snow depth). I predicted the effect to be greatest in the year immediately after vegetation clearing, when all tree- and bush vegetation had gone, and then to decrease as the vegetation returned (which might result in attractive browsing opportunities, Fig. 1). I also expected a lower probability of UVC on uncleared road stretches, as vegetation clearing is most likely to be conducted where the collision rate was initially high (Fig. 1).

# METHODS

## STUDY AREA AND SPECIES

The study area, the county of Nord-Trøndelag, consists of 23 municipalities (Fig. 2), with a total area of 22 412 km². The length of the public road network is about 5700 km, of which E6, the main highway in the county, stretches over about 410 km in a north-south direction.

The study area holds one of the largest moose populations in Norway (about 12000 moose in 2005, (Rolandsen, 2010), and roe deer is also locally abundant in the study area. During the last ten years, about 150-300 moose have been killed in traffic each year, of which about 50 % are killed on roads (Rolandsen, 2010, Statisitics Norway, 2015). For roe deer, the corresponding numbers are about 200-400 killed annually, of which almost all collisions happen on roads (Statisitics Norway, 2015).

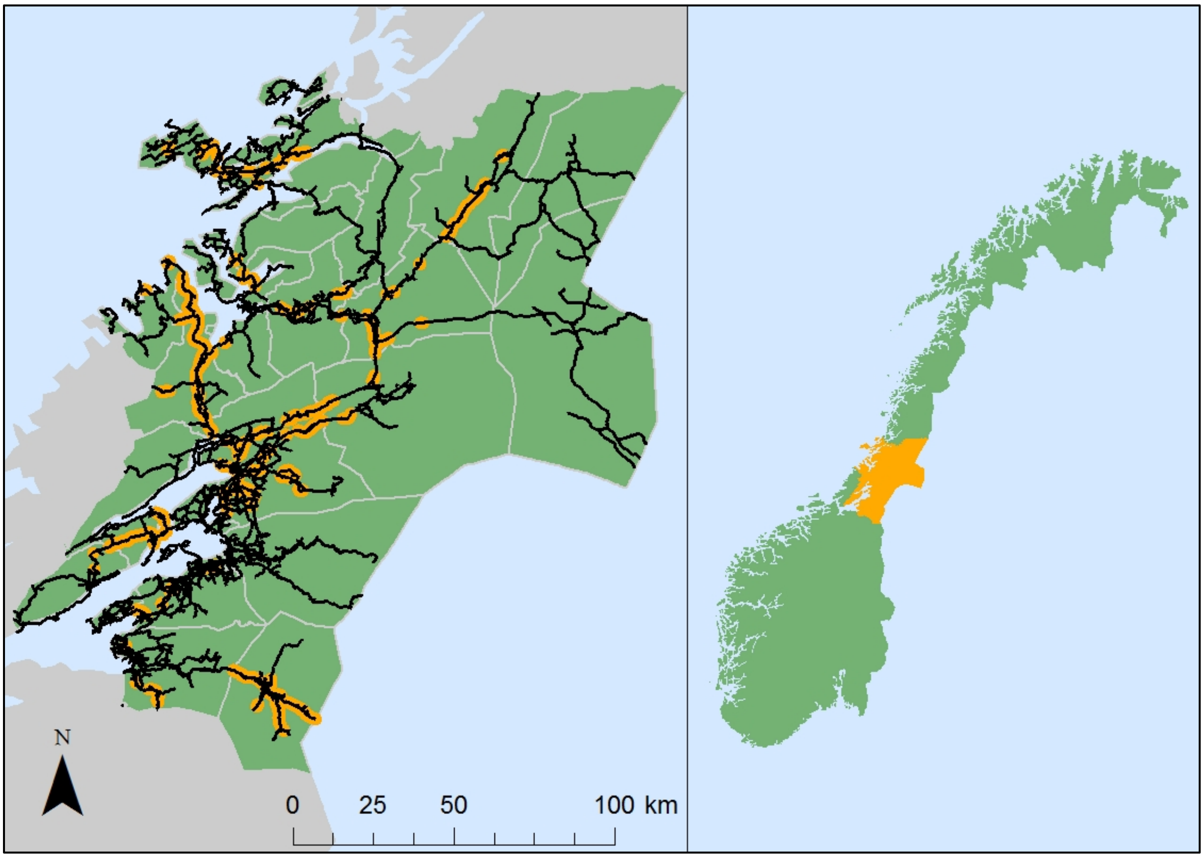



Figure 2. The study area, Nord-Trøndelag County, with the public road network. The orange markings on the map to the left represents road stretches were roadside vegetation clearing was conducted in 2011 and 2012.

## DATA COLLECTION

Collision data used in the analyses were recorded by the municipalities and reported to the National Cervid Register (www.hjorteviltregisteret.no) from where I received the data. The main data set consists of location (point), date and time for UVCs. In the period 2009-2015 (to September only), 3253 UVCs with the necessary information (location, date and time) were reported in Nord-Trøndelag. The collisions included 1267 moose collisions and 1986 roe deer collisions (Fig 3).

In addition, I analysed the annual variation in moose and roe deer killed in traffic during the periods 1980 – 2014 for moose (N = 2790) and 1987-2014 for roe deer (N = 5064). These are data reported from the municipalities to Statistics Norway (www.ssb.no). Unlike the more recent data, however, these data include no information on place or date of the collisions.

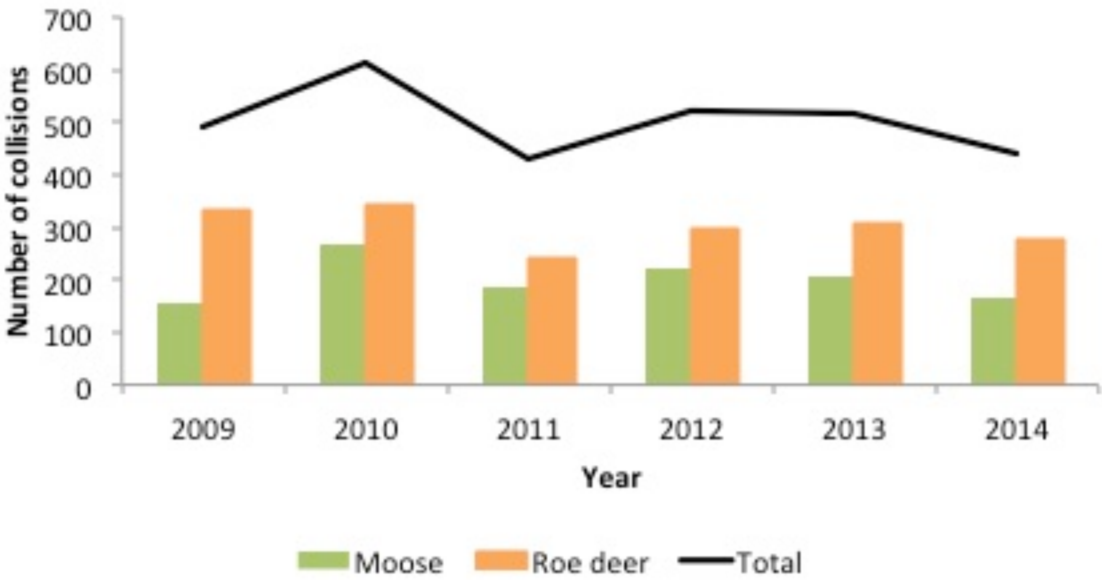



Figure 3. Number of moose and roe deer collisions in Nord-Trøndelag in the period 2009 – 2014.

