potential avoidance and barrier effects of a power line on range use and migration patterns of semi-domestic reindeer (rangifer tarandus tarandus)

Potensielle unnvikelses- og barriereeffekter av en kraftlinje på områdebruk og vandringsmønster hos tamrein (rangifer tarandus tarandus)

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PREFACE

This thesis is a part of the “Kraft Rein” project and is written at the department of Ecology and Natural Resource Management at the Norwegian University of Life Sciences. The thesis provides 30 credits for my Master of Science degree in Natural Resource Management, and is based on field studies in two reindeer herding districts in northern Norway, summer 2010.

First, I would like to send a special thanks to my supervisors Stein R. Moe and Jonathan E. Colman for their great efforts during the entire process of working on this thesis. I would also like to thank Sindre Eftestøl for help in preparations for fieldwork and methods. Thanks to Marte S. Lilleeng for the invaluable help in the field and with other things during the writing process (*e.g.* raw data processing issues, maps, GIS analyzes, statistics). Thanks also to Agnes Kammerhofer for helping me with registrations in the field.

Thanks are also due to Kjell Arne Seppola for useful information about the test area, and Nils Johan Utsi and Isak Mathis Utsi for transport across the plains, valuable information about the control area and help with the car after successful field work. Thanks to Grethe Hillersøy for reading and commenting my thesis and thanks to my other “study friends” for always having time to discuss things and being such good company in the study hall.

Last, but not at least, I would like to thank my mum and dad for helping me with technical issues before my fieldwork and for always supporting me.

I hope that this thesis can contribute to increasing our knowledge relating to potential effects of human instillations such as power lines on free ranging reindeer.

Norwegian University of Life Sciences
Ås, Norway 12th May 2011

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ABSTRACT

Infrastructure like roads and power lines may be a disturbance to, or be perceived as a barrier, for reindeer (*Rangifer tarandus tarandus)*. Possible avoidance and barrier effects, in addition to reindeer habitat selection near a power line, were investigated using faecal pellet group counts in two semi-domestic Sami reindeer herding areas in Northern Norway. Distribution of reindeer pellet groups, vegetation type, height and cover, slope and direction of slope was mapped during summer 2010 using a point transect survey design. I sampled a test area with a power line, and used an area without power lines as an experimental control. The control area is presently proposed as a corridor for a new 420 kV power line. Interactions between pellet group density and distance to “power lines” were tested. I found pellet groups in 68.5% of the sampled plots. Mean reindeer density remained constant within five kilometers on either side of the existing power line and decreased significantly with increasing distance from the “control” power line, indicating an absence of avoidance behavior. I did not find any differences in reindeer pellet group distribution on either side of the power line, indicating than the line does not work as a barrier. Reindeer selected more for heather rich alpine ridge, mires, heather and grass vegetation and early and late snow patches, compared to the rocky vegetation type exposed alpine ridge. Reindeer used areas with high vegetation cover more than areas with low vegetation cover. At the population level, my results indicated that the existing power line did not cause any avoidance behavior or act as a barrier for semi-domestic reindeer (at a medium landscape scale of approximetely 10+ km radius). Therefore, the reindeers’ habituation or indifference towards this power line resulted in no negative effects measurable on their movement patterns or optimal pasture use in my study area. Nevertheless, more knowledge about reindeer behavior in response to human infrastructure is necessary to prevent the degradation of habitats that are currently used, to secure optimal management and avoid conflicts between the reindeer husbandry and energy industries.

Keywords: *Rangifer tarandus, reindeer, disturbance, infrastructure, power line, habitat selection, avoidance, barrier.*

SAMMENDRAG

Infrastruktur som veier og kraftlinjer kan virke forstyrrende eller oppfattes som en barriere for reinsdyr (*Rangifer tarandus tarandus*). Mulige unnvikelses- og barriereeffekter, samt reinsdyrs habitatseleksjon ble undersøkt nær en kraftlinje gjennom en møkktellingsmetode i to samiske reinbeiteområder i Nord-Norge. Fordeling av reinmøkk, vegetasjonsklasse, -høyde og -dekke og helning og retning av skråningen ble kartlagt ved hjelp av en punkttransekt-undersøkelse sommeren 2010. Metoden ble brukt i et testområde med en kraftlinje og i et kontrollområde uten kraftlinjer (for tiden et forslag til trasé for en ny planlagt 420 kV kraftlinje), og interaksjoner mellom møkktetthet og avstand til kraftledningen ble testet. Det ble funnet reinmøkk i 68,5% av de observerte punktene. Gjennomsnittlig reintetthet var konstant langs en linje på fem km på hver side av den eksisterende kraftlinjen og nedadgående med økende avstand fra "kontroll"-linja, noe som indikerer et fravær av unnvikelsesatferd. Jeg fant ikke noen forskjeller i fordelingen av reinmøkk på hver side av kraftledningen, noe som indikerer at kraftlinjen ikke fungerte som en barriere på tamrein. Reinsdyrene selekterte for som lavdekte rabber, gress og lav vegetasjon, myrer og snøleier, sammenlignet med mer steinete vegetasjon som eksponerte rabber. Reinen brukte områder med høy dekning av vegetasjon mer enn habitater med lite vegetasjon. På populasjonsnivå viser resultatene mine at den eksisterende kraftlinjen ikke forårsaker noen unngåelsesatferd eller fungerer som en barriere for tamrein (på en middels landskapskala fra omtrent 10 + km radius). Dette kan komme av at tamrein etter hvert venner seg til kraftlinjer når de erfarer at kraftlinjer ikke forbindes med fare. Vi trenger likevel mer kunnskap om reinens oppførsel rundt menneskelig infrastruktur for ikke å ødelegge eller forringe habitater som brukes i dag, og for å sikre optimal forvaltning og unngå konflikter mellom reindriften og energibransjen.

INTRODUCTION

Industrial development and human activity in semi-domestic reindeer *(Rangifer tarandus tarandus)* areas has accelerated over the past few decades, and the increasing number of cottages, roads, windmill parks, hydroelectric plants and power lines could threaten reindeer husbandry in Norway (Reindriftsforvaltningen 2010). The Sami people have old traditions in herding reindeer, a very land-intensive activity where reindeer utilize pastures over large areas throughout the year (Holand 2003). It is important to investigate possible negative effects of human infrastructure on semi-domestic reindeer and reindeer husbandry before, during and after construction to prevent degradation of habitats that are currently used, to secure optimal management and avoid conflicts between the reindeer husbandry and energy industries. The aversion and barrier effects are two key aspects of reindeer avoidance behavior related to linear structures like power lines (Dahle et al. 2008). Avoidance effects in response to power lines might be related to both the direct disturbance from the installation itself, and/or from increased human use of areas in proximity to the infrastructure (Colman et al. 2001). Human-made structures are likely associated with humans and thus a perceived risk of mortality which may cause a behavior similar to predator avoidance for reindeer (Frid & Dill 2002). Barrier effects and the resulting reduction in size or quality of pastures are some of the most controversial effects of human activity in reindeer areas. Knowledge of reindeer habitat selection and area use is also an important aspect when analyzing possible effects of human infrastructure. Reindeer habitat selection is influenced partly by predator avoidance, insect harassments, weather, forage availability, and plant phenology and biomass (Skogland 1980; Skogland 1986), in addition to human infrastructure and activity (Reimers & Colman 2006; Vistnes & Nellemann 2008).

