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Evaluating Wildlife Cameras as a Method to Sample Reindeer Behavior

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Ecology

Preface

This thesis was conducted as part of a larger project concerning the effects of power infrastructure on reindeer populations across the Fennoscandian region. Main funding sources for this project come from the Swedish Energy Department, the Norwegian Water Resources and Energy Directorate (NVE), Statkraft, Fosen Wind, Statnett, and The Reindeer Herding Council of Norway.

This thesis was made possible through the help of my supervisors, Jonathan Colman and Sindre Eftestøl. I would like to thank Jonathan for involving me in this project, as well as for his guidance, insight, and encouragement to challenge myself. I am thankful to Sindre for his advice, and for his help in developing my GIS skills, which have been extremely useful in the completion of this thesis. I would also like to thank Diress Tsegaye for his instrumental help with the statistics of this project, as well as Richard Bischoff and Kjetil Flydal for their insights regarding the direction of analyses. Finally, I am deeply grateful for all the support from my friends and family, who have made completing this project possible throughout a uniquely challenging year.

Abstract

Increasing amounts of infrastructure intersecting reindeer habitat in Fennoscandia also increases concern over negative effects on reindeer behavior and area use. Previous studies have shown variable results regarding area use, often related to spatiotemporal scale, while research on the effects of infrastructure on reindeer behavior has been limited. Can wildlife cameras contribute novel data? I analyzed data from wildlife cameras near power lines in two reindeer herding districts in Trøndelag and Nordland counties, Norway to investigate the reliability of wildlife cameras in identifying behavior and area use patterns, comparing with GPS collar data from the same sites and scales. Animal behavior data from wildlife cameras was used to test proportions of behavior types against habitat and distance to the line, compared with movement rate data from GPS collars. Meanwhile, presence/absence analysis based off camera data was used to identify area use relative to distance from power lines, compared with area use analyses based off GPS positions. Camera and GPS-data agreed in finding no significant negative effects by power line proximity on animal stress or relaxation behaviors, however camera data found behavior patterns not detected using GPS-data. Results were generally consistent between cameras and GPS-data for area use, finding no negative effects by power lines, however the limited scale and detail of the camera data, especially at the Trøndelag site, limited the power of results. Results suggest that cameras are a useful tool for the analysis of behavior relative to infrastructure, while camera data is likely more useful as a supplementary data source for area use analysis when alternative methods are limited. Potential issues with data handling and study design were also identified, which future studies using this technology can take into consideration. It is recommended that wildlife cameras be further applied and developed in this context in order to better inform management of reindeer populations.

Contents

1 - Introduction

Reindeer habitat in Norway has been subject to significant changes over the past century, due in large part to greatly increasing development of infrastructure. This includes high-voltage power lines, which are used to connect developed areas to power generation facilities such as hydropower dams and wind power, and commonly intersect with reindeer habitat (NVE 2021). These developments have led to increased concern that this infrastructure negatively affects reindeer through avoidance in area use and increased stress when in close proximity to lines.

Previous studies focusing on the effect of power lines on reindeer have shown varying results, often depending on the spatiotemporal scale of study (see review by Flydal et al 2019). Studies conducted on larger spatial scales over longer periods, such as in selection of home range over many years (e.g., over 20 km from infrastructure), have generally found reindeer tend to avoid infrastructure such as power lines (Vistnes & Nellemann 2001, Vistnes et al 2001). However, on smaller scales such as in selection of habitat within home range over several seasons (e.g., up to approx. 10km from infrastructure), studies have found less significant avoidance effects by power lines themselves, and more effects by variation in local habitat and human activity (Colman et al 2015, Eftestøl et al 2016). Limited research has been conducted on the individual behavior patterns of reindeer relative to power lines and has found only small to negligible effects of power line proximity on stress behaviors (Flydal et al 2009). Debate remains as to whether the differences in effects according to scale is indeed indicative of different patterns dependent on scale, or if it is a result of differences in sampling methodology.

A wide variety of methodologies have been used in previous studies regarding infrastructure and reindeer, where some of the most prominent include aerial surveys (Vistnes et al 2001, Nellemann et al 2001, Reimers et al 2007), direct observation (Vistnes & Nellemann 2001, Nellemann et al 2001), pellet counts (Colman et al 2013, Skarin 2007), and GPS collaring (Eftestøl et al 2016, Colman et al 2015, Panzacchi et al 2013). Each of these methodologies have their own unique set of drawbacks: for example, while aerial surveys, direct observation and pellet counts can observe the entirety of a herd or home range over longer time scales (weeks, months, and years), they have poor temporal resolution, meaning one only gets short 'snapshots' of a population, which can be affected by extraneous factors, especially at larger scales. Meanwhile, GPS collar data, while having a high temporal resolution (usually hours), is often limited to observing a maximum of several dozen individuals in a herd, which can limit application of results to the herd as a whole, especially for those with a high number of individuals. There can also be concerns regarding pseudo replication, as individual GPS positions from the same animals are not independent from each other. Finally, GPS data gives limited insights into behavioral responses to environmental stimuli, being able to mostly document position and movement rates. Given these drawbacks, additional data collection methods that can supplement existing methods for sampling individual reindeer behavior and site-specific conditions may be useful, for which wildlife cameras are a promising option.

Wildlife cameras have an advantage in that they can observe large proportions of a given reindeer herd with high temporal resolution, at relatively low cost compared to GPS, aerial surveys, or direct observations. Moreover, they can document behavior data as well as presence in distinct habitat areas, providing information for both behavior and area use patterns. Cameras can also be applied on a variety of spatial scales, where the main limitation is the visual range of individual cameras, as well as the cost and logistics of the total number of cameras deployed. This makes them useful at scales up to 10km from infrastructure, and used alongside previously established methods such as GPS, wildlife cameras could then be used to provide additional insight into the specific ways in which reindeer select habitat and behave relative to environmental conditions, external stimuli, and infrastructure such as power lines.

In this study, I wanted to evaluate the utility of wildlife cameras in the context of reindeer behavior and area use relative to power lines in order to see whether cameras provide novel data when used in tandem with other methods. To do this, I used data from wildlife cameras in two semi-domestic reindeer herding districts in Nordland and Trøndelag counties, Norway, and compared behavior and area use analysis results to those obtained from GPS collared individuals in the same sites and periods. I predicted the following:

a) Camera and GPS data would provide similar results in evaluating behavior indicative of stress when reindeer are near power lines.
b) Camera and GPS data would also estimate animal area use similarly relative to power line proximity.

Another goal of this project was purely methodological, aimed at identifying practical issues and drawbacks related to the application of wildlife cameras in this context, in order to inform future studies using this technology. Such studies would then be able to provide more nuanced insights into the effects of infrastructure on reindeer, and better inform future management and development decisions. Such decisions could include where and when to construct new infrastructure, and how activity can be conducted and planned in order to minimize disturbance to reindeer.

2: Materials and Methods

2.1 - Reindeer Districts

2.1.1 - Ildgruben

The Ildgruben reindeer district, located in Nordland county, is a sub-arctic heath/grassland interspersed with small lakes and characterized by moderately sloping topography. Snow cover is generally constant from October to late April, where temperatures range from well below freezing throughout the day in winter to the upper teens and low twenties in the summer. Prominent plant species include various grasses, lichens, and mosses, interspersed with small forest stands. The winter reindeer population within the district numbers approximately 900 individuals (Landbruksdirektoratet 2019). Lynx, wolverines, and golden eagles, predators to reindeer, are seen in this area, and are the most common cause of mortality for animals in the district (Rovbase 2021, Landbruksdirektoratet 2019). Human activity is mostly concentrated along the coast and in some smaller valley areas where cabins have been built. Large amounts of hydropower development have occurred in the area over the past 50 years, with several power lines intersecting the district, including a large 420 kV line running in a north-south direction crossing three ridges in the western part of the range. The study site within the Ildgruben district (Figure 1) is located on the middle ridge crossed by this 420 kV line (66.2422N, 14.23418E). The town of Mo i Rana lies approximately 9 km to the Northwest, with a population of over 18,000 (Statistisk Sentralbyrå 2020), having extensive infrastructure, however the immediate area around the site has limited infrastructure.

