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The correlation between final fellings and ungulate vehicle collisions

Korrelationen mellan slutavverkningar och klövviltsolyckor

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Omslagsbild: A red deer in Blekinge, southern Sweden. Photograph: Victor Hedvall.

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FOREWORD

Every year thousands of motorists collide with wildlife in Sweden. The consequences are economic costs for both individuals and society. Some collisions have even a deadly outcome.

The collisions with ungulates have increased during the last five years and the deadly outcomes. The factors of why the collisions occur might be several. It is therefore essential to study this area to acquire and maintain knowledge about why ungulate vehicle collisions happen.

Sweden has a developed forestry and is a country where 56 % is productive forest land of the total land area (41 millions of hectares). The forests are living environments for many ungulates but also the place of where the forestry's measures take place. When the forest is grown up it is being harvested which exposes land area. This furthermore changes the wildlife's habitat and can increase the biomass on the final felling site.

This report's purpose is to study if there is a correlation between the final fellings by the forestry and ungulate vehicle collisions.

Finally, I would like to express my gratitude to my supervisor Andreas Seiler at *Grimsö Wildlife Research Station* for his support and for sharing his knowledge in the subject. I would also like to thank Eric Sundstedt and Staffan Stenhag at *Skogsmästarskolan* for their support and guidance in the writing arrangements and formalities.

Skogsmästarskolan in Skinnskatteberg, april 2017.

Victor Hedvall

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1. ABSTRACT

The purpose with this study, is to study the correlations between the ungulate vehicle collisions and the final fellings in the forestry. The report is a bachelor thesis at Skogsmästarskolan at the Swedish university of agricultural sciences.

When a final felling is performed an area is exposed in the landscape, which is an encroachment on the wildlife's habitat and living environment. The hypothesis in the study is that a final felling might lead to a change in the ungulate vehicle collisions frequency. The effect of the final felling might be an attraction of ungulates due to an increase of available food or a distraction since the ungulates shelter decrease and hereby their tendency to stay in the area. The correlations can differ on diverse levels such as local, landscape and county levels as well between the ungulates.

To study the correlations, a database has been created with data of the ungulate vehicle collisions for Sweden's 21 counties. The frequency of collisions has been compared with the final fellings data at county level. In addition, the collision statistics was also compared with final fellings at landscape level, a buffer zone of 2 km from the roads. To gather local level, a buffer zone with a range of 500 meter from the roads was made. Both landscape and local level were studied within the counties. The data of final fellings was gathered from Skogsstyrelsen.

The average numbers of police reports of moose collisions from 2010-2016 presented a significant positive correlation (R^2=0,2451, n=21, t=2,48 p<0,0225) with the areas of final fellings. In counties with more areas of final fellings more moose collisions occur. As one zooms in from county level to local level the correlations increase remarkably (R^2=0,5239, n=21, t=1,72, p<0,0002). This indicates that final fellings nearby roads might increase the risk of a moose collision.

For wild boar, a significant correlation was achieved at county level (R^2=0,284, n=21, t=-2,75, p<0,0129). This correlation was however negative which indicates that counties with more area of final fellings might expect less wild boar collisions. As one zooms in to local level the significant connection dissolve. The cause of this dissolved correlation might be connected to the choice of habitat for wild boar which differs from the habitat choice of moose. These two species, moose and wild boar, were the only with statistical significance in the study.

The method of this study was not optimal to prove the final fellings importance for the ungulate vehicle collisions. The present study compared the number of ungulate vehicle collisions at county level with areas of final fellings within the counties but also nearby roads within the distances of 2 km and 500 meters from the roads.

The data material however, is limited and several disturbing factors make these

results unsure and difficult to interpret. For further studies, it is recommended to study the coordinates of the actual collision in relation to the final fellings performed in the local area. Different counties differ in terms of wildlife populations, area, traffic intensity etc. By entering more in detail at county level and clarify the cause of the ungulate vehicle collisions, this could contribute to greater knowledge about wildlife and traffic.

2. SAMMANFATTNING

Syftet med denna undersökning är att studera om det finns något samband mellan trafikolyckor med klövvilt och föryngringsavverkningar i skogsbruket. Rapporten är ett examensarbete och kandidatuppsats på Skogsmästarskolan vid Sveriges lantbruksuniversitet.

När en avverkning utförs exponeras en yta vilket är ett ingrepp på viltets habitat och levnadsmiljö. Hypotesen i studien är att en avverkning kan leda till en förändrad frekvens av viltolyckor i området. Avverkningseffekten kan antingen antas bero på en ökad attraktion av vilt genom en större fodertillgång eller också tvärt om, en minskad attraktion då viltets möjlighet att ta skydd minskar och därmed också benägenheten att vistas i området. Sambanden kan skilja sig på olika nivåer så som närområde, landskapsnivå och länsnivå men även mellan viltarterna.

För att undersöka sambanden har en databas skapats med data om viltolyckor för landets 21 län. Olycksfrekvensen jämförs sedan med Skogsstyrelsens databas över de avverkningar som genomförts i länen, i närområdet med 500 meters avstånd från väg, samt med avståndet 2 km från väg. För att fånga avverkningsdata för närområdena har buffertzoner använts längs med vägarna inom länen.

Medelantalet polisrapporterade älgolyckor per län åren 2010 – 2016 visar på en signifikant positiv korrelation (R^2=0,2451, n=21, t=2,48, p <0,0225) med mängden avverkad skog. Ju fler hektar skog som avverkas i ett län desto fler älgolyckor sker också där. När man zoomar in från länsnivå till närområde med dess buffertzon på 500 meter stärks sambanden markant (R^2=0,5239, n=21, t=1,72, p <0,0002). Detta indikerar på att avverkningarna kan ge en förhöjd risk för älgolyckor.

Även för vildsvin framkom ett signifikant samband på länsnivå (R^2=0,284, n=21, t=-2,75, p <0,0129). Detta samband var dock negativt så att ju mer skogsavverkningar i hektar som skedde i länet desto färre blev också olyckorna med vildsvin. Om man för vildsvin zoomar in på närområdet för vägarna (500 m) försvinner det signifikanta sambandet. Förklaringen till att det signifikanta sambandet försvinner kan vara kopplat till vildsvinets habitatval, som skiljer sig från älgens. Dessa två viltarter, älg och vildsvin, var de enda med statistisk signifikans i studien.

