Home range and movement of reindeer (*Rangifer t. tarandus*) in three Sámi reindeer herding districts in Norway

- Influence of winter feeding and weather

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Degree project/Independent project • 30 credits
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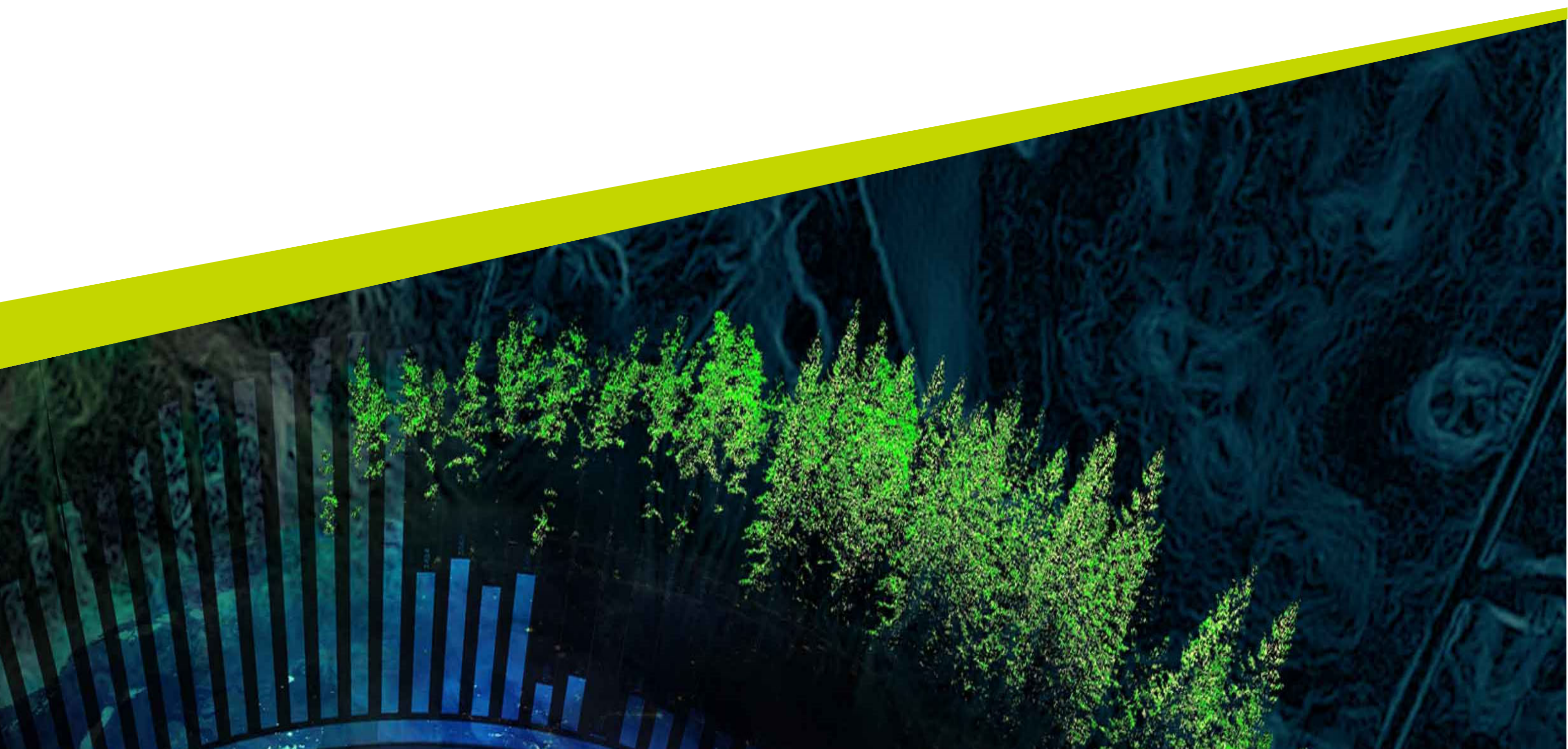
Uppsala 2024



Home range and movement of reindeer (*Rangifer t. tarandus*) in three Sámi reindeer herding districts in Norway - Influence of winter feeding and weather

Hemområden och rörelse hos renar (Rangifer t. tarandus) i tre samiska renbetesdistrikt i Norge - Påverkan av vinterutfodring och väder

Jessica Andersson

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Credits:	30 credits
Level:	A2E
Course title:	Independent project in Biology
Course code:	EX0871
Programme/education:	Master's programme in Biology – Ecology and Conservation, Uppsala University
Course coordinating dept:	Department of Applied Animal Sciences and Welfare
Place of publication:	Uppsala
Year of publication:	2024
Copyright:	All featured images are used with permission from the copyright owner.
Keywords:	GPS, Brownian Bridge Movement Model, home range, reindeer herding, supplemental feeding, Norway, climate change.

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Abstract

Reindeer husbandry is an essential part of the indigenous Sámi society carrying cultural and ecological significance, both historically and today. Herders face issues such as loss of pastures to expanding infrastructure, a decline of lichens and deteriorating conditions of pastures due to climate change. Because of this, many herders are forced to use feed the animals in the winter. Within the research project WELFED, GPS data was collected from 90 reindeer across three different herding districts in Norway; Rákkonjárga, Ildgruben and Riast/Hylling, with varying feeding practices. The purpose of this thesis was to examine how home range size, overlap and movement rate was affected by supplementary feeding during two periods in the winter of 2022/23. The first time period took place before feeding had started, while the second time period was set when winter feeding was used in two of the studied districts. Movement was also analysed in relation to different weather parameters.

Home range size was found to be significantly larger, and step length significantly longer, during feeding in Rákkonjárga compared to the timeperiod before feeding, while the opposite was true in Ildgruben. In Riast, no feeding occurred in the winter of 2022/23 and no significant difference could be detected between the two time periods. Multiple linear regression models revealed that wind speed had a significantly negative effect on step length during the first time period, when feeding had not started, while precipitation had a significantly negative effect in the second time period, when feeding occurred in two areas.

The results from this thesis imply that feeding practices and weather conditions influence home ranges and movement of reindeer. As reindeer husbandry confronts escalating challenges, such as climate change and encroaching infrastructure, supplementary feeding is thought to become a growing practice among herders. The results revealed here, together with previous studies and knowledge, underscores the need for careful consideration when implementing such measures. Concerted efforts among Sámi communities, government agencies and competing land use is essential for preserving a sustainable future for reindeer herding.

Keywords: GPS, Brownian Bridge Movement Model, home range, reindeer herding, supplemental feeding, Norway, climate change.

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Abbreviations

SLU	Swedish University of Agricultural Sciences
GPS	Global Positioning System
QGIS	Quantum Geographic Information System
BBMM	Brownian Bridge Movement Model

1. Introduction

1.1 Reindeer in Scandinavia

Archaeological findings show that reindeer (*Rangifer t. tarandus*) occurred in Scandinavia and were utilized by humans through hunting as early as the last Glacial Period (Aaris-Sørensen et al. 2007). Hunting developed into herding by using fencing and enclosures to better utilize the species. Evidence shows that reindeer keeping might have started as early as 500 AD (Mulk 1988; Tryland et al. 2022). The species played a crucial role in the survival of Arctic residents and continues to have an important role in Fennoscandia, both culturally and economically in the Sámi communities, and ecologically through grazing and trampling (Kofinas et al. 2000; Suominen & Olofsson 2000; Pape & Löffler 2012).

Today there is roughly 250 000 semi-domesticated reindeer in Sweden and 200 000 in Norway and Finland respectively (Nordic Forest Research 2024). The reindeer herding area in Norway covers about 140 000 km^2, or 40% of the country´s surface (Jernsletten & Klokov 2002). Norway is divided into six grazing areas, which are divided into several districts, including both winter and summer pastures where reindeer from one or several herders can occur in the same district. Though reindeer herding is not an exclusive right for the Sámi people, they own the majority of all reindeer in Scandinavia (Horstkotte et al. 2022).

The European distribution of wild reindeer is mainly restricted to southern Norway, which holds about 30 000 wild reindeer managed as 23 units (Røed et al. 2014). The conservation of wild reindeer shares challenges with the management of semi-domestic reindeer, such as e.g. disturbance from human activity and infrastructure as well as climate change (Bargmann et al. 2020), but also faces genetic challenges (Reimers et al. 2012).

1.1.1 The Sámi and reindeer herding

The Sámi are the indigenous people of northern Europe, inhabiting the geographical area of Sápmi, which today covers parts of Norway, Sweden, Finland and Russia (Kaiser et al. 2010). Through history and today still, reindeer herding is a crucial part of the culture and livelihood of Sámi communities, and one that has been forced to develop with a modernizing world (Williams 2003).

The timing of Sámi communities shifting from a hunter-gatherer lifestyle to reindeer-herding is debated, however some sources claim that it happened gradually somewhere between 1550-1750 (Vorren 1973, see Røed et al. 2022). The reason behind this shift can also be discussed, with Vorren (1973) emphazising the impact of increased taxation as well as increased possibilities of turning a profit from herding, while other sources claim that conflicts within Sámi communities favoured ownership over hunting of a shared resource (Hansen & Olsen 2013; see Røed et al. 2022). Infrastructure development have caused loss of traditional land and in many areas it has forced reindeer herders to abandon long migrations and nomadic lifestyles for more sedentary reindeer herding (Jernsletten & Klokov 2002).

1.1.2 Reindeer feeding habits

During summer, reindeer feed mainly on grasses and herbaceous plants, while lichens are generally the preferred and dominant food source during winter, often making up more than 50% of the winter diet and thought to make up as much as 80% of the diet when abundant (Gaare & Skogland 1975; Danell et al. 1994; Heggberget et al. 2002; Mårell et al. 2002). Vascular plants can also be included in the winter diet (Heggberget et al. 2002).

