A field-based estimation of eagle predation and scavenging on reindeer calves

Towards mitigating human-wildlife conflicts

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Degree project/Independent project • 60 credits
Swedish University of Agricultural Sciences, SLU
Department of Wildlife, Fish, and Environmental Studies Master Thesis 2023:31
Umeå 2023

A field-based quantitative estimation of eagle predation and scavenging on reindeer calves: Towards mitigating human-wildlife conflicts

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Credits:	60 credits
Level:	A2E
Course title:	Master degree thesis in Biology at the Department of Wildlife, Fish, and Environmental Studies
Course code:	EX0970
Programme/education:	Management of Fish and Wildlife Populations
Course coordinating dept:	Department of Wildlife, Fish, and Environmental Studies,
Place of publication:	Umeå
Year of publication: Cover	2023
picture:	Golden eagle
Part number:	2023:31
Keywords:	Aquila chrysaetos, Haliaeetus albicilla, Rangifer tarandus, predation, repelling, human-wildlife conflict

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Abstract

Eagle predation on semi-domesticated reindeer (*Rangifer tarandus*) calves, both golden (*Aquila chrysaetos*) and white-tailed eagle (*Haliaeetus albicilla*) is a well-known issue in Sweden. However, there is a knowledge gap regarding the balance between scavenging and hunting and the role that each of the eagle species has in this issue. This project was set up to fill the knowledge gaps of eagle abundance before, during, and after reindeer calving and the testing of two potential deterrents to repel eagles from reindeer calving areas. During the study period, we made 12, 47, and 17 eagle observations before, during, and after calving respectively. Of these observations, 34 were of GE, 33 of WTE, and for 9 observations the species could not be confirmed. Observations increased during calving and decreased again after calving. No direct attacks on calves have been observed. Two dead calves have been found, but the cause of death could not be allocated to any eagle species. The efficiency of 20 wind ventilators and 17 pyramid prisms was tested for deterring eagles from specific areas. The majority of eagle observations were made in the respective control area, with GLMMs showing significantly higher odds of observing an eagle in the control area compared to the ventilator area. Comparison between control and prism area showed no significant effect, but overlap between the two areas was small. No difference between the two treatments was found. A conclusion on the effect of deterrents can however not yet be made since the study needs more replication.

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Abbreviations

GE	Golden eagle
WTE	White-tailed eagle
Prism/pyramid	Peaceful Pyramid
RHA	Reindeer herding area
CAB	County Administrative Board
SEPA	Swedish Environmental Protection Agency
SFS	Svensk författningssamling
DEM	Digital elevation model
RLB	Rough-legged buzzard
AMSL	Above mean sea level

1. Introduction

With predators declining globally over the past two centuries, the conservation of these species has become more important than ever (Ripple et. al, 2014). Conservation of predators however often clashes with modern society, for instance in the form of fear, lethal encounters, or predation on livestock or pets (Vittersø et. al, 1998; Linell et. al, 2002). One of these issues is predation on reindeer (*Rangifer tarandus*) by large predators in Scandinavia. Predators like bears (*Ursos arctos*), lynx (*Lynx lynx*), wolverines (*Gulo gulo*), wolves (*Canis lupus*), and golden eagle (*Aquila chrysaetos*) prey on reindeer calves, juveniles, and sometimes even adults (Nybakk, 1999; Norberg, 2006; Horstkotte et. al, 2022). Furthermore, there are rising concerns among reindeer herders that white-tailed eagles (*Haliaeetus albicilla*) are also a part of the issue (Ekblad et al, 2020). For both the golden eagle and white-tailed eagle there is a lack of data in Sweden regarding the predation issue. Predation on reindeer has been documented, but the balance between directly attacking reindeer and scavenging on animals that are already dead is unknown. More knowledge is required to establish better-fitting compensation schemes and management decisions (Mattisson et. al, 2018). Sami herders are being compensated for the presence of golden eagles, where the total amount compensated is 1 million SEK annually for the Sami community as a whole (Sametinget, 2023). The white-tailed eagle has by researchers so far not been observed attacking reindeer (Mattisson, 2018) but is taken into account for this study as well since this is a subject of discussion between herders and researchers. This study aims to mitigate this human-wildlife conflict before it further escalates. Effective management of the conflict is crucial to solving the issue. Redpath et. al (2013) have produced a framework for the mitigation of conservation conflicts (Figure 1). When looking at the framework, ecological science can provide aid in conflict mitigation in several steps of the process in both 'mapping', and 'managing' the conflict. Our aim is to provide scientific knowledge in this regard and address both sides of the issue. On the 'mapping conflict' side, it is ecological science that 'gathers all scientific evidence, together with gaps & uncertainties'. It is known that golden eagles predate on reindeer calves, but what is the balance between predation and scavenging? Is predation on neonates higher than previously documented? What is the role of the white-tailed eagle in this conflict? On the 'management conflict' side, it is the ecologists' job to try and find solutions for the issue where both parties agree to the resolution mechanism, and test these mechanisms. In this study, we have tested the efficiency of two different potential eagle-deterring devices. These ethical devices could provide herders with protection for the reindeer cows and calves. When proven the devices are proven to be effective it will give an outcome where both herders and other stakeholders (i.e. conservationists) are satisfied.

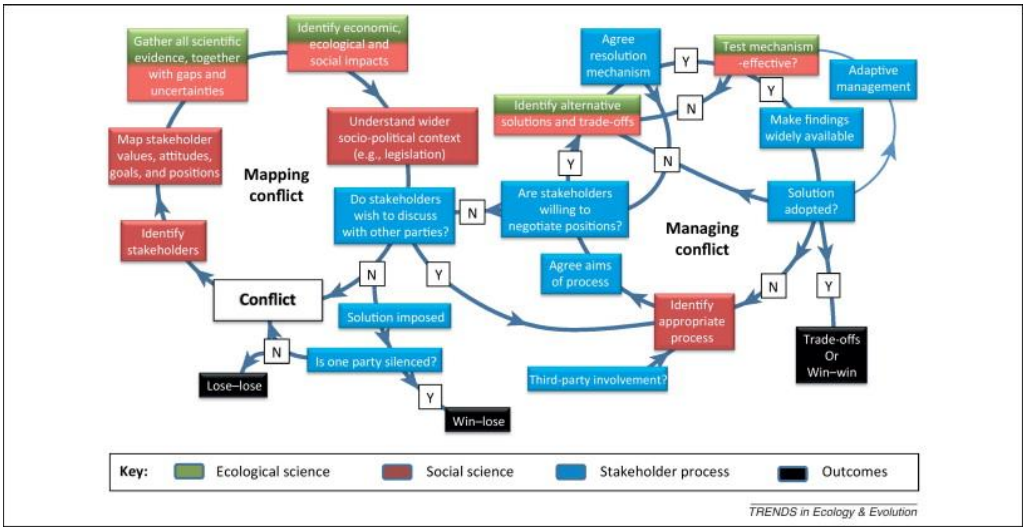

Figure 1: Roadmap to effectively guide management of conservation conflicts. Taken from Redpath et. al (2013)

1.1 Golden eagle

The golden eagle is one of Scandinavia's biggest birds of prey, only surpassed by the white-tailed eagle in size (Cramp, 1992). The species occurs in most parts of Scandinavia, and there is great overlap with the areas where reindeer herding is prominent. The current population of golden eagles in Sweden has been fluctuating around 1500 individuals between 2006 and 2021 (Åsbrink & Hellström, 2022). The two northernmost counties hold the majority of the eagle territories, with more scattered populations in the south, and a noticeable population on the island of Gotland (Åsbrink & Källman, 2023). Golden eagles face serious threats like lead poisoning (Legagneux et. al, 2014; Ecke et. al, 2017; Helander et. al, 2021), illegal shooting (Palmer, 1988), habitat loss, and human disturbances (Watson, 1997). Besides small mammals, birds, fish, reptiles, and insects their diet partly consists of reindeer (Cramp, 1992; Tjernberg, 1981). For golden eagles, the proportion of reindeer in their diet can vary from 6% to 43% (Mattisson, 2018). Golden eagles mostly scavenge on afterbirths, stillborn calves, or deceased reindeer but have also been reported to attack young reindeer (Nybakk et al., 1999). True numbers of eagle predation, especially determining whether it killed an individual, or merely scavenged are hard to grasp since data is lacking (Hjernquist, 2011; Mattisson, 2018). Estimated predation rates on reindeer calves range from 0 – 4.2% annually (Nybakk et. al, 1999; Norberg et. al, 2006; Nieminen et. al, 2011). Nybakk et. al (1999) showed a predation rate on calves of 2.4%. Nybakk et. al's study however was started in August, when the calves are already around two to three months old. Predation on neonates is claimed by herders to be the most serious problem, since that's when calves are most vulnerable (Tjernberg, 1981). This has recently been proven to be true in the case of brown bears (Støen et. al, 2022). 98% of predation by brown bears occurred between the first of May and the 9th of June and the same may be true for golden eagles. The hunting technique used by golden eagles to catch large prey, like the reindeer, especially in snowy conditions, is described by Watson (2010) as the 'glide attack with tail chase. It describes an instance where the golden eagle dove on the head of a sheep and held it down for 15 minutes, resulting in the sheep's death. Animals killed this way are generally too heavy for the birds to lift, and are therefore consumed on the spot, suggesting these individuals are either non-breeding or subadults since prey cannot be taken to the nest (Watson, 2010). Damage of golden eagles to reindeer is compensated in Sweden. The current compensation scheme for reindeer herders is conservation incentive payment (Schwerdtner & Gruber 2007, Pekkarinen et al. 2020), where herders are paid for the presence of golden eagles in the area, but also based on the size of their area (similar to the other large carnivores).