Metoden för arbetet har inte varit optimal för att påvisa avverkningens betydelse för viltolycksfrekvensen. I föreliggande studie jämfördes det totala antalet viltolyckor uppdelat per län med hur många hektar skog som avverkats i inom länen samt inom vägarnas närområde inom avståndet 500 meter och 2 km från väg med hjälp av buffertzoner.

Datamaterialet för studien är litet och ett flertal störande faktorer gör resultaten osäkra och svårtolkade. För vidare forskning rekommenderas därför att studera koordinaterna för den enskilda olyckan i relation till de avverkningar som skett i närområdet. Olika län ser mycket olika ut beträffande viltförekomst, areal, trafikintensitet etc. Genom att gå in mer i detalj på länsnivå och klargöra viltolycksorsakerna där skulle man kunna bidra till mer kunskap kring vilt och trafik.

3. INTRODUCTION

In Sweden, more than 50 000 incidents occur between wildlife and traffic each year. Most of these collisions happen with ungulates. Accidents are not randomly distributed in space but cluster along certain roads and in certain areas presumably reflecting the spatial variation in factors that control the movement of ungulates and thereby their exposure to traffic.

This study's purpose is to reveal if there is a correlation between wildlife accidents in traffic compared with forestry's final fellings. Each final felling creates new or alters habitat with consecutive effects on wildlife's movements and abundance. Most ungulate will benefit from final fellings when young successional vegetation provides attractive forage. This may in turn increase the risk for accidents on nearby roads or railroads.

To understand why traffic accidents, occur with ungulates and if there is a correlation with final fellings and whether final forest fellings alter accident risks. One must have knowledge about forest measures as well as wildlife. Therefore, this study will start with an introduction to describe the forestry, the related ungulates and the aspects of the traffic.

3.1 The forestry

Sweden is a country with a well-established forestry. The land consists of 41 000 000 hectares and the productive forest land covers 56 % of the total land area (23 million-hectare productive forest land). The forest area consists of 42 % spruce, 39 % pine and 12 % birch and 7 % other species. Compared to the population, Sweden is one of the richest forest countries with 2,5 hectares per individual (Skogsstyrelsen 2016, Link A).

Since Sweden has this access to a renewable natural resource the forestry is well developed. The Swedish forestry model however, is a cycle where cleaning and commercial thinning are common measures in the silviculture. When the forest has reached the legal age for final felling the forest can be cut down. The Swedish Act of Forestry requires reforestation, which is often made by plantation (Skogsstyrelsen 2016, Link B).

The Swedish forestry model is like a cycle, which is presented in figure 1 below:

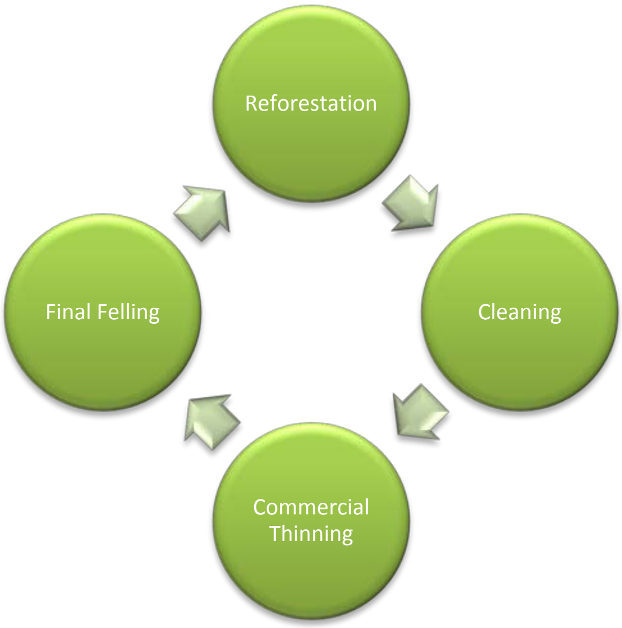

Figure 1. The cycle of the Swedish forestry model.

When speaking of moose population management, the Swedish forestry is often in regard. The modern forestry model in Sweden creates a lot of forage for the moose by a variety of areas with food from vegetation, bushes and trees. (Skogforsk 2005, link H)

3.2 The ungulate's ecology

3.2.1 The red deer *(Cervus Elaphus)*

Image 1. Red deer (Photograph: Victor Hedvall)

Description
The red deer is Sweden's second largest ungulate. The body length is 175 – 200 cm for an adult male and the shoulder height for an adult male is 120 – 150 cm. The average weight is 200-230 kilograms for an adult stag meanwhile an adult doe has an average weight of 100-150 kilograms.

Home range and movements
The home range and the movement pattern vary between different areas, counties and landscapes. The doe in open and agricultural land with fragmented forest areas have a wider home range than red does in homogeny forest landscapes. In Södermanland the average home range is about 1150 hectares with a variation between 400 – 1800 hectares. Skåne, in southern Sweden the red doe shows an average home range of 2 600 hectares. They seem as well be seasonal nomadic or wander among different areas with distances most commonly between 5 – 27

kilometers from each other. How far the deer wanders vary depending on breeding season or due to the season of the year.

The stags tend to have wider home range compared to the does. In Södermanland the stags home range is about 3 500 hectares which is three times bigger than does in the same area. In Skåne, southern Sweden, only one stag has been placed with a GPS. This specific stag has shown a home range of 8 500 hectares.

Habitat and biotope
The red deer is an ungulate that easily adapt itself to live in various climates, landscapes and habitats. In Europe, it occurs in highlands, slopes, homogeny coniferous landscapes and agricultural land. It occurs as well in dry environments and deciduous forests. Therefore, the red deer also can live in several places in Sweden.

In Sweden, the red deer is in agricultural land as well as forest land. The diurnal pattern is often to seek shelter in forests during the day while visiting cultivated and deforested land during nighttime. The red deer is not a night active mammal originally, however this is an adaption due to the human hunting pressure.

Feeding preferences
The developed sense of smell is used for the deer's foraging. The red deer grazes grass, buds, branches and twigs and although it can graze of trees, the red deer prefer grass types. A majority of the feed is grazed from the soil and field layer although bushes and trees are being pastured.

During the winters with a high depth of snow the red deer takes advantage of the shrub layer of snow to graze trees even though red deer is known to be able of digging through easier snow to find its food. Popular types of food are rice from lingonberry, blueberry and heather from the soil layer and several types of grass. Branches and buds from ash, aspen, oak, juniper, rowan and willow are popular as well as bark from numerous tree species.