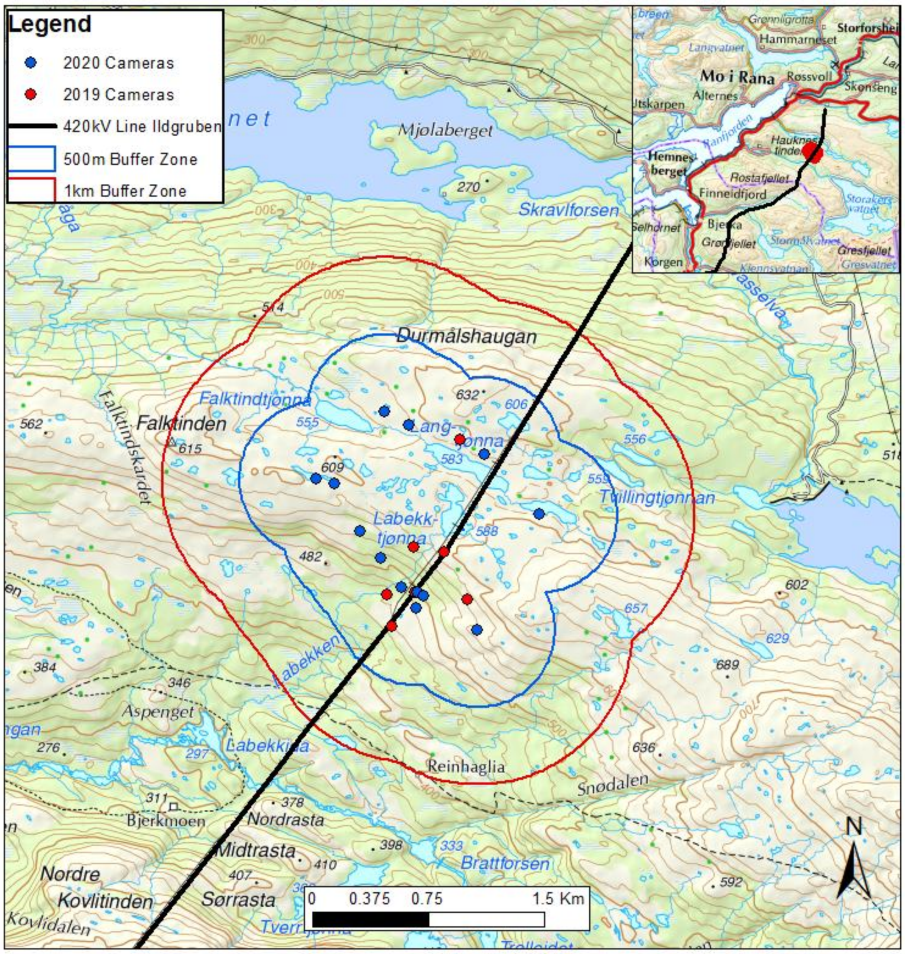

Figure 1: Map of the Ildgruben study site.

2.1.2 - Fosen

The Fosen reindeer herding district lies approximately 280 km southwest of Ildgruben, in Trøndelag county. Similar to Ildgruben, it is an open and hilly heathland dominated by grasses, lichens, and mosses, interspersed with small forest stands, and punctuated by small lakes. The reindeer population in this district numbers approximately 1900 individuals (Landbruksdirektoratet 2019), where the district's population is divided into two independent sub-populations (north and south) of approximately equal size. Like Ildgruben, predators such as lynx, wolverines and golden eagles are present in the area, and are responsible for the majority of documented animal losses (Rovbase 2021, Landbruksdirektoratet 2019). The specific study site is located in Osen municipality within the northern sub-population's winter and spring range (64.19804N, 10.5922S). This portion of their range is intersected by a northeast-running 420kV line, where during spring of 2019 a smaller parallel line was built. The study site lies a similar distance from human settlements (~5 km), however these settlements are not large, with a population for the entire municipality being less than 1000 people (Statistisk Sentralbyrå 2020).

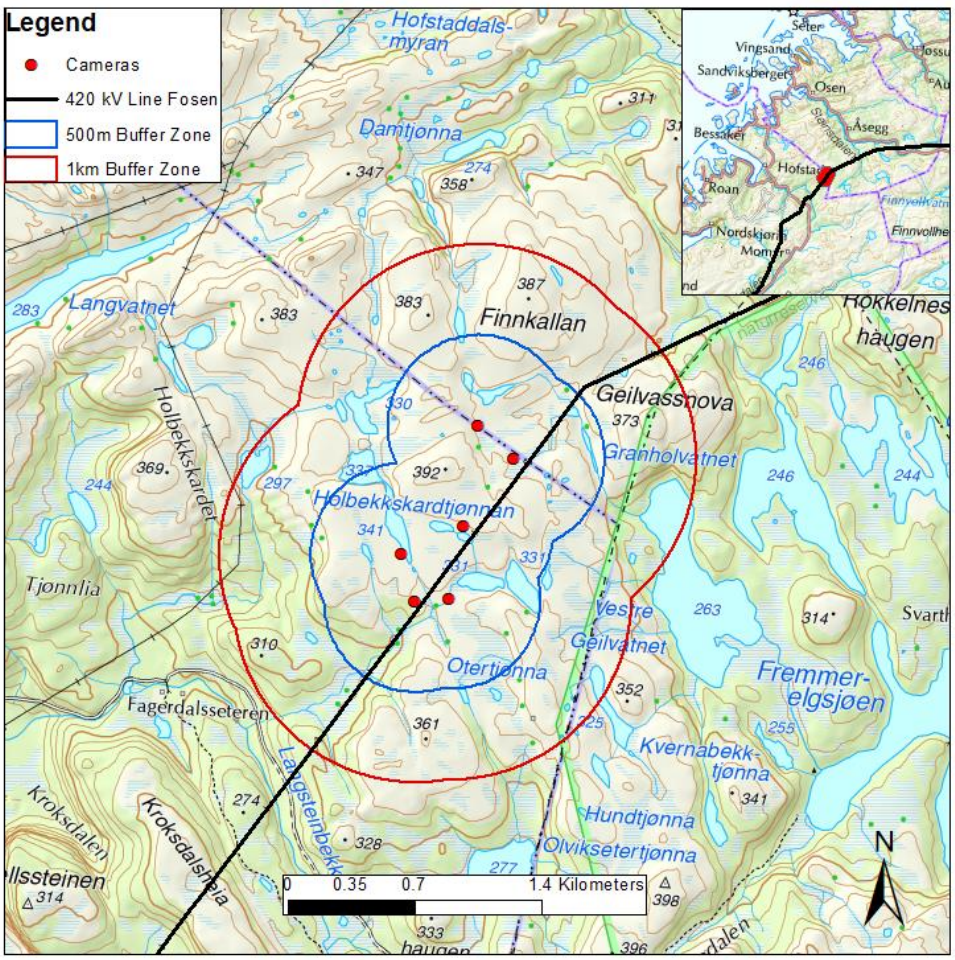

Figure 2: Map of the Fosen study site.

2.2 - Camera Placement and Recording

All cameras used in this project were Reconyx Hyperfire 2 Professional Covert Visual/Infrared cameras (Reconyx 2021), which take photos automatically at an adjustable rate, and are equipped with a thermal sensor that detects movement a short distance in front of the camera, which triggers a burst of 3 photos taken once every second. Cameras were mounted by strapping them securely to trees, and GPS coordinates for each camera's position were recorded. View distance for each camera was not measured, however most cameras under normal weather conditions had an effective visual range of between 100 and 300 meters.

2.2.1 - Ildgruben

Cameras were mounted from spring to fall in 2019 and 2020, 8 cameras during 2019 and 13 during 2020. The overall study period for 2019 lasted 231 days from 25th April to 12th December, while in 2020 it lasted 150 days from 4th May to 2nd October. Some cameras did not last the entire study period due to malfunctions and/or battery drainage, making the total number of camera days 3523 (1806 in 2019, 1717 in 2020). Cameras were installed at varying distances to the power line ranging from directly underneath it to approximately 800 meters away. The Ildgruben site was characterized by a large central ridge spanning several kilometers east to west, where cameras were either installed on top of the ridge or its southern side (3 cameras on top in 2019, 6 on top in 2020). Cameras in Ildgruben were programmed to take one photo automatically every 15 minutes 24 hours a day. In addition, the motion trigger on each camera was active, taking 3 pictures with 1 second between, every time the motion sensor was triggered. The total number of photos taken by cameras at the Ildgruben site was 721,436 (216,248 for 2019, 505,188 for 2020). However, this number was significantly inflated due to wind moving foliage in front of the cameras during spring and summer months, especially during 2020, causing high numbers of false motion trigger photos being taken.