Reindeer are migratory animals whose needs differ across the year, requiring a variety of natural pastures (Pape & Löffler 2012). Through grazing, reindeer control certain species and their presence has shown to increase species richness and diversity (Souminen & Olofsson 2000).

1.2 Home ranges and movement of reindeer

Historically, semi-domesticated reindeer would make long seasonal migrations from summer pastures in coastal Norway to winter pastures in Sweden, Finland or even Russia (Tveraa et al. 2007). Laws and government policies put more restrictions on reindeer herding, for example putting a stop to cross-border migrations with fencing, natural borders and herding (Tveraa et al. 2007; Riseth et al. 2016). Migrations between summer and winter pastures are significantly shorter today and food availability in the fewer available pastures becomes more vital.

Movement rate of reindeer varies across the year and can depend on vegetation type and weather conditions (Skarin et al. 2010). Habitat selection is, among other things, affected by predator presence, quality and quantity of forage and human activity (Skarin 2007). This means that home range sizes can vary a lot between herding districts and individuals, especially when looking at a short time period. In Hardangervidda, Norway, Falldorf (2013) found that home range size was larger in winter than summer, and significantly larger during late winter compared to early winter. In a study on a Siberian forest reindeer (*Rangifer t. valentinae*) by Vasilchenko et al. (2023), the winter home range during three months, based on the 'real core area fixed kernel 70%', was 48 km^2.

1.3 Challenges for reindeer herders

1.3.1 Climate change

Climate change and global warming is affecting ecosystems across our planet, not least in the Arctic, where warming is reported to occur up to almost four times faster than the rest of the globe (Rantanen et al. 2022). This is a recognized phenomenon known as arctic amplification, with effects reaching beyond the Arctic region and thought to grow stronger in the coming decades (Arrhenius 1896; Serreze & Barry 2011).

Snow depth and hardness are the two most important factors for natural food availability in winter (Moen 2008). Increasing temperatures during winter means that precipitation, a phenomenon known as ROS (rain on snow) and thawing events become more common, creating ice crusts once it freezes over (Putkonen & Roe 2003; Bartsch et al. 2010; Sokolov et al. 2016). Ice crusts hinder reindeer from accessing the vegetation underneath the snow and can also limit their ability to smell and identify lichens (Sokolov et al. 2016; Horstkotte et al. 2020; Rosqvist et al. 2022). Increased temperatures can also affect migration routes and access to winter pastures as lakes and rivers might not freeze over or stay frozen for as long (Riseth & Tømmervik 2017).

Climate change leads to longer growing seasons and higher plant productivity, particularly in the vascular plant abundance (Cornelissen et al. 2001; Moen 2008). This could in turn lead to denser vegetation in the Arctic and shrub coverage both increasing and spreading to higher altitudes, competing with other tundra species (Wookey et al. 2009; Myers-Smith et al. 2011). Lichen abundance is thought to be negatively impacted, as competition from mosses increases with decreasing light (Pharo & Vitt 2000). Increased plant coverage is hypothesised to increase snow depth, lower albedo and cause additional greenhouse gas emissions through permafrost thaw (ACIA 2004; Sturm et al. 2005; Myers-Smith et al. 2011).

1.3.2 Land use conflicts and loss of pastures

Reindeer herding takes place over large parts of Fennoscandia, and shares the space with other, increasing, forms of land use. Expansion of infrastructure, mining, hydro- and wind power, recreation and forestry are causing loss of pastures, fragmentation and changes in migratory routes (Jernsletten & Klokov 2002; Skarin et al. 2015). Pasture loss leads to a reduced capacity of adaptation for reindeer herding communities, as fewer alternative pastures are available during bad years (van Rooij et al. 2023). During the last 50 years, competing land use has caused a 25% loss of pastures in the Barents region (Jernsletten & Klokov 2002).

Other than loss and fragmentation of pastures, growing infrastructure and increased human activity in the Arctic also can affect reindeer in other ways. Wolfe et al. (2000) reviewed several studies on the response of reindeer and caribou to human activity. Disturbance leads to increased activity and energy use, and reindeer tend to avoid areas with human activity. Vistnes & Nellemann (2007) found that a majority of reindeer reduce the use of areas within 1-5 km of development. In a study by Anttonen et al. (2011), reindeer avoided all areas of human activity, such as snowmobile tracks, roads and buildings, when selecting home range areas. The results also indicated that avoidance was strongest during late winter. The authors theorise that this could be due to the higher vegetation cover during summer reducing disturbance, as well as reindeer gravitating towards e.g. roads to avoid insects (Skarin et al. 2004). Disturbance causes stress and requires vigilance, which costs energy. This is a smaller issue during early winter when food is more abundant (Anttonen et al. 2011). It is clear that reindeer are not only impacted through direct habitat loss, but also change their movement and space-use within the remaining area.

The loss of pastures results in more intensive use of remaining pastures, at times leading to “overgrazing” and deterioration (Forbes 2006; Pape & Löffler 2012). One effect of heavy use of pastures is declining lichen abundance (Pape & Löffler 2012). Johansen och Karlsen (2005) report a decline of lichen heath coverage from 30 to 1% in Finnmark, Norway. In a Swedish study by Sandström et al. (2016) a 71% decline of lichen-abundant forests was found in the study area. Often, the practices of reindeer herders are blamed rather than investigating the complex combination of factors threatening the viability of reindeer herding and finding long-term solutions (Forbes 2006).

1.3.3 Predation

The reindeer husbandry area in Fennoscandia overlaps to a varying extent with the range of wolf (*Canis lupus*), brown bear (*Ursus arctos*), wolverine (*Gulo gulo*), lynx (*Lynx lynx*) and golden eagle (*Aquila chrysaetos*). Due to conservation and increased legal protection, predator populations have increased during the last 50 years (Chapron et al. 2014), resulting in increased predation (Åhman et al. 2022). In 2010, 251 019 semi-domesticated reindeer were registered in Norway (Tryland et al. 2012) and during the reindeer herding year of 2009-2010, 19% of all reindeer were reported lost. Predators; primarily lynx, wolverine and eagle, were thought to be responsible for 88% of lost calves and 77% of lost adults. Though some sources claim that the main predators only have a compensatory effect on reindeer mortality (Tveraa et al. 2003), many reindeer herders do not agree with this conclusion.

Predation causes direct losses, but also makes additional land unsuitable for reindeer herding and can cause herds to break up or disturb calving (Åhman et al. 2022). Feeding can become more difficult since gathering the animals over extended periods can be risky, and fencing is sometimes the only way to keep predators out. However, feeding can also be used to keep reindeer away from areas where they are exposed to predation. Though compensation systems for lost reindeer are in place, herders express how the compensation does not include the indirect costs and additional work that is required when predators are present (Åhman et al. 2022).

1.3.4 The need for winter feeding

Traditionally during bad winters, reindeer were herded to reserve pastures as an emergency solution, or allowed to spread out in search of natural feed (Persson 2018; Tryland et al. 2022). Today, the loss of pastures, snow conditions and decline of lichen abundance, in combination with the large number of reindeer, forces reindeer herders to use supplementary feeding; a practice that has become more common in all three Fennoscandian countries (Helle & Jaakkola 2008; Persson 2018; Horstkotte et al. 2020). This is generally considered a last resort as it is not a long-term solution to the growing deficiency of grazing resources and is a threat to the culture and traditions of the Sámi (Horstkotte et al. 2020).

Winter feeding has many positive short-term effects, such as increased survival, increased calf weights and improved body condition, as it allows the reindeer to fullfill their dauly intake even when grazing conditions are poor (Helle & Jaakkola 2008; Bårdsen et al 2009; Ballesteros et al. 2013). Though long-term effects are not fully understood, and could possibly depend on feeding practices, there are lessons to be learned and caution to take moving forward. Winter feeding has been a common practice in many herding districts in Finland since the 1960s with its longer history of poor natural pastures and in many areas supplemental feeding has become the norm rather than an emergency solution, which is more so the case in Sweden and Norway (Helle & Jaakkola 2008; Horstkotte et al. 2020; Rautiainen 2024). In a study by Turunen et al. (2014) the long-term effects of winter feeding were discussed based on herders knowledge and experience. The herders describe how feeding increases contact between reindeer and humans, resulting in less vigilant animals. They describe an increase of individuals who rely entirely on food provided by the herders and how some reindeer migrate to feeding sites when natural forage becomes more scarce, waiting for feeding to start. They point out that reindeer becoming more habituated to humans from feeding can complicate the herding, as they become less afraid of e.g. snowmobiles, something also found by Persson (2018) and Skarin et al. (2024). The thesis by Persson emphazised that feeding is no easy task, but one that can be difficult for both reindeer and herders as it requires years of knowledge and takes time and focus away from traditional Sámi herding with substantial cultural importance, a concern brought up in the workshop by Horstkotte et al. (2020) as well.

Economic support for supplementary feeding differs between the Nordic countries. In Norway, partial compensation is provided for herders who have lost access to winter pastures or for feeding with the purpose of predator protection (Horstkotte et al. 2022). Though it is economically sensible to use supplementary feeding during difficult winters to uphold calving success and survival, feeding is very costly, potentially affecting the sustainability of reindeer herding (Pekkarinen et al. 2023).

2. Aim and questions

2.1 Aim

Winter feeding of reindeer is thought to affect the movement and area use of reindeer. Possible consequences can be higher densities of animals gathering in smaller areas or a lower extent of foraging and utilization of natural forage. The aim of this thesis was to, with the help of GPS data gathered across three different reindeer herding districts in Norway with different feeding practices, analyze how home range size, overlap and step length were affected by supplementary feeding. Additionally, an estimation of how movement is affected by temperature, precipitation and wind was performed. As feeding attracts reindeer, I expected home ranges to be smaller, step length shorter and overlap between individuals larger, during the feeding period.