The red deer is also keen on fields with cultivated crops. Especially with clubs, wheat, oats, corn, potatoes etc.

Reproduction and the rut
The red doe produces one calf each year. They get their calf when the doe is 2-3 years old and normally they produce one calf a year up to the age of 12. After the year of 12 the doe has a decreasing fertility.

The rut that starts in the end of august and the peak of the rut is during the middle of September. Usually, the stags are building up harems of does and roars to attract females. The stags are also defending these harems from other stags and combats are not uncommon and sometimes, severe injuries happen to the stags, which can even cause death (Svenska Jägareförbundet 2012, Link D; Jarnemo 2001; Jarnemo 2011).

3.2.2 The fallow deer *(Dama Dama)*

Image 2. Fallow deer (Photograph: Victor Hedvall

Description

The fallow deer is present in several color variations, which most likely is a result of breeding in human enclosures. The size between the doe and the buck has a significant difference compared to the moose and roe deer. The fallow buck can be up to 75 % bigger than the doe. This is explained as the doe invests more in her offspring and put a lot of energy on her fawn compared to the buck whose size is directly connected to bring success in the reproduction.

The shoulder height of an adult buck is 80 – 100 cm and for an adult female 70 – 90 cm. The weight of an adult buck is 70 – 110 kilograms meanwhile the doe holds a weight of 45 – 65 kilograms.

Home range and movements

The fallow deer spreads slowly compared to other ungulates. Their ability to create herds and tolerance for high populations is the reason of their moderate spread in the landscape.

The establishment is as well effected by their home range and the formation of the landscape. The landscape can vary from its appearance to open pasture land to forest land. In Sweden fallow deer individuals has not been set with a GPS so the information of their movements is brought from abroad. Compared to the other ungulates the fallow deer do not have a home range for a specific individual. The fallow deer creates a home range for a primary group of does and fawns of where they move around during the year. The home range is not however invariably. The access of food can lead one specific group to another area, or a part of the home range for some periods of the year. The density of the population, the placement of feed stations, areas for winter grazing and crops have an effect of how wide the fallow deer home range becomes. The areas together are furthermore one annual home range.

The home range for the does and fawns are about 100 – 200 hectares and an input of agricultural land is almost essential. The buck’s home range is more difficult to estimate in cause of the annual wandering. A movement up to 10 kilometers is not uncommon since the buck divides his area in summer- and winter areas.

Habitat and biotope

The fallow deer prefers a fragmented landscape. It prefers both forest land and agricultural land due to its feeding preferences described below. It is not fearful to expose itself on open areas and have a lot of diurnal movement, which makes it easy to discover during the entire day.

Feeding preferences

The fallow deer is not a gourmet when it comes to its feeding preferences. It grazes what the soil produces. It prefers grass types but grazes as well herbs, leaves from trees and bushes as well as crops. It grazes intensely which leads to some areas become totally scraped. Reforestation has seemed to be impossible in some areas with uncommonly high populations of fallow deer.

The summer feed are herbs, bushes, crops and grass and during the autumn nuts from oak and beech are important food as well as berries and fruits. The winter food however is mainly rice of blue- and lingonberries and heather. Branches and bark from deciduous trees and dried grass from last year is also common food during the winter.

Reproduction and the rut

The peak of the rut is during the turn of the month between October and November. Many bucks move to their established rut area and mark their presence with rut pits and marks on trees. As the red deer, the fallow deer is roaring as well to warn other bucks but also to impress on the rivals and does. The bucks can injure each other but due to the formation of the antlers the death causes are not as common as it is for the red deer who has long pointy antlers while the fallow deer has an antler most like a paddle. The doe chooses its partner and most common is a production of one fawn per year.
(Carlström 2005)

3.2.3 The wild boar *(Sus Scrofa)*

Image 3. Wild boar piglets (Photograph: Victor Hedvall)

Description

The wild boar gives a heavy impression with its high shoulder and sloping back. From behind the wild boar can look thin but is a rather compact animal with a lot of weight.

An adult wild boar is around 1 meter in height and 1,5 meters long. An adult female, a sow, is often carrying a weight of over 100 kilograms while the boar can weigh up to 200 kilograms.

Home range and movements
The wild boar is shy and is rather not exposing itself in daylight. The tracks they are leaving, however, are rather easier to discover. They root in the soil to find eatable plants, brush themselves against trees and bask in mud pots.

The average area for a male boar being active during the night is 100 hectares. It is active for 6-8 hours nighttime. The total area of the home range is at least three times bigger than this. Some groups with sows and juveniles are using several thousands of hectares as their home range. The home range seems to vary due to the food stations many hunters have in Sweden that leads to that wild boars are not required to wander far to gain its daily consumption of food. That reduces the need of a larger home range. A study of wild boar's home range was made 2013 in the middle of Sweden. These wild boars had an average home range of 1156 hectares (Svenska Jägareförbundet, 2012, Link E; P-O Eriksson, 2013).

Habitat and biotope
The wild boar easily adapts themselves to various environments. They live in forest land and are often seeking agricultural land for attractive food of corps and grass. It is not uncommon to discover their occurrence on golf courses, cemeteries, gardens etc.

The wild boar prefers broadleaved forests or forest with elements of broadleaves. The wild boar therefore occurs in both the nemoral as well as the boreonemorala zone in Sweden. Cold temperatures and ground frost do not prevent the spread of wild boar in northern Sweden. The main prevention is the snow depth. The average snow depth of 70 centimeters during more than 120 days seems to be a limit for wild boar establishment (Naturvårdsverket 2010).

The wild boar furthermore prefers mixed coniferous forest and has seasonal selections of its habitat. Therefore, it occurs in agricultural fields, open areas, coniferous- and deciduous forests. Water is a desire for wild boar and therefore it occurs during all seasons in damp habitats with water (Thurfjell 2009).

Feeding preferences
The wild boar is an omnivore and around 90 % of the feed is vegetables and several types of roots and underground plants are common food, especially during the winter. In addition to roots, the wild boar eats windfall as well as nuts from oak, beech and hazel particularly during the summer and autumn.

In the middle of the summer and towards the autumn the wild boar is keen on crops like wheat, oats, canola, forage and potatoes. The animal food is often worms, caterpillars, bird's eggs, small rodents and other invertebrates.

A daily consume is in average four kilograms of food for an adult wild boar while a piglet often consumes half of that.