2.2.2 - Fosen

Six cameras in the Fosen site were installed for one season in 2019, for 135 days from 12th February to 27th June. Similar to Ildgruben, not all cameras took photos for the entire period due to battery drain or malfunctions, leading to 642 total camera days. Cameras were set up either near the power line (within 100 meters of the line) and in control areas (over 200 meters away from the line). Cameras were programmed to take a single photo automatically every 5 minutes between 0300 and 2200 hours. Motion trigger was also active for these cameras, taking 3 photos with 1 second in between when movement is detected. The total number of photos taken at the Fosen site numbered 188,380, however similar issues to Ildgruben with false motion trigger also inflated the total number of photos.

2.3 - Camera Data Encoding

Photos taken from the cameras were examined manually using the Microsoft Windows Photos application, where data regarding reindeer and other relevant information was recorded into Microsoft Excel spreadsheets (Microsoft 2021). Checking of photos was expedited using an AutoHotkey keyboard script, which automatically scrolled through photo feeds at an adjustable rate, between 50 ms and 500 ms depending on the detail of photo sets (Open-source Software 2020).

Data regarding observations of reindeer were recorded to a separate spreadsheet for each site. For every instance a reindeer was detected, the following was recorded: the photo's timestamp, the camera number, number of individuals observed, number of calves (if applicable), count of animals performing grazing, lying, or moving, temperature, weather, year (for Ildgruben) and whether or not the observation came from a timed photo or from motion trigger. The categorization of behavior types was done as follows: For observations taken from timed photos at further distances from cameras:

- Animals were categorized as **grazing** if they were observed to linger in the field of view for more than one timed photo (5-15 minutes), while still moving in frame.

- Animals were categorized as **lying** if they were present for more than one timed photo, while not moving in frame between said photos.
- Animals were categorized as **moving** if they were captured in only one timed photo.

For observations taken from motion trigger photos at closer distances to cameras:

- Animals were considered **grazing** if they were clearly bowing their heads to eat, clearly chewing, or periodically stopping.
- Animals were considered **lying** if they were clearly lying on the ground for prolonged periods.
- Animals were considered **moving** if they were observed to be walking or running in a clearly identifiable manner without stopping or bowing their heads.

Weather conditions were defined into one of six categories: clear, cloudy, overcast, rain, snow, and fog. Temperature was recorded from the camera's onboard thermometer, which is displayed on every photo taken. Timed photos (every 5 minutes for Fosen, 15 for Ildgruben) were considered separate observations in the initial data set, while motion trigger photos occurring within 5 minutes of each other were considered a single observation for both sites.

Tracking of individual reindeer was not possible for all observations due to the varied distance at which they were captured in photos, and due to moving in and out of frame during periods of high activity. Also, since reindeer have a behavior cycle of approximately 2 hours (Colman at al. 2001), behaviors from consecutive observations will not be independent of each other. Therefore, to avoid pseudo replication, reindeer observations were merged into time intervals for both behavior and area use analyses (see chapter 2.5 and 2.6 for further details). Two instances of clear calving events were captured in the Ildgruben site, where lone individuals spent over 10 hours in front of a camera, periodically moving and lying down, and by the end of the observation event a calf was present. These observations were considered to be in one observation in both analyses regardless of interval, in order to avoid skewing the data.

Other data from photos not containing reindeer were also recorded, including periods of low visibility, snow cover, and incidental sightings of other species. Low visibility was recorded by events, with each event recorded with a time stamp for the first photo where visibility began to drop, the first photo where visibility improved, and the duration between the two timestamps. The cause of low visibility was also recorded for each event, being either from fog, obstruction of the camera lens, or by glare from sunlight. This was done in order to measure the effect of low visibility on the amount and quality of data taken between different cameras. Snow cover was recorded at a 24-hour interval, approximated into 5 categories ranging from 0 for no snow cover, to 4 for total cover. Finally, any instance where other species were detected by cameras was recorded, with additional data recorded similarly to reindeer observations. In the case for humans, no identifying information was recorded, where only the timestamp and habitat variables were included. According to ethics guidelines, all photos containing humans were deleted at the end of the project.

2.4 - Habitat Data for Camera Positions

Coordinates for cameras in both sites were imported into ArcMap (Esri, 2020), where habitat variables and distances to the respective power lines were extracted. For both sites, values for distance to the power line (meters), elevation (meters), hill aspect (north vs south facing), slope, and vegetation cover were also extracted for each camera's position. Vegetation cover was classified as one of 25 types, then sorted into 5 main groups: lichen and deciduous forest, rocky areas/snow patches/glaciers, heath, other ridges, and other (Appendix). In addition, cameras in Ildgruben were labeled as either mounted on top of the site's main ridge, or on its southern side. In Fosen, cameras were labeled as either being mounted in the control area further away from the power line or mounted alongside it.

2.5 - Camera Data Processing: Behavior

Data sets for analysis of behavior were organized from the original reindeer observation sheets, where observations were condensed at 2-hour intervals in order to avoid pseudo replication and to account for 2-hour behavior cycles (Colman et al 2001). This was done by taking the sum of individuals observed and the respective behavior counts for observations occurring within 2 hours of each other, then calculating a new proportion for each. This condensed the Ildgruben set from 667 observations down to 274 consolidated observations, and the Fosen set from 100 initial observations down to 19. The resulting data sets were then reorganized so that behavior type was added as a separate variable, along with its respective proportion, in order for all behavior types to be analyzed simultaneously.

2.6 - Camera Data Processing: Area Use

New datasets for each site were created for the Presence/Absence analysis, with an observation corresponding to every timed photo taken by cameras (15-minute intervals for Ildgruben, 5 minutes for Fosen). Columns were then added which grouped these observations into 1, 2, 3, and 4-hour intervals, respectively. Multiple intervals were used as it was not clear at the beginning of analyses which interval would be most useful. In addition to the 1-, 2-, 3-, and 4-hour intervals, a 24-hour time interval was also used for the Fosen set to see if that would improve the clarity of results due to its relatively lower number of observations. In order to standardize the data, it was decided not to include motion trigger photos in this analysis. This also simplified the creation of these data sets and given the majority of reindeer observations came from timed photos, a minimal amount of data was excluded. Distance to power lines and habitat variable values were added to each observation according to their respective camera. Reindeer observation and snow data from the encoding phase was then merged into these sheets using R, where every observation containing reindeer was given a '1' value for presence, and all others a '0' value for absence. Additionally, in the Ildgruben set, observations were labeled by season either as "Spring", occurring before the 1st of July, and "Summer" for observations occurring afterwards. Due to incompatibility in data processing and recording methods, periods of low visibility were not included in these sets or included in any of the analyses.

2.7 - GPS Data Processing

GPS data was retrieved from radio collared individuals from both reindeer districts during the same periods the cameras were active (Spring 2019 to Fall 2020 for Ildgruben, Spring to summer 2019 for Fosen). Observation intervals were 3 hours for the Fosen district, and 2 hours for the Ildgruben district. Data was saved to Excel spreadsheets and checked for errors. Missing single observations were extrapolated by taking the average position between the previous and consequent observations, while longer strings of missing coordinates were removed from the set. The GPS data from both districts was then imported into ArcMap (Esri 2020), where values for distance to the power line (meters), elevation (meters), hill aspect, slope, and vegetation cover (categorical, 5 levels) were extracted. In order to compare results from camera analyses, GPS points within 1 kilometer and 500-meter buffer zones around the cameras for each site were selected for analysis (Figures 1 and 2). Differently sized buffer zones were used as it was unclear at what scale the selection of GPS points would give sufficient data while also remaining comparable in terms of area surveyed. During the study, there were a total of 23 and 26 GPS-collared individuals in Ildgruben and Fosen reindeer district, respectively. The number of observations included in the analyses after final selection was as follows: 705 observations within the 1km buffer zone, and 379 for the 500-meter buffer zone for Ildgruben from 16 and 13 animals, respectively. For Fosen the corresponding observations numbered 279 and 107 from 7 and 6 animals, respectively. For the Ildgruben GPS data, points were classified as either being on top of the site's main ridge, or on the side, in the same manner as the camera analysis. The buffer zones in Ildgruben encompassed both the top and sides of the site's central ridge, where for the 1-kilometer buffer zone included both the northern and southern sides, while for the 500-meter buffer zone, only the top and southern side was encompassed (Figure 1). Season was also determined for observations in Ildgruben, either as "Spring" or "Summer", using the same July 1st cutoff as in the camera analysis. Finally, movement rate between observations was calculated for the Ildgruben data by first finding the distance traveled between observations, then dividing that by the observation time interval in order to get a movement rate in meters per hour.