Vegetation clearing data were collected from the County Council of Nord-Trøndelag (www.gint.no) to which the municipalities that are receiving mitigation funding are reporting such information. The data indicate where and when vegetation clearing has been conducted. All clearing data in the study period (2009-2015) were from 2011 and

2012. I also collected data on previously cleared road stretches (i.e. 2003-2009) to avoid including these stretches among the stretches used as a reference group (i.e. not recently cleared stretches).

To calculate the distance to forest, I used the AR5 land cover map in vector format (http://www.skogoglandskap.no/temaer/ar5/subject_view). This is a detailed land cover map, with a scale of 1:5000. The distance to forest was later used to cancel out points located outside forest, as I was mainly interested in the effects of vegetation clearing in forested areas.

Finally, I collected snow depth data from the Norwegian Meteorological Institute's web service – eKlima (www.eklima.met.no). The average winter snow depth was calculated as the mean of the average snow depth in December, January and February (the winter months) from all the 12 meteorological stations in Nord-Trøndelag with continuous data between 1980 and 2014.

### DATA PREPARATION

To be able to link collision data to road and land cover data, I first snapped collision points to the road using ArcMap (version 10.1). I then created a set of 100,000 random points along the road network and calculated the distance from collision points and random points to the nearest forest. In addition, I calculated the distance to nearest cleared stretch for both collision and random points. Only points that were located in forest, defined as within 5 m from a forest map polygon, were used in the analyses.

Using R (version 3.1.2), I gave each random point a random date in accordance with the range of collision dates within municipalities. Random points were assigned to a species according to the distribution of moose and roe deer in the collision data (41 % moose, 59 % roe deer). I also calculated the number of years since last clearing at each collision and random point (year since last clearing) using 1$^{st}$ of October as the break between years (all vegetation clearing were done during summer, whereas most UVCs occur during winter). For points (collision and random) on previously uncleared stretches, the year since last clearing was set to 60. I cancelled from the analyses all collision points and random points that were located on stretches cleared prior to 2009 to avoid including these stretches among the stretches used as a reference group, and points in areas outside forest according to the AR5 map since I was interested in the effects of vegetation clearing in forested areas. Finally, I created a binary variable (recently cleared) that described if a point had been cleared within the study period, or had not been recorded as recently cleared. After this process, the data set contained 1565 collision points (646 for moose, 917 for roe deer) and 36790 random points (15119 for moose, 21671 for roe deer) for use in the analyses.

## FIELD VALIDATION OF DATA

Road and land cover data associated with the collision and random points were all extracted from digital maps. However, to check the extent to which map data correctly resemble the environment surrounding the collision and random points, I conducted a field trip to a subsample of points (locations). The main purpose was to check if 1) areas marked as cleared were actually cleared, 2) if areas marked as forest were actually forested and 3) if the distance between forest and road differed between cleared and uncleared stretches.

To conduct the survey, I randomly selected 125 points in cleared areas and 125 points in uncleared areas along a pre-defined route. The route covered a large part of Nord-Trøndelag and included several stretches where vegetation clearing had been reported. All points were located in forest according to the AR5 map.

The 250 points were uploaded as waypoints to a GPS (Garmin *et*rex 30x) to simplify the navigation to each location. I drove by car to the location and when possible, the car was stopped at the point and attributes (Table 2) were recorded at both sides of the road. In addition, photos were taken in all directions. Where I found it impossible to stop the car, photos were taken in motion and the different attributes were recorded based on the images. Due to time constraints, not all the pre-selected points were visited. In total, I recorded data from 108 points (one observation on each side of the road = 218 roadsides), of which 53 (106) and 56 (112) were from uncleared and cleared points, respectively.

Table 1. Attributes recorded during the field trip.

| **Recorded variables:** |
|---|
| **Time** – time stamp for visiting the point |
| **Fence –** presence of fences or crash barriers at the side of the road or between the driving directions |
| **Landscape –** forest, agriculture, water, built-up areas, other |
| **Topography –** topography at the side of the road: flat, slope (+ or -), cliff (+ or -) |
| **Edge zone –** distance to edge zone (if present) |
| **Distance** to nearest forest |
| **Distance** to forest in a 90-degree angle from the road |
| **Vegetation height** for<br>• Roadside<br>• Cleared area (if present)<br>• Nearest forested area |

## STATISTICAL ANALYSES

I used generalized linear mixed-effects models (GLMM) with collision (0 = random point, 1 = collision point) as the binary response variable to model the probability of an UVC on cleared and uncleared road stretches (i.e. recently cleared). In addition, I included years since last clearing and collision year as main effects (Table 2), and used municipality ID as random factor to account for the inter-correlations among observations within municipalities. The models were fitted for moose and roe deer separately. For each species I fitted four models with the following fixed effects:

Model 1) P(Collision) = Intercept + Recently cleared + Year+ Year since last clearing
Model 2) P(Collision) = Intercept + Recently cleared + Year
Model 3) P(Collision) = Intercept + Recently cleared
Model 4) P(Collision) = Intercept

Table 2. List of explanatory variables used in statistical analyses.

| Variable name | Explanation |
|---|---|
| **Recently cleared** | Categorical variable describing if a point has been cleared or not sometime before or after the collision. 0 = never been cleared, 1 = cleared sometime before or after the incident. |
| **Years since last clearing** | Categorical variable describing the number of years since the last clearing. If never cleared the value was set to 60 years. |
| **Year** | Year of collision – from 1st October – 30th September (e.g. collisions between 1st October 2014 – 30th September 2015 = 2014). |

I used Akaike Information Criterion with correction for small sample sizes to select the best model ($AIC_c$) where the model with the lowest $AIC_c$ was considered the best model given the data and the candidate models (Burnham and Anderson, 2002). Models differing in $AIC_c$ of less than 2 were considered equally good when interpreting the results. I also calculated the Akaike weights for the model set, by normalizing the relative likelihoods to sum to 1. The $AIC_c$ weight gives the weight of evidence in favour of a model, and can be interpreted as the probability of a model being the best given the data and the candidate models (Burnham and Anderson, 2002).

I used R (3.1.2) and RStudio (0.98.1102) to perform all statistical analyses (R. Core Team, 2014). The mixed effect models (family = binomial) were run with the lme4 package (Bates et al., 2014).