Reproduction and the rut
Both sows and boars are early sexually mature. The most common is for sows to get mate at the age of one and a half. The boars, however, are sexually mature at the age of two year.

During the rut, the wild boar is less shy and the rut is regulated by the daytime. The most common mating occurs in August to December. However, the sow is susceptible in several months and therefore the mating in a population can occur for several months. However, the sow becomes fertilized for in about 115 days and Swedish science has revealed that 85 % of the births takes place during the months February to Mars. The births might nevertheless occur any time of the year but births during August - September are often explained because of a re-rut of those sows who has lost their piglets during the spring.

Commonly, the sow only has one annual group of juveniles and the numbers are often connected to her age. A young sow has 3-4 piglets and a 3-year-old and elder have 5-6 piglets and sometimes even more. The wild boars increase is exponentially (Svenska Jägareförbundet 2012, Link E).

3.2.4 The roe deer *(Capreolus Capreolus)*

Image 4. Roe bucks (Photograph: Victor Hedvall)

Description
The roe deer is the smallest deer, neat and the most common deer in Sweden. A normal size of the roe deer is a shoulder height of 70-75 centimeters with the same body length. It weights around 20-30 kilograms.

The male is called buck and the female is called doe and the juveniles are called fawns. The size of a buck and doe are about the same. Therefore, it might be difficult to see a difference between those, especially during winter when the buck folds his antlers (Svenska Jägareförbundet 2012, Link F; Pettorelli et al. 2002).

Home range and movements
The home range of the roe deer varies depending on summer or winter season. As for other species, the buck has a wider home range than the females. The main home range is between 30-120 hectares. A wider home range during the winter is explained as the energetic requirements to have available food. Therefore, a wider home range in areas less available food is common (Kjellander et al. 2004).

Furthermore, the movements vary during the day. The roe deer are more active during dawn and dusk. At the end of July and the beginning of August the movements increase due to the rut (Ericsson et al. 2016)

Habitat and biotope
The roe deer is spread all over Sweden except for the mountains above tree line. They prefer forest environment and do not build big herds. The protection against predators does improve by a herd in their environment. Groups of roe deer can, by this, occur during the winter and in open environments. Since defoliation happens during the autumn and the vegetation is low the roe deer can take advantage of each other and discover predators easier.

Feeding preferences
The roe deer prefers food with high nutrition and high digestibility. Therefore, the roe deer does not graze variously but chooses wisely its food.

During the winter period rice of heather and berries are common. If the snow is too deep branches of coniferous- and deciduous trees becomes food. The roe deer is keen on herbs so in addition to other food types, herbs like fireweed, cow-wheat and wood anemone is common food.

The roe deer eat 2-4 kilograms of food each day during the summer period and during the winter this daily consume is reduced to 0,5-1,5 kilograms.

Reproduction and the rut
The rut starts during the beginning of august. The buck is the only deer in Sweden with a territory, which is defended to August – September. The buck as well as the doe is sexually mature during its first year. However, young bucks are prevented to persuade the doe due to the elder buck's territory.

The reproduction of roe deer is connected to the food access and the population's density. If high-energy leaves, herbs and rice are available for the doe she can produce more fawns. The doe has an annual reproduction of 1-3 fawns, which are born at the end of May – June. The doe has a delayed fetal development and therefore the fawns are not born until spring (Svenska Jägareförbundet 2012, Link F).

3.2.5 The European Moose *(Alces Alces)*

Description
The moose is the largest deer and animal in the Swedish forests. Therefore, it is easy to recognize. An adult moose can weigh up to 200-550 kilograms and have a shoulder height of 2 meters. The bull is in average 20 % bigger than the cow and is as well higher and heavier.

Image 5. Moose (Photograph: Victor Hedvall)

Home range and movements
The moose is not territorial. They have home ranges with specific areas for a specific time. It can vary depending on a winter, a year or a summer. The area of

a home range can vary between individuals, gender and environments and they are also nomads. The males have, as for many other ungulates, bigger home range than the cows. This is explained as the bull's social life since a bull should move over wide areas during the rut to find a cow to mate with, and as well, compete against other bulls.

The moose however has a wider home range in northern Sweden compared to the south. It is explained as the food is more sparsely spread in the north, and by this, the moose must wander wider to gain the same amount of food as in the south of Sweden.

In Bergslagen the moose home range was in average 1 400 hectares for a cow and 2 600 hectares for a bull which was measured by transmitters by Grimsö Research Institute (Svenska Jägareförbundet 2012, Link G).

Habitat and biotope

The moose lives in both coniferous forest as well as in varied forests with broadleaves and trivial trees. It is adapted for the Nordic climate. It prefers both juvenile forests as well as old forests as shelter and food. However, during the seasons the moose prefers different habitats. For example, studies have shown that during the spring the moose selects elder coniferous forests and during the summer earlier successional forests before deciduous forests. During the winter and fall the moose is most likely in early successional forests before other habitats. Humid coniferous forests with fragmentations of mires and marsh-land are in general seen as essential moose habitat due to food access and cover during snow and snow-free periods (Olsson et al. 2010).

Feeding preferences

The moose eats various kinds of varied species and the food types varies depending on where in Sweden the moose lives. However, a specific pattern is confirmed by diverse studies. During the winter, the moose grazes branches of coniferous, mainly pine, and deciduous trees. Depending on the snow depth the rice of berries and heather can become food. During the spring when the snow has melt down rice is important food.

The moose prefers to graze on aspen, oak, rowan and sallow. They also like birch and pine and can graze of alder and spruce although they less prefer the last two species mentioned.

The moose as adult eat around 6-10 kilograms of fresh food. During the summer, they eat 2-3 times more than this. The amount of food depends on individuals and as well body size.

Reproduction and the rut

The rut for moose starts at the end of September and continues in to October. It starts earlier in southern Sweden than in the north. The cow is only susceptible for the fertilization for 1 day and night. If the cow does not get fertilized during this day she can re-rut some weeks later. Calves that are born in the end of June are a result of a re-rut during the autumn.

The calves are furthermore born at the end of May and in the beginning of June and hold a weight of around 10-15 kilograms as newborns. The calves are born earlier in southern Sweden compared to the northern parts. The cow has one or two calves each year and in rare cases three calves has occurred.

The growth of the calves increases fast during their first month. In November, the weights are approximately around 150 kilograms and the fast growth starts to decrease by then due to the winter. The calves however are following the cow until the following year when the next calving starts. Last year's calves are then being expelled by their mother and becomes confused and wander a lot. During this period, they wander a lot and the curiosity increase the risk of collisions (Svenska Jägareförbundet 2012, Link G).