1.2 White-tailed eagle

The white-tailed eagle is the biggest raptor in Scandinavia (Cramp, 1992). It occurs throughout the whole of Sweden (Artfakta, 2022). Currently, the number of WTEs breeding pairs is 400 (Artfakta, 2022). White-tailed eagles are coming back after a rapid decline in the 1900s (Helander, 2009). Protection in 1924 caused a slow recovery, but in the '50s and '60's the population decreased again due to toxins. Persecution of the raptors, urbanization, toxins, and the forestry industry were the main reasons for population decline (Helander, 1975). Nowadays, the white-tailed eagle has recovered, leading to rising concerns of reindeer herders, for they are not compensated for WTE presence (Ekblad, 2020). According to herders, reindeer calves have also been observed being hunted by WTE. Similar concerns are present in Scotland, where WTEs are claimed to have killed red deer, and in Norway, where they are assumed to predate on livestock. In the Scottish case, it was a subadult WTE that had killed a two day old red deer calf (Love, 2013). There were however no punctures in the carcass that were indicated as the cause of death, only the opening up of the carcass using its' beak. The Norwegian case is a unique event where two immobilized lambs were predated while still alive. During this 'pseudo predation' event the WTE essentially acted as a scavenger on prey that turned out to be still alive, but unable to move. 166.000 reports of damage by predators have been collected from 1987-2017 by a Norwegian carcass autopsy program, with only the one case described above as being assigned to the WTE (Birdlife Norge, 2019). Regarding reindeer, WTEs are known to scavenge on dead individuals, both calf and adult, but attacks have not been recorded (Mattisson, 2018). The arrangement of claws on their feet seems to make grappling ineffective when trying to grab a reindeer since they are not designed for catching larger prey (Mattisson, 2018). Although the literature suggests that WTE are of no concern to reindeer herders, they possibly influence it indirectly. White-tailed eagles, especially subadults, are more sociable compared to golden eagles. Aggregation of immature individuals around food sources is not uncommon, and although golden eagles are dominant, these aggregations can quickly reduce the food availability of an area (Mattisson, 2018). Lower food availability for golden eagles could potentially mean that they would have to rely on attacking calves more frequently, but there is no published literature on this matter as of yet.

1.3 Reindeer & current management policy

Semi-domesticated reindeer in Sweden are owned by the indigenous Sami people of Sweden. Reindeer cows usually calf at the end of May (Horstkotte, 2022). During this period both cows and calves are vulnerable to predation, with newborns being easy targets for predators (Linnell, 1995). In Sweden, the county administrative board (CAB) is responsible for golden eagle management. The management for Sweden is split in three areas: The northern area: Jämtland, Västerbotten, Västernorrland, and Norrbotten; the central area: Dalarna, Gävleborg, Örebro, Stockholm, Uppsala, Västra Götaland, Värmland, and Västmanland; the southern area: Blekinge, Gotland, Halland, Jönköping, Kalmar, Kronoberg, Östergötland, Skåne, and Södermanland. The CABs of these areas work together regarding predator policies. The central and northern areas have representatives from the Sami parliament that are included in the councils. The CAB makes a proposal that states the minimum reproductions per year for all large carnivores (bear, golden eagle, lynx, wolf, and wolverine) for its respective county. The CAB's proposal is forwarded to the council and when agreed upon, send to the Swedish Environmental Protection Agency (SEPA), and they, in turn, set minimum levels for the large carnivores for each county. Once every five years, the SEPA has to review the distribution of minimal levels. The CAB needs to do annual inventory surveys (after consultation with Sami villages) for each respective carnivore species, which are evaluated by the SEPA. When inventories have not been possible, the SEPA has to estimate these numbers. The SEPA can make changes to the plans when they deem it necessary. If the decision affects reindeer husbandry, the Sami Parliament always needs to be consulted before the regulations, as stated in SFS (2009: 1263). The SEPA is satisfied with the current adaptive golden eagle management (Naturvårdsverket, 2012). The minimum set level for golden eagles is 150 breeding pairs, and from 2006-2021, on average, there have been 184 successful breedings annually (Åsbrink & Hellström, 2022). Reindeer herders are compensated for damage done by big carnivores, including golden eagles. The total annual sum for golden eagles compensation is around 1 million SEK and depends on the size of the herding district (Sametinget, 2023; Pers. comm. Tim Horstkotte, 1st march 2022). Compensation for predators is in advance and is based on the predicted economic losses of the given carnivore (Schwerdtner & Gruber 2007, Pekkarinen et al. 2020). Before 1996, herders were compensated for found reindeer that were killed by predators. This method was deemed unsatisfying since a bulk of the killed reindeer were never found, and the costs of locating the animals were very high. Other problems with such compensation schemes are moral hazard (Swenson & Andrén, 2005), fraud, inadequate compensation, long delays in payment, and high transaction costs (Pers comm. Tim Horskotte, 1 March 2022). Reindeer herders can, at best, break even in this compensation scheme, but not profit. This in turn makes it more difficult to improve attitudes toward the golden eagle, possibly hurting golden eagle conservation. Since in cases of high calf mortality due to predation, an application for a licensed hunt can be made to prosecute the potential problem individual (Naturvardsverket, 2023). As individualization of free-roaming golden eagles is difficult, it's hard to efficiently persecute, which would have negative effects on the golden eagles' population without solving the herders' problems.

Our main objective study is to better understand the extent of eagle predation pressure on livestock by both eagle species to facilitate and improve management in such a way that benefits for both wild predators and livestock are maximized. The balance between scavenging and active predation is therefore a crucial factor to take into consideration. Furthermore, the study aims to reduce predation on reindeer by testing the efficiency of a pair of two different deterring devices. Lastly, GPS analysis will shine some light on where eagles in the area came from, and whether surveying hours are sufficient in areas with polar nights. To answer the questions above, the following hypotheses were tested:

1. Number of eagle observations of both species increases during calving when compared to before, and after calving.

2. The control area will have more eagle observations compared to each individual treatment area.

3. Golden eagles do not fly/hunt during the night, even though there is sunlight available.

2. Material & methods

2.1 Study area

The study area (Figure 2) is located in the Vilhelmina Norra sameby (65.37°N, 14.64°E). Vilhelmina Norra is a reindeer herding area in northwestern Sweden that borders Norway. The total herding area is over 14.000 km2, whereas our study area is around 250 km2. The county administrative board has permitted a maximum of 11.000 reindeer in the whole area (Sametinget, 2023). The study area is a mountainous area with high, rolling mountains of approximately 800 to 1300 meters. At around 800 meters the tree line occurs. During most months of the year, the area is covered in a thick pack of snow. Vegetation consists predominantly of birch (*Betula pubescens*) forests, Norway spruce (*Picea abies*), and Scots pine (*Pinus sylvestris*) trees, ground vegetation consists of subshrubs like crowberry (*Empetrum nigrum*) and blueberry (*Vaccinium myrtillus)*. Both golden eagles and white-tailed eagles are known to occur in the area. During the calving period, reindeer aggregate in specific areas, for our study we chose one of these concentrated areas for our experiment.

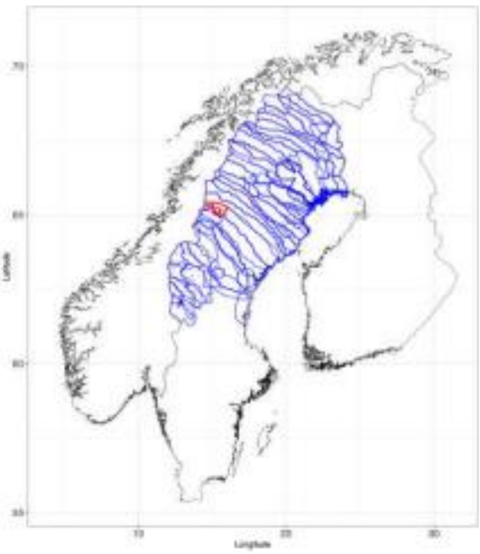

Figure 2:Map of Sweden with reindeer herding districts (in blue) and the study area of Vilhelmina Norra (in red)

Field work was performed in three separate weeks; before calving (25/4/2022 – 29/4-2022), during calving (20/5/2022 – 26/4/2022), and after calving (26/6/2022 – 1/7/2022). Traditionally most calving happens during the second week of May (14/5 - 20/5), this year however the snow cleared later than expected. After talking to one of the reindeer herders the 'during' fieldwork was therefore postponed by a week in order to arrive during peak calving. The before-during-after set-up allowed us to set a baseline of the number of eagles in the area before possible migrating individuals came in. The after period is to see how long the potential effects of calving last, to better identify the extent of the issue. Observations were done from 08:00 until 17:00.

Spotting scopes and binoculars were used for eagle sightings. Observations were done from vantage points selected for the highest visibility and area coverage. In order to reach these places mainly a snowmobile was used, but some days the places were hiked to for logistic reasons. Observers rotated between points throughout the weeks on a daily basis to randomize observer bias. Point count methods as well as territory mapping (in the first period) were used to determine the number of eagles in the area. Observation locations were selected on a daily basis, not fully predetermined. Being flexible and adapting to current situations, weather being the most important one, to get the best coverage of the area was deemed higher than a theoretically perfect prefabricated set-up. In the mornings the locations were discussed according to the needs to equalize effort across all areas. Occasionally the starting point was left in search of a better area based on current weather conditions but always located within a reasonable distance from the starting point. Mobility was kept limited, in order to keep disturbance to both reindeer and eagles to a minimum.