A series of studies have found that both caribou *(Rangifer tarandus granti)* and wild and semi-domestic reindeer are negatively affected by human infrastructure at distances of up to 12 km (Cameron et al. 2005; Dyer et al. 2001; Mahoney & Schaefer 2002; Nellemann & Cameron 1996; Nellemann et al. 2001; Nellemann et al. 2003; Vistnes & Nellemann 2001; Vistnes et al. 2001; Vistnes et al. 2004). Results mainly show that reindeer have a wide range of responses to disturbances; including individual and physiological responses, behavioral changes and altered habitat use (Reimers & Colman 2006). However, some studies report less negative effects of human infrastructure on reindeer or find that other variables, such as elevation or habitat selection over-ride potential negative effects (Dahle et al. 2008; Flydal et al. 2004; Flydal et al. 2009; Noel et al. 2004; Reimers et al. 2000; Reimers & Colman 2006;

Reimers et al. 2007). This is mainly explained by the possibility that reindeer habituate to the man-made infrastructure or human activity in question (Reimers et al. 2010).

Reasons for different findings in studies on various disturbances could be caused by the use of different methods (Reimers & Colman 2006). There are several techniques used to measure reindeer habitat selection and distribution in the field; direct observations, *e.g.* using GPS collars, registrations of animal positions in the field, flight and fright registrations and aerial observations, and indirect observations, *e.g.* measurements of coverage of lichen and pellet and track counts (Skarin 2006; Skarin 2007). An important advantage of pellet counts as an "indirect observation" as opposed to vegetation measurements is the fact that pellets undoubtedly represent the presence of reindeer. Pellet group counts also provide relatively good estimates of the overall animal abundance at relevant spatial scales (Campell et al. 2004; Marques et al. 2001; Månsson et al. 2011), and can be an inexpensive way to assess the relative habitat use of an animal (Quayle & Kershaw 1996). For estimations of habitat selection in landscapes of alpine heath (*i.e.* vegetation types with a low decay rate), a faecal pellet group count method is useful because it provides a general habitat selection and area use covering several years (Skarin et al. 2010). Another benefit is that habitat variables (*e.g.* vegetation type, cover and height) can be recorded at the same time and spatial scale as the pellet group count (Härkönen & Heikkilä 1999; Neff 1968; Skarin 2007). Although there have been numerous studies focusing on effects of human infrastructure on reindeer, reliable knowledge is still lacking on the impacts of future developments.

In Northern Norway, there are presently plans for the construction and expansion of a high voltage transmission line (420 kV) connecting Balsfjord and Hammerfest. This power line will be approximately 370 km and 40 m wide, and will affect 31 different Sami reindeer herding districts with more than 100 000 semi-domestic reindeer (Colman et al. 2009).

The objectives of this study were to 1) examine whether power lines influence semi-domestic reindeer area use in alpine regions in terms of possible avoidance and barrier effects, and 2) test reindeer habitat selection to detect whether reindeer select habitat differently due to the presence of a power line. Based on previous studies (Nellemann et al. 2001; Vistnes & Nellemann 2001; Vistnes et al. 2004), I predicted that reindeer would avoid the power line, resulting in increasing density of reindeer with an increasing distance from the power line (the avoidance hypothesis). Based on the study by Vistnes et al. (2004), I predicted that I would find more reindeer pellet groups on one of the sides of the power line than the other side (north-south), because the power line is expected to act as a barrier (the barrier hypothesis). I also predicted that reindeer would choose different vegetation types and habitats with different distance to power lines. Information from this study can be used to predict reindeer responses to present and planned power lines in areas inhabited by reindeer.

METHODS

Study area

The study was conducted during July 2010, in the summer ranges of two reindeer herding districts in Northern Norway. One area with an existing power line constituted the test area, while another area without power lines, which was expected to be affected by a high voltage transmission line in the planning constituted the control area (Colman et al. 2009) (Fig.1). The areas were dominated by lichen heaths, rocks and gravel and consisted of a mixture of alpine ridge vegetation, fens and early and late snow patch vegetation. In both areas, reindeer were herded under the migration period in spring and autumn, and also grazed freely during the summer.

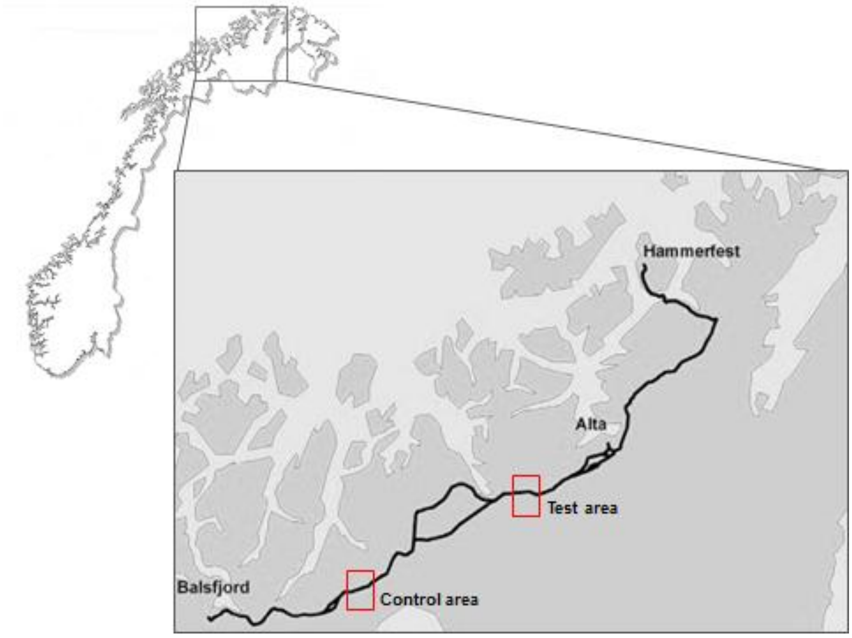

Figure 1. The planned 420 kV power line connecting Balsfjord and Hammerfest in northern Norway (Statnett 2011). The planned corridor will mostly be paralell to the existing power line, like in my test area, but will have a new corridor in my control area, where there are no power lines today.

The test area, along an existing 132 kV power line, is located in Kvænangen Municipality (69°45’N, 22°33’E; Fig.2). This area covers roughly 60 km^2, and is situated between Kvænangsbotn and Mathisdalen. The Sami reindeer herding district 33, *Spalca*, use the area as spring, summer and autumn pasture for about 7000 reindeer (Reindriftsforvaltningen 2010). Their total summer grazing area covers 609 km^2 and is normally used from May to October. The power line crosses both summer pastures and migration routes. Four other Sami reindeer herding districts also migrate through this area, to their summer pastures at the coast (Colman et al. 2009). Elevation ranges from approximately 500 to 800 meters above sea level.