2.2 Questions

- What is the average home range size for reindeer in the three reindeer herding districts?
- How does overlap of home ranges differ between the three reindeer herding districts?
- Which effects does supplemental feeding have on home range size, overlap and step length in the three different areas?
- How is movement affected by weather parameters; temperature, precipitation and wind?

3. Method and material

3.1 Study site descriptions

GPS data from in total 90 female reindeer born in the spring of 2022, was gathered across three reindeer herding districts in Norway: Rákkonjárga, Ildgruben and Riast/Hylling (*Figure 1.)*. The data was gathered from 30 individuals within each district during the winter of 2022/23, with GPS positioning once every six hours. The data was gathered when reindeer were in winter pastures, located in areas with mainly continental climate. Reindeer were collared during December of 2022 and January of 2023 and the data used in this thesis was gathered between January 13th to April 13th, with exact dates differing between areas. Supplementary feeding was used in Rákkonjárga and Ildgruben during the winter of 2023, while there was no feeding in Riast/Hylling.

Figure 1. A map showing the geographical location of reindeer herding districts Rákkonjárga, Ildgruben and Riast/Hylling in Norway. Created in QGIS.

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3.1.1 Rákkonjárga

Rákkonjárga is a reindeer herding district within the herding area East Finnmark. The district covers an area of 253 844 hectares and stretches from the Norwegian coast down to the Finnish border. The total number of reindeer in the district after slaughter is approximately 4000 individuals (Landbruksdirektoratet 2023). The area used by the reindeer in this study is in the southernmost part of the district, situated roughly at latitude 70°N, and was estimated at a size of 42 411 hectares (*Figure 2*). Supplementary feeding in Rákkonjárga occured from February 16th to April 7th of 2023 in the area southeast of the river and from March 1st to April 7th of 2023 in the area northwest of the river. The total general feeding areas are highlighted in the map in Figure 2, though feed was spread over different parts of the area on different dates, making it difficult to specify the exact area. Supplemental feed consisted mainly of baled grass silage with pellets mixed into it if necessary.

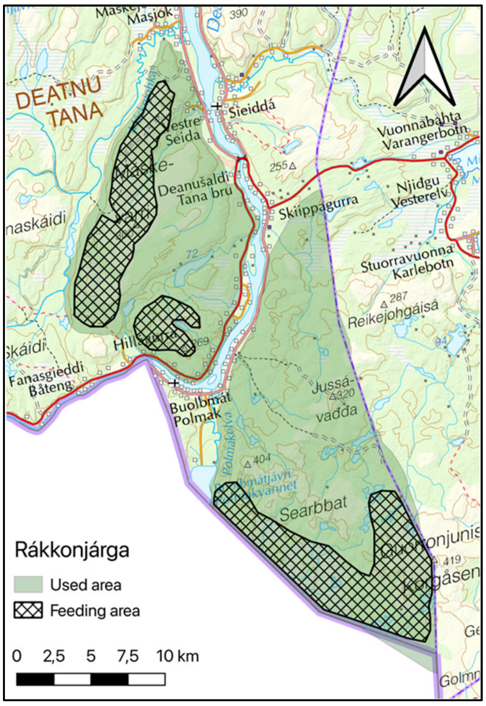

Figure 2. A map showing the area in Rákkonjárga used by the reindeer during the study period, highlighted in green, as well as the general feeding areas. Created in QGIS.

3.1.2 Ildgruben

Ildgruben is a reindeer herding district within the herding area Nordland. The district covers an area of 265 644 hectares along the Swedish border east of Mo i Rana, Norway. The total number of reindeer in the district after slaughter is approximately 900 individuals (Landbruksdirektoratet 2023). The area used by the reindeer in this study is in the northern part of the district, situated at latitude 66.2°N, and was estimated to cover approximately 65 550 hectares (*Figure 3*). Supplementary feeding occured in Ildgruben from February 5th to April 22nd during the winter of 2023 in an area marked on the map in Figure 3. The feed consisted mainly of pellets from the producer Felleskjøpet, with the occasional addition of lichens collected during the previous fall to help with digestion at the start of feeding. Due to climate change, the area usually receives heavy snowfall as well as rain during winter. Because of this, the district has been forced to use supplementary winter feeding for the past ten years.

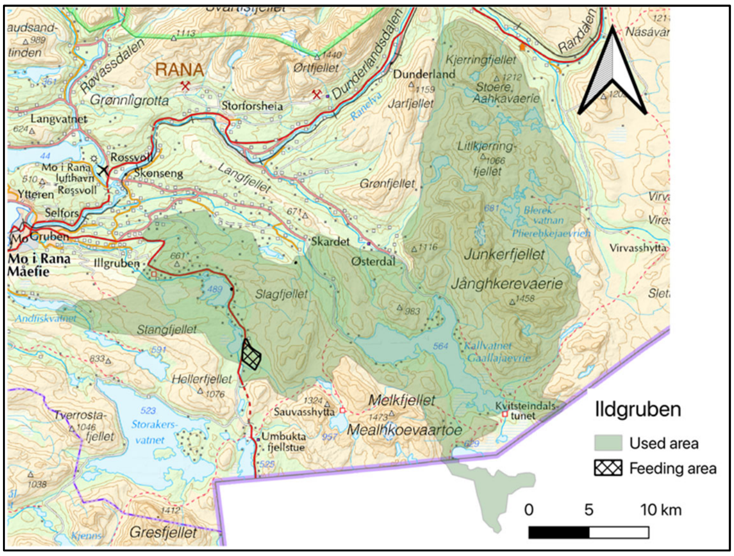

Figure 3. A map showing the area in Ildgruben used by the reindeer during the study period, highlighted in green, as well as the general feeding area. Created in QGIS.

3.1.3 Riast/Hylling

Riast/Hylling is one of the most southern reindeer herding districts in Norway, situated in the herding area south-Trøndelag and Hedmark. The district covers 190 724 hectares and the total number of reindeer in the district after slaughter is approximately 5000 individuals (Landbruksdirektoratet 2023). However, during the decided time periods in this thesis, the reindeer utilized an area south of Riast/Hylling (*Figure 4*), partly overlapping with the district Femund. The size of the area used during both time periods was 38 000 hectares and is situated roughly at latitude 62.5°N. Supplementary feeding was not used in Riast/Hylling.

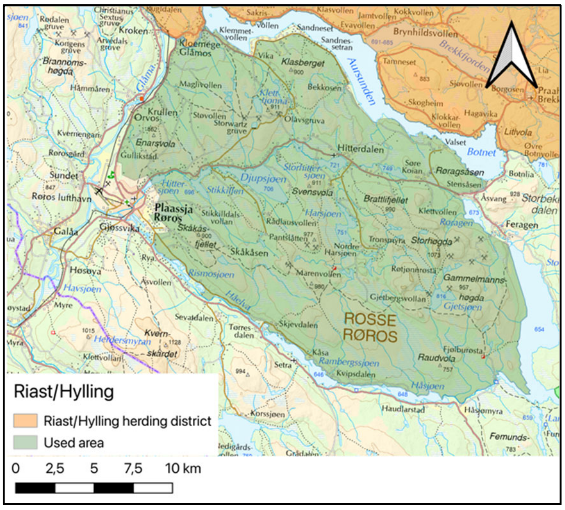

Figure 4. A map showing the geographical position of reindeer herding ditrict Riast/Hylling, as well as the area used by the reindeer during the study period.

3.2 Data preparation

The raw data was sorted in R (R Core Team 2023) by area and individual, and exported as shapefiles. With the plugin 'Time Manager' in QGIS, the movement of each individual in each district could be followed. Through this, incorrect positions could be excluded from the dataset and individuals whose data could not be used were identified (*Table 1*). General movement patterns could be identified which could at times be connected to facilities, fencing or migration routes used during herding, leading to additional exclusion of positions or time-periods where the movement of reindeer was influenced by the herders. To help interpret GPS positions, the map service Kilden by Norsk institutt for bioøkonomi (NIBIO) was used. It contains data on, among many other things, land use, forests, administrative borders as well as fencing, herding routes, facilities and feeding sites for reindeer husbandry (NIBIO 2024). Removing the unusable data resulted in data from 27 individuals from Rákkonjárga, 26 individuals from Ildgruben and 26 individuals from Riast/Hylling.

Table 1. Individuals removed from the dataset, and the reasoning behind their exclusion.

ID number	Motivation
Rákkonjárga	
2207994	GPS positions available only until December 17th
2208036	GPS collar dropped and position invalid from March 19th
2209079	Missing GPS positions in January
Ildgruben	
2209791	Irregular timestamps
2209803	Suspected dropped GPS collar
2209836	GPS positions available only until February 11th

2209840	Gap in GPS positions from January 16th until April
Riast/Hylling	
2209991	Suspected dropped GPS collar
2210282	Suspected dropped GPS collar
2210288	Missing GPS positions
2210429	Majority of GPS positions located in facility

The data was divided into two periods within each area, the first time period capturing movement before feeding started and the second capturing movement during feeding. Although supplementary feeding was not used in Riast/Hylling, two periods were used, to compare different time periods of the winter. This could also give a better understanding of whether potential differences in the other areas could be due to feeding, or if movement can differ only due to different time periods of winter. For home range sizes to be comparable between areas, positions from the same number of days were needed for all time periods. The length of the periods was limited by the pre-feeding period in Ildgruben, where data was available from January 20, and, eventhough feeding started on February 5th, the first individual in this study started utilizing the supplemental food on February 14th (*Figure 5*). This allowed for a 26-day limit on all time periods. The second time period in Ildgruben was set over 26 days starting on February 26th, after all individuals in this study had started utilizing the feed.

In Rákkonjárga, all individuals were collared and had moved away from the area where they were collared by December 20th 2022 (*Figure 6*). However, 11 individuals were moved from the southeast area to the northwest area at the beginning of January 2023. The first 26-day time period was therefore set to start on January 13th. The second time period was set from March 7th, after feeding had started in the areas on both sides of the river and with a buffer of a few extra days to make sure the reindeer started utilizing the feed.