# RESULTS

## FIELD VALIDATION OF DATA

One of the aims of the field trip was to find out if areas that was reported as cleared actually had a clearing zone. According to the clearing data from the County Council, 56 of the visited points were supposed to be cleared on one or both sides of the road. However, during the field trip only 32 (57.1 %) of these points were recorded with a clearing zone along one or both roadsides. Most of these points were cleared on both sides (62.5 %), while the rest was only cleared at one side of the road. For points only cleared on one side the other side either had uncleared forest or agricultural areas on the other side. Moreover, on 25 of 57 points (47.2 %) located at uncleared stretches I found zones that appeared to be recently cleared, but most of these points (80.0 %) only had a clearing zone on one side of the road. This suggests that there are inaccuracies when recording vegetation clearing.

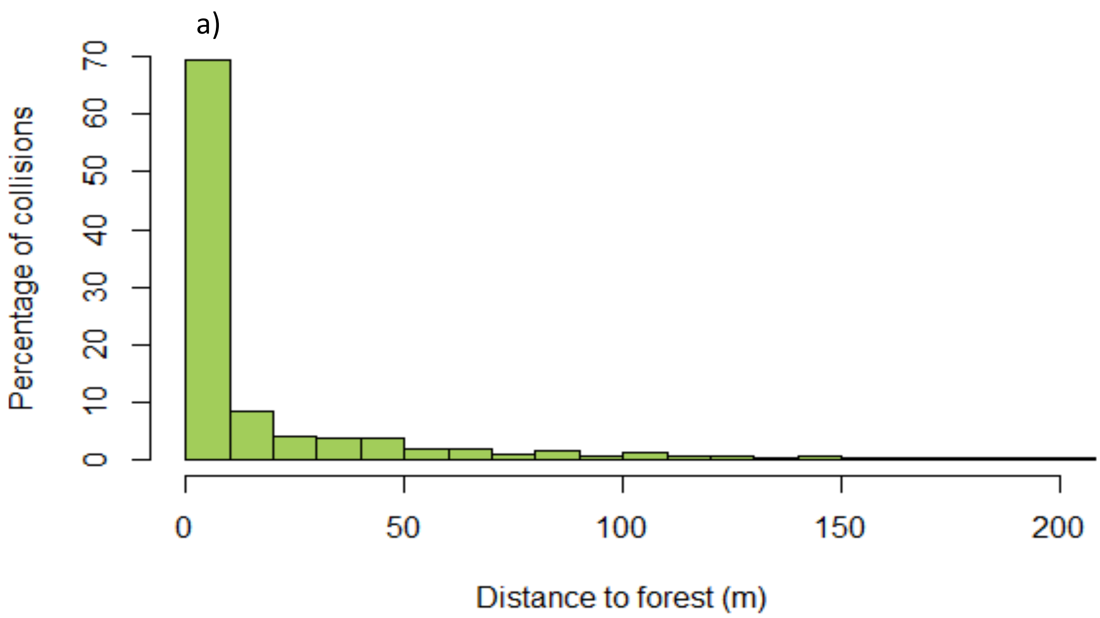
All points visited during the field trip was selected from areas that was supposed to be forested according to the AR5 map. Of the 108 points I visited 51 (46.8 %) were recorded with forest on both sides of the road, while 47 (43. 1) had forest on only one roadside. The remaining 11 points (10.1 %) did not have forest on either roadside. Of the 218 roadsides that were classified as forest in the AR5 map, 149 (68.3 %) were bordering to forest, whereas the remaining roadsides bordered to agricultural areas (35 observations, 16.1 %), water (16, 7.3 %), built-up areas (10, 4.6 %) or other landscape types (8, 3.7 %). Of the roadsides not bordering to forest, 81.2 % were at points in uncleared areas, whereas 18.8 % were at points located in cleared areas. This means that the land cover in the AR5 map did not always correspond with my observed land cover.

This was confirmed by investigating the average distance to nearest forest. All points visited during the field trip was selected from forested areas according to the AR5 map, meaning that they were supposed to be located within 5 meters of a forested area. However, when investigating the distance to forest measured during the field trip I found that the distance to forest often was longer than 5 meters: for all roadsides where distance to forest was measurable, the mean of the nearest distance to forest was 83 meters (SE= 11, N = 172). For points that were recorded in forest during the field trip, the mean of the distance to nearest forest was 40 (SE = 4, N = 145) meters. Roadsides bordering to other landscape features were also recorded with distance to forest, but in many cases the distance to forest was too far away to be measured with reasonable accuracy. For agricultural areas, the mean distance was 286 (SE= 49 N = 19) meters. For land cover types recorded as 'other', the mean distance was 383 (SE = 98, N = 6) meters and for water 500 (SE = 200, N = 2) meters. All points in built up areas were too far away from forest to be measured.

For points recorded with a clearing zone the mean distance to forest was 55 meters (SE = 8, N = 74), while it was 89 meters (SE = 16, N = 94) for points recorded without a clearing zone.

## DISTRIBUTION OF COLLISIONS IN SPACE AND TIME

In the period 2009–2015, 3253 UVCs were recorded in Nord-Trøndelag, including 1267 (38.9 %) moose and 1986 (61.1 %) roe deer. In total, 55 % of the UVCs were located in forested areas. As indicated by the distance of collision points to forest (Fig. 4), the moose seemed to have a stronger connection to forest than roe deer. Of all moose collisions, 65 % were located in forest while the corresponding figure for roe deer was 45.2 %.



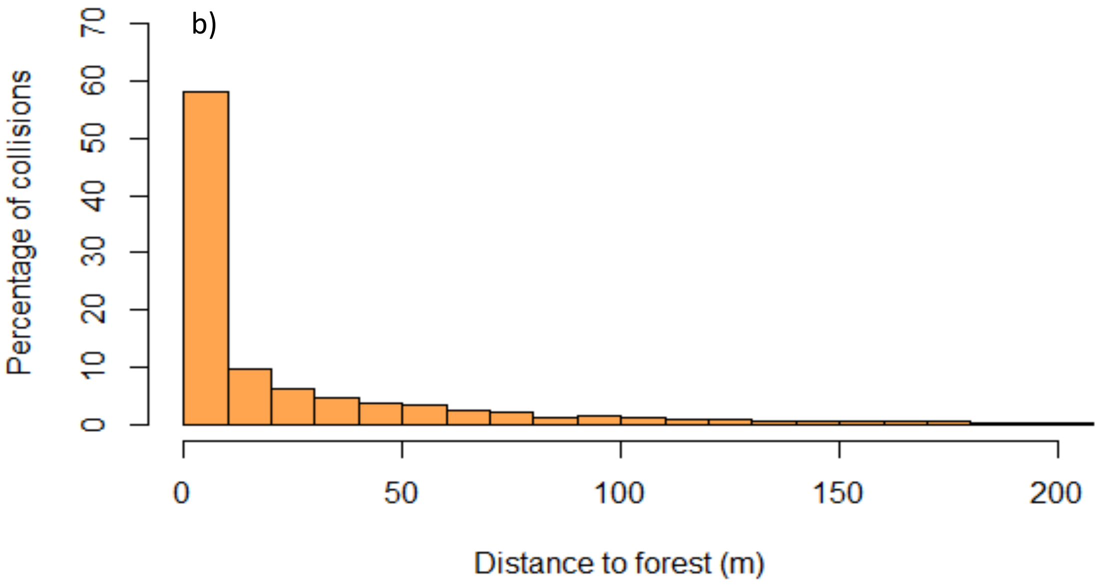



Figure 4. Percentage distribution of collisions' distance to forest for a) moose and b) roe deer for collisions in Nord-Trøndelag in the period 2009 – 2015.