2.2 Repelling devices

Raptors make great use of their excellent eyesight, which is why this characteristic trait was decided to be the target for repelling them from certain areas. This study tests the effect of two potential repelling devices: wind turbine ventilators and the peaceful pyramid later referred to as ‘prisms’ (Figure 4). The study area was split into three areas, one allocated to ventilators, one to prisms, and one control area (Figure 4). Not a lot of research has been done on raptors regarding mirror/reflective devices, but there have been some successful trials (Bishop et. al, 2003; Levin et. al, 2008). Last year’s pilot study on the prisms showed promise but a proper experimental set-up lacked. This year the set-up is improved using the ‘before-during-after’ set-up, while also splitting the study area in 3, one for each treatment and a control area. The rotating, triangular, prisms are 12 cm high, run through a 12 V motor, and are powered by a 12 V car battery. The angle of the mirrors throws reflections obliquely upwards and thus scares the birds that fly into a field. This device was used by Viltskadecentre and recommended by them. In addition to the prisms, wind ventilators are tested. The wind ventilators are the typical ventilators seen on rooftops. Sunlight is constantly reflected on the rotating metal ventilator, possibly repelling eagles similar to the prisms, just bigger and sturdier. The abundance of wind in the mountainous regions of the calving area makes these devices an energy-free option, a great benefit when compared to the prisms. 20 ventilators and 17 prisms were placed in the study area separate from each other (Figure 4). The devices have been carefully placed in places with the highest visibility, predominantly on mountain tops. The repelling devices have been placed just before the ‘during’ calving period. No devices were present before calving, but devices could not be removed in time for the ‘after’ calving period. The effect of the deterrents will only be tested during calving, even though they had not been removed after calving. Analysis was performed in R (. To analyse the effect of the repelling devices, Generalized Linear Models with a poisson distribution were built through the R package lme4, and compared to a null model with an Omnibus test. Amount of observations was used as response variable. “Day” was tested for effect and showed no effect on the number of eagles. “Day” was then included as a random effect in the model to account for daily fluctuations in for instance weather. This analysis was performed for control, ventilator, and prisms, but also for control vs. treatment.

Figure 3: A. Light reflecting prisms. B. Wind-powered ventilator

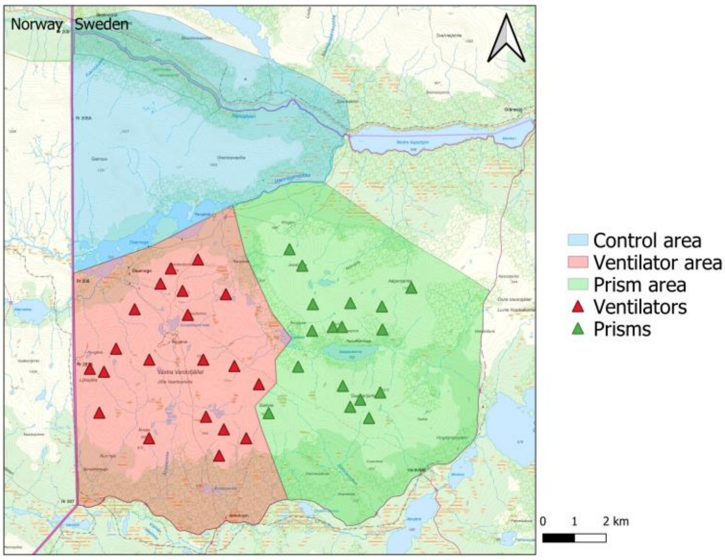

Figure 4: Study area with control area (blue), ventilator area (red), and prism area (green).

2.3 Observations

When an eagle was spotted, its species, age, flight path, behavior, observers, and time of observation were recorded. Flight paths were drawn on maps while in the field on a 1:50000 scale map. For golden eagles, when determining their age the images of Tjernberg were used as a reference (http://www.orrhult.eu/projekt/orn/aldersbest.kungs/text%20alder/text%20alder%20index.htm) In case of uncertainty in age (costumes have transition states that are hard to distinguish) a range was given, 3-4 years for instance, or a plain 'adult' or 'subadult' as a last level of distinguishment.

For white-tailed eagle age determination, we looked at both the tail and the overall plumage. Subadults of white-tailed eagles have a plumage with a mix of white and brown, with a tail that is not yet fully white. Adult WTEs have a clear white tail, and completely brown plumage. When exact aging was not possible because of distance, time, or weather conditions an indication of 'adult' or 'subadult', was tried as a second option for determining age. Both species of eagle do show sexual dimorphism, but to such a low extent that it is not possible to determine sex using only visual cues For both GE and WTE, the females are larger and heavier than their male counterparts (Cramp, 1992). It is impossible to reliably distinguish size at great distances for the human eye, therefore sex was not determined. Recognizing eagle species is challenging at great distances. In order to distinguish golden from white-tailed there are several differences; GEs have a larger tail compared to their body size, and their wings are more roundly shaped than the white-tailed eagle. The WTE shows a bigger spread in the 'fingers', and they are therefore more recognizable. Furthermore, when soaring, the WTE is more horizontal whereas the golden eagle remains a slight V-shape in its wings. At great distances and in certain light conditions one of the other, smaller, raptors in the area, the rough-legged buzzard (*Buteo lagopus*) can be confused with an eagle. This species, however, has a more fan-shaped tail, and its wings are positioned slightly more forward. The RLB also has a plumage that is mainly white on the belly side with two black circles on each shoulder. Also, the RLB is significantly smaller, but, as said before, this can be deceiving at larger distances against a clear sky. Other species present, general descriptions of the behavior, interaction between eagles, etc. were written down in field notebooks. At the end of the day, the observations were documented in an Excel sheet and all drawn on an overview map to make digitalization easier afterward. Observations were later added to a map in QGIS with both starting position and flight path.

2.4 Predation

The hunting technique used by golden eagles to catch large prey, like the reindeer, especially in snowy conditions, is described by Watson (2010) as the 'glide attack with tail-chase'. It describes an instance where the golden eagle dove on the head of a sheep and held it down for fifteen minutes, resulting in the sheep's death. Once an eagle has taken hold of its prey, it uses its claws to press into the prey's vital organs, until the prey collapses after a few minutes. Most notable are the holes left by the claws in either the head (all the way to the brain), neck, back, and or sides of the prey to puncture the lungs (Levin et. al 2008), as can be seen in Figure 3. Animals killed this way are generally too heavy for the birds to lift and are therefore consumed on the spot, suggesting these individuals are either non-breeding or subadults (Watson, 2010). With herders' help, dead calves were located and inspected. In the case of a found dead calf, autopsies were performed as described in Levin et. al (2008). When born, reindeer calves have a soft membrane over their hooves to protect it from damaging the cow during birth. After walking, this membrane quickly disappears. A deceased calf that still has the soft membrane on its' hooves is a sign that the calf never walked. This sign means that the calf was stillborn, and predation can be ruled out. The inspection then starts with checking for tracks and blood tracing at the site. Deep bites or sharp objects (like claws) cause heavy bleeding when large arteries are punctured. In the snow, these types of wounds create a phenomenon known as pipe bleeding. The blood runs deep through the snow and does not leave a puddle of blood. Starvation, disease, or being stillborn does not create these typical pipes of blood. The animal needs to be skinned after in order to do further damage assessment, where it is important that the skin is separated from the flesh as clean as possible. In the case of golden eagles, claw marks made *after* death appear as holes in the skin, with no blood or red skin surrounding the puncture. Calves directly killed by golden eagles show deep punctures, with no surrounding teeth, in the flesh, with redness surrounding it. Identifying the cause of death on reindeer can be extremely challenging, and much caution is needed when drawing conclusions from the autopsies. When a deceased reindeer calf was found, we placed a camera trap a few meters away from it to continuously monitor it after observation hours. These pictures could provide us with more information on both eagle species' behaviour and species interaction. The Dörr SnapShot Mobil Black 5.1 (SMS) camera was used. (outdoor-focus.de). This camera sends the images to one of the team members' phones. This allowed us to check whether eagles were present at the carcass before traversing into the area where the camera was placed, avoiding possible disturbance.

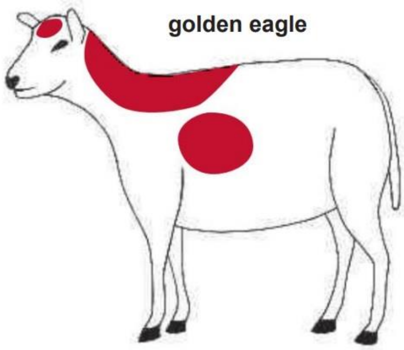

Figure 5:Typical areas targeted by golden eagles on livestock. Taken from Levin et. al 2008.

2.5 Reindeer distribution & behaviour

The abundance of reindeer, and thus calves, was a factor that was predicted to correlate with eagle presence. Reindeer distribution was determined by overlaying a grid on a zoomed-in map with labels. Each square had an X and Y label and observations were noted on the map for that day. Whenever possible the number of calves was also counted to get a general estimate of the percentage of cows that had calved. Since reindeer move constantly during the day the estimate is mostly used to see which of the three areas has the most reindeer on which day. Estimating reindeer densities and distribution with higher accuracy would require daily aerial surveys of its own. With four to five people constantly looking for eagles it is hard to keep track of which group of reindeer went where since visibility from tops could range across several square kilometers, which is ideal for finding flying eagles but harder for the slower moving, but more numerous reindeer.

2.6 Choice of observation points

Vantage points were selected based on altitude and visibility to maximize the possibilities of detecting eagles. Figure 5 shows the study area with vantage points and the visibility of those points. This analysis was performed in QGIS with the Viewshed plug-in, where observer height was set at 1.60, and target height at 0 and 50 meters (see section 2.7 for the reasoning of height) for sitting and flying eagles respectively. The dark blue area shows where sitting eagles could be spotted whereas the light blue area shows where eagles flying at a height of 50 meters could be detected. The maximum distance at which an eagle could be spotted was set at 5km which was based on the observer's experience. At distances greater than 5km, it was virtually impossible to distinguish species, age, and sometimes even activities because losing sight of a bird at this distance was not uncommon. As can be seen, all three three areas were sufficiently covered by manning these posts in a rotating manner.