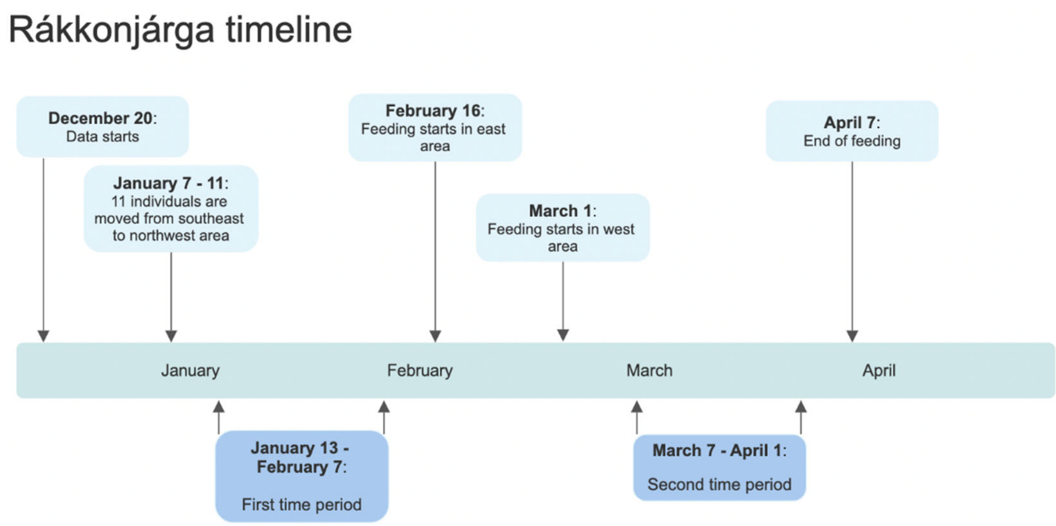

Figure 5. A timeline showing the chosen time periods for analysis in Rákkonjárga, as well as the date from which data from freely moving reindeer was available and important events. Created with smartdraw.com.

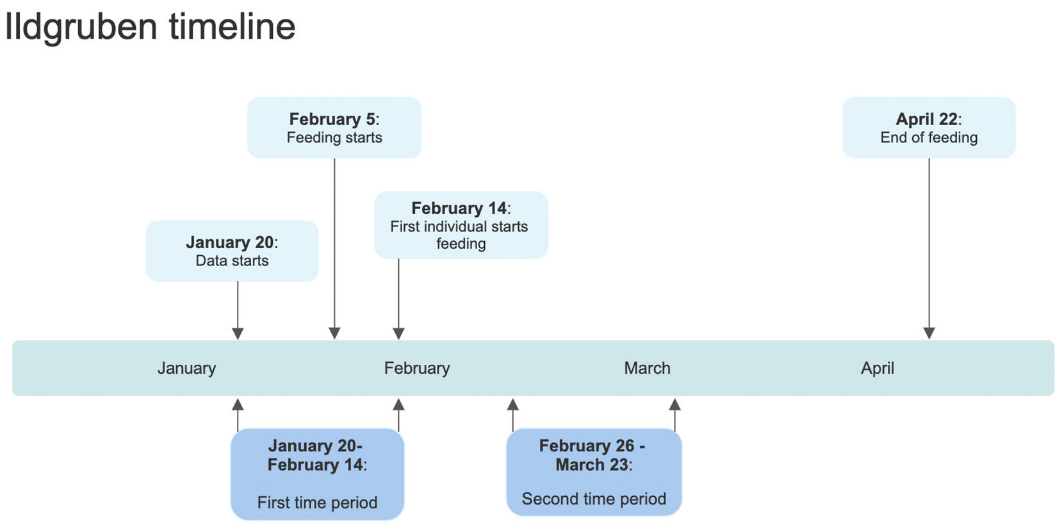

Figure 6. A timeline showing the chosen time periods for analysis in Ildgruben, as well as the date from which data from freely moving reindeer was available and important events. Created with smartdraw.com.

In Riast/Hylling, data was available from February 1st and on February 19-20 all individuals were moved from the north part of the area to the south (*Figure 7*). The north and south areas are separated by a large road and water, meaning that the reindeer could not move freely between the areas. To reach the 26 days for both time periods in Riast/Hylling, and for possible differences in movement to not be due to the smaller available land area in the north, both time periods were set after the reindeer were moved to the south.

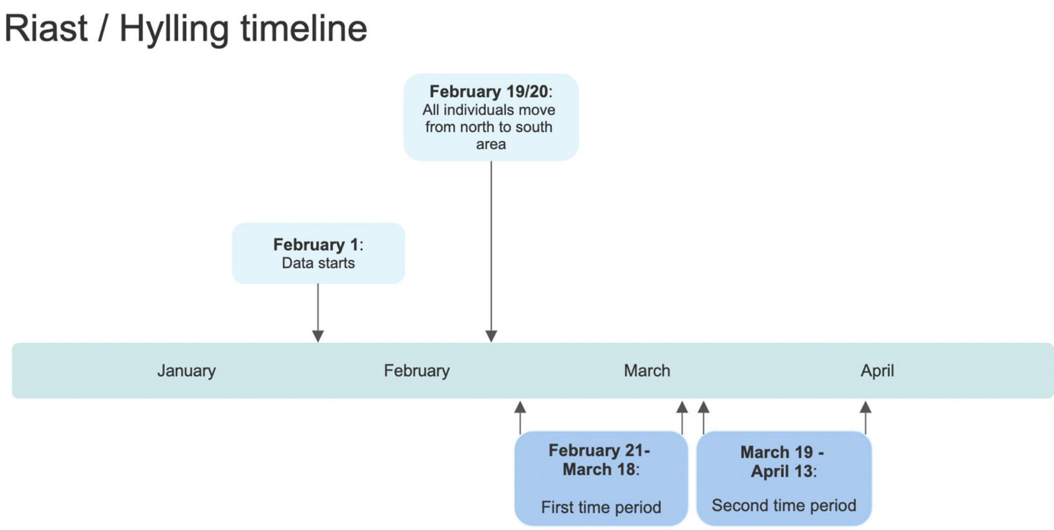

Figure 7. A timeline showing the chosen time periods for analysis in Riast/Hylling, as well as the date from which data from freely moving reindeer was available and important events. Created with smartdraw.com.

3.3 Analysis

3.3.1 Home range size

The GPS data for the decided time periods was imported back into Rstudio as GeoPackages from QGIS and saved as tracks of class track_xyt. Individual home ranges were calculated using the Brownian Bridge Movement Model (BBMM), for all individuals during both the first and second time periods across all areas. When estimating home range, utilization distribution is often used, to make calculations based not only on the area used by the animal but also on how intensely different areas within the range are used (Worton 1989). The BBMM is a type of utilization distribution method to estimate home range, first proposed by Bullard (1999; see Horne 2007). It is a stochastic continuous-time movement model that consider the order of locations and time between points (Horne 2007).

A Shapiro-Wilk test was used to evaluate the normality of the data, revealing that datasets from two areas was not normally distributed. Because of this, a Wilcoxon signed-rank test was performed within each area to evaluate if there was a difference in home range size between time periods, since the Wilcoxon signed-rank test does not require normally distributed data. The data from Ildgruben was divided into two groups; feeding individuals and non-feeding individuals, since all reindeer did not utilize the supplemental feed.

3.3.2 Overlap

After computing home ranges for all individuals during both time periods for all areas, the overlap between home ranges was calculated using the function st_intersection() in the R-package amt (Signer et al. 2019). The pairwise overlap between individuals was calculated in Rstudio, showing data on average overlap with standard deviation, as well as maximum and minimum overlap. In Ildgruben, the overlap during the second time period was calculated separately for individuals who utilized feed and those who did not. In Rákkonjárga, the overlap between individuals was calculated separately for those in the northwest area and those in the southeast area.

3.3.3 Step length

To get an understanding of reindeer movement within the utilized areas, step lengths were calculated from the GPS positions during all 26 day time periods. In this thesis, step length refers to the geographical length between two following GPS positions. Histograms were computed to give an overview of the distribution of step lengths within each area and time period. Along with this, average step length with standard deviation as well as maximum and minimum step lengths was calculated. The Welch two-sample t-test was used estimate difference between step lengths during the first and second time periods within each area.

3.3.4 Weather

The three weather parameters used to analyze the effect of weather on movement were temperature, precipitation and wind speed.

Data on mean temperature per day, precipitation and maximum daily wind speed was retrieved from Norsk Klimaservicesenter. The weather station closest to each study site containing necessary daily data was chosen. For Rákkonjárga, weather station *Tana Bru* was used. For Ildgruben, *Umbukta* was used for temperature and *Hjartåsen* for precipitation and wind. For Riast/Hylling, *Sølendet* was used for temperature and precipitation, and *Røros Lufthavn* for wind. Along with daily weather parameters, mean step length per individual and day during all 26 day time periods was calculated.

The step lengths were transformed using the natural logarithm (log) prior to analysis. This transformation was implemented to achieve a distribution of the data to better meet the assumptions of normal distribution in linear regression modeling. Visual inspection of histograms revealed that the log transformation resulted in a distribution of step lengths, approximating a normal distribution. A Spearman-rank correlation test was also used before the regression analysis to examine correlation between the continuous weather parameters. A threshold of >0.7 was set, and if the correlation between two variables was higher than 0.7, one of them was excluded from the model.

Two multiple linear regressions were fitted, one for each time period, to investigate the relationship between step lengths and the three weather parameters. The geographical area variable was included as a categorical fixed effect to account for potential regional differences in step lengths. The model was fitted using the 'lm' function in Rstudio.

4. Results

4.1 Home range

The average home range size was largest in Riast/Hylling during the second time period and smallest in Ildgruben during the second time period for individuals who utilized the supplemental food (*Table 2*). Average home range size, as well as maximum home range, were smaller during the second time period compared to the first time period only in Ildgruben, both for individuals who utilized feeding and those who didn´t.