A large proportion (38.4 %) of the collisions occurred during winter (December, January, February, Fig. 5). This pattern was more evident for moose, with 50.7 % of the collisions happening during winter, than for roe deer collisions (29 % winter collisions). For roe deer many collisions also occurred in May, July and autumn (Fig. 5).

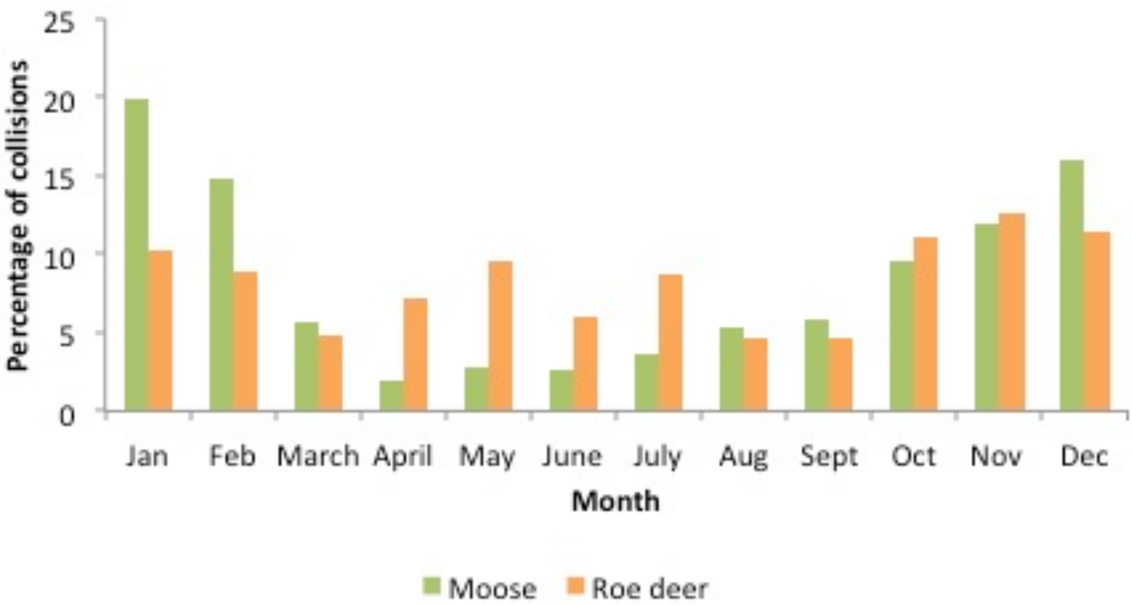



Figure 5. Monthly distribution of UVCs in Nord-Trøndelag County in the period 2009-2015, distributed on moose and roe deer collisions.

About 80 % of the collisions were recorded with an exact time stamp. Most UVCs seem to happen during dusk and dawn, particularly during winter (Fig. 6). Moose collisions also seem to occur more often during dawn (47.7 %) than roe deer collisions (35.5 %), whereas for collisions during dusk the proportions were almost the same (19.6 % of the moose collisions and 22.1 % of the roe deer collisions).

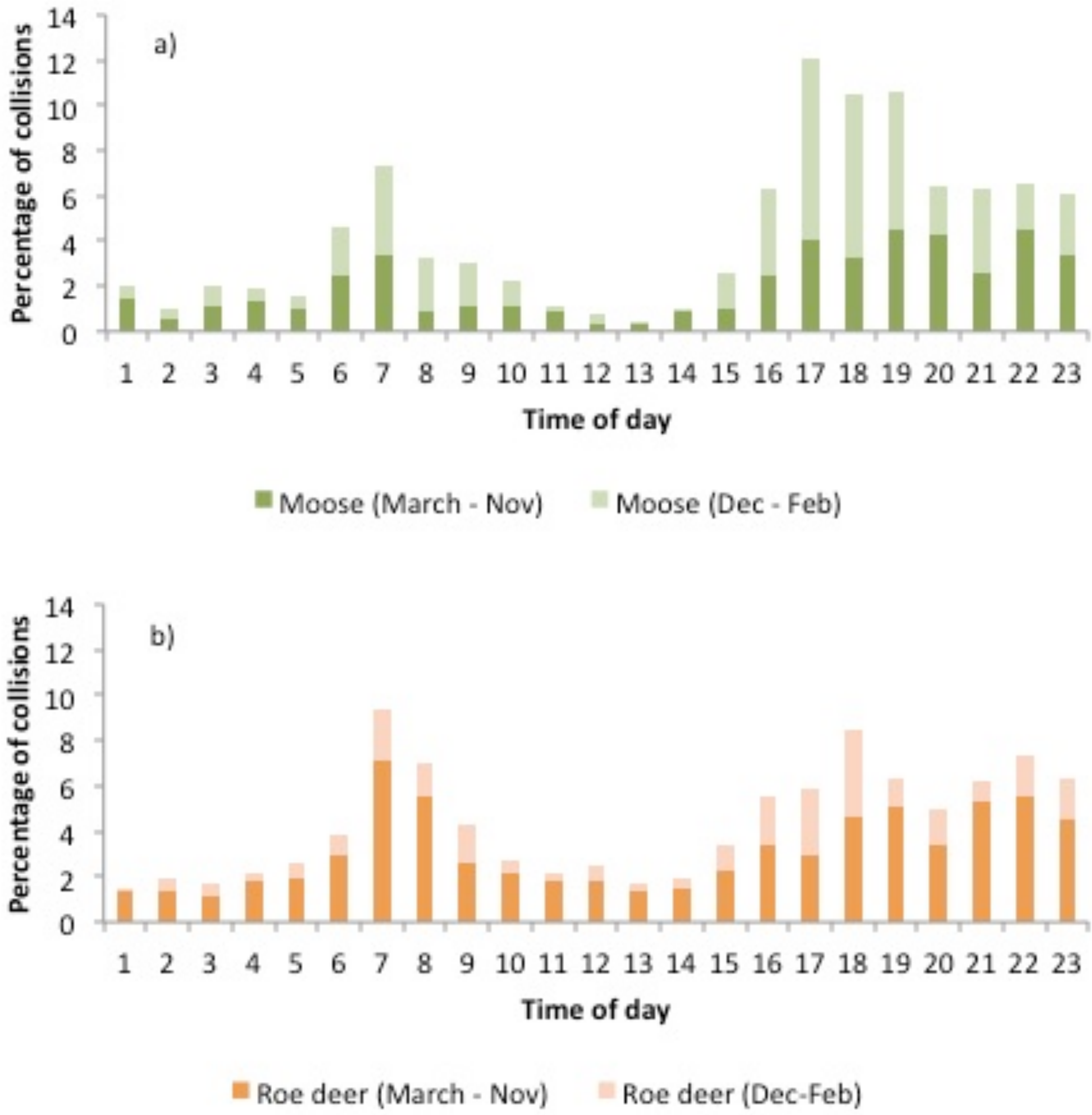
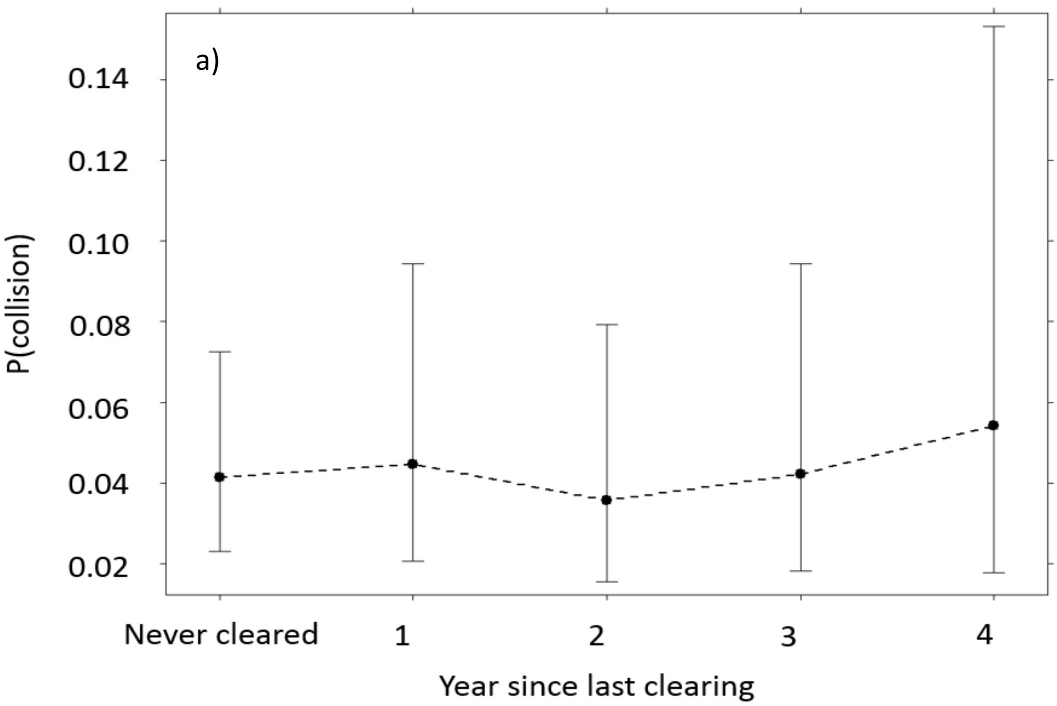