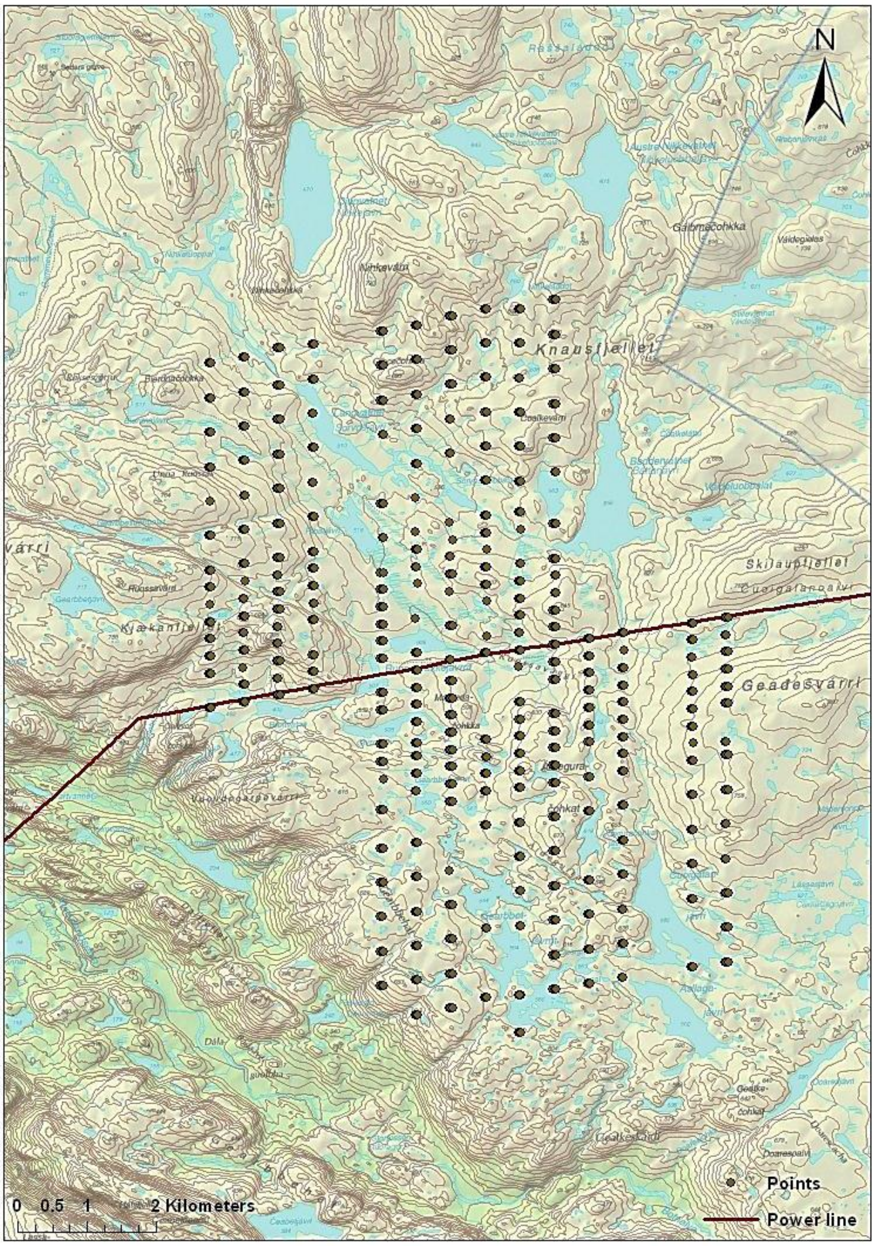

Figure 2. The transect lines showing sampling points in the test area with the power line (solid line), Kvænangen (GeoNorge 2011).

The control area is located in Kåfjord Municipality (69°20’N, 20°47’E; Fig.3). The studied area covers roughly 60 km^2, and is situated between Kåfjorddalen and Manndalen, near the largest lake in Troms County, Goulasjavri. The reindeer herding district 37, *Skárfvággi*, use the area as spring, summer and autumn pasture for about 1500 reindeer (Reindriftsforvaltningen 2010). Their total summer pasture covers 445 km^2, and is normally used from May to October (Colman et al. 2009). The planned high voltage power line will cross central parts of the summer pasture, comprised of calving areas and migration routes (Colman et al. 2009). Elevation ranges from approximately from 800 to 1200 meters above sea level.

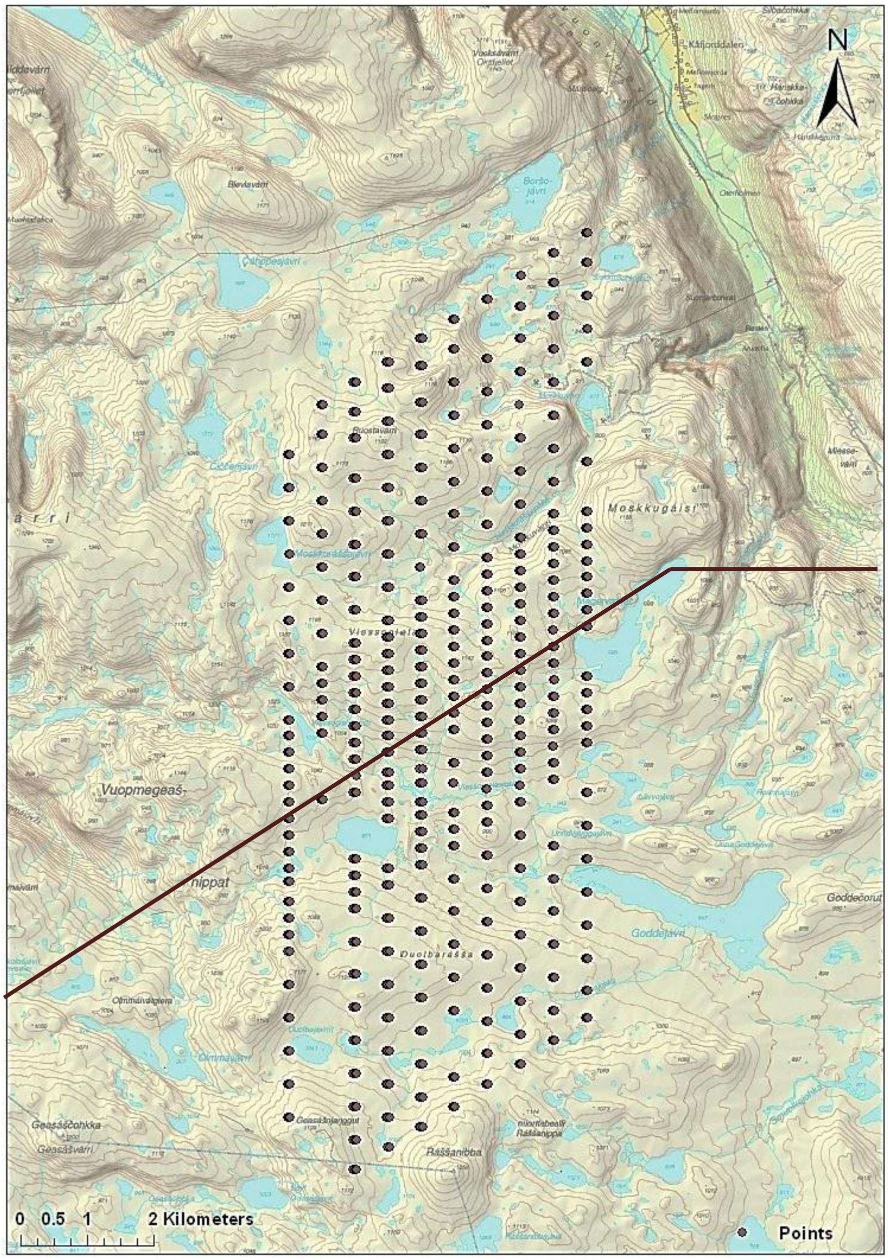

Figure 2. The transect lines showing sampling points in the control area without power lines, Kåfjord (GeoNorge 2011). A possible corridor to the new planned 420 kV power line is drawn in the midle of the transect lines (solid line).