Table 2. Mean, standard deviation, minimum and maximum values of home range size (km^2) across all three reindeer herding districts and time periods.

	First time period				**Second time period**			
	Mean	Std. d	min	max	Mean	Std. d	min	max
Rákkonjárga	9.44	± 4.8	2.54	17.99	21.51	±18.34	1.97	92.89
Ildgruben								
In feeding area	46.65	±15.79	19.97	93.25	8.55	± 12.26	0.35	46.46
Not in feeding area					22.75	± 16.41	4.46	53.04
Riast/Hylling	44.58	± 9.92	29.42	64.76	49.94	± 10.82	27.14	73.62

The GPS data shows that the total area covered by GPS positions during the second time period in Rákkonjárga is larger than during the first time period (*Figure 8*). In Ildgruben, the GPS positions are spread put over a larger range of geographical area, and gathered in smaller clusters (*Figure 9*). In Riast/Hylling, the area over which the GPS positions are spread out is roughly the same, but the area most used has shifted slightly from the first to the second time period (*Figure 10*).

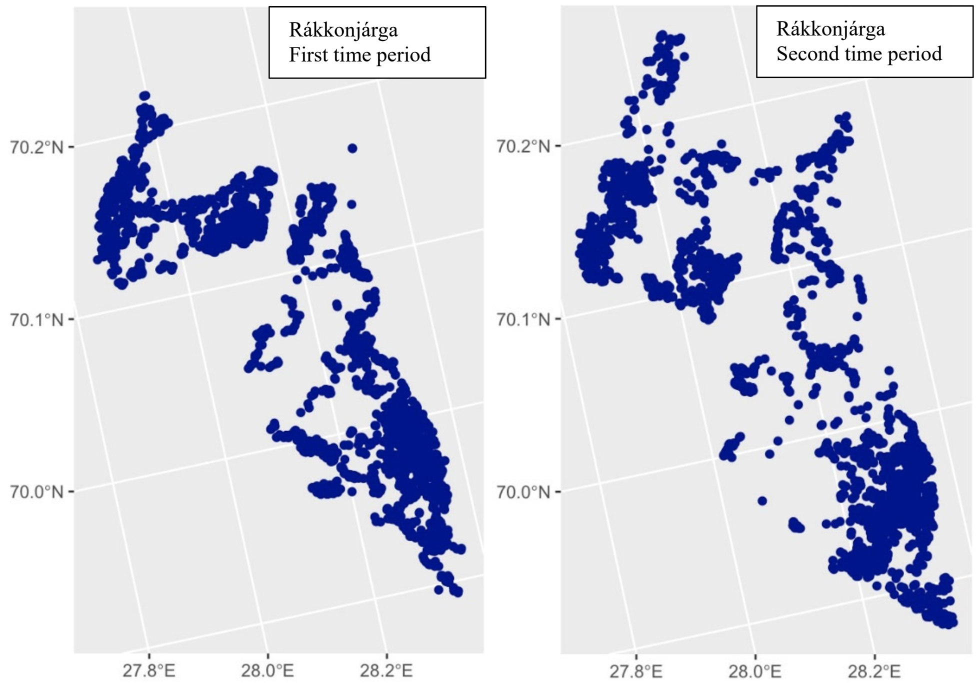

Figure 8. GPS positions from all reindeer in Rákkonjárga during the first and second time period.

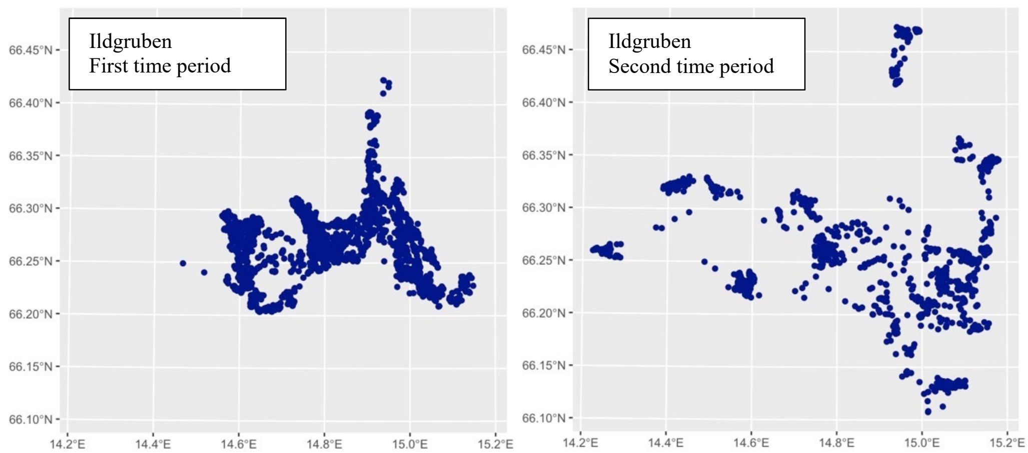

Figure 9. GPS positions from all reindeer in Ildgruben during the first and second time period.

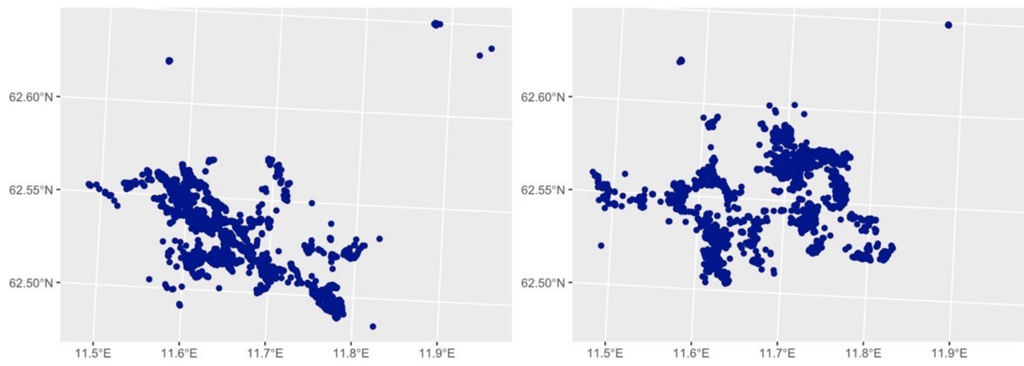

Figure 10. GPS positions from all reindeer in Riast/Hylling during the first and second time period.

The Shapiro-Wilk test showed that the values deviated from a normal distribution in both Rákkonjárga and for non-fed individuals in Ildgruben (*Table 3*).

Table 3. The output from the Shapiro-Wilk test for all study areas, showing if the differences in home range size between the first and second time period were normally distributed.

	W	**p-value**
Rákkonjárga	0.7411	1.528e-05
Ildgruben		
In feeding area	0.94411	0.3702
Not in feeding area	0.82904	0.04356
Riast/Hylling	0.9813	0.9003

There was a significant difference in home range size between the first and second time period in both Rákkonjárga and Ildgruben, both for individuals in Ildgruben who were within the feeding area during the second time period and those who were not (*Table 4*). For Riast, the p-value from the statistical test showed that there was no significant difference. Interpreted in combination with the results in Table 2, home ranges were significantly larger in Rákkonjárga during the second time period, and significantly smaller in Ildgruben during the second time period.

Table 4. Results of the Wilcoxon signed rank test indicating the significance of differences in home range size between the first and second time periods within each area.

	V	**p-value**
Rákkonjárga	342	7.29e-05
Ildgruben		
In feeding area	0	1.526e-05
Not in feeding area	2	0.01172
Riast/Hylling	248	0.06688

4.2 Overlap

The average overlap was largest in Riast during both the first and second time period, followed by Ildgruben for fed individuals, and finally overlap was lowest in Rákkonjárga (*Table 5*). The minimum value of overlap was 0 in all datasets, and ranged up to as high as 0.99 in Ildgruben for feeding individuals.

Table 5. Mean, standard deviation, minimum and maximum values of overlap between individual home ranges across all three reindeer herding districts and both time periods.

	First time period				**Second time period**			
	Mean	Std. d	min	max	Mean	Std. d	min	max
Rákkonjárga								
Northwest	0.23	0.16	0	0.72	0.28	0.25	0	0.48
Southeast	0.0078	0.0094	0	0.018	0.0086	0.21	0	0.87
Ildgruben								
In feeding area	0.32	0.17	0	0.98	0.55	0.39	0	0.99
Not in feeding area					0	0	0	0
Riast/Hylling	0.67	0.19	0	0.97	0.59	0.18	0	0.92

4.3 Step length

The average step length (distance between two consequtive GPS-positions) ranged between 301 m/6 h to up to 871 m/6h (*Table* 6). Average step length was largest in Riast during both the first and second time period and shortest in Rákkonjárga during the first time period (*Table 6*). In Rákkonjárga and Riast, the average step length became larger during the second time period compared to the first, while in Ildgruben the average step length was smaller during the second time period. The standard deviation of all step lengths was larger than the average step length for all areas and time periods. The maximum step length was larger in the second time period compared to the first for Rákkonjárga and Ildgruben for individuals within the feeding area, while it was smaller during the second time period for non-feeding individuals in Ildgruben and Riast.

Table 6. Mean, standard deviation, minimum and maximum values of step lengths (distance between two consequtive GPS positions) in meters across all three reindeer herding districts and both time periods.

	First time period				**Second time period**			
	Mean	Std. d	min	max	Mean	Std. d	min	max
Rákkonjárga	301.02	± 415.8	0.38	5984.1	472.5	±894.3	1.12	12767.5
Ildgruben								

In feeding area	591.4	±845.9	0.9	9141.6	370.6	±729.3	1.43	15663.8
Not in feeding area					422	±615.9	2.12	6902.1
Riast/Hylling	809.2	±1378.3	1.03	12472.9	871.2	±1199.7	0.51	7414.9

The Welch two-sample t-tests show that there was a significant difference in step length between the first and second time period for Rákkonjárga and Ildgruben, both for feeding and non-feeding individuals, but not for Riast/Hylling (*Table 7*). Step length was significantly larger in Rákkonjárga during the second time period compared to the first, while it was significantly smaller in Ildgruben, however, more significant for feeding individuals. Step length was lower during the second time period in Riast, but not significantly so.