Figure 6. Circadian variation in number of UVC for a) moose and b) roe deer in the period 2009-2015. Different shading indicates time of the year.

## EFFECT OF VEGETATION CLEARING ON UNGULATE-VEHICLE COLLISIONS

For both moose and roe deer, the highest ranked model gave no support for the hypothesis that vegetation clearing reduces the probability of UVC. For the moose data, recently cleared and year was the only variables included in the highest ranked model, and this model was far better than the second best model that also included years since last clearing ($\Delta$ $AIC_c$ = 7.21, Table 3a). Hence, the probability of moose-vehicle collisions did not change after clearing as compared to the conditions prior to clearing and with stretches that were not previously cleared (Fig. 7). For the roe deer data, the highest ranked model was the full model, while a competing model only included recently cleared and year ($\Delta$ $AIC_c$ = 1.54, Table 3b). No other models were within $\Delta$ $AIC_c < 2$. In the highest ranked model the parameter estimates of years since last clearing were uncertain and of varying direction. If anything, the estimates suggest that the probability of collisions with roe deer may equally likely increase as decrease in the years following vegetation clearing. (Fig. 7).

In common for both moose and roe deer models, I also found that the probability of UVCs was significantly higher on road stretches that had undergone vegetation clearing compared to those that had not (Fig. 8). This suggests that vegetation clearing is mainly conducted along stretches with initially higher probability of UVCs than along uncleared stretches.



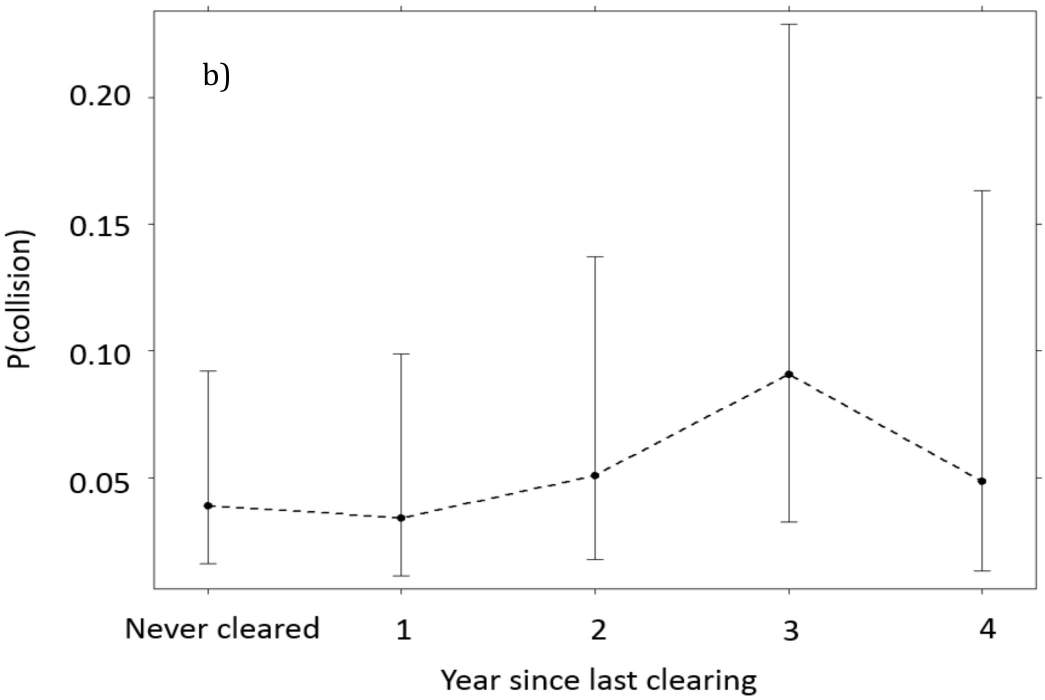



Figure 7. The probability of collisions with a) moose and b) roe deer relative to year since last clearing. The figures are effect plots based on the full model for both species (Table 3).