Study design

A faecal pellet count method was used to estimate reindeer distribution close to the existing 132 kV power line and at the planned corridor for the 420 kV power line, to detect avoidance and/or barrier effects, and changes in habitat use. A point transect survey design was used

(Skarin et al. 2004; Skarin 2007), and pellet groups were counted in plots along 39 parallel transects running in a north-south direction (20 transects in the test area, and 19 in the control area). In the test area, each transect was five km, while they were six km in the control area. The distance of six km in the control area was sampled to be sure that the last point on each transect was always five km or more from the corridor of the planned 420 kV power line. Transects were separated by a distance of 500 m (Fig.4). Transects for both areas combined had a total length of 214 km.

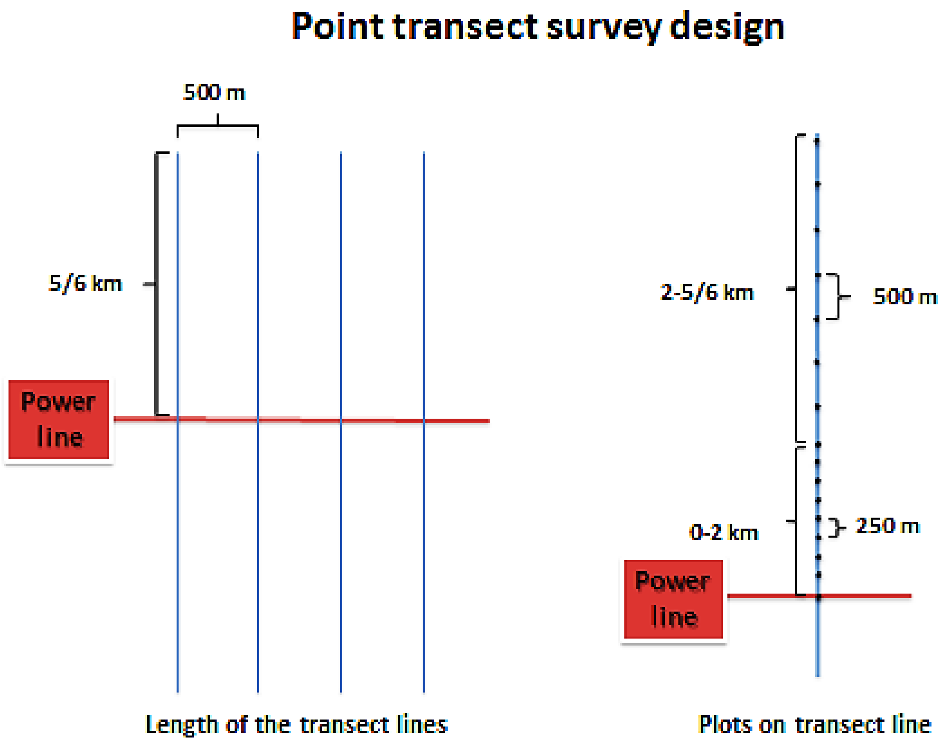

Figure 4. The piont transect survey design with length of the transects (n=39) on the left drawing and length between each plot (n=1554) on the transects in the rigth drawing.

Each plot was located 250 m apart along the transect, up to two kilometers from the power line, and subsequently 500 m apart (from two kilometers to five and six kilometers) (Fig.4). At each plot, three circular subplots of 15 m^2 (radius 2.18 m) was examined. The center subplot was directly on the transect line and the two others were 20 m on each side at 90 degree angles. Of the 1821 pre-determined subplots, 1554 were accessible for sampling (85.3%) and located using a handhold GPS. Some plots were not accessible (14.7%), because they were in water, on snow or in deep, wet mires.

In the test area, 704 subplots were sampled by two observers between 7th and 13th of July. Between 21th and 28th of July, 850 subplots were sampled in the control area, also here by two observers. Within each subplot, all pellet groups were counted, both fresh and old, *i.e.* counted pellets could be up to three years old (Skarin 2008). The center of each subplot was marked with a wooden stick with a rope to measure whether a pellet group was within the circle or not (as described in Skarin (2007)). A pellet group was defined as more than 10 pellets with similar features (color, size and shape). Distance to the power line and mid-point of the planned power line was used to test potential avoidance and/or barrier effects from the respective corridors in each study area.

Habitat variables

Habitat variables such as vegetation type, cover and height, slope and direction of slope, as well as distance from the nearest power line were recorded in each subplot. Vegetation type was classified in the field according to a short version of vegetation class categories developed by Johansen et al. (2009). When a subplot contained a mixture of vegetation types, the predominated type was recorded. To make the results in the two areas comparable, vegetation types represented in only one area were pooled with a similar vegetation type represented in both areas. Eight different vegetation types were recorded in field, but to facilitate statistical analysis, they were pooled into five (Table 1).

Table 1. Vegetation types recorded in field and used in statistical analyses (Johansen et al. (2009)).

	Vegetation type	**Description**
Recorded in field	Ombrotrophic bog and low-grown lawn vegetation	No.9 Vegetation on peat that periodically dries out at the surface.
	Exposed alpine ridges, scree and rock complex	Nr.12 Area without vegetation or thinly vegetated.
	Graminoid alpine ridge vegetation	No.13 Vegetation on ridges and plateaus. Thin snow cover, relatively slow melting.
	Heather-rich alpine ridge vegetation	No.14 Tiny vegetation on the upper ridge. Field layer of heather, dry grasses and tiny dwarf birch.
	Heather- and grass-rich early snow patch communities	No.16 Vegetation in lower part of the ridge. Acts with several shapes depending on rocks and snow cover.
	Fresh heather and dwarf-shrub communities	No.17 Dense vegetation with shrub layer of dwarf birch, willow and juniper.
	Grass and dwarf willow snow-patch vegetation	No.19 Vegetation with a considerable snow cover and late melting. Characterized by dwarf willow, grasses and herbs.
	Bryophyte late snow patch vegetation	No.20 Moss rich snow patch with very late melting in the summer.
Used in statistical analyses	Mire (M)	Same as no.9
	Exposed alpine ridge (EAR)	Same as no.12
	Heather-rich alpine ridge (HAR)	Pooled between no.13 and no.14
	Heather and grass vegetation (HGV)	Pooled between no.16 and no.17
	Early/late snow patch (SP)	Pooled between no.19 and no.20

Vegetation height was measured in three spots in each subplot; in the middle and on both sides. The mean height was used in the statistical analyses. Slope was recorded if there was a difference of over one meter of height within the circle. Measurements of altitude were obtained from a digital elevation model (DEM) in ArcMap 9.0^{TM} (ESRI) GIS Software. Digitalized geographical map information was obtained from GeoNorge (2011).