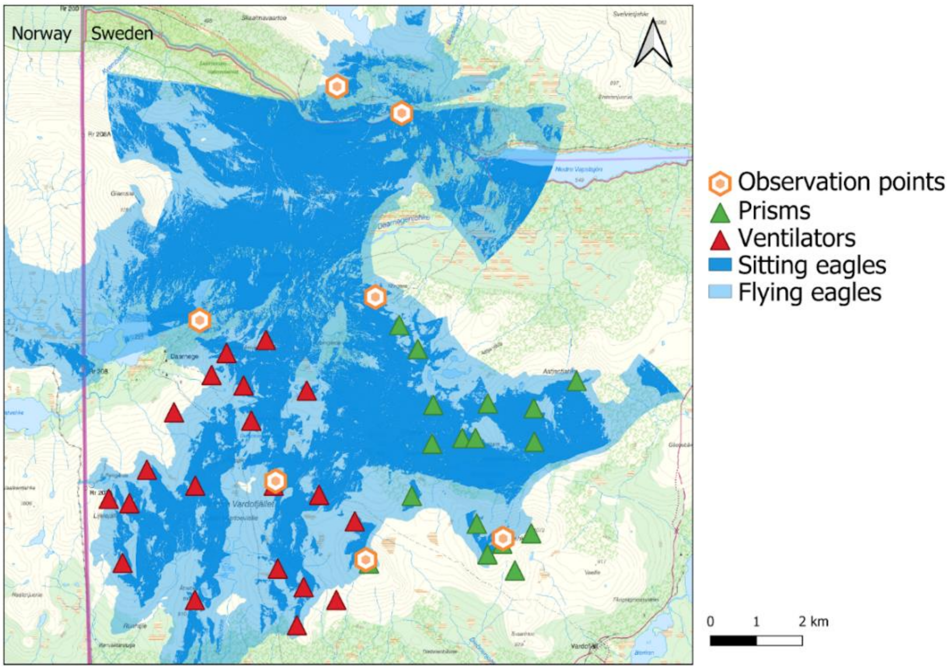

Figure 6:Observation points with visible areas for sitting eagles (blue) and flying eagles (light blue). The map was constructed in QGIS and used as a background map Naturkartan

2.7 GPS data

In addition to the fieldwork, previously gathered GPS data (2010-2019) by SLU will be used to further understand eagles' behaviour in the calving areas. The data is from 74 golden eagles tagged in 2010-2011, and 2014-2015 where eagles were equipped with backpack-type GPS units from several manufacturers (Microwave Telemetry, Vectronic Aerospace GmbH & Cellular Tracking Technologies). Adult eagles were trapped in autumn using bow-nets (Bloom et. al, 2015) and tagging of subadults happened during ringing them in the nest. Data points on XYZ-scale can clarify the eagle's behaviour to some extent regarding its activity; flying or sitting. In order to better understand eagles' behaviour and improve future surveys this information on activity patterns is essential. One of the concerns of the pilot study was regarding the working hours; is 08:00-17:00 sufficient to document predation? The sun does not fully set during the time of reindeer calving, meaning there is daylight available throughout the whole day. This raises the question of whether eagles use this opportunity to also hunt during the night, which will be explored through the GPS data. Furthermore, the data will be used to check whether the GPS-tagged eagles have shown up in the current study area, and where they came from. Note that this data is from 2010-2019, not from the year of fieldwork, 2022.

GPS data was analysed using Rstudio (version 4.1.1) (R Core Team, 2022). through the packages: sp (version 1.5-0), amt (version 0.1.7), and raster (version 3.6-3). In order to know at what time the eagles are active in the calving areas during the months of April, May & June first all the points that were not inside the calving area had to be removed. The GPS points were intersected with a previously acquired map containing the calving areas of all 51 reindeer herding areas. I applied a 10 km buffer to the calving shapefile to account for bordering eagles. The retained GPS points were then filtered for month, leaving only April, May & June. The GPS data frame shows Z-axis in meters above mean sea level (AMSL). In order to obtain the height of the eagle, the elevation had to be subtracted from this value. Via Maps.slu.se a digital elevation map with an accuracy of 2x2 meters was obtained. This DEM was then overlaid on the GPS points and the elevation for each data point was extracted in R. The elevation value was subtracted from the AMSL for each GPS point. This left us with the actual flight height of the eagles. Points with a flight height higher than 2000 meters were excluded from the dataset. GPS points in Norway were removed since they showed a value of 0 for altitude since the DEM was solely for Sweden. Now that the 'actual' height of the eagles was known, a separation between sitting and flying had to be made, in order to know when eagles are active. Height can not simply be put to a 0 meter range due to inaccuracies in GPS positions but more importantly, the DEM is based on terrain but does not include trees. Eagles perch in trees for large amounts of time over the course of the day. To set the threshold for flying and sitting, these factors had to be taken into account. Previous studies on GPS-tagged golden eagles regarding wind turbines have used 30 meters as a threshold for flying eagles (Hipkiss et. al, 2013). In the case of our GPS devices, the vertical accuracy is very low, and the number of satellites the position was based on is unknown. Vertical accuracy for the devices ranged from 2-22 meters (Microwave Telemetry, 2013; Sandgren, 2013). The threshold for flying eagles was set at 50 meters, in order to be safe in terms of perching birds and the inaccuracy of the GPS devices.

3. Results

3.1 Observations

A total of 75 eagle observations were made during the study (Figures 8, 9, & 10). Of these 75 observations, 34 were of GE, 32 were of WTE, and for 9 observations the species could not be identified. The number of observations was highest during the calving period for both GE and WTE. The number of observations was lowest during the ‘before’ calving week. The after-calving week had slightly more observations than before calving, but fewer than during calving. Figure 7 shows the daily observations per species for each round. Instead of the total number of counts, the daily average is used because not all periods had the same amount of observation days. The amount of golden eagle observations remained stable across all periods. White-tailed eagles showed an increase in daily observations during calving. The standard errors of the data were not normally distributed so an ANOVA test could not be performed. A Chi-squared test performed in R also showed no significant difference in observations between periods for both golden eagle and white-tailed eagle. The amount of white-tailed eagles decreased after calving, compared to during calving but not to the level it was before calving.

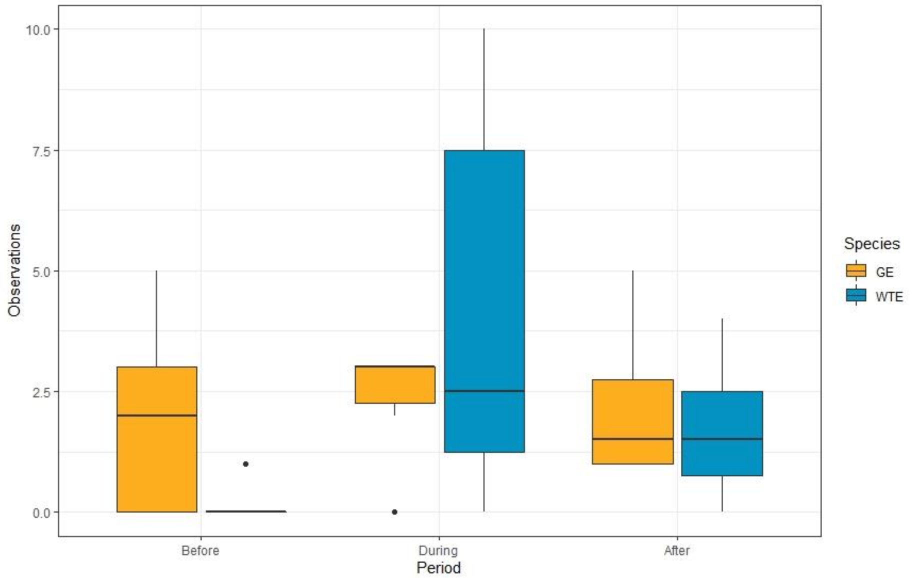

Figure 7: Daily observations of GE in yellow, and WTE in blue

3.2 Before calving

Figure 8 shows the locations of eagle observations before calving with golden eagles represented in yellow, and white-tailed eagles shown in blue. Before calving, 12 observations of eagles were made. Weather conditions were not optimal during this period, with two days of limited visibility. An overview of the weather report can be found in Appendix X. The majority, 11, of eagles spotted were golden eagles, with only a single white-tailed eagle observation during this period. Some of the observations made in this period were outside of the study area. Several known nests and territories were checked for nesting eagles with two of the territories showing incubating females. Eagles would also fly over the observers' cabin outside of working hours. These observations were recorded, but are not taken into account for testing the effectiveness of the repelling devices. The eagles were mainly seen flying in the area, but no hunting behavior has been observed. Reindeer were only just arriving in the study area, therefore numbers were low. Some groups of less than twenty reindeer were spotted and some scattered individuals, but no large groups.