Table 3. Parameter estimates (β) and standard errors (±SE) for models analysing the probability of vehicle collisions with moose (a) and roe deer (b). RC = recently cleared (0,1), YSLC = year since last clearing (never cleared, 1, 2, 3). Ranking of models based on $AIC_c$ model selection, with $AIC_c$ value, Δ $AIC_c$, and $AIC_c$ weights for all candidate models

| **a)** | **Moose models** | **Model 1** | **Model 2** | **Model 3** | **Model 4** |
|---|---|---|---|---|---|
| **Explanatory variables** | **Intercept** | -3.42 ± 0.33 | -3.42 ± 0.33 | -3.20 ± 0.31 | -2.98 ± 0.34 |
| | **RC 1** | 1.61 ± 0.18 | 1.62 ± 0.13 | 1.61 ± 0.13 | |
| | **Year 2010** | 0.72 ± 0.15 | 0.72 ± 0.15 | | |
| | **Year 2011** | 0.22 ± 0.16 | 0.23 ± 0.16 | | |
| | **Year 2012** | 0.27 ± 0.16 | 0.27 ± 0.16 | | |
| | **Year 2013** | $-0.3\times10^{-4}$ ± 0.17 | $-0.4\times10^{-3}$ ± 0.17 | | |
| | **Year 2014** | $0.8\times10^{-3}$ ± 0.18 | $-0.4\times10^{-3}$ ± 0.17 | | |
| | **Year 2015** | 0.05 ± 0.22 | 0.08 ± 0.21 | | |
| | **YSLC 1** | 0.08 ± 0.28 | | | |
| | **YSLC 2** | -0.15 ± 0.31 | | | |
| | **YSLC 3** | $0.3\times10^{-2}$ ± 0.50 | | | |
| | | | | | |
| | **$AIC_c$** | 4763.62 | 4765.41 | 4785.09 | 4916.71 |
| | **$\Delta AIC_c$** | 7.21 | 0 | 28.68 | 160.30 |
| | **$AIC_c$ weight** | 0.03 | 0.97 | 0 | 0 |
| | **$AIC_c$ rank** | 2 | 1 | 3 | 4 |

| b) | Roe deer models | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|---|
| Explanatory variables | **Intercept** | -3.14 ± 0.48 | -3.16 ± 0.47 | -3.24 ± 0.46 | -3.11 ± 0.48 |
| | **RC 1** | 1.18 ± 0.18 | 1.36 ± 0.13 | 1.36 ± 0.13 | |
| | **Year 2010** | 0.02 ± 0.12 | 0.03 ± 0.13 | | |
| | **Year 2011** | -0.41 ± 0.14 | -0.41 ± 0.14 | | |
| | **Year 2012** | -0.18 ± 0.13 | -0.18 ± 0.13 | | |
| | **Year 2013** | -0.08 ± 0.13 | -0.05 ± 0.13 | | |
| | **Year 2014** | -0.16 ± 0.13 | 0.06 ± 0.15 | | |
| | **Year 2015** | $0.4 \times 10^{-3}$ ± 0.15 | | | |
| | **YSLC 1** | -0.13 ± 0.34 | | | |
| | **YSLC 2** | 0.28 ± 0.31 | | | |
| | **YSLC 3** | 0.23 ± 0.50 | | | |
| | | | | | |
| | **$AIC_c$** | 6544.23 | 6545.77 | 6549.57 | 6644.35 |
| | **Δ $AIC_c$** | 0 | 1.54 | 5.35 | 100.13 |
| | **$AIC_c$ weight** | 0.65 | 0.30 | 0.05 | 0 |
| | **$AIC_c$ rank** | 1 | 2 | 3 | 4 |

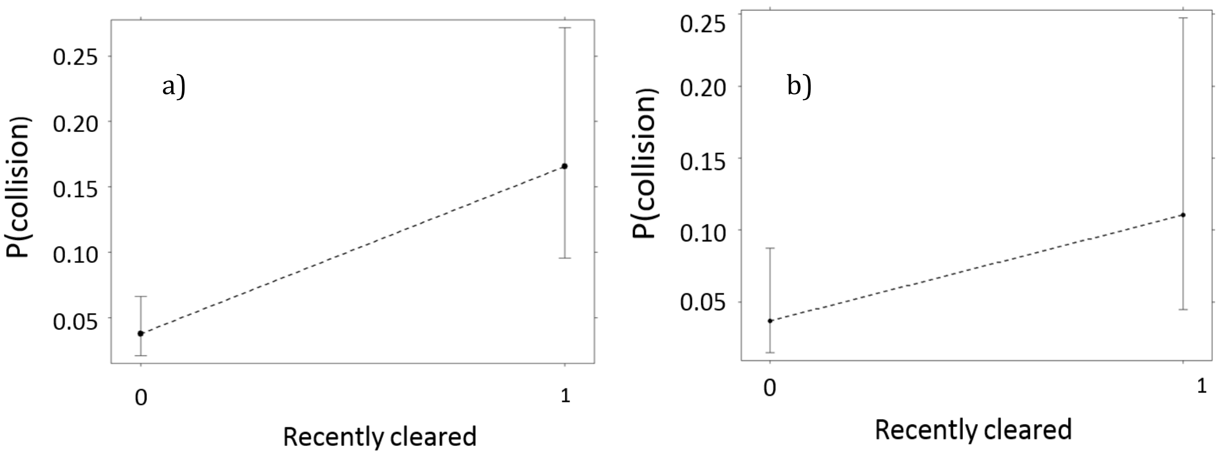



Figure 8. The probability of collisions with a) moose and b) roe deer on road stretches that had been recently cleared (1) or not (0). The figures are effect plots based on the full model for both species (Table 3).

In Fig. 9, I also show the proportion of collision points of all points in forest (collisions points + random points) on cleared and uncleared stretches against year. Based on a visual inspection, there is no absolute decrease in the proportion collision in the years following clearing for roe deer (Fig. 9b), and even less so when compared to the proportion collisions on never cleared stretches. For moose (Fig. 9a), a similar pattern is apparent for stretches cleared in 2012, whereas a decrease in collisions is found in the year immediately following the clearing in 2011. However, an almost similar decrease is also recorded on stretches that were first cleared in 2012 and on stretches that have not been recently cleared.

I also compared the annual variation in proportion collisions among stretches cleared in 2011, 2012, and uncleared stretches. For moose, I found positive correlations in collisions among years (Table 4a), whereas for roe deer only one of three correlation coefficients was significantly positive (Table 4b). A positive correlation may suggest that one or several common factors have generated the annual variation.