Statistical analyses

Statistical analyses were performed in the statistical software R 2.12.1 (Crawley 2007). A generalized linear mixed effect model was fit by the Laplace approximation (lmer) to evaluate the relationship between pellet group density (dependent variable) and explanatory variables with a poisson distribution, combined for both areas. The explanatory variables fit in the model was; distance to the power line or the alternative “control “corridor, vegetation type, cover and height, elevation, slope and direction of slope, observer and north or south of the power line or mid line (Crawley 2007; Zuur et al. 2009). Subplots were nested within plots, and plots were nested in transects and used as a random variable to avoid pseudo-replication. For model selection, the least significant variable was removed in backward elimination procedure until only statistically significant terms were left in the model. Each removal was tested with Analysis of variance test (ANOVA), and the new model was rejected or accepted according to Akaike’s Information Criteria (AIC). A Mann Whitney U-Test was used to see if there were differences in the areas. A Tukey multiple comparisons of mean test were used to test interactions between pellet groups in all the different vegetation types. In all cases, p-values ≤ 0.05 were considered statistically significant.

RESULTS

I found pellet groups in 1065 (68.5%) of the 1554 sampled plots, and the maximum number found in one plot was seven pellet groups (Fig.5). Total number counted was 2323 pellet groups. The test area had significantly more pellet groups than the control area (Mann Whitney U-Test; $p<0.001$). Vegetation type heather-rich alpine ridge and exposed alpine ridge were the most abundant vegetation types (37% and 36%, respectively), while early and late snow patch and mire were least abundant (7.2% and 5.9%, respectively).

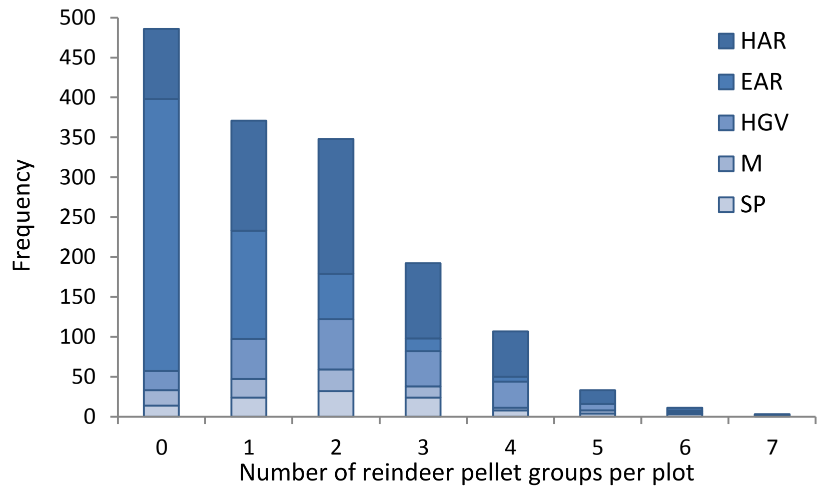

Figure 5. Frequency of pellet groups found within the vegetation types; heather-rich alpine ridge (HAR), exposed alpine ridge (EAR), heather and grass vegetation (HGV), mire (M) and early and late snow patch (SP).

Avoidance and barrier effects

Combined for both areas, density of reindeer pellet groups decreased with increasing distance from the power line and the alternative corridor to the new power line ($p<0.001$; Table 2; Fig.6). The strongest decrease in reindeer pellet groups with increasing distance to the power line was found in the control area (Fig.6).

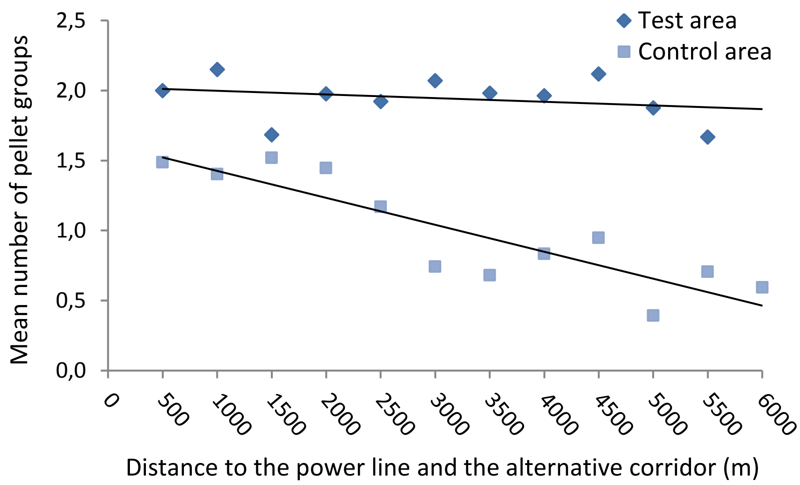

Figure 6. Mean number of pellet groups in relation to distance from the power line and alternative corridor (Table 2).

Table 2: The generalized linear mixed model fit by the Laplace approximation (family=Poisson): Number of pellet groups (dependent variable) and distance to the power line and the alternative corridor (combined), area, elevation, vegetation cover, vegetation type, distance to line × area, vegetation cover × area, and elevation × area as explanatory variables. Non-significant variables and interactions removed from the model were: Area × vegetation type, distance to power line and the alternative corridor × vegetation type, slope, observer, north-south of the line, and vegetation height.

Explanatory variables	Estimate	SE	Z-values	P-values
(Intercept)	2.422	0.660	3.615	0.0002
Distance to power line	<-0.001	0.000	-5.305	< 0.0001
Elevation	-0.003	0.001	-4.416	< 0.0001
Vegetation cover	0.017	0.001	11.683	< 0.0001
Vegetation type				
Exposed alpine ridge vs. Heather-rich alpine ridge	-0.289	0.086	-3.367	0.0007
Heather and grass vs. Heather-rich alpine ridge	-0.035	0.058	-0.592	0.5537
Mire vs. Heather-rich alpine ridge	-0.160	0.087	-1.839	0.0659
Early/late snow patch vs. Heather-rich alpine ridge	0.125	0.075	1.671	0.0947
Test area vs. Control area	-2.695	0.756	-3.567	0.0003
Distance to power line × Area				
Test area vs. Control area	<0.001	0.000	4.724	< 0.0001
Vegetation cover × Area				
Test area vs. control area	0.010	0.002	-5.541	< 0.0001
Elevation × Area				
Test area vs. control area	0.003	0.001	3.946	< 0.0001

There was no significant differences in pellet group density north and south of the power line and the alternative power line, combined (p>0.05). There was no significant interaction between observers and pellet groups counted (p>0.05).

Habitat selection

Exposed alpine ridge (EAR) had a significantly lower mean number of pellet groups than all the other vegetation types (p<0.001; Table 3; Fig.7), both areas combined. Heather and grass vegetation (HGV) had a significantly higher numbers of mean pellet groups than mire (M) (p=0.045) and tendency to higher number of pellet groups than heather alpine ridge (HAR) (p=0.056; Table 3; Fig.7). It was more reindeer pellet groups in HAR, EAR and SP in the test area compared to the control area, and less HGV and M (Fig.7).