2. 8 - Data analysis

All statistical tests were performed using R version 3.6.3 (R Core Team, 2021), using Generalized Linear Models (GLMs) and Linear Regression Models (LMs). GLMs were used in area use analyses where response variables were binary (e.g. Zuur et al 2009), while LMs were used for behavior and movement rate analyses, as response variables were continuous. Model selection was conducted by evaluating the quality of variables themselves, in addition to the use of Akaike's Information Criterion for comparing different model outputs. Attempts were made to use Generalized Linear Mixed Effects Models (GLMMs) by including year and individual animal ID (GPS only) for area use analyses as random factors to account for yearly and individual variations. However, it was found that such mixed models did not perform well compared to GLMs and were therefore not used. A number of other variables were also removed from camera analyses following preliminary testing. This included discrete habitat variables (elevation, north/south hill aspect, slope, and vegetation cover), as elevation, slope, and vegetation cover were correlated with the location factor for Ildgruben (ridge side versus top), while north/south hill aspect was not highly varied at the Ildgruben site due to cameras being placed only on flat or south facing hills (ridge top or side). For the Fosen set the limited sample size necessitated the use of simpler models, and therefore all habitat variables were removed, in addition to using a categorical variable (i.e. control area versus along the line) instead of continuous distance to the line. There was also concern that the values for discrete habitat variables were not accurate summations of habitat variation for the camera data, as they only represented values for the exact point at which cameras were placed, and not the actual areas surveyed. Snow data was also removed, as non-zero snow cover values were only present for a fraction of the total study periods, and its inclusion in models increased the size of confidence intervals. Finally, weather variables were excluded from camera analyses, as they were unbalanced, there were and concerns that a variable with so many levels (6) could cause false significance in results.

Preliminary testing found that 500-meter buffer zones were more useful for selecting GPS points in order to compare with findings from camera analyses. The 1-kilometer buffer zones, while including more GPS observations, nevertheless tended to include areas that were not representative of the areas observed by the cameras, limiting comparability. This is exemplified by the 1-kilometer buffer zone at the Ildgruben site encompassing parts of the ridge's northern side, which cameras did not survey (Figure 1).

2.8.1: Behavior

Camera Data

I tested whether proximity to power lines and habitat variables had a significant effect on the proportion of animals performing particular behaviors using linear regression models (LMs). Variables used in final models were as follows: For Ildgruben: behavior proportion, (response variable), distance to the power line, behavior type, location relative to the main ridge, and season. For Fosen: behavior proportion (response variable), location relative to the line (control area or alongside), and behavior type.

GPS Data

Movement rate relative to line distance and habitat variables was conducted on GPS data from Ildgruben using a 500-meter buffer zone around camera placements using linear regression models (LMs). The variables used were distance to the power line, location relative to the main ridge, and season. The goal of this analysis was to determine if movement rate significantly increases at closer distances to the power line, suggesting stress, and to see how results compared to those from the proportion of movement behaviors found in the camera behavior analysis. Movement rate analysis was not conducted for Fosen, as the amount of data was judged too low to produce useful results.

2.8.2- Area Use

Camera Data

Analysis of area use with the camera data was done using Generalized Linear Models (GLMs) using reindeer presence and absence observations in order to predict probability of detecting reindeer relative to power line distance.

For the Ildgruben data, preliminary testing showed that a 4-hour time interval produced the clearest results, and therefore that interval was chosen. The final model for Ildgruben included the following variables: distance to the line, location relative to the site's main ridge, season, interactions between distance and season, and interactions between distance and location (ridge side/top). The Fosen model only included location relative to the line (control vs next to line) due to its limited sample size. Furthermore, the 4-hour interval model produced results with smaller confidence intervals compared to the 24-hour interval model, so results from the 4-hour model were used.

GPS Data

In order to analyze reindeer area use versus available area relative to power lines and habitat variables, equal numbers of random points were generated for each site, within the same 500 meter buffer zones as real GPS points in order to represent used versus available area. Similar to the camera area use analysis, General Linear Models (GLMs) were used to estimate probability of use relative to power lines while controlling for habitat variation. Models were created that included the following variables for both sites: distance to the line, elevation, hill aspect, slope, and vegetation cover for both sites. Model selection based on AIC scores was then conducted, comparing models using different sets of these variables to find the most parsimonious models. In addition to these models, a separate model for Ildgruben within the 500-meter buffer zone was created that included the same variables as the area use analysis using the camera data for better comparison with results from the camera analysis: distance to the line, location (ridge top or side), season (spring or summer), and interactions between the latter two variables and distance.

3 - Results

At the end of the camera encoding phase, 667 observations of reindeer (1811 photos) were found in the Ildgruben set for both seasons, and 100 observations were found in the Fosen set (114 photos). Of the Ildgruben set, 83 % of observations came from timed photos, while 27 % originated from motion trigger events. For Fosen, the count was 97 %

and 3 %, respectively. The total low visibility time for cameras in Ildgruben for both seasons was 214 days out of 3523 total camera days (approx. 6 % of total period), and for Fosen it was 25 days of low visibility out of 642 total camera days (approx. 3 % of total period). Proportion of low visibility varied between cameras, ranging from 2 % of total time to 10 % of total time. Considerable amounts of human activity were detected by cameras in the Fosen site, while there were very few detections of humans at the Ildgruben site.

The time taken to process photos in the encoding stage varied between different datasets. Processing time for the second season set for Ildgruben was recorded, where it took approximately 35 hours to process ~500,000 images from 13 cameras. This is similar to the time taken for the first Ildgruben set and for Fosen, however, processing time was not formally measured.

3.1 - Behavior Analysis

3.1.1 - Ildgruben Cameras

The model found that distance to the power line had a significant effect on behavior proportions, with the proportion of lying and moving significantly lower relative to grazing (Table 1). Proportion of lying had a significant, albeit very weak positive interaction with distance to the line, while proportion of moving had a stronger positive interaction, meaning the proportion of animals both lying and moving was higher at distances further from the line (Figure 3). Grazing had a significant negative interaction with distance to the line, where proportion of grazing decreased with increased distance to the line. Interactions with location relative to the main ridge showed that the proportion of animals moving was higher on the side of the ridge, while the proportion grazing was significantly lower on the side relative to the top. Lying was not significantly different between the ridge side and top.

Table 1: Model estimates for proportions of reindeer behaviors relative to distance to the line, season, and location (ridge top/side) based off the Ildgruben camera data. "Grazing" was used as the reference level for the behavior types, "Spring" was the reference level for season, and "Ridge top" was the reference level for location.

Coefficients	Estimate	SE	t-Value	p-Value
Intercept	0.649	0.031	20.686	**<0.001**
Distance to line	-0.082	0.025	-3.349	**<0.001**
Lying	-0.571	0.044	-12.871	**<0.001**
Moving	-0.369	0.044	-8.316	**<0.001**
Location: Side (Ref = Ridge top)	-0.123	0.049	-2.481	**0.013**
Distance*Lying	0.076	0.035	2.199	**0.028**
Distance*Moving	0.169	0.035	4.869	**<0.001**
Location:Side*Lying(Ref = Ridge Top)	0.105	0.070	1.493	0.136
Location:Side*Moving(Ref = Ridge Top)	0.258	0.070	3.668	**<0.001**