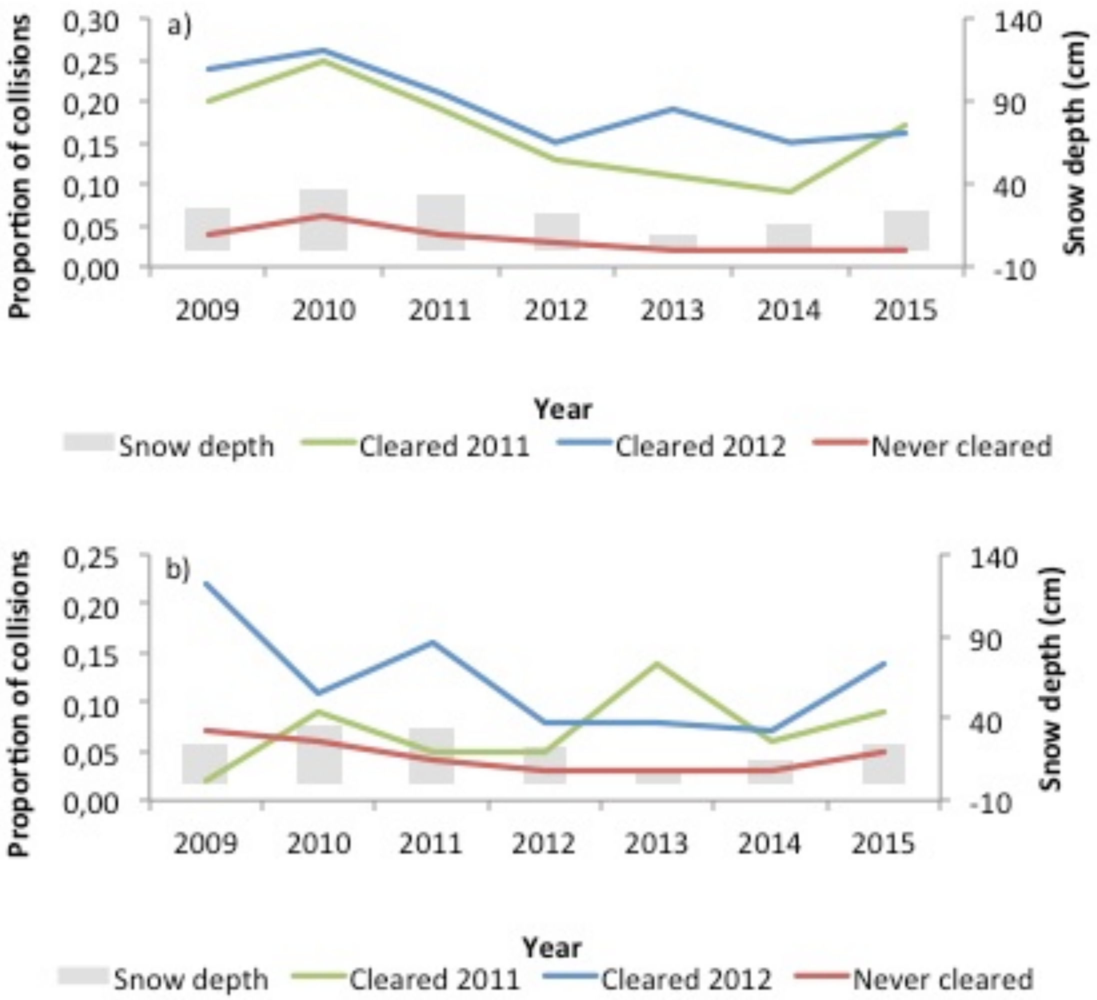



Figure 9. The proportion of collision points of all points (collisions points + random points) in forest on stretches cleared in 2011 and 2012 and stretches that have never been cleared for the years 2009 - 2015 for a) moose and b) roe deer

To further test this hypothesis, I also used the annual number of moose and roe deer recorded as killed in traffic in Nord-Trøndelag since 1981 and compared them with the annual variation in snow depth. I first de-trended the time series to reduce the influence of other factors on the variation in UVC (e.g. moose and roe deer density). This was done by dividing the number of collisions in a given year by the number of collisions in the previous year to calculate the annual change in collisions. The same was done for the snow depth data. For example will a change of 2 mean that the number of collisions was doubled from the previous year. I then conducted a correlation test between the annual change in the number of collisions and snow depth. I found a significant positive correlation between the annual change in moose-vehicle collisions and snow depth ($r = 0.67$, $df = 32$, $p = <0.001$) and a positive, but not significant correlation between annual change in roe deer-vehicle collisions and snow depth ($r = 0.27$, $df = 25$, p-value = 0.163) (Fig. 10). This suggests that varying snow depth is a likely candidate for explaining the large annual variation in moose-vehicle collisions, but to a lesser extent for the variation in roe deer-vehicle collisions.

Table 4. Correlation matrix for the annual proportion of collisions between the areas cleared in 2011 and 2012 and the never cleared areas for a) moose, and b) roe deer with corresponding p-values. Data from 2009 – 2015. Df = 5

| **b) Roe deer** / **a) Moose** | **Cleared 2011** | **Cleared 2012** | **Never cleared** |
|---|---|---|---|
| **Cleared 2011** | | -0.56 (p = 0.190) | -0.36 (p = 0.434) |
| **Cleared 2012** | 0.84 (p = 0.019) | | 0.80 (p = 0.031) |
| **Never cleared** | 0.88 (p = 0.009) | 0.86 (p = 0.013) | |

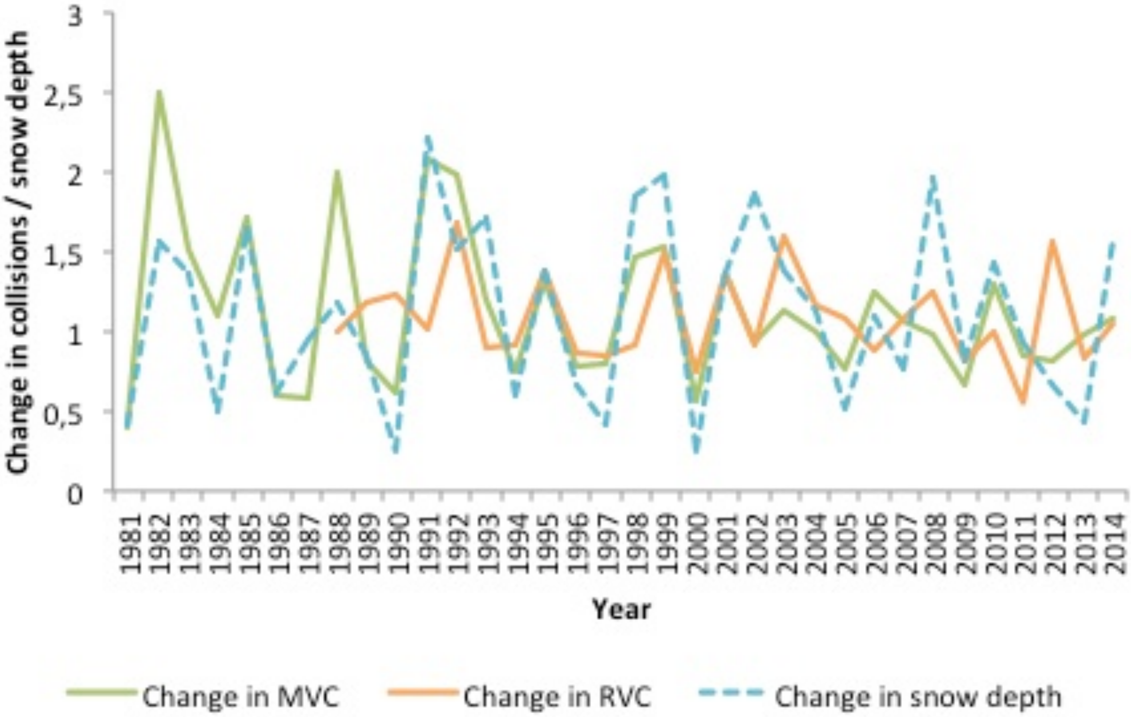



Figure 10. Change in in moose-vehicle collisions (MVC), roe deer-vehicle collisions (RVC) and snow depth in the period 1981 – 2015 for moose and 1988-2014 for roe deer. Change in collisions was calculated by dividing the number of collisions in a given year with the number of collisions in the previous year. The same was done to calculate change in snow depth.