Table 7. Results of the Welch two sample t-test indicating the significance of differences in step lengths between the first and second time periods within each area.

	t	df	p-value
Rákkonjárga	9.16	3888.5	< 2.2e-16
Ildgruben			
In feeding area	-9.05	3810.8	< 2.2e-16
Not in feeding area	-6.54	2246.9	7.711e-11
Riast/Hylling	1.76	5276.7	0.0785

The frequency of step lengths during the first and second time period in Rákkonjárga show that there was a larger number of shorter step lengths during the second time period. However, there was also a larger range of lengths (*Figure 8*).

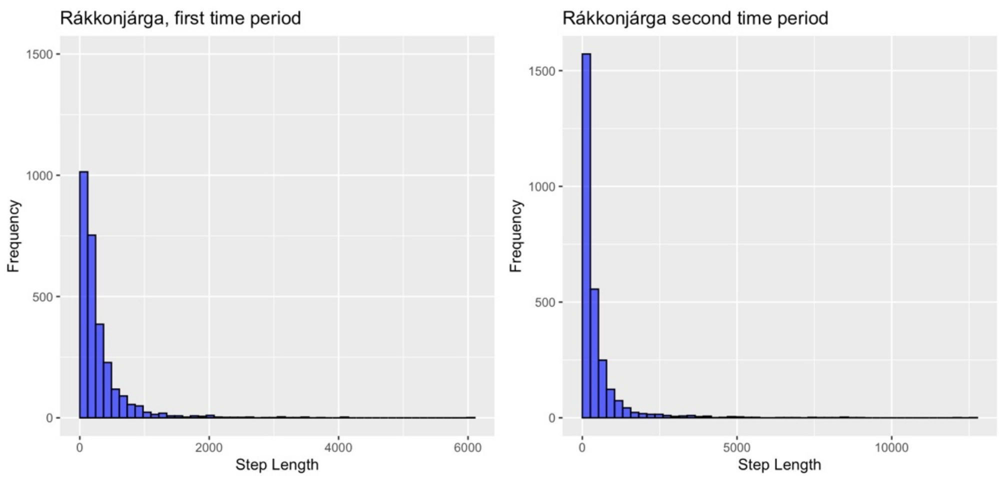

Figure 11. Step length histograms for Rákkonjárga during the first and second time period.

The frequency of step lengths for Ildgruben, during the first and second time period, divided into individuals who utilized feeding and those who did not, indicate that there was a higher number of short step lengths for individuals within the feeding site compared to individuals away from the feeding site (*Figure 9*), but also a higher maximum step length (*Table 6*).

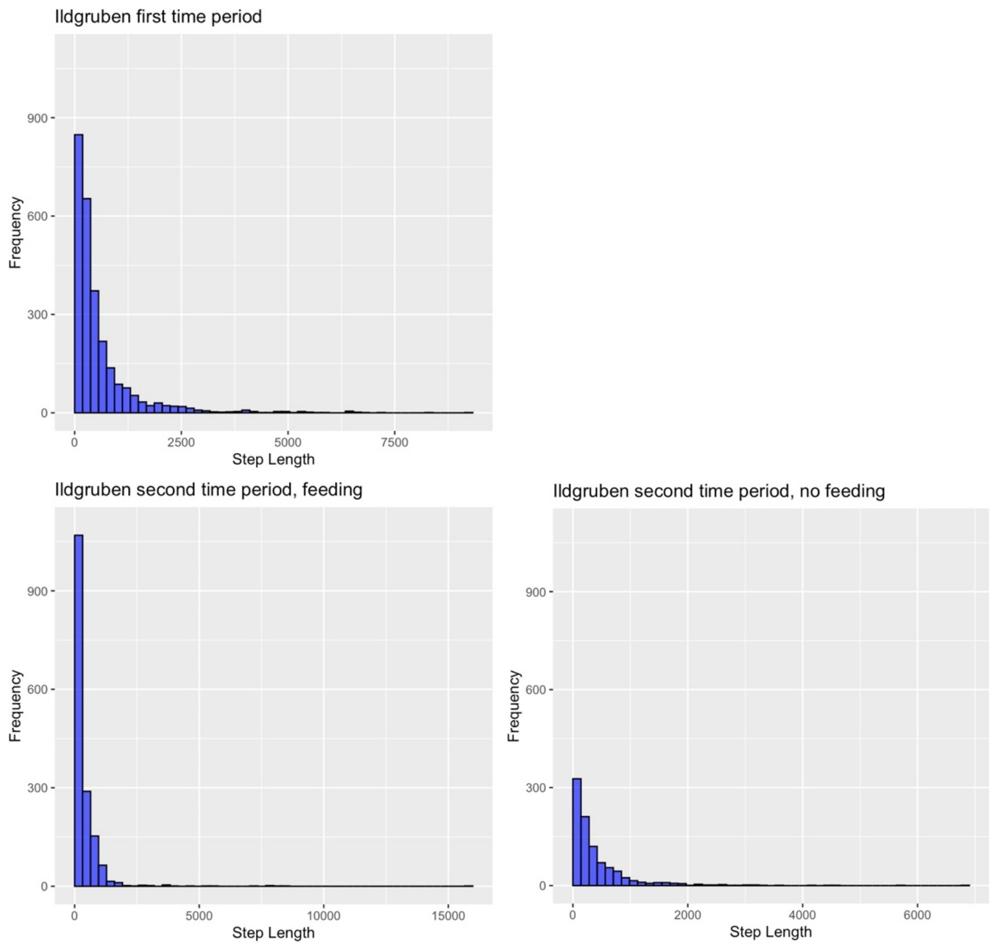

Figure 12. Step length histograms for Ildgruben during the first and second time period, with the second time period divided between individuals who did or did not utilize supplemental feeding.

The frequency of step lengths for Riast/Hylling are quite similar between the first and second time period (*Figure 10*). The histogram for the first time period is slightly more skewed towards the lower values, while at the same time having a larger maximum value.

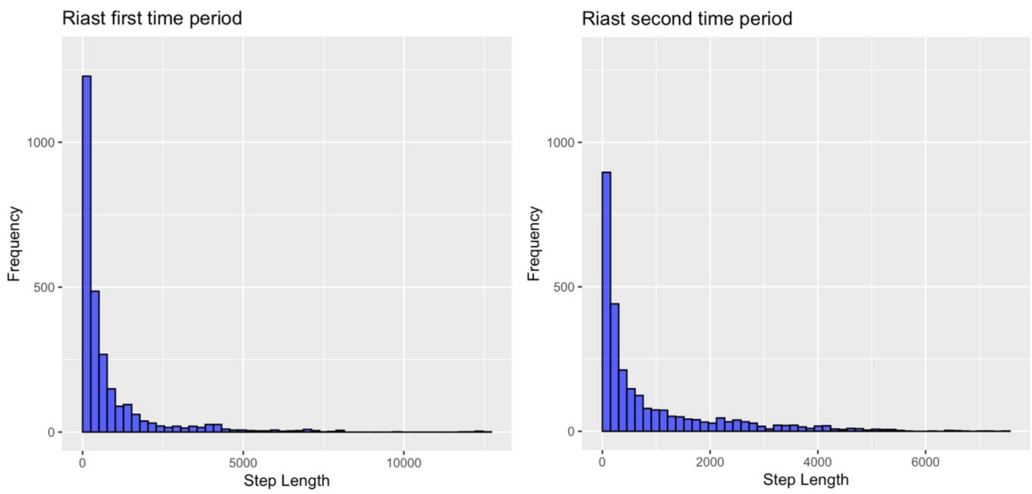

Figure 13. Step length histograms for Riast/Hylling during the first and second time period.

4.4 Weather and step length

The correlation found between temperature and wind was 0.62, and between rain and wind, 0.44 (*Table 8*).

Table 8. Results from the Spearman-rank correlation test, indicating the correlation between weather parameters during the selected time periods

	Temperature	**Precipitation**	**Wind**
Temperature	1	0.53	0.62
Precipitation	0.53	1	0.44
Wind	0.62	0.44	1

The output from the multiple linear regression model using the data from the first time period showed that wind had a significant effect on step length, where every increase of m/s in wind speed results in a decrease of step length by 0.98 meters (exp(-0.024)) (*Table 9*). There was also a significant difference between the areas, where step length in Rakkon was approximately -0.531 units shorter than in Ildgruben, while in Riast, step length was significantly longer than in Ildgruben, by approximately 0.308 units.

Table 9. Output of the linear regression model with step length data (m) from the first time period, before supplemental feeding. Ildgruben is used as the reference area, refered to as intercept in the model.

	Estimate	**Std. error**	**T value**	**Pr(>|t|)**
Intercept	6.2053	0.06421	96.633	< 2e-16***
Wind	-0.0236	0.006988	-3.388	0.000718***
Temperature	0.002	0.003775	0.538	0.5905
Precipitation	0.003	0.003122	1.013	0.31119

Rákkonjárga	-0.5309	0.053114	-9.996	< 2e-16***
Riast	0.3075	0.05899	5.214	2.03e-07***

The linear regression model using the data from the second time period showed that precipitation had a significant effect on step length, where every unit increase in precipitation resulted in a decrease of step length by approximately -0.033 meters (*Table 10*). During the second time period, step length was significantly longer in both Rakkon and Riast compared to Ildgruben, by 0.148 and 0.694 units respectively.

Table 10. Output of the linear regression model with step length data (m) from the second time period, during supplemental feeding in Ildgruben and Rákkonjárga.. Ildgruben is used as the reference area, refered to as intercept in the model.