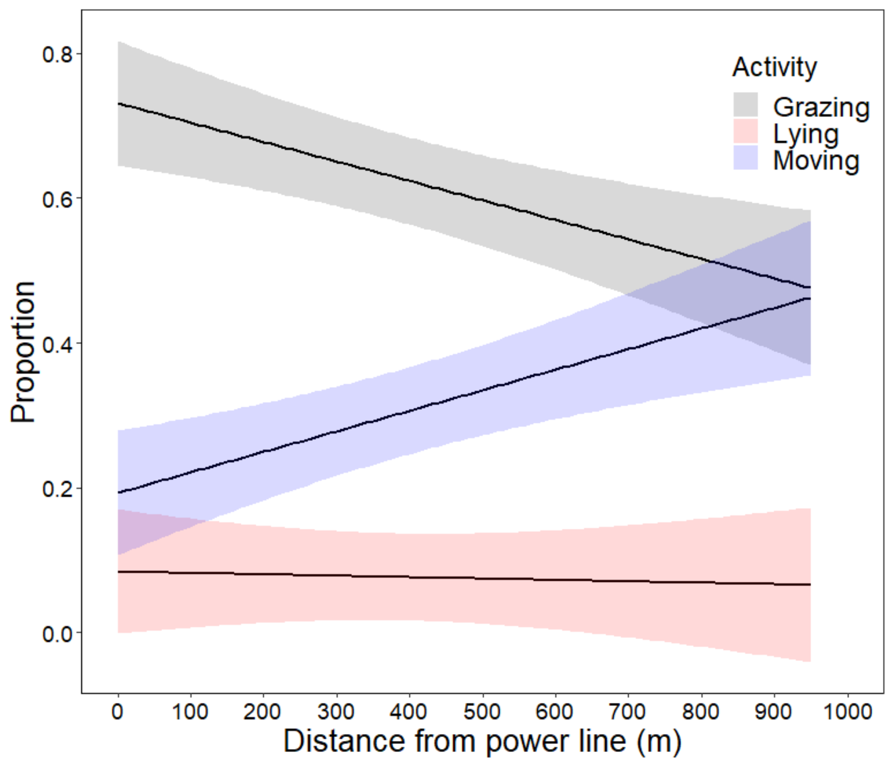

Figure 3: Predicted proportions for the 3 behavior types relative to power line distance in Ildgruben according to models based off camera data. Shaded areas indicate 95 CI.

3.1.2 – Fosen Cameras

No significant effect was found for camera location (along line or control area) on the proportion of different behaviors, however, there was a significant difference between behavior types overall. Proportions for both lying and moving were significantly lower compared to those for grazing, while not significantly different from each other (Table 2).

Table 2: Model estimates for behavior proportions relative to camera location (control or along the line), and interaction between location and behavior proportion in Fosen. Reference levels for behavior types and locations were "grazing" and "control", respectively.

Coefficients	Estimate	SE	t Value	p Value
Intercept	0.800	0.108	7.421	**>0.001**
Location: Line (Ref = Control)	-0.167	0.157	-1.064	0.292
Lying	-0.800	0.153	-5.247	**>0.001**
Moving	-0.600	0.153	-3.935	**>0.001**
Location*Lying	0.218	0.222	0.982	0.331
Location*Moving	0.282	0.222	1.275	0.208

3.1.3 - Ildgruben GPS Movement Rate

Movement rate was not found to be significantly related to either distance to the power line, location relative to the main ridge, or season (Table 3).

Table 3: Model estimates for movement rate based on Ildgruben GPS data in a 500-meter zone surrounding cameras, using the same habitat and season variables as the camera-based behavior analysis.

Coefficients	Estimate	SE	t Value	p Value
Intercept	289.660	254.960	1.136	0.257
Distance from power line	56.390	185.340	0.304	0.761
Location: Side (Ref: Ridge Top)	-130.920	445.080	0.294	0.769
Season: Summer (Ref: Spring)	294.800	356.790	0.826	0.409

3.2 - Results: Area Use

3.2.1 – Ildgruben Cameras

A significant negative relationship (i.e., attraction) between detection probability and distance to the line was found, meaning reindeer were more likely to be detected by cameras closer to the line compared to further away for the entire study period and site (Table 4). However, there was a significant interaction between location to the main ridge and distance to the line, where detection probability was significantly higher on the ridge side with increasing distance to the line compared to the ridge top. A significant interaction between distance and season was also found, where detection probability increased with increased distance to the line during summer months (i.e., avoidance) while it decreased during spring months (i.e., attraction) (Table 4, Figure 4). Finally, detection probability was significantly lower for the side of the main ridge compared to the top, as well as for summer compared to spring.

Table 4: GLM estimates for probability of reindeer detection in 4-hour intervals in Ildgruben taken from the best performing camera data model.

Coefficients	Estimate	Standard Error	z Value	p Value
Intercept	-4.193	0.1399	-29.966	**<0.001**
Distance to Line	-0.737	0.1602	-4.598	**<0.001**
Location: Side (Ref = Ridge Top)	-0.658	0.1601	-4.122	**<0.001**
Season: Summer (Ref = Spring)	-0.393	0.1629	-2.410	**0.016**
Distance * Location: Side(Ref = Ridge Top)	0.659	0.200	3.278	**0.001**
Distance*Season: Summer (Ref = Spring)	0.919	0.178	5.177	**<0.001**

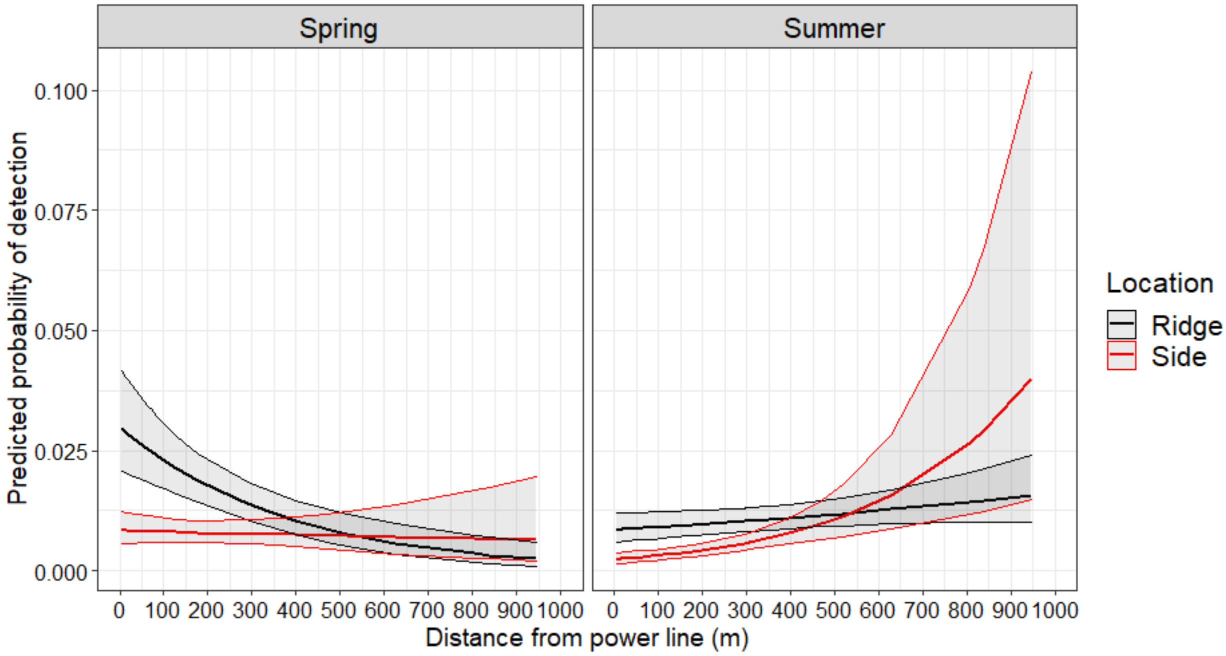

Figure 4: Predicted reindeer detection probability relative to distance to the power line, season, and location (ridge top/ridge side) in Ildgruben based on GLM estimates. Shaded areas indicate 95 CI.

3.2.2 – Fosen Cameras

The Fosen model found no significant difference in detection probability between cameras placed in control areas and cameras placed along the power line (Table 5). Construction activity along the power line was detected using cameras during the study period, however this data was not included in analyses due to ethical concerns for privacy.

Table 5: GLM estimates for probability of reindeer detection relative to camera location (control area or along the line) for Fosen at 4 hour intervals.

Coefficients	Estimate	SE	z Value	p Value
Intercept	-5.191	0.317	-16.369	**<0.001**
Location: Line (Ref = Control)	-0.250	0.476	-0.526	0.599

3.2.3 – Ildgruben GPS

According to models using discrete habitat variables, no significant effects of the power line were found, where animals preferred south-facing aspect, and a near-significant preference for higher elevations was found (Table 6). Vegetation cover and slope were not significantly related to probability of area use and were removed from the final model. Results from the model using the same variables as the camera analysis again found no significant effect on area use by distance to the power line (Table 7). Furthermore, location relative to the main ridge, its interaction with distance, and season were not significantly related to area use. However, a significant interaction between distance to the line and summer was found, meaning area use increased with increased distance from the line in summer, whereas the opposite trend was apparent during spring (Figure 5). Here, GPS and camera data showed similar results in finding no significant relationship between distance to the line and area use, as well as in finding similar seasonal differences in said pattern. However, they differed in how specific area use patterns arose relative to habitat variation; namely GPS finding no interaction between distance to the line and location relative to the main ridge, instead finding a preference for south-facing aspect and potential selection for higher elevations.