# DISCUSSION

Due to the high number of UVCs recorded in many parts of the world, there is a constant search for cost effective measures to prevent or reduce their occurrence. Vegetation clearing is one option, but its preventive effect has been poorly validated. In the present study, I evaluated the use of vegetation clearing as a mitigation measure of UVCs in Nord-Trøndelag County in central Norway during 2009-2015. Following clearing along substantial parts of the public road network in 2011 and 2012, I found no indications of subsequent reduction in the number of moose and roe deer being hit by cars, suggesting that vegetation clearing in its current form has no collision preventive effect. Still, the results revealed that for both species the probability of a collision were substantially higher in cleared stretches relative to uncleared stretches, which indicate that high-risk areas are targeted for vegetation clearing. The main results raise the obvious question why vegetation clearing has no seemingly effect.

The field trip revealed inaccuracies in both the vegetation clearing data and the land cover map (AR5). For example some road stretches seemed to be recorded as cleared even though vegetation clearing only had been conducted on smaller sections along the road. This was for example seen along the road through Namdalseid (FV 17) where a long road stretch (ca. 40 km) was recorded as cleared, even though the road largely consists of agricultural areas and also pass small settlements. In addition, several points had a clearing zone, even though no such clearings had been reported. This indicates that several collision points can have been wrongly categorized, which may have deflated the predicted effects of vegetation clearing in the analyses. These inaccuracies will increase the noise in the data set, and I acknowledge that this may have affected the results. However, I find it unlikely to have caused the lack of effect of vegetation clearing.

Another possible explanation is that inadequate removal of vegetation is the underlying cause for the lack of positive results. Good clearing routines with regular clearings is a prerequisite when conducting vegetation clearing, since the early succession stages of forest often are dominated by plant species that are attracting ungulates (Iuell, 2005). The optimum clearing frequency will vary between areas depending on soil conditions and forest productivity (Sivertsen, 2010). Because ungulates select food based on quality in terms of high digestive energy and protein (Regelin et al., 1987), Rea et al. (2010) pointed out that the time of the year for clearing is also of importance, as this is essential for the nutritional value of the regrowth. In their study they found that moose often selected plants cut late in the year and thus cutting early in the season (June and July) would be best. Rea (2003) also expresses the importance of removing or mulching slash after cutting because of its attractiveness to ungulates. This also applies when mature vegetation is removed, since crowns of many tree species are attractive food resources, especially for moose (Rea, 2003).

Also the width of the clearing zone could be important for the effect of vegetation clearing as a mitigation measure (Sivertsen, 2010). Some studies were the clearing zone has been wide (20-30 meters) have shown positive results of vegetation clearing: Jaren et al. (1991) found a 50 % reduction in the number of moose collisions on railways, while Lavsund and Sandegren (1991) found a 20 % reduction in moose-vehicle collisions. I found that most collisions happen closer to forest (Fig. 4), and the same is supported in other studies (see for example (Rolandsen et al., 2015)). It is therefore likely that vegetation clearing will work as long as the distance to forest is long enough. Seiler (2005) found that an increase of 100 meter in distance to forest might decrease the probability of a MVC with 15 %. But clearing zones up to 100 meters wide would not be a viable option due to high maintenance costs and loss of large habitat and forestry areas. In the present study I did not have information about the width of the clearing zone, but the impression from the fieldtrip is that few stretches was cleared wider than 20 meters, which could partly explain the lack of predicted effects. In Norway, the clearing zones are seldom wider than 8-20 meters, and it is questionable whether this is sufficiently to deter moose from crossing the road. After all, moose are mainly active during twilight hours and night (Fig. 6) and are more likely to aggregate around roads during winter (Fig. 5). In practice, this means that moose will mainly cross roads in the darkness when the need for cover is lower. The potential strongest effect of vegetation clearing in my study area may therefore be to increase the probability that a crossing moose is spotted by the driver. Accordingly, Antonson et al. (2015) found that drivers responded faster to moose encounters in open versus closed landscapes. However, as drivers may also increase their speed when driving in an open landscape compared to where forest edges are close to the road (Antonson et al., 2009), the net effect of vegetation clearing on the drivers ability to avoid collision may be small. If this is a general behaviour among drivers, vegetation clearing should mainly be perceived as a method to reduce the crossing probability of moose, but in such a case the clearing zone would probably have to be substantially increased.

Given the questionable effect of the current width of clearing zone, other more effective mitigation measures could also be considered. Reducing ungulate density or traffic intensity are two potentially effective measures, as indicated in several studies (Lavsund et al., 2003, Seiler, 2004, Solberg et al., 2009, Rolandsen et al., 2011). However, while a reduction in ungulate density could be a viable option, it is highly unlikely that traffic intensity will be reduced. Also speed limit reduction has been shown to reduce collision rate, especially during winter (Seiler, 2005, Meisingset et al., 2014), as is the case with roadside fencing (Iuell, 2005, Seiler, 2005). However, fences are costly to implement and creates constant barriers that can have major ecological consequences (see for example Andrews, 1990). Accordingly, fencing is currently only being recommended for large roads with high traffic intensities, and where other mitigation measures have been proven to be ineffective (Iuell, 2005).

In lack of any clearing effect, the substantial variation in the number of UVCs calls for another explanation, for instance an effect of weather conditions. Studies of ungulate collisions on railways (Gundersen et al., 1998) and roads (Rolandsen et al., 2011) have shown that the number of MVCs increases with snow depth and cold temperatures. This is probably because deep snow are forcing moose to migrate to more low-lying areas to reduce the locomotion costs and increase the availability of food (Andersen and Sæther, 1996). Such aggregation of moose in the valley bottoms is likely to increase the risk of collisions, as human infrastructure typically is located in these areas. As the probability of collision was positively related to the annual variation in snow depth, such an explanation may also apply for moose in Nord-Trøndelag — but not for roe deer. The latter was however not unexpected as roe deer are confined to human populated areas all year round, and are not to the same extent as moose congregating closer to roads during winter.

## CONCLUSION

In this study I did not find any effect of vegetation clearing on the probability of UVCs despite a relatively high number of UVCs in the study period and large stretches of roadsides being cleared. Part of the reason for a lack of effect can have been inaccurate data and/or inappropriate clearing of vegetation (clearing zone and maintenance frequency). Inaccuracies were found in the map information as well as in the reporting of vegetation clearing zones, but I find it unlikely that this was the sole reason for lack of effect. In most cases there were no decline in UVC in the year after clearing, and to the extent it was, that was more likely to be due to a change in environmental conditions (less snow). To improve our abilities to validate the effectiveness of future mitigation measures, I think it is important to further improve data sampling routines and how mitigation measures are being reported. Preferably, the implementations of new measures should be done as part of an experiment, were data are systematically sampled and most confounding variables are controlled for as part of the design. To facilitate such a process researchers should be included as early as possible when new measures are going to be implemented.

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