3.3 The wildlife and the traffic

Wildlife has an impact on the society and it leads to large socioeconomic costs. According to Ingemarsson, Fredrik (et al. 2007) presented in the repost *Costs and benefits of moose and roe deer populations.* The annual discounted costs for the moose and roe deer populations are estimated to 2 billion SEK. Two thirds of these costs are found in traffic while the other third is reflected in the forestry. These numbers of costs only represent costs for roe deer and moose and not all ungulates.

The costs however, decrease linearly with decreased wildlife populations since both traffic accidents and forest damages are proportionally with the wildlife populations (Ingemarsson et al. 2007).

During the period 2010-2016, the average of wildlife vehicle collisions per year in Sweden was 48 033 and the number of collisions increase each year. The trend and numbers of the wildlife collisions are shown in figure 2 below.

Figure 2. The annual vehicle collisions with wildlife in Sweden during 2010-2016.

As seen in figure 2 the total vehicle collisions with wildlife have had a minor increase and 2016 was a high-frequent year and the highest numbers of collisions ever measured (58 579). This figure represents the total wildlife collisions and therefore, it does not only refer to the ungulates.

Since this report will study the ungulates, trend lines for these species are presented in figure 3 below. The diagram shows a declining trend for moose collisions meanwhile the collisions with wild boar increases. The fallow deer has a similar linear increase and red deer is stable with a minimal increase for each year. Roe deer collisions increase as well and since roe deer represents approximately 75 % of all UVCs, the numbers are divided with 10 so an overview of all species can be pictured in the same figure.

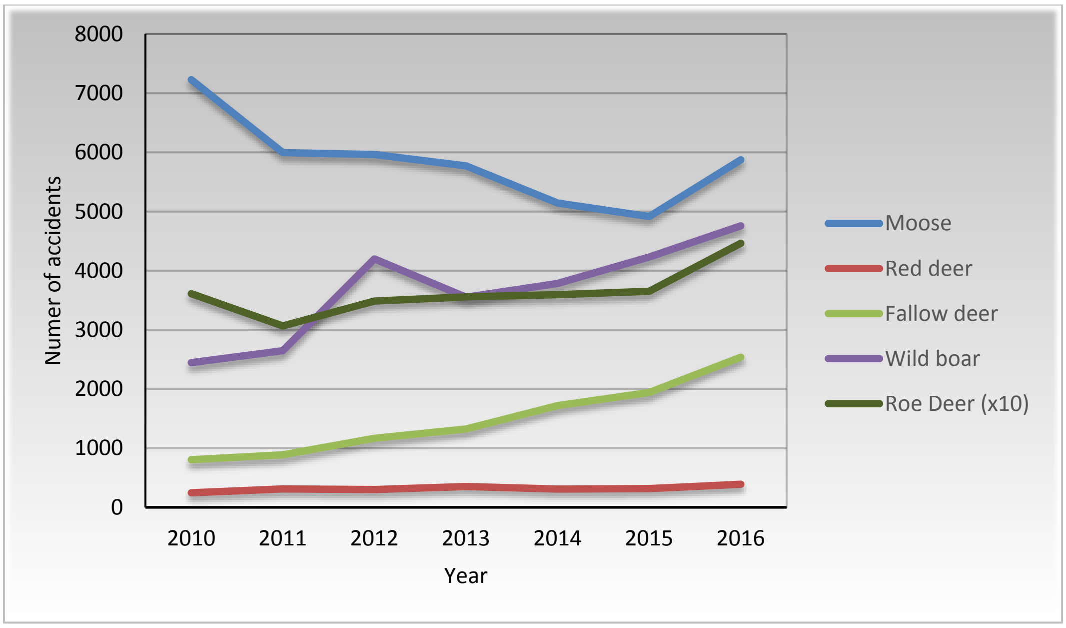

Figure 3. The annual trend lines for the ungulate collisions in Sweden. The roe deer frequency is divided with 10 for a proper overview compared to other species.

3.4 Prevention against ungulate vehicle collisions

The collisions with ungulates vary in Sweden and due to the variation of diurnal movements for each ungulate the risk of collisions vary as well. However, several factors seem to have impact on the reasons of why the collision occurred. There are connections between UVCs and visibility, weather conditions and snow depths. Therefore, the risk of collisions varies as well due to the latitude and location in Sweden.

The collisions occur during the periods of high activity among ungulates and high-traffic periods. A single motorist is at higher risk of colliding with a moose during dusk in September due to low visibility and high activity among moose. In addition, the highest frequency of UVCs occurs in general during dawn when traffic is significantly higher comparing to the traffic at dusk.

The most effective prevention of UVCs is traffic speed reduction. However, measures combined are supposedly the most efficient way of reducing collisions (Seiler 2004).

3.4.1 Game fences

The most effective way to prevent ungulates from reside on our roads are game fence. Studies reveals that 80 % of the moose with intention to cross a road was prevented due to fence. This fence needs to be 2, 2 meters above ground from the terrain side but in snowy parts of Sweden the fence might be higher because of the snow crust that might be bearable even for a moose.

The disadvantages, however, is that longer road sections with game fences prevents ungulates from crossing the road and reach different geographic areas.

The openings must be adapted to the moose population. Game fence requires maintenance to maintain its function. This must be in regard when choosing which roads, one wants to build these fences on.

3.4.2 Other measures

In forestry cleaning for extended visibility is mainly performed in measures of commercial thinning, cleaning and pruning. The cleaning might make the roads less attractive for ungulates but in the meantime, it can attract ungulates when the cleared area begins to refoliate. For landowners though, commercial thinning and pruning is more attractive from an economic point of view.

The cleaning for visibility, on the other hand, has presented a collision reducing effect of 23 % when all brushwood and branches up to 3,5 meters was cleared.

Other measures like mirrors to reflect spotlights from vehicles and smell repellents from predators have been tested. The effect of reducing collisions has been difficult to prove in decreased numbers. The repellents have had effect on the moose’s movement patterns.

These types of measures, both cleaning for visibility among roads as well as mirrors and repellents are currently used in small scale so the costs and effects are negligible (Ingemarsson et al. 2007).

The road itself creates a barrier effect, which limits the movement patterns of the ungulates. The roads can prevent ungulates from available forage, partners and biotopes and by this also separate local populations.