Table 6: GLM Estimates of area use taken from GPS data in a 500-meter buffer zone surrounding cameras in Ildgruben using discrete habitat variables. "DLF" was used as a reference level for the vegetation categorical variable.

Coefficients	Estimate	SE	z Value	p Value
Intercept	-0.046	0.076	-0.611	0.541
Distance from power line	0.077	0.075	1.027	0.304
Heath				
OR				
Others				
RSG				
Elevation	0.149	0.080	1.862	0.063
Slope				
Cosine aspect	-0.224	0.104	-2.160	**0.031**

Table 7: GLM estimates of area use taken from GPS data in a 500-meter buffer zone surrounding camera placements at Ildgruben, here using the same variables as those in the camera area use analysis.

Coefficients	Estimate	SE	z Value	p Value
Intercept	0.035	0.108	0.327	0.744
Distance from power line	-0.159	0.105	-1.508	0.132
Location: Side (Ref: Ridge Top)	-0.229	0.197	-1.164	0.244
Season: Summer (Ref: Spring)	-0.017	0.148	-0.116	0.908
Distance*Season: Summer	0.528	0.150	3.512	**<0.001**
Distance*Location: Side	-0.126	0.221	-0.569	0.569

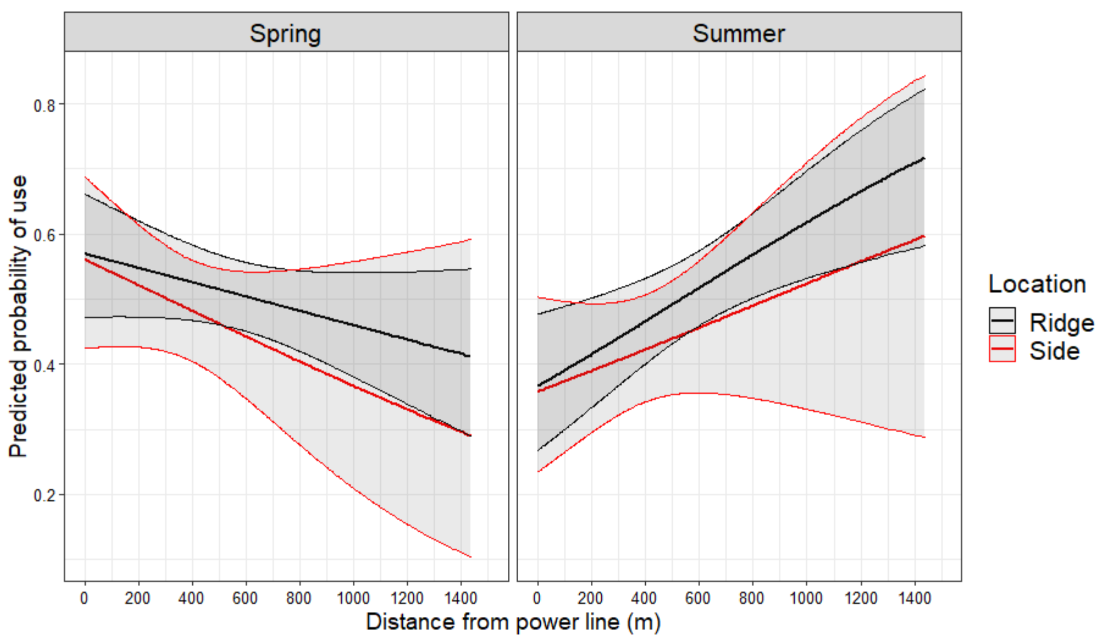

Figure 5: Predicted probability of area use from Ildgruben GPS data in a 500 meter buffer zone around cameras, using the same variables as the camera analysis (ridge side vs top, spring vs summer). Shaded areas indicate 95 CI.

3.2.4 – Fosen GPS

The model for Fosen found no significant relationship between area use and distance to the power line. AIC model selection for the 500-meter buffer zone only included vegetation cover, but this was not significantly related to area use (Table 8). These results were consistent with those from the camera analysis.

Table 8: GLM Estimates of area use taken from GPS data in a 500-meter buffer zone surrounding cameras in Fosen using discrete habitat variables. "DLF" was used as a reference level for the vegetation categorical variable.

Coefficients	Estimate	SE	z Value	p Value
Intercept	-16.656	979.115	-0.017	0.986
Distance from power line	-0.085	0.145	-0.587	0.557
Heath	16.906	979.115	0.017	0.986
OR	16.534	979.115	0.017	0.987
Others	16.556	979.115	0.017	0.987
RSG	18.128	979.116	0.019	0.985
Elevation				
Slope				
Cosine aspect				

4 - Discussion

4.1 - Behavior

Behavioral responses to stress, while not necessarily leading to as drastic population consequences as outright avoidance, can still have significant repercussions on the condition of animals and herds. In periods of stress such as insect harassment for example, reindeer have been observed to alter their behavior patterns away from grazing and relaxation behaviors in favor of movement (Colman et al 2003, Hagemoen & Reimers 2002), causing significant negative impacts on body condition and reproductive success due to lost nutrient intake (Colman et al 2003, Weladjii et al 2003). Moreover, in the context of reindeer herding such as for the populations observed here, a change of grazing time relative to other behaviors might affect productivity. If proximity to power lines affects behavior, then such effects on body condition, reproduction, and productivity can also be expected. Research on the effects of power lines on such behaviors has been sparse, and only conducted on animals in enclosures, finding that line proximity did not significantly change the overall behavior patterns of reindeer (Flydal et al 2009). This highlights the need for reliable data from observing free ranging animals in open environments, where results from this project suggest that cameras can provide useful information.

No significant increase in stress behaviors or disruption in grazing or relaxation behaviors was detected relative to power line proximity at either study site. Results from these analyses show that given sufficient amounts of data, wildlife cameras can be useful tools in finding behavior patterns related to infrastructure that GPS data cannot show as clearly.

Using behavior data gathered from wildlife cameras at the Ildgruben site, movement behaviors were found to be more common with increasing distance from the power line, while grazing behaviors showed the opposite trend, with lying behaviors being unaffected by line distance. Behavior proportions were also found to differ depending on habitat (ridge top versus ridge side), with more grazing taking place on the ridge top, and more movement occurring on the ridge side. The lack of increased movement behaviors and no effect on lying behaviors associated with line proximity supports the idea that the power line is not a source of significant stress toward reindeer, while the increased proportion of grazing behaviors near the line suggests that reindeer were actually calmer within its proximity. This is consistent with the limited research conducted regarding reindeer behavior and power lines, however in that case calm behaviors were not associated with line proximity (Flydal et al 2009). Results from these analyses are some of the first showing reindeer behavioral trends relative to power lines in free-ranging animals.

While broad-scale habitat variation was accounted for using the categorization of ridge and side at the Ildgruben site, differences in habitat conditions between individual cameras was not included in the analyses, which could have contributed to the patterns seen in this study. For example, if grazing quality was higher in certain areas near the line on the ridge top, then that could explain why increased grazing was common there. Future studies can test this possibility by including accurate habitat variables for each camera in the analyses.

A possible explanation for the behavior patterns observed could be other stress sources not fully controlled for, some of which may correlate with the power line. One such stress source is predation, which is a common threat to animals in these areas and is often dependent on habitat structure. For example, lynx prefer to hunt in forested areas at lower elevations, wolverines prefer higher, more rugged areas, and eagles often hunt in open and exposed habitat (Bouyer et al 2015, May et al 2008, Nybakk et al 1999). Power lines may modify the risks of predation through their structural effects on habitat areas (e.g., acting as a barrier to eagles attempting to attack animals) or even create spatial refuges from predation since human infrastructure and activity is known to have a strong negative effect on predators (Muhly et al 2011). Therefore, information regarding the presence and relative risk of predation in the area would be useful to include in analyses, where the effect of power lines on such risk would be an important avenue to pursue in further research. Another stress source that was not fully controlled for in this analysis was insect harassment. As previously mentioned, harassment by parasitic insect species is common in reindeer habitats and is therefore likely to play a role in how reindeer behave in addition to other factors (Colman et al 2003, Hagemoen & Reimers 2002). Unlike predation, there is little reason to believe that insect harassment is correlated with line proximity, however not controlling for it may still affect results, especially if studies are conducted over larger areas with greater degrees of habitat variation. Insect activity has been shown to correlate with environmental conditions such as elevation, vegetation cover, temperature, cloud cover, and snow depth (Colman et al 2003, Hagemoen & Reimers 2002). While elevation, vegetation, and temperature were controlled for in this study, insect harassment could be better controlled for by including higher quality, on-site weather data which uses continuous values for variables such as snow cover/depth and cloud cover to produce more robust analyses (Weladji et al 2003).