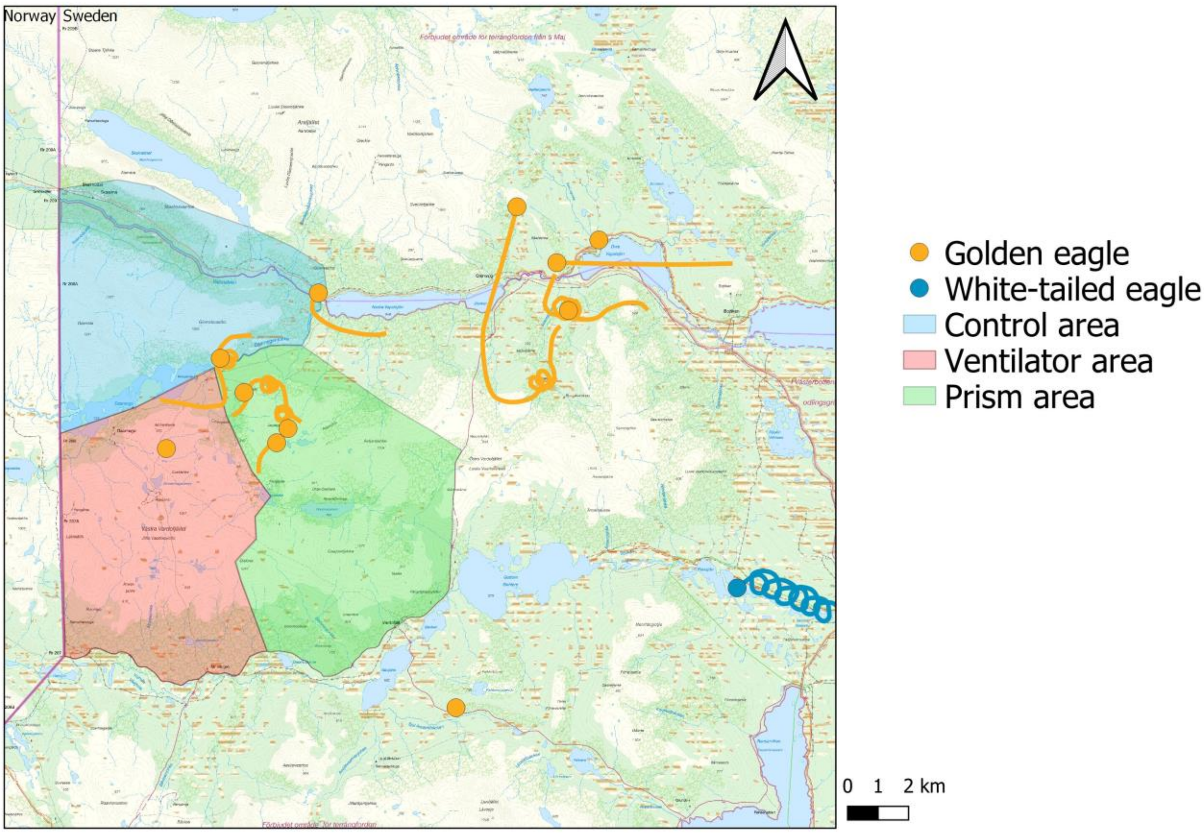

Figure 8: Map of observations before calving with golden eagles in yellow, and white-tailed eagles in blue.

3.3 During calving

Figure 9 shows the locations of eagle observations during calving with golden eagles represented in yellow, white-tailed eagles shown in blue and unidentified species in grey. A total of 47 observations were made in this period. Of these 47 observations, 14 were of GE, 25 of WTE, and for 8 observations the species could not be identified. During calving, the majority of the reindeer had arrived in the area, with the bulk of them located in the ventilator area. Big groups of over 100 reindeer were spotted in both the ventilator area and the control area. In the second round of fieldwork, less than half of the cows had calves, fewer than expected. The snow coverage in the area was still high which could explain why spawning was delayed. An overall increase in eagle observations was seen. Whereas there was only one observation of a WTE in April, in May the majority of observations were white-tailed eagles. Some of the observations in the northern part of the area did not fall within the study area, but some of this can be explained due to the abundance of reindeer in the adjacent reindeer calving area north of our study area. Most observations have been made in the control area, the two other areas had similar eagle occurrences.

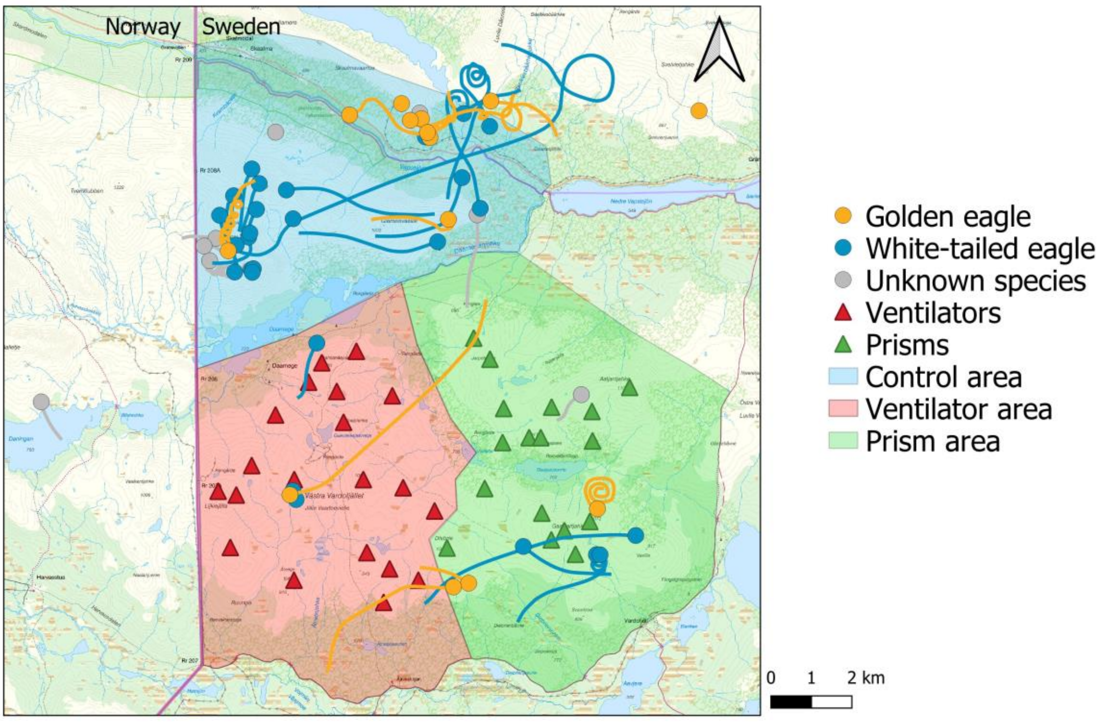

Figure 9: Observations during calving with golden eagles (yellow), white-tailed eagles (blue) and unknown eagles (grey)

3.4 After calving

Figure 10 shows the locations of eagle observations after calving with golden eagles represented in yellow, white-tailed eagles shown in blue, and unidentified species in grey. A total of 17 observations were made in this period. Of these 17 observations, 9 were of GE, 7 of WTE, and for 1 observation the species could not be identified. The number of golden eagles had remained relatively stable with some white-tailed eagles still in the area. It seemed that most of the white-tailed eagles had already left the area after calving had occurred. At this point, the ground cover situation had completely reversed when compared to the previous round. The snow had almost fully melted and only a few patches of snow were left. The reindeer were shown to use these patches of snow to cool themselves from the higher temperatures in June.

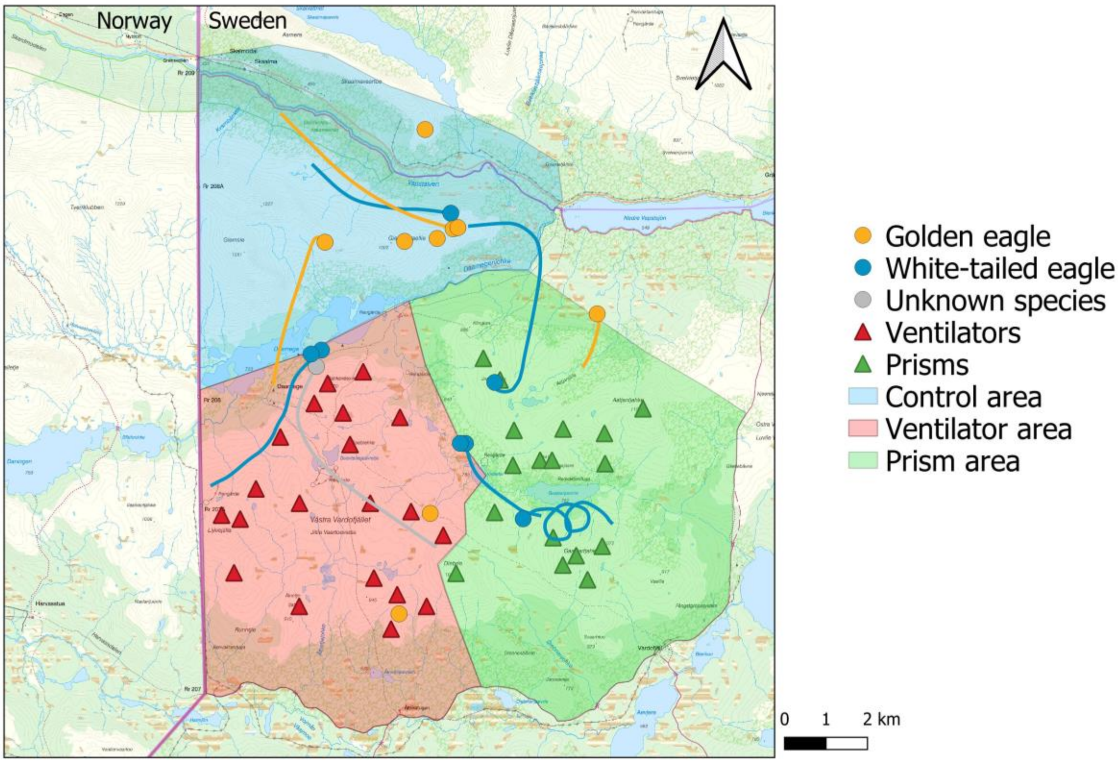

Figure 10: Map of observations after calving with golden eagles in yellow, and white-tailed eagles in blue