Imagine a group of individuals, which desire to cross a road. The barrier effect is affecting in the way that some individuals are frighten or prevented in some way. Other individuals are either killed during their road cross or surviving. The factors in this barrier effect are traffic speed, game fence and physical obstacles like central barriers as well as the road width. The behavior of the animal, its size and its ability to perceive the traffic as danger are factors to remind as well. (Seiler et al. 2015)

3.4.3 Conclusion of the introduction

The ungulates have various areas of home ranges in Sweden with various movements depending on factors such as food preferences, snow depths, rut, season and other movements. Still, most of the ungulates time is spent in their home range where essential resources are available. The movements are important to study and have knowledge about when studying wildlife collisions. The factors and movements differs in each county in Sweden.

The background of the UVCs was pictured so the trend lines reveal the increase of collisions. The costs however are estimated to 1,3 billion SEK for ungulate vehicle collisions in Sweden and 2016 was a year of wildlife vehicle collisions ever measured (58 579 WVCs) which makes it essential to study about wildlife and traffic. Collisions with roe deer represent almost 75 % of the UVCs.

It is important with scientific research to predict collisions and should as well be in the interest of the society. If the collisions can be predicted the socioeconomic cost should decrease by measures. Most important of all, it can save lives and prevent injuries for both humans and animals.

The most effective prevention of UVCs is traffic speed reduction and game fences. Still, measures combined should the most efficient way of reducing collisions.

3.4.4 The hypothesis

The hypothesis for this study is that final fellings might have correlations with the ungulate vehicle collisions. This, since the final felling either attract ungulates by the forage growing up on the felling site, or repel ungulates by the exposed land area since limited shelter.

In a landscape, an ungulate can live in its home range without crossing a road. However, an assumption is that a final felling might lead to a desire of crossing the road to achieve attractive food for the ungulates. If so, this can be reflected in the study. The correlation between collisions and final fellings is expected to be higher at local level since it is more nearby roads. Another expectation is to see a stronger correlation with moose due to its food preferences and choice of habitat.

An expectation of different results between the ungulates is reasonable as well due to their variation of food preferences and habitat choice and movements.

4. MATERIAL & METHODS

4.1 Method

By building up a database a spreadsheet will be used to study the correlations between final fellings and ungulate vehicle collisions. The database consists of data of areas of final fellings, buffer zone data and police reported ungulate collisions.

By using buffer zones, measures can be made to gather the total area within the zone and intercepts areas of final fellings, forest land and site class uses. This data can further on be exported to the database for further statistical analysis. By using this data, studies can be made to analyze if there is a correlation between the UVCs and the final fellings.

4.2 Material

4.2.1 The Final Fellings

The data of the final fellings are gathered by using a program, which handles files via *Geographic Information System* (GIS). The registered final fellings are downloaded via Skogsstyrelsen and filtered afterwards so the final fellings during 2009-2015 are collected. The final fellings are also sorted out after area, with criteria of 1 hectare or bigger.

4.2.2 The Ungulate Vehicle Collisions and the roads

The ungulate vehicle collisions, mentioned UVCs, are the police reported collisions. These collisions are defined as where an actual collision has occurred with an ungulate. Therefore, if a driver swerves to avoid an accident with an ungulate and thereby collide with a tree, it is not considered as a UVC.

The police reports are gathered for deer, moose, roe deer and wild boar. Even though, fallow- and red deer occurs in Sweden. There is a great uncertainty in the reports from motorists, which has led to the reports and statistics are gathered as one “deer.” The police reports started to separate fallow and red deer after 2008. Still, it is still more reliable to use the statistics of one deer and therefore it is used in this study. The uncertainty is due to the lack of knowledge about varied species identification among drivers. The police reports gathered are the reports during 2010-2016 and were gathered via Nationella Viltolycksrådet.

The roads are the roads defined by Nationella Vägdatabasen (The national road database), which basically are the public state-owned roads. These roads are the roads where most data are gathered by agencies and therefore the most reliable to use for this report.

4.2.3 The Buffer zones

Since the study is to analyze if there is a correlation with final felling a buffer zone is made among the roads. To see if a correlation can be seen on a landscape level a buffer zone of 4 km will be used. The zone goes 2000 meter from each side of the road and along the roads. On the local level, the zone is 1 km. Therefore, the local buffer zone has 500 meters from each side of the road. This zone can gather areas of final felling within the zone but also the area of forest land but also intercept various kinds of data.

The buffer zones are created in ArcGIS where *Buffer* is used from the *Proximity* tool. This creates a buffer at a specified distance around the input feature, which in this case are the roads. The buffer can be merged and dissolved which leads to a non-overlapping buffer along the roads.

4.2.4 The statistics

When the statistics are studied the correlations are based on this:

- $R^2 \leq 0,35$ = low correlation
- $R^2 \leq 0,36\text{-}0,67$ = moderate correlation
- $R^2 \leq 0,68\text{-}0,9$ = high correlation

For each comparison, the level of statistical significance is regarded when $p<0,05$.

5. RESULTS

5.1 Moose

5.1.1 County level

At first the correlations were studied at county level. The figure 4 below shows the correlation for moose. The comparisons are the average number of police reports during 2010-2016 per county correlated to the final fellings during 2009-2015 in kilo hectares.