No significant difference was found in behavior proportions between control areas and areas along the power line at the Fosen site. However, the number observations in Fosen were extremely low (19 observations after merging) which severely limits the reliability of these results. While the collection and analysis of behavior data is not as dependent on spatial scale as analysis of area use to provide useful data, it still requires a sufficient number of observations in order to detect any response patterns by animals with an acceptable level of statistical confidence. Therefore, any study using camera data to analyze behavior data must require a sufficient level of detection probability and long enough study period in order for such analyses to be useful. In the context of this study, reindeer detection at Fosen was far too low to make any solid conclusions, where larger scale studies using a sufficient number of cameras, study period length, and area is necessary to produce insightful results. This is especially relevant for the Fosen site, since there was construction activity along the line during the study period, which also likely reduced the number of animals equally both along the power line and the control area (discussed further in area use section).

One final consideration for camera-based behavior analysis is in the likelihood of certain behavior types being detected by either timed or motion trigger photos. Photos taken on timers are less likely to pick up moving animals that do not spend long periods in front of the camera, while the motion trigger mechanism is only sensitive to a maximum of 30 meters. Moreover, motion trigger observations are more likely to detect movement behaviors compared to grazing and lying behaviors. Both timed and motion trigger photos were used in this analysis to increase sample size; while this likely did not cause a large sampling bias, it should always be kept in mind, where erring on the side of caution and only using timed photos for future analyses is likely the best solution.

4.1.2- Movement Rate

Consistent with initial predictions, analysis of GPS movement rate from the Ildgruben site generally agreed with results from the camera-based behavior analysis, namely in finding no increases in stress (i.e., increased movement rate) near the power line. Furthermore, habitat and season also did not affect movement rate, which was not expected, given that reindeer have been observed to move at different rates under different habitat and seasonal conditions (Skarin et al 2010). This may be a result of the two-hour time interval at which GPS observations were made, which may not have been small enough to detect short-term increases in movement speed due to habitat variation, as well as the limited number of observations available. The finding of no effect whatsoever by power line distance on movement rate is not fully consistent with what was observed using wildlife camera data, as according to the camera data movement behaviors were more common further away from the power line. Movement rate and proportion of animals moving are two separate measurements however, and considering that the speed at which animals performing movement was not differentiated in the camera data, it is possible that these results were not contradictory. Nevertheless, the clear differences in results obtained between GPS and camera data show that cameras are able to detect behavioral patterns that GPS data could not, in much higher detail and from observing a larger proportion of the herd. This suggests that cameras are a more useful tool compared to GPS, at least for the 2-hour time interval used here, in analyzing reindeer behavior responses to infrastructure relative to other ecological conditions. Further study over longer time periods and over larger areas would also be useful in confirming these results.

4.2 - Area use

Across all methods and at both study sites, no consistent negative effect of power lines on area use by reindeer was detected. Specific aspects of results differed between methodologies however, where it is important to ascertain which of these differences are due to real ecological effects, or a result of biases in their respective methodologies. Among these potential biases are the degree to which habitat variation was controlled for, biases in detection between cameras, sample size, and the spatiotemporal scale at which reindeer were observed. Considering the results from these analyses and the potential drawbacks, future studies seeking to use cameras to analyze area use will require the deployment of significantly more cameras over larger areas, longer time periods, and a clearly defined area for each camera to procure robust results, where on smaller scales, cameras are likely more useful as a tool to analyze behavior and simply act as a supplement to other methods for analysis of area use.

Consistent with original predictions, GPS and camera data found similar results, specifically in finding no significant negative impacts on reindeer area use by power lines at the Ildgruben site. However, line proximity was associated with an overall positive effect on reindeer area use only according to the camera data, where detection probability reduced with increased distance from the power line over the entire Ildgruben study site and period. This generally agrees with what was found in the behavior analysis, as grazing was more common along the line, and one would expect grazing animals to spend more time in areas compared to those simply moving. While GPS did not show a similar overall positive effect, it did support the camera data in finding a significant interaction between power line distance and season on area use, where area use was higher near the line during spring months compared to summer. The behavior analysis found no such seasonal differences, suggesting that seasonal changes in avoidance and attraction were likely not a result of changing stress associated with the line. Finally, camera data found a significant difference in area use relative to the power line based on habitat variation, with less area use near the line detected on the southern ridge side compared to the top, whereas GPS found no significant interaction. Taken as a whole, these results indicate that area use related to line distance is not mediated by stress or fear reactions directly related to the line, but more based on the context of the habitat surrounding the line. The inconsistency between methods in how these patterns specifically arise highlights that sampling must be improved in order to produce more conclusive results. This mostly relates to the camera data, as it was the most limiting aspect of area use analyses in this project.

Increasing the number of cameras and spatiotemporal scale for this type of camera-based area use analysis would significantly improve the quality of results, as well as the results of methods used alongside it. The use of more cameras would improve the amount of usable data, as well as increase the detail at which area use can be documented. Meanwhile, larger overall study areas would provide more representative samples of home ranges and allow for the use of more GPS observations to be used alongside camera data. Finally, deploying cameras over longer periods would help to control for longer-term variations in area use independent of infrastructure, which have been observed to confound the effects of infrastructure (Skarin & Åhman 2014, Flydal et al 2019).

Biases in detection between cameras is also a challenge that should be addressed in future applications of cameras for area use analysis. All cameras have a chance of not detecting animals within their direct vicinity, where this phenomenon is called imperfect detection (Burton et al 2015). While this issue is not as significant of a drawback for area use analysis compared to studies seeking to measure animal abundance or density, it is still relevant in this context as imperfect detection can be different between cameras, potentially leading to patterns in detection not caused by actual area use patterns. The main concern for imperfect detection in this case was cameras' differently sized fields of view, which can lead to large differences in detection rate, as larger fields of view mean more animals will be detected, and vice versa. This issue can be solved in future studies by ensuring that fields of view are similar between cameras, and that other factors which can lead to artificial differences in detection are minimized.

The same concerns regarding the control for finer-scale habitat variation from the behavior analysis also apply for area use. In this case it is likely even more important, as the connection between habitat variation and area use is very well documented (Skarin & Åhman 2014, Mårell & Edenius 2006). This drawback can be seen from the Ildgruben GPS analysis using discrete variables, which found a preference for south-facing aspect not detected using the ridge top-versus-side variable. Therefore, habitat variation in future studies should be recorded on a per-camera basis in order to best control for habitat conditions.

Consistent with original predictions, wildlife camera and GPS data from the Fosen site agreed in finding no significant negative effects by a power line on area use at smaller habitat scales. However, key differences from the Ildgruben site such as poorer data quality, human presence in the area, and spatiotemporal scale limit the conclusions regarding area use that can be made. While reindeer detection was not significantly different in control areas compared to areas near the power line, the scale at which reindeer were observed may not have been sufficiently large to detect actual avoidance effects. Larger scale studies have shown that during periods of construction and high human presence, reindeer will avoid infrastructure on the scale of at least several kilometers (Eftestøl et al 2016, Colman et al 2015, Skarin & Åhman 2014), which greatly exceeds the maximum 300-meter distance used here. Construction activity was common along the line during the study period, where the significantly lower detection rate compared to Ildgruben suggests that reindeer were may have avoided the power line, simply at a larger spatial scale which the cameras could not detect. Likewise, GPS data was sampled from the same spatial scale as the cameras, meaning that it was also limited in finding larger scale avoidance patterns. If reindeer were indeed avoiding the area at a larger scale, then the individuals observed here may have been the small minority of the herd who still remained in the area during the construction period, for which they may be more tolerant to human presence. Alternatively, animals may have used areas in periods between active construction periods, for example during weekends, and then left the entire area when construction work restarted during weekdays (Eftestøl et al 2019). However, given the limited number of observations and lack of comprehensive control periods and areas, this cannot be fully verified.