3.5 Treatment

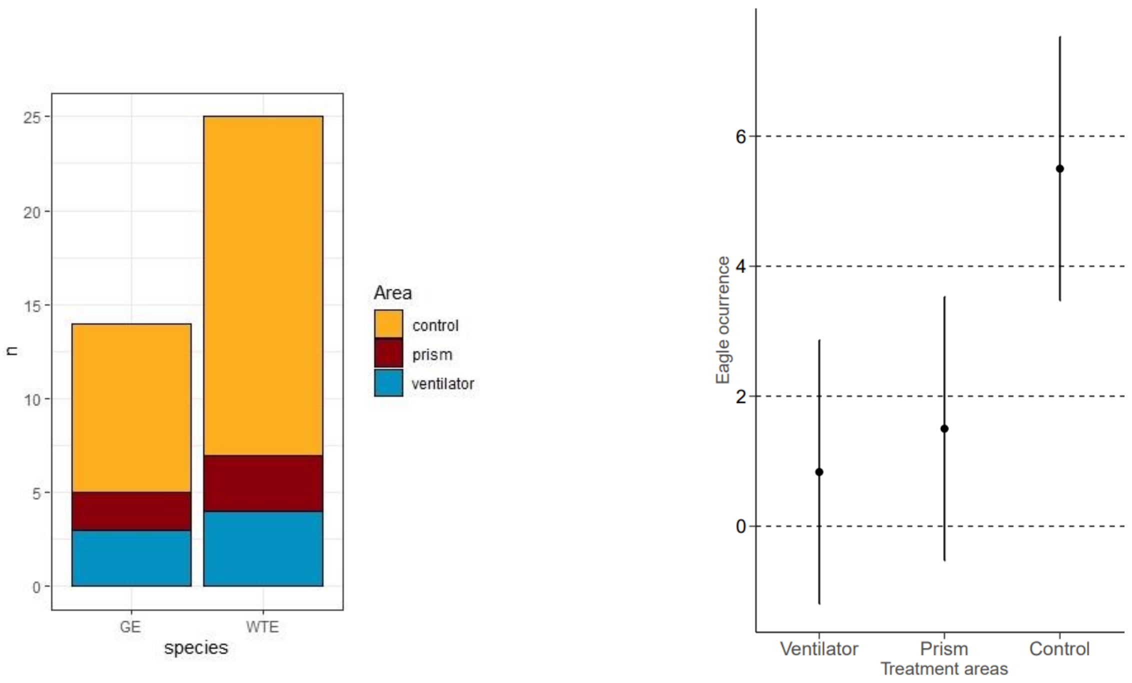

Figure 11A. Eagle observations per treatment area during calving. B: Result of GLMM showing eagle occurence per area.

Figure 11A shows the number of observations per respective treatment area during calving. GLMMs showed that the likelihood of observing an eagle was significantly higher in the control area when compared to ventilator area, and almost significant in the prism area (Figure 11B). For each individual area this was 1.7, and 1.1 for ventilator and prism respectively. Treatment predicted 41% of the number of eagle observations. When taken together, the control area showed a 2.2 times higher eagle occurence compared to the treatment areas.

3.6 Predation events

During the study, no predation was directly observed. However, two dead calves were found during the study. Autopsies as described in the methods section could not confirm that the calves were killed by eagles (Figure 12C), nevertheless a camera trap was set up to monitor them. One of the reindeer calves had the soft membrane still on its feet (Figure 12A), meaning it was probably stillborn. The other individual had walked since the membrane had worn off, but the exact cause of death could not be assigned to a golden eagle (Figure 12B). Apart from raven (*Corvus corax*), no animals were seen on the camera traps. Eagles of both species were spotted several times performing reconnaissance flights over groups of reindeer, indicating they opportunistically looked for dead, weak, or sick animals, or possibly an attack option. One dive was seen from a golden eagle on a group of reindeer, possibly in an attempt to kill a reindeer calf, but to no success.

Figure 12. A: reindeer calf hooves with soft membranes still present. B: Reindeer calf hoof without soft membrane. C. Reindeer calf that had walked, but wounds could not be assigned to the golden eagle.

3.7 Age distribution

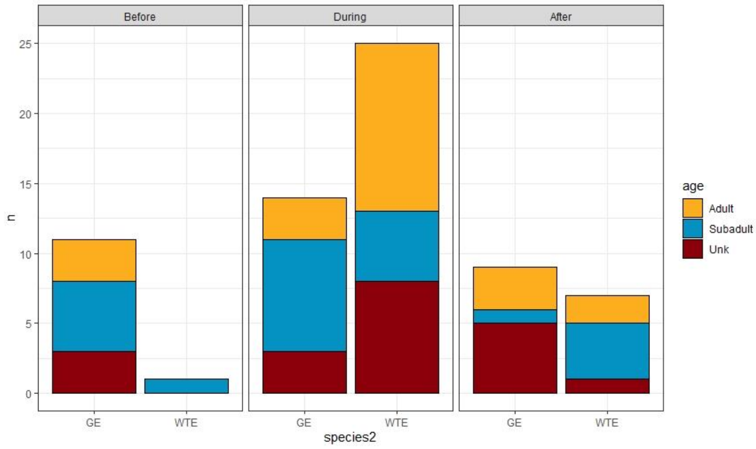

Figure 13. Eagle age distribution per species for each period.

Figure 14 shows the age distribution for each species per round. The exact age of the individuals was in some cases not possible to establish due to the distance between the observers and the eagles (sometimes >5km), light conditions, or plumage transition states. The amount of adult golden eagle observations remained stable across the fieldwork weeks. During calving, the number of observations of golden eagle subadults in the area slightly increased and declined again in the ‘after’ calving period. WTE observations reached their peak during calving, with both subadult and adult observations increasing. Subadult WTEs observations remained higher in the after-calving period compared to the respective decline in adult observations. For golden eagles, it’s hard to draw conclusions on age classes for the ‘after’ calving period, given the fact that for the majority of the observations, the eagle’s age remained unknown.

3.8 Behaviour

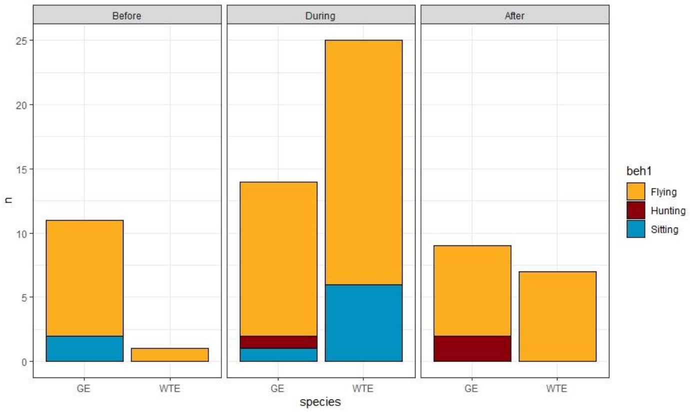

Figure 14. Eagle behaviour per species for each round.

Figure 15 shows eagle behaviour by observations per species for each period. Eagles were mostly observed while flying since that's when they are easiest to detect for observers. On some occasions, the eagles were found while sitting, with two cases of hunting eagles.

3.9 GPS data

Figure 15 shows the activity patterns of golden eagles during the months of April, May, and June combined. The birds start flying at 06:00 in the morning, and stop at 18:00, with peak activity from 09:00 until 15:00. There is some activity during the night, but activity is mainly during the day hours. This means that even though it's light during these hours, eagles are generally not active during the night. The data is based on a range from 5000-25000 points for each respective hour (Appendix X)

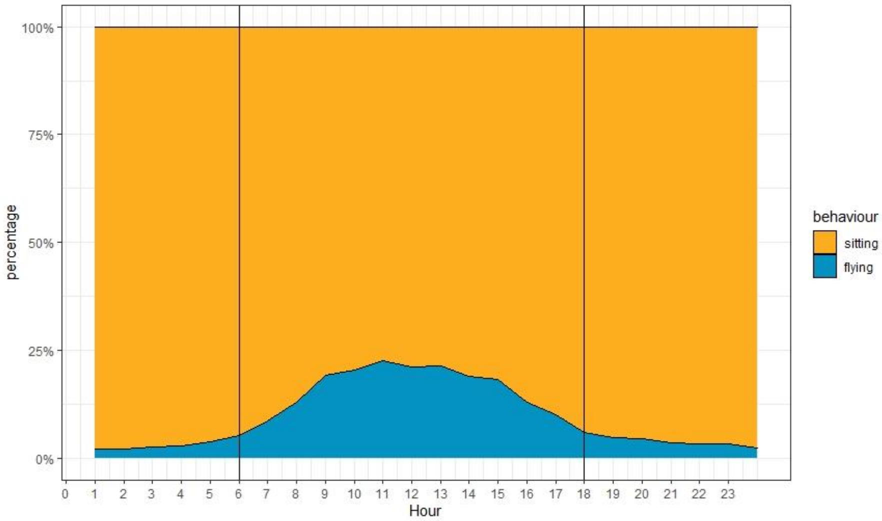

Figure 15: Hourly activity pattern for GPS-tagged golden eagles during April, May & June.

Figure 16 shows the GPS points of golden eagles in the study area. Note that this is data from 2010-2019, so not the year of the repelling devices. Out of all the tagged eagles, five individuals showed up in the study area. One of the individuals was an adult female, and the other 4 were subadults (both males and females). Three out of the five eagles had been tagged in the east of Västerbotten (see figure 17), the other two more west in Vasterbotten. Figure 16 shows the recorded positions for all five eagles that showed up in the study area.