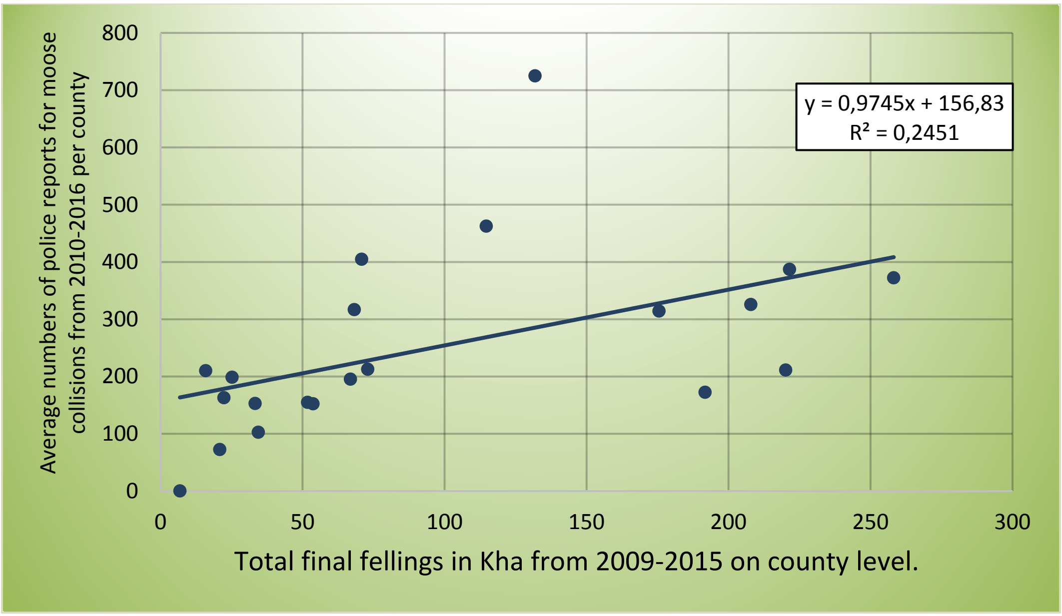

Figure 4. The correlations between the average numbers of police reports for moose collisions from 2010-2016 per county with the total final fellings in Kha from 2009-2015

The figure 4 reveals a positive correlation for moose collisions (R^2=0,2451, n=21, t=2,48 p<0,0225). The figure indicates that counties with a higher amount of final fellings per county can expect a higher frequency of moose collisions. The results are low correlated but have a statistical significance.

5.1.2 Landscape & Local level

When zooming in from county level to landscape level the correlation for moose increases (R^2=0,4652, n=21 t=4,07 p<0,0007). The correlation is still positive correlated but the R^2-value is higher compared to county level. The result in figure 5 has a statistical significance and the correlation is considered as moderately correlated.

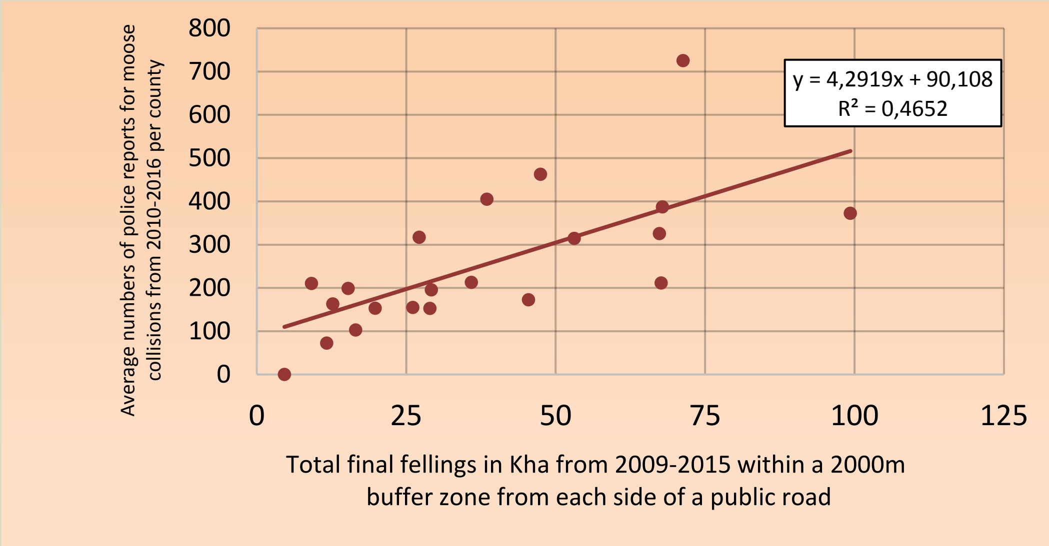

Figure 5. The correlations between the average numbers of police reports from 2010-2016 per county with the total final fellings within a 2000-meter buffer zone from each side of a public road in Kha from 2009-2015. The figure shows results for moose collisions.

As one zooms in to local level, the buffer zone is 500 m from each side of the road. The result is presented below in figure 6.

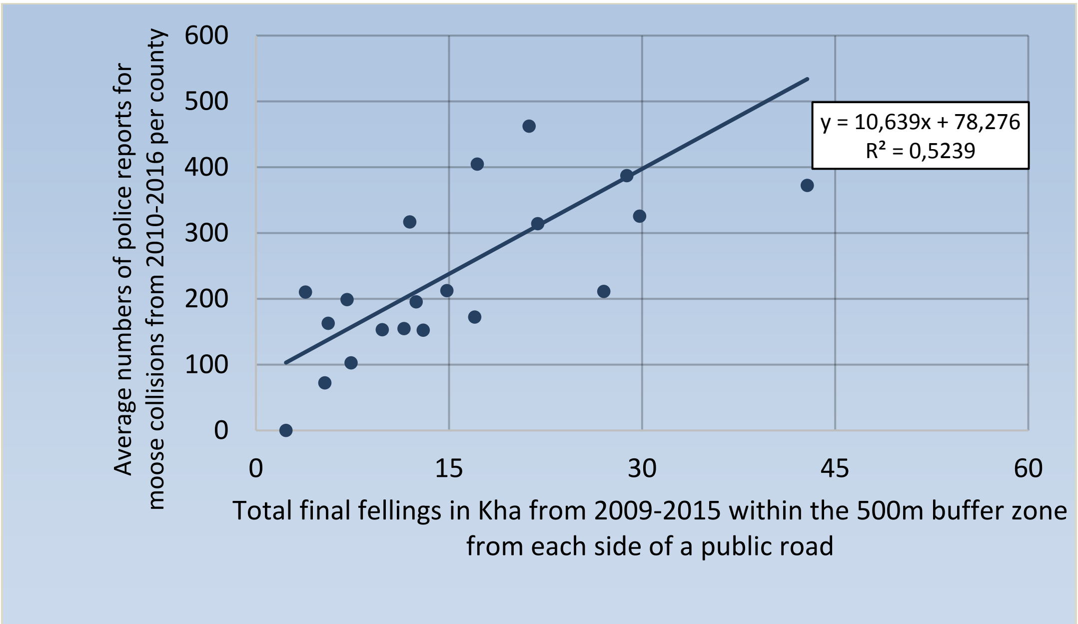

Figure 6. The correlations between the average numbers of police reports from 2010-2016 per county with the total final fellings within a 500-meter buffer zone from each side of a public road in Kha from 2009-2015. The figure shows results for moose collisions.