	Estimate	Std. error	T value	Pr(>|t|)
Intercept	5.8169	0.109404	53.169	< 2e-16***
Wind	-0.01512	0.011402	-1.327	0.18482
Temp	0.006740	0.005254	1.283	0.19969
Rain	-0.033841	0.011697	-2.893	0.00386**
Rákkonjárga	0.148330	0.064374	2.304	0.02133*
Riast	0.694298	0.063074	11.008	< 2e-16***

Wind was shown to have a significant effect on step length during the first time period. A prediction of step length with increasing wind speed was estimated based on the first fitted linear regression model (*Figure 11*). The downward trend in the plot indicates that as wind speed rises, reindeer move less.

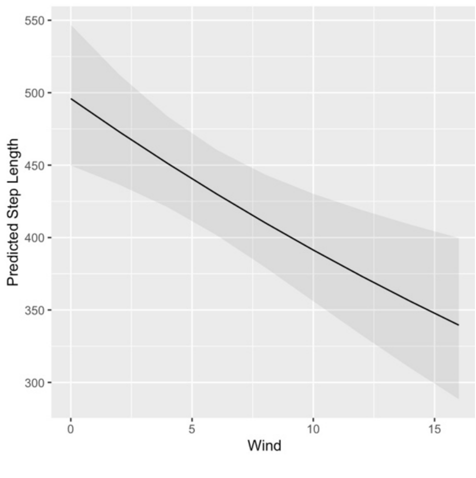

Figure 14. Predicted step length with increasing wind speed, based on the linear regression model during the first time period. The shaded area represents the 95% confidence interval.

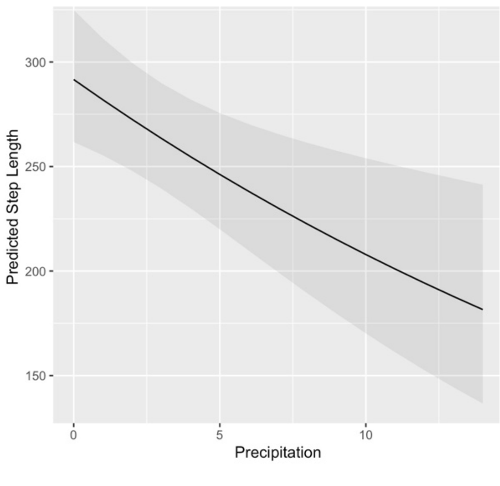

Figure 15. Predicted step length with increasing precipitation, based on the linear regression model during the second time period. The shaded area represents the 95% confidence interval.

Precipitation was shown to have a significant effect on step length during the second time period. Figure 12 illustrates the predicted step length with increasing precipitation, based on the second fitted linear regression model. The downward trend in the plot indicates that as precipitation increases, the predicted step length decreases, reinforcing the negative association between these variables.

5. Discussion

5.1 Home range size

The home ranges were significantly larger in the second time period in Rákkonjárga compared to the first. In Ildgruben, home ranges were significantly smaller during the second time period, both for individuals who were in the feeding area and those who were not. In Riast, where no feeding occurred, there was no difference in home range size. The result of home ranges becoming larger in Rákkonjárga was not expected, as home range size was hypothesized to be smaller during feeding in both areas where feeding occurred.

5.1.1 Feeding practices

One possible explanation for the difference in home range sizes was the feeding practices used in the two areas. In Rákkonjárga, feeding took place over a much larger area and the food was spread out on the ground over different parts of the areas each day. The feed consisted of mainly hay with small amounts of pellets mixed into it if needed. In Ildgruben, feeding was concentrated in a much smaller area and consisted mainly of pellets, available to the reindeer in several feeding throughs across the feeding area to give all reindeer access to the food. Lichens are collected each fall and used in case digestion issues are noticed, mainly during the start of feeding. In Rákkonjárga, part of the feeding was also conducted in the forest, and the reindeer herder expressed that this is to encourage reindeer to continue utilizing the arboreal lichens and not only the provided feed. This was not the case in Ildgruben. Of course, these differences are not necessarily only due to decisions of herders, but can also be due to differences in economy or availability or forests and lichens.

Turunen et al. (2014) mention how reindeer-human interaction is affected by multiple factors, such as frequency of feeding and density of reindeer in the feeding area, how this effects the tameness of reindeer and how dependent reindeer become on the feed provided by herders. Since feeding in Ildgruben takes place across a much smaller area, it is reasonable to believe that human-reindeer interaction becomes more frequent and reindeer depend more on the supplementary feed, possibly making them less inclined to search for natural food, resulting in smaller home ranges during feeding. The same study mentions how reindeer in areas with yearly feeding start to seek out feeding areas independently, without being herded towards them. Since feeding in Ildgruben takes place in a very limited area, reindeer may have learned exactly where feed can be found and make little effort to search in other areas. In Rákkonjárga on the other hand, feeding takes place over large areas and is spread out in different parts of the area during the feeding period, possibly making the reindeer less aware of where to find food from day to day, forcing them to continue to utilize larger home ranges. It is also possible that not all reindeer find the supplemental feeding each day, encouraging them to continue searching for natural forage instead of relying solely on feeding.

One unexpected result was that home range sizes in Ildgruben were significantly smaller during the second time period also for individuals who did not utilize the supplemental feeding. It was hypothesized that individuals who did not have access to supplemental feed would keep roughly the same home range size during both time periods, as they were forced to carry out the same foraging behaviour. A possible explanation is the reduced competition over natural food for remaining individuals, after parts of the herd move to the feeding area. Foraging competition is documented to occur between reindeer gathered in the same area (Uccheddu et al. 2015). A higher density of reindeer on natural pasture not only means that forage availability may decrease faster, but also that subdominant individuals may be prevented from eating by more dominant individuals and forced to move on to other areas (Nilsson 2003). Once a large part of the reindeer in Ildgruben started utilizing the supplemental feed, there was reduced competition for remaining individuals, and once an area with good natural pasture is found, the resources can last longer, meaning that the individual can stay in that area for a longer time period.

The results from this thesis imply that the different feeding practices could possibly effect movement in different ways and could possibly make the reindeer more or less inclined to continue foraging for natural feed despite the access to supplemental food. This partly corresponds to the findings by Rautianinen (2024), where it was expressed how regularly fed reindeer sometimes leave proficient grazing grounds to use only the provided feed.

5.1.2 Snow depth

Rákkonjárga and Ildgruben differ not only in feeding practices, but also in e.g. latitude and weather during the two time periods. This could be one explanation as to why home ranges were smaller in Ildgruben during the second time period compared to the first, while this was not the case in Rákkonjárga. Snow depth data was retrieved from senorge.no, from the date in the middle of both time periods in each area. In Rákkonjárga, snow depth in the utilized area did not exceed 100 cm in either time period, and was in fact below 50 cm in the majority of the area. In Ildgruben, the snow depth during the first time period ranged between >100 cm to up to 200 cm across the utilized area. In the second time period, about half of the utilized area was covered with up to 400 cm of snow, including the feeding area. In Riast/Hylling, the majority of the utilized area had a snow depth of up to 100 cm with a small area of up to 150 cm, this was true for both time periods.

The high snow depth in Ildgruben during the second time period could contribute to the small home ranges for both feeding and non-feeding individuals. Snow depth not only makes it harder for reindeer to move around (Couriot et al. 2023), but also makes it more difficult to find forage (Rosqvist et al. 2022). This could then make the reindeer who utilized feeding forced to rely solely on the supplemental feeding, if they had no way of finding natural forage. Another aspect is that during such snow conditions, herders must use the same tracks to transport the food as the days before, making the feeding site almost the same each day (Eilertsen 2024). However, in Table 2, we can see that home ranges in Ildgruben were larger than in Rákkonjárga during the first time period, even though snow depth was much higher in Ildgruben during this time period as well. Therefore, even though an increase in snow depth could have been a contributing factor for the decrease in home range size in Ildgruben from the first to the second time period, it is not likely that snow depth alone determines movement and home range size.

5.2 Step length

Step length was, just as home range size was larger, significantly longer in Rákkonjárga during the second time period compared to the first, and significantly smaller for both feeding and non-feeding individuals in Ildgruben. The standard deviation of step lengths was consistently larger than the mean step length for all areas and time periods (*Table 6*), indicating a wide variety of data points around the average value. This observation reflects the complexity of reindeer movement behavior and the natural variability in their movement patterns.

The correlation between larger home ranges and longer step length is logical, as utilizing a larger area would require longer movements. However, it does signify something important; that reindeer in Rákkonjárga not only utilized a larger home range during the 26 day time period of feeding because of supplemental feeding occurring at different places on different dates, but that their daily movement increased in spite of feeding. This could indicate that they not only moved to the next area with supplemental feed every few days, but continued to move across larger areas each day. Though it could be due to supplemental feed being spread out across large surfaces, it could also suggest that reindeer continue to search for natural feed in addition to the supplemental feed they come across.

5.3 Effect of weather parameters

The multiple linear regression models revealed significant associations between step length and specific weather parameters during different time periods. However, the correlations observed between weather variables emphazise the need for careful consideration when interpreting these results. Another consideration is that data of temperature, precipitation and wind speed was gathered from the closest possible weather station of each area, meaning that weather conditions in the utilized areas might not have been the exact same as at the weather stations, or the exact same within the entirety of each utilized area.

5.3.1 The first time period

In the first multiple linear regression model with data from the first time period (*Table 9*), wind was found to have a significant negative effect on step length. This corresponds to results found by Kolloen (2015), where the response of Svalbard reindeer to different weather parameters was investigated and wind was found to decrease movement.

Here it is important to note that the correlation test showed the highest correlation between wind speed and temperature, at 0.62. Therefore, while the linear regression analysis identified wind speed to have a significant effect on step length and while temperature did not reach statistical significance in this thesis, its correlation with wind speed implies that it could still play a role in driving the observed results. The correlation between temperature and precipitation as well as precipitation and wind speed were more moderate.