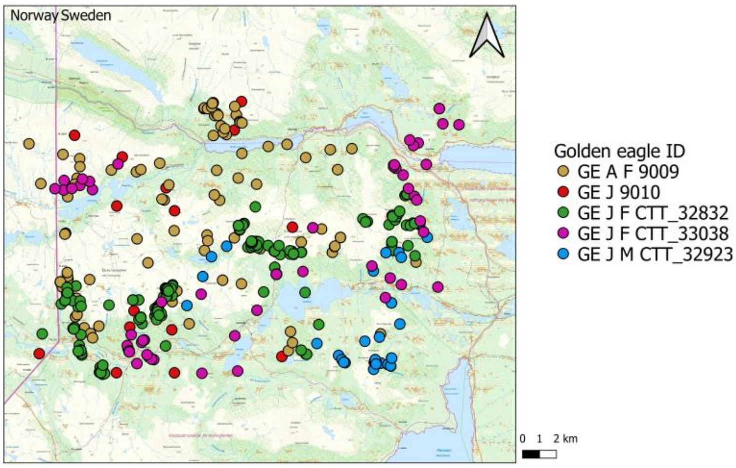

Figure 16: GPS points of tagged golden eagles in the study area.

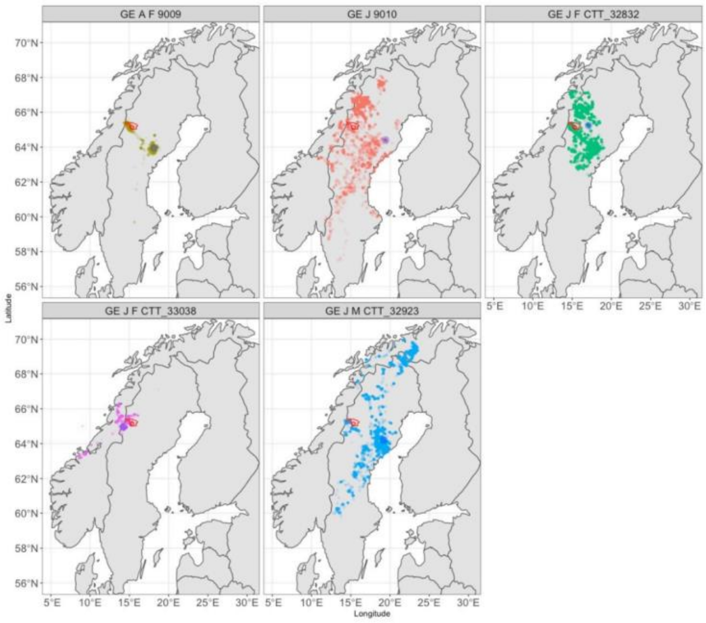

Figure 17: Recorded positions for GPS-tagged golden eagles with larger dots representing capture location.

Figure 17 shows all recorded GPS positions for the eagles that showed up in the calving area (figure 16). Eagles have been recorded in both Sweden and Norway with a spread all across the countries.

4. Discussion

Experimental designs are a valuable tool in ecology to understand cause-and-effect relationships (Tilman, 1989). Nonetheless, experiments on wild animals in their natural habitat can be expensive, and require lots of effort, and therefore not many of these experiments have been performed in raptors in general (Fuller & Mosher, 1981; Hull et al. 2010). This study allowed us to delve deeper into the eagles' behaviour, both inter- and intraspecific, response to herders, reindeer, and the effect of the two types of repelling devices. With the before-during-after experimental set-up, patterns could be recognized in terms of species abundance, age class distribution (Stewart-Oaten et al., 1986). GPS data allowed us to give an insight in where eagles came from, and when they were active (Cagnacci et al. 2010).

It is reasonable to assume that repeated observations of individuals (adult or subadult) at certain locations for multiple periods indicate that the birds were at least stationary in the calving area during this whole study period, for instance a pair of golden eagles along the Norwegian border (Watson, 2010). For GE, monitoring of known territories was done in addition to direct observations from vantage points, to gather more information about the number of resident eagles in the area (Gregory, 2004; Singh, unpublished data). Nevertheless, the residency status of eagles was in most cases impossible to determine due to for instance variation in plumage per year, or distance from observer (Madge, 1979; Ligouri, 2004; Bibby, 2000).

During the study, the number of observations fluctuated between the three periods. There was an increase in observations during calving, especially for WTE, as was expected. Their numbers increased for both adults and subadults during calving. The increase in white-tailed eagle observations could mean that food availability from reindeer is possibly more important to WTE than to GE. Nesting white-tailed eagles do not actively seek out reindeer carcasses (Ekblad et al, 2020), but will exploit them when encountered. For non-breeding white-tailed eagles, this information is unknown, but it seems plausible that non-breeders that are migrating into the area (from either Norwegian or Swedish coasts) to opportunistically seek out reindeer in a similar way to the golden eagle (Singh et al. 2021). There are no known territories of white-tailed eagles in the area, suggesting the WTEs coming in the area are transient eagles, either subadult or non-breeding adults. Golden eagles excluding WTEs from the area seems unlikely since they can coexist, even in areas with higher dietary overlap (Evans, 2010), and WTEs often breed in closer proximity to coastlines (Treinys, 2016; Ekblad, 2020).

All age classes were represented in the study period. As expected, most eagle observations were made during the calving period. Before calving, predominantly golden eagles were observed. The golden eagle observations seemed relatively stable during the whole study period, but unknown identifications of species could have made a difference here. Especially the observations of adult golden eagles seemed to remain stable, which would make sense from a breeding perspective (Watson, 2010). If adult eagles had entered the area they would be non-breeding individuals, since the territories are already taken, and starting at this stage of the year would possibly lead to unsuccessful breeding (Verhulst & Nilsson, 2008). Subadult golden eagles do not keep territories and are roaming freely (Watson, 2010), looking for the best feeding opportunities and dispersing, possibly explaining the slight increase during calving.

Two types of repelling devices have been tested during this study. The pyramid prism has previously been successfully used to exclude birds from certain areas (Levin, 2008). The control area showed a significantly higher eagle observation rate when compared to treatment areas. The ventilator area eagle observation rate was clearly different from the control area, meanwhile the prism area showed a little overlap in observation rate for the control area. The deterrents seem a promising mechanism to divert eagles from certain areas. Although there were no significant differences between the two deterrent methods, our results seem to support that ventilators could be more effective. Moreover, the downside of the pyramid prism is that it uses a car battery. In harsh weather conditions, the pyramids battery could run out, or be destroyed, which could lead to various heavy metals contaminating the environment, which are known to be hazardous for wildlife (Fisher, 2006; Ecke et. al, 2017). The self-propelled wind ventilators could make for a more sustainable alternative for the prisms. The ventilators are sturdier, and since wind is an almost constant factor in the Swedish mountains, they are self-sufficient, replacing the need for batteries.

No direct kills on reindeer from eagles have been observed during this study. One dive was seen from a golden eagle on a group of reindeer, possibly in an attempt to kill a reindeer (calf), but to no success. Besides reindeer, there are plenty of other animals to hunt in the area, mountain hares (*Lepus timidus*) and grouse (*Tetraonid)* for instance, but only one attack on a tetraonid was observed. Concerns of white-tailed eagles hunting calves instead of scavenging have been rising (Ekblad, 2020). So far white-tailed eagles have not been observed actively hunting reindeer calves, just as in our study (Mattisson, 2018; Ekblad, 2020). Predation rates can differ throughout years depending on fluctuations of availability of other prey species (Sulkava, 1999) which could explain why no hunts on reindeer were recorded. Other studies like Nybakk et al, 1999, and Norberg, 2006 have found 12 cases of golden eagle predation in over 850 mortality-sensing radio-collared reindeer, and 17 cases out of 621 radio-collared calves respectively, showing that predation can be challenging to record.

Causality and correlation are often mixed up in eagle predation and reindeer. When an eagle is present at a reindeer calf carcass, it seems obvious that it was killed by the particular eagle species. Predation is however only one of the options, and since eagles are likely to be one of the first predators to arrive at the site because of their soaring abilities (Peterson, 2001). It's likely eagles are already present before an observer or other predator could have spotted the calf, even though they had not killed the calf themselves. Predator misidentification is another issue, and observer bias could lead to higher predation assumptions than are realistic (Duriez, 2019). On top of that, often the two eagle species are confused, possibly falsely blaming white-tailed eagles for the damages done to reindeer by golden eagles, or wrongly estimating abundances of a certain species (Bibby, 2000; Mattisson, 2018).

Before calving, only a handful of reindeer was spotted, but no big groups. During calving, the control area showed the highest amounts of reindeer, followed by the ventilator area, whereas the pyramid area showed the least. During calving, a shift in reindeer abundance was observed from the ventilator area to the control area. Translocation of the devices at this point was not possible, and would only hurt the experimental set up. The usage of snowmobiles was kept to a minimum to ensure eagles, and/or reindeer would not behave differently due to our presence (Skarin et al., 2004; Steenhof & Kochert, 2014).

Concerns about attacks being missed during the early morning hours and late evening hours have been addressed through analysis of GPS data. Since the peak of eagle activity (09:00-15:00) fell inside observation hours, it's safe to assume that most attacks would have been recorded, had they occurred. In terms of managing the reindeer predation issue, this means that protection from golden eagles through other means, herder presence for example, would have to focus on reindeer safeguarding from the hours of 06:00- 18:00. There is however of course still the threat from other predators outside these hours (Karlsson, 2012; Falk, 2009), but when golden eagle predation is presumed to be the highest factor of reindeer loss these hours can be kept into account.

Golden eagles can migrate into calving areas from all across Sweden as was shown by the GPS data (Figure 17; Singh et al. 2021). The eagles migrate into the calving areas from far away and leave after calving in pursuit of other food sources (Singh, 2021). This shows that it is challenging to tell where eagles come from and predict where they would migrate to.