In summary, future studies using cameras will need to deploy more cameras over larger areas, over longer periods, and use more standardized study design in order to effectively investigate patterns of area use relative to infrastructure. Furthermore, the methodology likely needs more development before it can be applied as a standalone method. Currently, it seems feasible as a supplement for when other sampling methods are limited, or in smaller areas which only a small proportion of the population uses (but still are important in a long-term perspective) and therefore may not be used by a limited number of GPS-collared animals.

4.3 - Wildlife Camera Setup and Data Handling

While the data obtained from wildlife cameras has proven useful in this study, technical issues related to setup of cameras and data handling can stand to be resolved or minimized, so that future studies using wildlife cameras to track reindeer behavior and area use can produce higher quality data that is easier to organize and analyze. The main issues related to camera setup and data handling identified in this project were periods of low visibility, measurement of camera fields of view, recording of habitat variation, false motion triggers, and the handling of data sets.

As previously discussed, periods of low visibility reduce the overall sampling power of cameras and can cause bias in detection when such periods are different between cameras. The majority of low visibility events affecting cameras here were caused by weather conditions such as snow, frost, and fog, for which there are few measures to mitigate their effects. Combined with the propensity of batteries to not last as long during periods of extremely low temperatures, the practicality of cameras in winter months is likely limited. Given that most low visibility events cannot be significantly reduced in camera setup, the next best solution is to record these events when encoding and take them into consideration during analysis and when interpreting results.

The standardization of wildlife camera fields of view is necessary to provide more useful results, as it would help to minimize detection bias between cameras. This can be done by measuring the field of view for each camera and ensuring that all cameras view areas similar in size. Methods for measuring camera field of view are relatively straightforward, where a simple solution is to use distance markers placed at the edges of camera fields of view ascertain how far cameras can detect animals. This comes with the added benefit of being able to estimate the distance at which animals are detected from the camera, which can give yet more detailed information (Hofmeester et al 2017). This measurement can also be used to obtain more accurate information for the areas surveyed by cameras, especially habitat variation.

The need for finer-scale control for habitat variation necessitates the ability to accurately summarize habitat values for each camera. In this project, this was initially attempted by simply taking the respective values for habitat variables at the point of a given camera's location. However, the sample area for a wildlife camera is not the point of the camera itself, but in the area in which it surveys, which can be large and have varied habitat characteristics. For example, if a camera observes a hill from below, the elevation of the surveyed area will be varied, and the point of the camera itself will be lower than the sample area. A possible solution would be to calculate average values for continuous variables such as elevation, slope, and north-south aspect, and percentage cover for variables such as vegetation within surveyed areas (Kelly & Holub 2008). Combined with accurate measurements for field of view as previously discussed, future studies could use this approach to include finer-scale variation that accurately summarizes the habitat characteristics of sample areas.

Another technical issue identified in this project was the high amount of false motion trigger photos taken by cameras during study periods. These events were primarily caused by foliage in front of the camera being moved by wind, which would set off the camera's motion trigger. In the worst cases, this added tens of thousands of unnecessary photos to camera feeds and caused cameras to run out of battery prematurely. A solution for this issue would be to trim foliage around cameras, either at time of set up or part way through the study period depending on the time at which the survey period begins. Other studies using motion sensor-equipped cameras in a similar context have used this method and reported minimal false motion captures as a result (Kelly & Holub 2008). Motion trigger systems also differ considerably among different wildlife camera models, so extra care must also be given to the exact camera type used, sensor range, and sensitivity settings (Swann et al 2004).

The approach to the handling of data in this project, while effective at providing useful data sets, nevertheless can be improved. In this project, observation data was not attributed to photos themselves, but rather recorded to separate data sheets using timestamps. While this minimized the effort at start-up due to not needing special programs or methods to encode data, it made preparing data for analysis more difficult, as separate data sets had to be merged into a constructed master sheet, where some could not be included due to conflicting formats. The alternative to this method would be to record data according to the photos themselves. This can be done in a variety of ways, such as using packages in R to extract metadata from photo files to create a data set, then recording relevant information according to each respective photo (Steen 2017). This would then have the benefit of including all relevant information into a single data set at the beginning of the encoding phase, without the need for merging and excluding data sources that would otherwise be difficult to integrate. These recommendations are mostly relevant to studies with amounts of data similar to those in this project, where the use of more cameras and therefore more data may necessitate the use of different methods.

Studies employing more cameras over longer periods will require significantly more time to encode and process data, where the use of emerging methods such as neural networks may be a useful alternative in such cases. Encoding time for a given data set depends on the qualities of individual datasets, where encoding for the Ildgruben site's second season took approximately 35 hours to encode. While feasible for this project, the increased time and human effort for larger scale studies may become a barrier for more common use of these wildlife cameras in the context of larger scale studies. Neural networks have developed rapidly over the past decade, and recent studies focusing on the identification of animals using wildlife camera photos have produced promising results (Chen et al 2014, Nguyen et al 2017). The bulk of time used for encoding in this project was checking photos for presence of animals, for which neural networks have shown a high level of accuracy. Therefore, neural networks could be used for detecting photos with animals or other notable observations, where humans then go over said photos and identify specific data points such as behavior, presence of calves, etc. This would drastically reduce the amount of time and resources needed to encode data, making research more efficient. Test studies will likely need to be conducted in order to standardize and troubleshoot potential issues, however afterwards this may become the primary methodology in which wildlife camera data is encoded and processed in the future.

5 - Conclusions

Based on the results this project, wildlife cameras appear to be a promising tool with which the effects of infrastructure on the behavior and area use of reindeer can be investigated. Wildlife camera data can provide useful behavioral information which is able to show smaller scale responses to infrastructure not detectable by methods such as GPS, with high temporal resolution and at much less cost compared to direct observation. Analysis of area use found no negative effects by power lines, however the limited quantity and quality of data served to emphasize the need for longer term, larger scale studies using detailed variables for habitat variation in order to provide more comprehensive results. While useful, wildlife cameras are likely not practical as a standalone tool to sample area use patterns due to biases such as imperfect detection and limitations for regional scale studies. Instead, they show promise as a supplement to GPS data and potentially other methods as a way to verify and elaborate on observed effects of infrastructure on small to intermediate spatial scales, especially in cases where data from other sources is limited. Finally, issues with data handling and processing were identified through this project, where future studies can avoid common pitfalls related to the use of camera data, and new technologies such as neural networks can be applied to significantly improve the time needed for encoding. Given their versatility of application, and compatibility with other methodologies, I recommend that wildlife cameras continue to be used and developed in this context, so that the development and management of infrastructure can be better informed regarding its impact on reindeer populations.

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Appendix

Table S1: Vegetation types and classification into five main groups used in models for Ildgruben and Fosen.

Vegetation class	Vegetation type	Main groups
1	Coniferous forest - dense tree layer	Others
2	Coniferous and mixed forests - open tree layer	Others
3	Deciduous forest	Lichen and deciduous forest
4	Low herb deciduous forest	Lichen and deciduous forest
5	Tall herb and fern forest	Lichen and deciduous forest
6	Blueberry and small fern birch forest	Lichen and deciduous forest
7	Crowberry birch forest	Lichen and deciduous forest
8	Lichen rich birch forest	Lichen and deciduous forest
9	Tussock bog with low herbs	Others
10	Bog with tall herbs	Others
11	Swamp with open plant cover	Others
12	Exposed ridge and rock, impediment	Rocks, snow patches and glaciers
13	Grass and wood rush ridge	Other ridges
14	Ridge with heather	Other ridges
15	Lichen moor	Other ridges
16	Lichen ridge, leeward side	Heath
17	Heather moor with low bushes	Heath
18	Herb rich meadow	Heath
19	Grass and dwarf willow snow bed	Rocks, snow patches and glaciers
20	Extreme snow beds	Rocks, snow patches and glaciers
21	Glacier and snow-covered soil	Rocks, snow patches and glaciers
22	Smaller bodies of water*	Others
23	Cultivated fields**	NA
24	Town and populated areas**	NA
25	Un-classified/ shadow	Others

Figure S1: Example of a photo containing reindeer captured by a wildlife camera at the Ildgruben study site.

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