Figure 6 shows a result for moose with a significant positive correlation (R^2=0,5239, n=21, t=4,57, p<0,0002). The result at local level are considered as a moderate correlation, still, this is the strongest connection regarding the studied levels. It is of importance though, to keep in mind that there are other factors, which can affect the results. One can by this not claim that the final fellings are the cause of the moose collisions.

5.2 Wild Boar

5.2.1 County level

The correlation for wild boar (R^2=0,284, n=21, t=-2,75, p<0,0129) is negatively correlated. The result has statistical significance. The result indicates that in counties with a higher amount of final fellings in hectares, less wild boar collisions can be expected at county level. Notice of importance is that the correlation does not reveal a causal connection, other factors can affect the results.

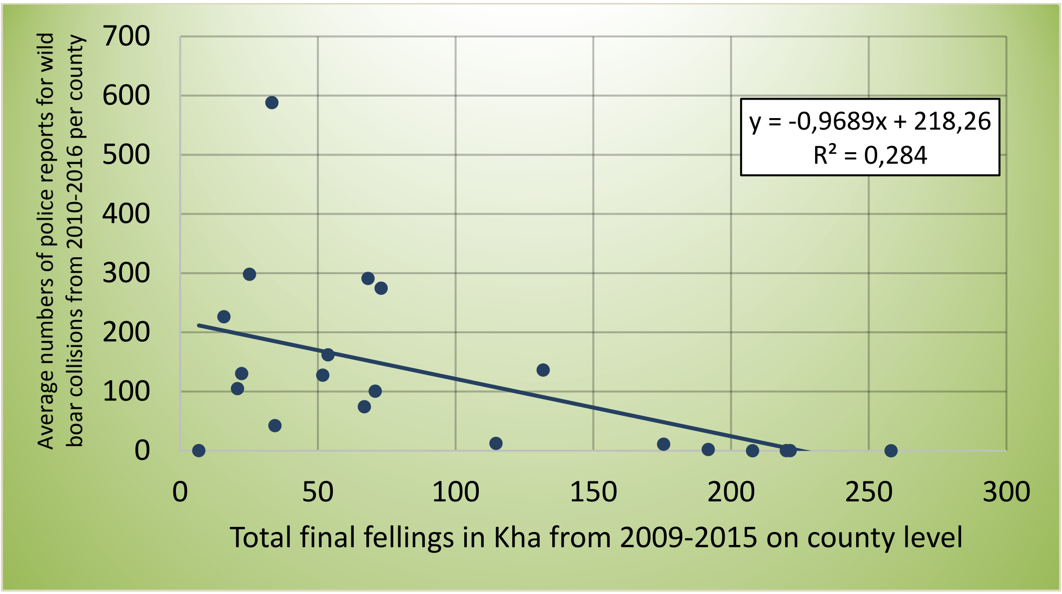

Figure 7. The correlations between the average numbers of police reports for wild boar collisions from 2010-2016 per county with the total final fellings in Kha from 2009-2015.

5.2.2 Landscape & Local level

What happens, as one zooms in to landscape and local level is that the correlation reduces between final fellings and wild boar collisions. At landscape level, there is a statistical significance but a lower negatively correlation (R^2=0,1954, n=21, t=-2,15, p<0,0448).

At local level, wild boar is neither low nor negatively correlated where no statistically significance is achieved (R^2=0,1673, n=21, t=-1,95, p<0,0656).

Regarding the hypothesis the results overall confirms the expectations of various results among the ungulates. The wild boar had a negative correlation with the final fellings and moose had a positive correlation with the final fellings.

6. DISCUSSION

6.1 Discussion of results

The hypothesis of various results among ungulates was as expected. The results indicated that in counties with more areas of final fellings the more collisions of moose could be anticipated since the correlation remarkably increase as one zooms in to local level. However, the results do not prove that the final fellings are the cause of the collisions.

Counties with more areas of final fellings are in the northern half of Sweden, where more moose collisions occur. The final fellings cannot by this study be considered causally connected to the collisions and might moreover be explained by other factors such as moose populations, habitats and established forestry within the counties.

The reason why the 500-meter buffer zone have a stronger correlation for moose indicates of an increased risk for moose collisions since the correlation remarkably increase as one zooms in. Several factors might affect the results of why an UVC occurred which makes the results difficult to interpret and analyze and due to this, there is an uncertainty if the collisions truly are connected to the final fellings.

The results by this method, does not reveal any causal connection between the UVCs and the final fellings. Therefore, this study cannot contribute considerably to the knowledge about ungulate vehicle collisions but the created database can be used for further studies. This study can therefore be regarded as a pilot study.

6.2 Discussion of method and alternatives

The weakness of this study is that it has no straightforward way to connect the final fellings to the collisions or how it affects the ungulates movements in the landscape. This, because the study analyzes the total numbers of collisions per county with the amount of final fellings nearby roads. If the study was repeated, one could use the coordinates of collisions, “hot-spots” or high-risk roads and relate these to nearby final fellings. One could also study the forest site class qualities to analyze if the correlations differ. Counties vary regarding wildlife populations, area, traffic volumes etc. This makes it essential to study more in detail in specific counties to reveal the cause of the ungulate vehicle collisions and by this contribute to more knowledge about wildlife and traffic.

6.3 Lessons of the study

Despite being well planned, I have relied too much during this report on the authoritarian persons, which were an effect partly due to my lack of knowledge in the subject. This became somehow shortcuts, which lead to a bit of lost grip back and forth during the study. It will become an important lesson for me in future projects that I must be the engine and responsible for the ongoing work and analysis. During the process, some methods has been discussed which I realized afterwards that I did not comprehend. This is also why I choose to critically discuss the results due to the complexity of the subject.

For me as writer, it has been instructive to complete a candidate thesis and it has made me realize the importance of being critical when doing researches. It also taught me the importance of delimiting the study depending on the type of analysis and the timetable obtained.

The strengths of this report are that an extensive database has been created. It can be used for further and numerous studies which, allows this to be regarded as a pilot study. The report in its entirety describes the importance of wildlife research, but also the complexity of the subject and how further studies can be performed to reveal the correlations between the ungulate vehicle collisions and the forestry's final fellings.

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<u>Photography:</u>

Image 1: *the red deer* (Photograph: Hedvall V. 2015)
Image 2: *the fallow deer* (Photograph: Hedvall V. 2015)
Image 3: *the wild boar* (Photograph: Hedvall V. 2015)
Image 4: *the roe deer* (Photograph: Hedvall V. 2014)
Image 5: *The European moose* (Photograph: Hedvall V. 2015)