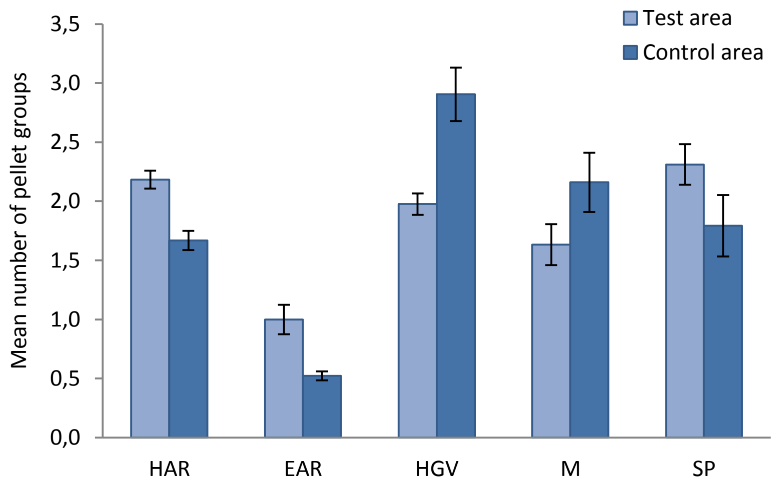

Figure 7. Mean number of pellet groups counted in heather alpine ridge (HAR), exposed alpine ridge (EAR), heather and grass vegetation (HGV), mire (M) and early and late snow patch (SP) in the test and the control area. Bars represent SE.

Table 3. Tukey multiple comparisons of means with 95% family-wise confidence level. Pellet groups in the different vegetation types. Four non-significant interactions were left from the table: M vs. HAR, SP vs. HAR, SP vs. HGV and SP vs. M.

Vegetation class	Difference	Lower	Upper	P-values
EAR vs. HAR	-1.351	-1.552	-1.150	<0.001
HGV vs. HAR	0.563	-0.010	0.522	0.056
HGV vs. EAR	1.608	1.341	1.874	<0.001
M vs. EAR	1.185	0.807	1.563	<0.001
SP vs. EAR	1.609	1.259	1.960	<0.001
M vs. HGV	-0.422	-0.838	-0.006	0.045

There was no interaction between vegetation types and distance to the power line or the planned corridor ($p>0.05$). Thus, reindeer used the available forage irrespective of distance to the power line or the alternative corridor. There was no interaction between counted pellet groups, areas and vegetation types ($p>0.05$), meaning that pellet groups had the same distribution in vegetation classes in both areas.

Reindeer pellet group density decreased somewhat with elevation ($p<0.001$; Table 2), and increased with increasing vegetation cover ($p<0.001$; Table 2; Fig.8), but was not affected by neither vegetation height nor slope ($p>0.05$; Table 2).

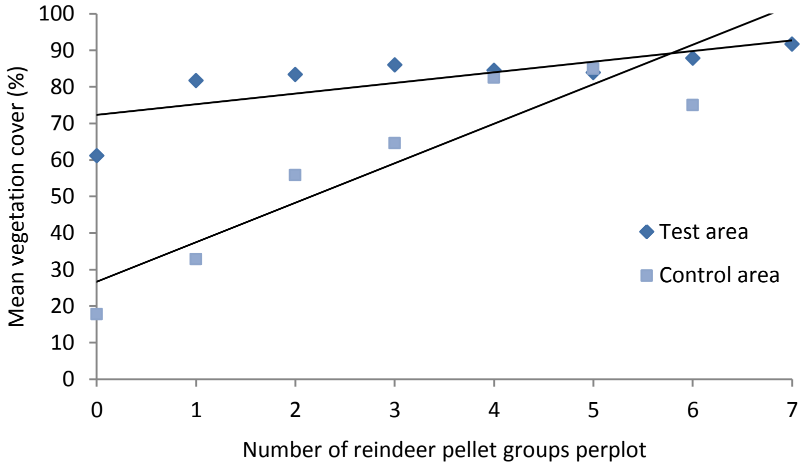

Figure 8. Number of reindeer pellet groups per plot in relation to mean cover of vegetation (%) in the test and control area.

Reindeer habitat use was not significantly different between the study areas (p>0.05). Vegetation cover (%) and height (cm) was significantly higher in the test area compared to the control area (Mann Withney U-Test, p<0.001 & p<0.001, respectively; Fig.9 & Fig.10). Elevation was significantly higher in the control area (Mann Whitney U-Test; p<0.001).

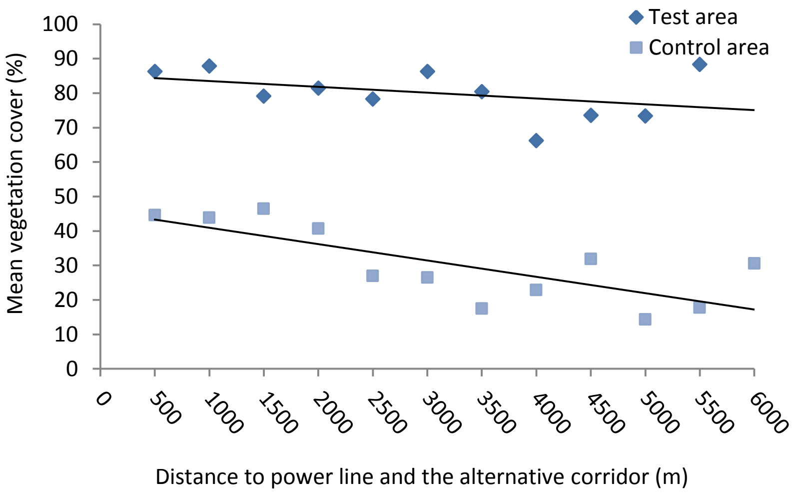

Figure 9. Vegetation cover (%) in relation to distance from the power line in the test area and alternative corridor in the control area.

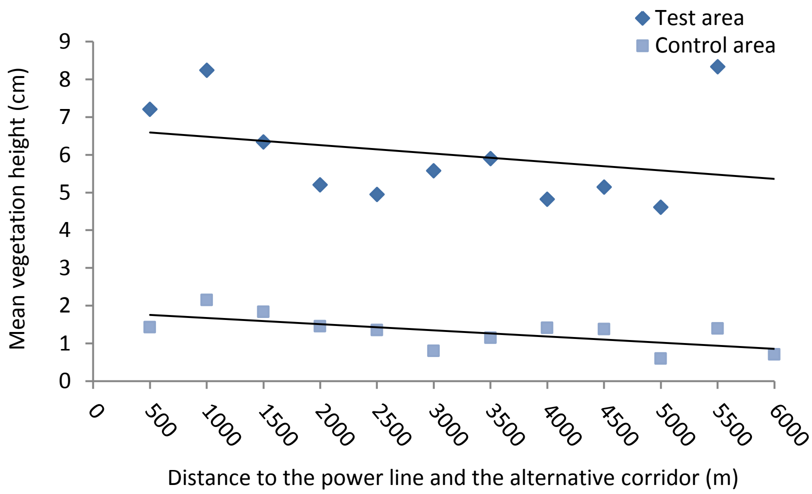

Figure 10. Vegetation height in relation to distance to power line and the alternative corridor.

The test area had a significantly higher vegetation cover and higher vegetation length in all vegetation types, in relation to the control area (Fig.11 & Fig.12).