Couriot et al. (2023) mention how warmer temperatures and low wind speed are often associated with soft and deep snow, making it more difficult for reindeer to move and, in their study, limits the female reindeers ability to reach calving grounds. This contradicts the results found in this study, as higher wind speed should then make it easier for reindeer to move around and therefore lead to a positive relationship between wind speed and step length, and not a negative one that was found here. However, in the study by Curiot et al. (2023), movement is studied in relation to migration to calving grounds, and not in regards to movement in between migrations. A different approach in interpreting the results could be that if higher wind speed leads to more shallow snow, that could then make it easier for reindeer to locate and access ground lichens, meaning that the need for movement becomes smaller when they come across an area with good amounts of food and can utilize that for a longer time rather than moving to new areas in search of more accessible food.

Another explanation, mentioned by reindeer herders themselves, is that during high wind speed, reindeer often lay down to stay out of the wind and reduce heat loss, and because sight becomes impaired. Laying down or staying in sheltered areas during high wind speed to reduce heat loss has also been found among caribou (Henshaw 1968).

5.3.2 The second time period

In the multiple linear regression model for the second time period (*Table 10*), precipitation had a significant effect on step length, where more precipitation correlated to decreasing movement. Rain-on-snow events lead to ice-formation, which has a limiting effect on access to ground lichens (Sokolov et al. 2016; Horstkotte et al. 2020). Though precipitation does not necessarily mean rain, it is reasonable to believe that part of the precipitation during the second time period was rain or wet snow, especially in the more southern areas. This assumption is supported by the data from Rosqvist et al. (2022) showing that rain-on-snow events can occur throughout winter in northern Sweden, though it becomes more common as spring approaches. The study by Rosqvist et al. (2022) concludes that even a single rain-on-snow event or more extreme snow fall event can significantly impact the reindeers ability to find forage. They also conclude that this can force the reindeer to seek out alternative pastures and routes, making them more inclined to move in high-risk areas such as roads or railroads.

It is likely that precipitation had an effect on the reindeer in this study during both time periods. During the first time period, where no supplemental feed was offered in any of the areas, rain-on-snow events of heavy snowfall could have limited the access to natural feed and caused lower energy intake, which in itself can cause problems such as starvation, poor body condition and low calf weights in the following calving period. Health or condition of the reindeer was not studied in this thesis, and only changes in movement were analyzed. It is possible that the reason why we see an effect of precipitation on step length only during the second time period is that the access to supplemental feed made the reindeer less likely to continue foraging for natural feed, as they were able to rely on supplemental feed. This behavioural change could have been emphazised during bad snow conditions. Since precipitation had no significant effect on step length during the first time period, we can see no implication that bad snow conditions make reindeer less likely to continue searching for natural feed before supplemental feeding starts. However, as supplemental winter feeding continues year after year, it is possible that reindeer will become less inclined to search for natural forage and more dependent on supplemental feeding, and might migrate to feeding areas before feeding even starts, a shift that has already been seen in Finland (Turunen et al. 2014).

Temperatures and precipitation are increasing due to climate change, especially in the north, and effects are hypothesized to potentially be larger during winter than summer (Räisänen 1994; Kjellström et al. 2022). This means that rain-on-snow events will become more and more common. The results from this thesis imply that increased precipitation will make reindeer less inclined to, or less able to, forage for natural food and more dependent on supplemental feeding. This result is supported by the results by Loe et al. (2007) and Kolloen (2015). The results emphazise the need for alternative pastures as well as mature forests with arboreal lichens during local harsh snow conditions and when ground lichens are locked in. These requirements will only grow larger in the future, with the increasing effects of climate change.

5.4 Future implications

Semi-domesticated reindeer are the most abundant terrestrial herbivore in arctic Fennoscandia, of great ecological, cultural and economic significance (Mallory & Boyce 2018).

Just one example of the their importance comes from their potential ability to counteract climate driven effects. As mentioned in the introduction, climate change causes higher plant productivity and increased shrub coverage (Cornelissen et al. 2001; Moen 2008). This is believed to potentially increase competition for other tundra species and have a negative impact on lichen abundance (Pharo & Vitt 2000; Wookey et al. 2009; Myers-Smith et al. 2011). Studies have shown that grazing from reindeer has a limiting effect on deciduous shrubs, meaning that reindeer can mitigate these effects (Olofsson et al. 2009; Spiegel et al. 2023). This highlights not only the importance of reindeer in the Arctic ecosystem, but the importance of natural grazing by reindeer over supplemental feeding.

Several articles used in this thesis express concerns over the future of traditional reindeer herding in Scandinavia. Vistnes & Nellemann (2007), studying reindeer avoidance of human development, mention that though co-existence is still possible, it will be problematic to uphold the same densities of reindeer in the future when human development limits herders ability to respond to other environmental changes. In a study by Uboni et al. (2020) in Sweden, it was found that herders tackled lost pastures and declining pasture quality through increased productivity, supplemental feeding and modernization. Despite governmental support and optimized productivity, concern was raised about the long-term sustainability of reindeer husbandry. Reindeer herding has adapted to infrastructure development and modernization in many ways, but adaptation to continuous change is not easy or even possible past a certain extent (Anttonen et al. 2011). Horstkotte et al. (2022) brings up how, though herders recognize the necessity of supplementary and emergency feeding under todays circumstances, concern has been raised about government agencies and the public seeing feeding as a replacement for natural and high quality pastures. If so, this could decrease the support and efforts for conservation and restoration of Arctic land.

With changing practices, such as a growing use of winter feeding, other issues could also arise, such as increased occurrence of diseases (Tryland 2012; Åhman et al 2018; Tryland et al. 2019; Tryland et al. 2022). Up until about the end of the nineteenth century, though the total number of reindeer was roughly the same as today, herding in Fennoscandia was mainly small scale within each herd, with close contact between herders and animals, being used for eg transportation and milk in addition to meat (Åhman & Turunen 2022; Tryland et al. 2022). Feeding was also though to be more common during this time (Salmi 2023). Major disease outbreaks were also more common, for example the reindeer pest (*Pestis tarandi*) causing mass mortality and largely impacting Sámi communities (Tryland et al. 2012; Tryland et al. 2022). In the early 20th century, more extensive reindeer husbandry emerged with larger herds and a larger focus on meat production rather than milk and fur (Riseth et al. 2020). In combination with many other developments, gathering of reindeer during extended periods became less common.

The process of gathering and feeding reindeer increases the contact between animals and can easily cause stress. Leftover feed and feaces at feeding sites can create an unhygienic environment, potentially increasing the spread and suceptatibility of diseases and parasites as well as the animals ability to cope with potential health issues (Tryland 2012; Åhman et al 2018; Tryland et al. 2019; Tryland et al. 2022). Though gathering and feeding is hardly the sole driver of disease (Tryland 2012), it is possible that the spread and susceptibility of diseases can become a larger threat to reindeer herding once again, as feeding becomes more common.

In this thesis, significant associations between changes in weather parameters and movement was found, however, correlations between the weather parameters were also found, making it more difficult to be sure which parameter really had an impact on movement. The most important lesson to take from this is that both observed significant effects resulted in a decrease in movement. With climate change, more extreme weather is thought to become more common, such as higher temperatures, heavy precipitation, wildfires and wind-storms (IPCC 2014). If the results from this thesis are any indication, this could potentially mean that the reindeers ability or tendency to move around during winter will decrease further. Whether this is because they are unable to find natural forage or because they choose to rely on the easily accessible supplemental feed is not made clear from this thesis, however it does imply that under todays circumstances, the need for supplemental feeding will continue to grow in the future. This is a threat not only to the economics and heritage of Sámi communities, but also the important effects reindeer have on the Arctic ecosystems.

6. Conclusion

The results from this thesis indicate that feeding practices could effect home range size and movement of reindeer, and possibly their tendency to search for natural forage. It also shows that weather and snow conditions effect the animals tendency to move and find forage. The issues that reindeer herders face, combined with the growing effects of climate change, indicate that the need for winter feeding will continue to grow in the future. This emphazises the importance of joined efforts to ensure a sustainable future for reindeer herders while honoring the traditions of Sámi communities.

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Popular science summary

Majority of reindeer in northern Fennoscandia are owned and herded my Sámi communities. They carry large ecological, economic, and cultural importance. During recent decades, expansion from other land users has increased within the reindeer herding area, meaning that herders have fewer available pastures to use. Climate change has also affected the quality of remaining pastures and the reindeer's access to natural forage during winter. Because of this, supplemental winter feeding has become a more common practice in many herding areas.

In this thesis, the effect of supplemental on home range size and movement was investigated in three different reindeer herding districts in Norway. The effect of different weather parameters on how much the reindeer moved within their home ranges was also analyzed. It was found that supplemental feeding made home ranges and movement larger in one of the areas, and smaller in a different area. In the third area where no supplemental feeding was used, there was no significant difference between the two investigated time periods. Increasing wind speed made reindeer move less during the first period, when feeding had not yet started in any of the areas, while increased precipitation had the same effect during the second time period, when feeding was used in two of the areas.

Although more studies should be made to make the results more secure, the results indicate that feeding practices and weather conditions can have important effects on the area use and movement of reindeer. This calls for careful considerations when implementing feeding. It also implies that with the growing effects of climate change, combined efforts should be made to ensure a sustainable future for reindeer herding.

Acknowledgements

I want to thank my supervisor Anna Skarin, my assistant supervisor Svein-Morten as well as PHD student Heidi Rautiainen for their help and guidance during my thesis work. I also want to thank the reindeer herders whose collaboration with the WELFED project made my analysis possible. A special thank you goes out to Frode Utsi and Magne Andersen who provided me with important insight into how supplemental feeding practices are implemented in the districts. Lastly I want to thank my family and friends for their support and words of encouragement.

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