Complementary to the repelling devices several other techniques could possibly be used to reduce predation. Supplementary feeding has been a conservation technique used with success in for instance the Spanish imperial eagle (Gonzalez, 2006), and hen harrier (Redpath, 2010). Diverting the eagles from calving areas through supplementary feeding could aid in reducing predation on reindeer (Knight & Anderson, 1990; McCollough et. al, 1994), but could also have adverse effects like disease transmission (Sorensen et al., 2014), attracting other predators (Pearson & Husby, 2021), depressed immune system (Blanco, 2011), and it possibly turning into an ecological trap (Robb et al., 2008). With both eagle species migrating from all over Scandinavia, assessing the amount of food that needs to be put out, and the locations for feeding stations in order for this measure to be effective is another knowledge gap. Human presence is another factor that could, divert eagles from reindeer (Bell & Austin, 1985; Vickery & Summers, 1992). The potential problem with this is that this human disturbance could also have an adverse effect on the reindeer (Skarin et al., 2004). Calving areas are large and reindeer are spread out, making human presence a challenge on its own.

Habituation for scaring devices is very common among a range of repellants (Bishop et. al, 2003). Sound, visual cues, and smell are things the eagles will eventually get used to. It's therefore crucial to set up guidelines for the usage of the repellents, so as to not habituate the eagles to these deterrents. Calf mortality by golden eagles early in the calving period is, according to the reindeer herders, the biggest problem (Nybakk, 1999). Therefore, devices must be set up just before the calving peak. To prevent habituation, these devices will be out in the field only during calving. Most calving should have happened in these two weeks, and habituation is kept to a minimum.

With reindeer husbandry struggling it is vital to enable co-existence with large predators to reach biodiversity targets, in which both reindeer and large predators have a role to play. (Pape & Loffler, 2012; Horstkotte, 2022). Overall this study shows a promising way of reducing eagle predation on reindeer through the use of deterrents. We showed that eagles appear into the calving areas during calving. GPS data showed that (golden) eagles do not fly frequently during the night, and thus do not use the sunlight available during the months with midnight sun. Not all questions have been answered as of yet, but I believe that through the suggested studies we could get a step closer to coexistence between reindeer husbandry and large predators.

Limitations & assumptions

Regardless of the promising findings regarding repellants to reduce reindeer calf predation, the study displays limitations. First and foremost, in raptor ecology low densities of birds can result in a sample size that often limits its statistical strength, which has also been the case in our study. This factor is however insurmountable when only testing in one area of interest for one year. Repeating this study in multiple areas over a multitude of years would provide more data, which could then be subjected to further statistical testing. Furthermore, it was assumed that all eagles (and thus hunts on reindeer) were detected with a 100% probability. The terrain, and big area needed to spot eagles (because of the low densities), make it highly likely that this assumption is violated. Eagles could fly behind ridges in the area, or close to the tree line where they are harder to detect. On top of that, the eagles that sit and walk instead of fly are almost impossible to detect at large distances (Widen, 1994). Violating this assumption could lead to underestimating the number of eagles present in the area (Bibby, 2000). Gathering observational data on birds requires the observers to have an exceptional level of visual skill. On a few occasions, the birds' species or age class was set to 'unknown', but some of the identified species/age classes may have been unknowingly mistaken for another, possibly under or overestimating species and/or age class distribution. This assumption leads directly to the next one: observer bias. The difference in birding skills between observers is always present. This difference has been attempted to be overcome by daily rotation between observation points.

Regarding the study design, it should be noted that both repelling devices have not been placed in random locations or in a systematic manner. The placement of devices was specifically on high tops at which they could be seen from great distances. This means that the concentration of devices within an area can vary, in order to keep the ability to repel as high as possible. All three areas (control, prism & ventilator) were equal in both size & structure (i.e. habitat, altitude, etc...). Despite these factors being equal, there was one factor regarding the areas that could not be accounted for: reindeer presence. During the calving period, there was a low presence of reindeer in the area allocated to the prisms. During calving, both the ventilator area and the control area had many reindeer present with a shift of reindeer numbers from the ventilator area to the control area. The assumption that all three areas were equal is therefore violated. More reindeer present means more afterbirths and possibly stillborn, or weak calves. This availability of food could possibly have increased the chances of eagles aggregating in these areas. In our study the number of reindeer was highest in the control area, followed by the ventilator area and prism area respectively.

All three areas were adjacent to each other, but ideally, the treatment areas would be separated and a control area assigned to each respective treatment area. More replicates in different reindeer calving areas would aid in statistical power for this experiment, with a minimum of three sites. More replicates would aid in the precision of the experiment, in compensation for the lower accuracy from the experimental set-up.

5. Future studies & improvements

In order to decisively say whether reindeer predation can be reduced by light-reflecting devices, more research needs to be done. This question can be tackled in a variety of ways. Upscaling the study to more calving areas, and multiple years of studying could give this study the statistical solidity it needs to succeed in giving definite conclusions. Overall I believe that the study was designed properly, but with limitations in time and money, the reliability and accuracy of it can be questioned. When analysing the results of multiple areas, location should be taking into account as a random effect. Moreover, comparison of the Vilhelmina Norra area for another year, or years, could answer the question of habituation. If eagles are habituated to the eagles, the effect of the deterrents would be less in subsequent year(s).

Another option for testing the two devices would be through the use of GPS devices. Resident golden eagles present in the area(s) are to be captured and tagged a before the devices are put out. This gives the option of showing equal usage of the area before any of the devices. Then in May, the repelling devices are put out, and GPS locations are compared between areas during this time. In support of the GPS data, point counts will also be performed during calving to further examine the extent of the golden eagle predation rate, and get an idea of reindeer distributions.

The GPS study could possibly be supplemented to answer the question of predation on neonate reindeer calves as opposed to calves that are a few months old. Similar to the brown bear study by Støen et al., 2022, eagles would be tagged with GPS proximity collars, with pregnant reindeer being tagged as well. The GPS units collect a data point every 30 minutes, and when in proximity of one of the reindeer GPS devices would switch to sending a location every minute. This would allow researchers to document when eagles are close to reindeer. Reindeer calves stay in close proximity to their mothers and this behaviour makes GPS proximity studies an ideal option to detect calf predation (Mathisen et. al, 2003). When triggered, the site of the intersection needs to be visited to perform autopsies to see if the golden eagle indeed killed a calf.

Acknowledgements

First and foremost I would like to express my thanks to my supervisor Navinder J. Singh. You've been very supportive and confident in my capabilities, which I deeply appreciate. I'd like to thank you for the unforgettable weeks we've had in the mountains, where you despite some bad days, always remained positive and enthusiastic. Furthermore, I'd like to thank my co-supervisor Hussein Khalil for helping me tackle statistical issues surrounding my data, with support in both analysis and visualization. Thirdly I'd like to thank Ante Baer, reindeer herder of Vilhelmina Norra, for his help, cooperation, and advice during this study. Thanks to the county administrative board of Västerbotten and Naturvårdsverket for financing this study. Thanks also to Michael Schneider, Stigbjörn Clementsson, Elinor Sahlen, and Jonas Gustavsson for their kind advice and help throughout this study and to P.O. Nilsson from the Golden Eagle Group, Västerbotten, for information on Golden eagle territories from the study area. Furthermore, I would like to thank my fellow observers Christian Emilsson, Peter Sunneson, Linus Ryderfors & Bosse Sjögrund, for without them this study would not have been possible. I feel grateful to have been in the company of such knowledgeable, enthusiastic, and most of all friendly people. I would like to thank my parents for their support, both during my thesis and during my whole Master in Sweden. Lastly, I would like to thank the members of the Fish & Wildlife Department and my fellow thesis writers for good advice, plenty of fika, and fun. Special thanks are in order for my dear friend, Andres Lopez Peinado for his endless amounts of help, advice, patience, and friendship.

Popular science summary

Eagles: Cold-blooded killers or carrion consumers?

Humans and large carnivores have been in conflict since the dawn of time. Predators are feared, either for our own lives, the ones we love, or our livestock and pets. These predators include the two biggest eagle species; the white-tailed eagle and golden eagle. Back in the day eagles were fiercely hunter for fear of taking our livestock. Nowadays, these eagles are protected throughout the world, and also in Sweden, where I did my research. Eagle populations of both species are still recovering from the old days of bounty hunting. In Sweden the eagles pose a threat to the traditional livelihood of the Sami: reindeer husbandry. Golden eagles are known to kill reindeer, but for white-tailed eagles this has not been shown. With their increasing populations the concerns about white-tailed eagles are however also rising. It is true that reindeer is part of the eagles diet, but we do not know so much about the balance between killing and scavenging. We went into the mountain three times for a week, once before calving, once during calving, and once after calving. We did this to see if eagles appear in the area during calving, and disappear afterwards.

In the spring of 2022 I set out to the Swedish mountains with three others to investigate the issue. In spring the reindeer cows give birth to their young, which are very vulnerable during the first days of their lives. With big heavy telescopes, and a book for fieldnotes we went out on the high mountain tops to look for eagles for many hours. In order to try and reduce the killing of reindeer calves we tested two different kinds of light reflecting devices. A rotating pyramid prism with a battery, and a wind ventilator as typically seen on rooftops. These devices reflect sunlight back into the eagles' eyes and should scare them out of the area where the vulnerable reindeer calves are being born. We split the study area into three: prism area, ventilator area, and a control area. During these months, the sun does not set in the north of Sweden. This got me wondering if the eagles also used this opportunity to hunt during the night.

As we expected, during calving we observed more eagles of both species, but the biggest increase was in white-tailed eagles. Whereas before we had seen only a single white-tailed eagle very far away, suddenly they were appearing. Most of our eagle observations were in the control area. The control area had no repelling devices, and thus our devices seemed to work! To see if the eagles were also active during the midnight sun, I used previously gathered GPS data. I analyzed the data based on the eagles height to see if they were flying in the night. I found that the eagles, just like us, are sleeping at night.

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