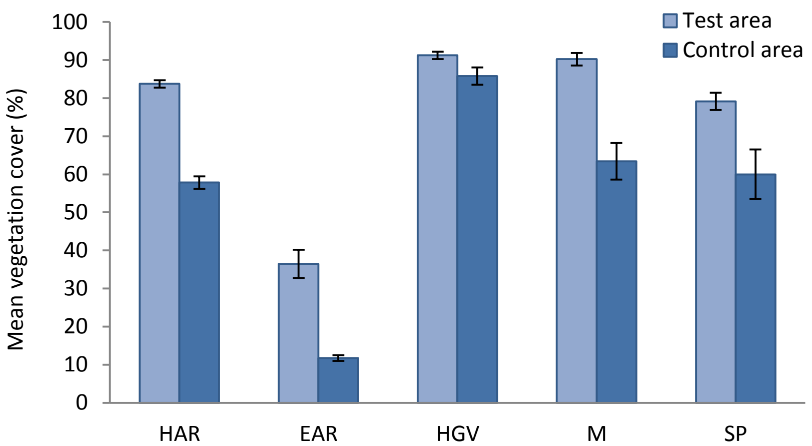

Figure 11. Vegetation cover in the five different vegetation types; heather and grass vegetation (HGV), exposed alpine ridge (EAR), heather alpine ridge (HAR), mire (M) and early and late snow patch (SP) in the study areas. Bars represent SE.

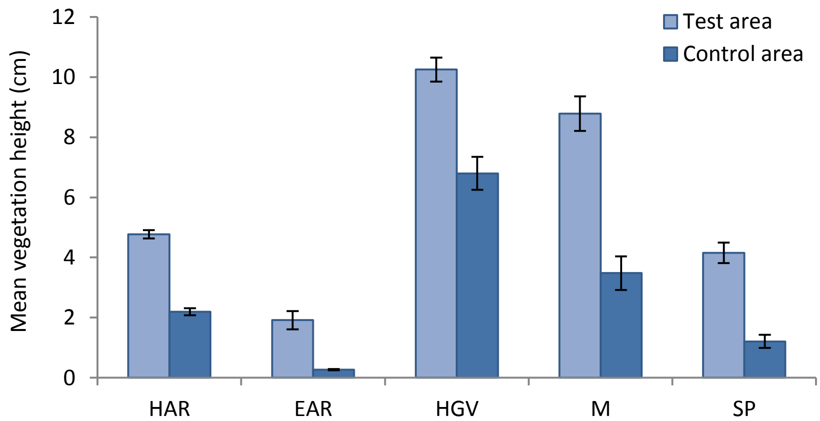

Figure 12. Vegetation height (cm) in the five different vegetation types; heather and grass vegetation (HGV), exposed alpine ridge (EAR), heather alpine ridge (HAR), mire (M) and early and late snow patch (SP) in the study areas. Bars represent SE.

DISCUSSION

Avoidance and barrier effects

My prediction that semi-domestic reindeer show avoidance behavior towards power lines is not supported by my results. The "avoidance hypothesis" must therefore be rejected. Reindeer use the areas close to the power line similarly to areas five km away; thus, the power line appeared to have no visible negative effect on semi-domestic reindeer area use. This corresponds with other findings where power lines were found to have minimal negative effects on reindeer (Flydal et al. 2009; Reimers et al. 2000; Reimers et al. 2007). Flydal et al. (2009) could not document behavioral responses or tendencies to changed area use for reindeer in enclosures exposed to two parallel power lines (132 and 300 kV). Direct observation (*e.g.* experimental study), like the study of Flydal et al. (2009), may observe and take into account other possible variables that can explain changes in behavior or aversion, and it may provide more robust data for testing the animals' reactions to a specific stimuli (Reimers & Colman 2006). Nevertheless, it can be difficult to transfer findings from studies with reindeer in enclosures to free ranging animals (Reimers & Colman 2006).

The lack of avoidance towards human infrastructure does not correspond with some studies on reindeer and caribou (De Vries Lindstrøm 2011; Nellemann et al. 2001; Nellemann et al. 2003; Vistnes & Nellemann 2001; Vistnes et al. 2001; Vistnes et al. 2004). In a study of semi-domestic reindeer, Vistnes & Nellemann (2001) found decreasing density of calving reindeer closer to a power line, and concluded that reindeer were negatively affected by power lines, roads and cabins within a zone of four km. This was explained as avoidance behavior towards the technical installations alone. It has been shown that reindeer cows and calves during the calving period are the most easily disturbed animals (Nellemann & Cameron 1996; Wolfe et al. 2000), and this could be one reason for different results compared to my study. De Vries Lindstrøm (2011) studied semi-domestic reindeer area use in relation to a power line and found that reindeer pellet groups increased with increasing distance to the power line below the tree line, although there was no effect above the tree line. The study was conducted in an semi-domestic reindeer area with an existing power line, in addition to an ongoing construction of a new power line parallel to the existing (De Vries Lindstrøm 2011). This could be a reason for the different findings, because reindeer show more aversion to human activity than infrastructures alone (Wolfe et al. 2000). In addition, my study was conducted above the tree line, and here are our results equal. Vistnes et al. (2004) found that power lines affected wild reindeer negatively and suggested that power lines cause aversion behavior in reindeer. Nellemann et al. (2001) found that wild reindeer used areas 2.5 km from power lines less than available in six of eight sampled years, by one day aerial winter population surveys. However, Nellemann et al. (2001) did not take into account variables that could have been explanatory for the reindeer's potential avoiding behavior, for instance, better forage in the area they were observed.

My second prediction, that there would be more reindeer pellet groups on one side of the power line compared to the other side was not supported. Thus, I found no sign of barrier effects of the power line on the semi-domestic reindeer in my study area and the "barrier hypothesis" was also discarded. This corresponds with studies from North Ottadalen, showing that a 66 kV power line was not a barrier to reindeer migration and that reindeer were not displaced by the power line (Reimers et al. 2007). Reimers et al. (2007) combined lichen measurements and aerial surveys of reindeer distributions. Direct visual observations alone can be misleading when testing barrier and aversion effects if the study is not controlled for other independent variables. This is because you can register the position of the reindeer, but may not know why they are in a particular position (Reimers & Colman 2006). Combining indirect and direct observations to identify effects of infrastructure on animal distribution can be an advantage because more information can be gathered and additional variables included. Vistnes et al. (2004) used lichen measurements to detect barrier effects of a power line, and suggested that reindeer perceive the structure as a barrier, explained with a physiological effect of danger associated with human-made structures. A possible reason for my results of no barrier effects of the existing power line could be because three other reindeer herds migrate through the area to reach their respective summer pastures at the coast. These reindeer herds are more or less forced to pass under the power line twice a year. If the herds have the same speed on each side of the power line (when moving), we can predict that we will find the same amount of pellet groups on both sides, and therefore no visible barrier effect.

A possible reason for non-corresponding results, on both avoidance and barrier effects, with other studies could be the use of different methods. Many studies (Nellemann et al. 2001; Nellemann et al. 2003; Vistnes et al. 2008; Vistnes & Nellemann 2001) used limited amounts of direct observations within very short periods of time, and assumed that this represented an entire population's true area use. I counted accumulated reindeer pellet groups that reflects area use of the entire population, and are a proof of reindeer actually being at the location (Skarin 2007). Some of the pellets could be at least three years old because of slow rate of decomposition in dry alpine terrain (Skarin 2008). This may control for short term environmental variables such as predator effects, climate, insects and possible effects from the reindeer herdsmen. My study area was also relatively homogenous in terms of elevation, other human activities, and distribution of vegetation types and habitats. This can be a key aspect of my findings, because the power line was found not to be an important influence on reindeers' distribution. In other words, I was able to control for important variables, something some field studies have not been able to do well enough (Reimers & Colman 2006).

Both semi-domestic and wild reindeer may use pastures near power lines because they have the ability to habituate to power lines over time if the power lines are not accompanied by other human activities such as road traffic and tourist activities (Reimers & Colman 2006; Reimers et al. 2007). My results support the view that if animals perceive human infrastructures, like power lines, as predictable and non-threatening, they may habituate to it (Bergerud et al. 1984; Colman et al. 2001; Reimers et al. 2010; Skarin et al. 2008; Skarin et al. 2010). However, a study on wild reindeer concluded that reindeer do not habituate to human infrastructure (Nellemann et al. 2010). Nellemann et al. (2010) suggested that disturbance in new areas that is not affected by humans should be avoided. However, this makes little sense in a larger perspective, because according to this, reindeer would in theory have nowhere to escape under the present amount of existing infrastructure. In other words, some reindeer must have habituated to a certain degree to the already huge amount of installations and human activities for their present populations to exist.

Reindeer density, based upon pellet density, decreased with increased distance from the planned power line. A likely explanation is the decreasing amount of vegetation cover further away from the alternative corridor. The mid-line, which will most likely be influenced by power lines in the near future (within three to four years), is a good summer pasture for the Skárfvággi district (Colman et al. 2009). Although the planned power line would be built in an area with the highest reindeer density, my results indicate that reindeer will most likely not suffer long-term negative consequences of the power line itself. However, an important thing to take into account is that human infrastructure affects reindeer differently depending on the degree of domestication, flock size, age and gender composition of the herd, season and previous experience with humans (Reimers & Colman 2006; Vistnes & Nellemann 2001). Responses will therefore vary among individuals of different sexes and at different times of year, as well as for different herds. At the local level, the interference level, topography and domestication degree are important factors that contribute to identify the degree of disturbance (Dahle et al. 2008; Vistnes & Nellemann 2008). Reimers et al. (2000) mention numerous factors that may influence whether animals choose to cross under power lines or not. It could be the topographical location of the line; whether it is located in forested or in open terrain; the location in relation to grazing, calving and rutting areas; time of the year; presence or absence of harassing insects; climatic factors that lead to corona or wind noise from the line; and the age, sex, physical and psychological condition of the animals and their earlier experience (Reimers et al. 2000). Predator avoidance is also important (Reimers & Colman 2006). Thus, based on these facts, it can be hard to draw firm conclusions on possible negative consequences. Reindeer and the reindeer herding industry will probably face problems during the construction period, when it will be considerable human activity in the area during construction, something my study does not control for. This topic needs more research for reliable conclusions.

The fact that the semi-domestic reindeer used the area near the planned corridor more than areas further away (three to six km), tells us that reindeer used areas in my study mostly according to pasture resources (see below), and often use some particular areas more than others, independent of human infrastructure. Therefore, it can be difficult to conclude on effects in cases where we do not have data on reindeer area use before the installation was built. The collection of data from both before and after construction of an installation is therefore very important. My study in the control area is essential for data on habitat and area use before the proposed construction occurs. We can then conduct the same study in subsequent years after construction of the future power line and test whether reindeer change their area use due to the new power line compared to before construction.

Habitat selection

My third prediction, that reindeer will choose different vegetation types and habitats with different distance to power lines, was also rejected. Vegetation cover, vegetation type and elevation explained reindeer pellet group distribution, irrespective of the distance to the power line. The fact that the reindeer selected for forage with high percent of vegetation cover was expected in the control area and indicated that reindeer selected forage with high quantity and quality. I found that this was also the case in the test area. Overall, reindeer preferred exposed alpine ridge least of all the vegetation types. This correspond with Skarin (2010) & Skogland (1980), showing that wild and semi-domestic reindeer avoid sparsely vegetated areas like rocky patches. Skogland (1980; 1986) found that reindeer habitat selection was influenced partly by insect harassments, weather, and forage availability, biomass and plant phenology. Vistnes & Nellemann (2008) added human infrastructure and activity to factors influencing wild reindeer habitat selection. This does not correspond with my findings, and reasons for the different results may be due to, as discussed earlier, the use of different methods. Predator avoidance is another important influence on reindeer habitat use, yet few studies, including mine, are able to include this important aspect into their analyses (Reimers & Colman 2006).

Reindeer pellet groups decreased with higher altitude. This does not correspond with Skarin's (2007) study of habitat selection on semi-domestic reindeer, where reindeer selected habitats at high altitudes with high forage quality. A reason for my findings could be the relatively high altitudes in the control area (800-1200 meter above sea level), and the highest peaks where relatively sparsely vegetated (reindeer more or less avoided areas over 1100 meter above sea level). Reindeer commonly avoid such rocky and non-vegetated areas for grazing (Skarin et al. 2010; Skogland 1980; Skogland 1986), but might use higher altitudes which often are wind-exposed to escape from insects (Hagemoen & Reimers 2002; Skarin et al. 2004; Vistnes & Nellemann 2008). There was no difference in habitat choice between the two study areas, but I found most reindeer pellet groups in the test area compared to the control area. This was certainly due to the fact that there were considerably more reindeer in the test area, 7500, compared to only 1500 reindeer utilizing the pastures in the control area. In addition, there were higher elevations and poorer vegetation (less vegetation cover and lower vegetation height) in the control area, and reindeer might have found better forage in surrounding areas in lower altitudes.

MANAGEMENT IMPLICATIONS

In conclusion, my study shows that semi-domestic reindeer do not avoid a power line or perceive it as a barrier. Reindeer habitat selection was dependent on forage quality and quantity (*e.g.* vegetation type, vegetation cover) and not the power line. Thus, a single power line does not appear to have negative effects on freely grazing semi-domestic reindeer. My findings may be important when analyzing the possible consequences when the new power line is planned built through both of my study areas. The need of studies like this is essential to resolve trust issues between scientist and reindeer herdsmen and between scientists and management authorities. The collection of data from both before and after construction of an installation is very important. Therefore, my study in the control area will be vital in the future because we now have pre-data that are needed to test avoidance or barrier effects or changed habitat use after the construction of the new power line. If we continue to perform pellet count studies annually, both before, during and after construction, until a few years after construction of the power line, we could clarify possible negative consequences for the reindeer and reindeer herders.

There are many power lines in Northern Norway today and there are many new power lines in the planning, including in my study areas. It is a common assumption that reindeer avoid human infrastructures, and this is a good precautionary principle to follow in cases where we know little about possible negative consequences. However, in some instances, much of the conflict might be more related to human perceptions of power lines. Results from this study indicate that semi-domestic reindeer sooner or later will habituate to a power line. However, results on semi-domestic reindeer are not necessarily transferable to wild reindeer and visa-versa. For future studies, I recommend combining both direct and indirect methods to measure effects of human infrastructure on reindeer, *e.g.* pellet count methods combined with GPS-collared reindeer can provide excellent data about reindeer behavior in relations to power lines, or other human installations.

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