NMBU

PREFACE

This study ends my Master degree in Natural Resource Management and was written at the department of Ecology and Natural Resource Management at the Norwegian University of Life Sciences. The thesis provides 30 credits and is based on data analyses of GPS-collared wild reindeer in Setesdal Vest-Ryfylke and Setesdal Austhei.

I would first especially like to thank my supervisor Jonathan E. Colman for the introduction of this topic and all the help during the study. Special thanks also to Diress Tsegaye, Sindre Eftestøl and Kjetil Flydal for invaluable help with the topic, data collection and analyses. I would also like to thank Johan Olav Bjerke and Sonja Bjerlijn from Statnett for all the help and information about power lines and the corona effect.

I would also like to thank my friends for a great couple of years at the Norwegian University of Life Sciences and my family for all the support during the studies to finalize my Master of Science degree at Ås.

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ABSTRACT

Human activities and infrastructure continue to increase in northern regions, and in Scandinavia, the progressive development of wind and hydroelectric power, cabins, roads, and power lines is in conflict with the conservation of wild reindeer (*Rangifer tarandus tarandus*) habitat. High voltage power lines produce corona noise and UV-discharges under particular weather conditions. A new hypothesis suggests that avoidance behavior in reindeer towards power lines might be linked with their adaptive UV-sensitive vision in winter combined with unpredictable UV outburst from high-voltage power lines. However, studies based on GPS data from several Norwegian reindeer populations have found limited negative effects of power lines alone or after the period of construction. The objective of this study was to test the "UV-hypothesis" for wild reindeer in Setesdal Vest-Ryfylke and Setesdal Austhei using data from GPS-collared reindeer for the years 2007 - 2014. Area use was studied within three test areas with 420 kV and 300 kV power lines and numerous control lines throughout the landscape. This study tested differences in area use between nighttime and daytime within a 1 km, 500 m, 200 m and 100 m corridor for autumn, winter and spring. The "UV"-hypothesis was not supported by my results. For all real power lines, there was no significant differences between daytime and nighttime in relation to distance to power line within the 1 km, 500 m, 200 m and 100 m corridors. This applies to both Setesdal Vest-Ryfylke and Setesdal Austhei. These results indicate that wild reindeer in Setesdal Vest-Ryfylke and Setesdal Austhei are not negatively affected by UV-discharge, nor show any aversion towards high voltage power lines during nighttime. Power lines do not facilitate human use after development and this could lead to a more rapid habituation. Over time, reindeer might habituate to UV-discharge stimuli because there is no danger related to the electrical phenomenon. However, UV-discharge might be more dominant under particular weather conditions, thus, future studies should include weather data. Also, due to classical conditioning, (or even large time scale autocorrelation) negative effects during nighttime may also lead to negative effects during daytime. This may be the reason for why there is an increase in density of GPS-points further away from the power line in Setesdal Austhei North and Setesdal Vest-Ryfylke South. It may also be caused by other factors like elevation, snow depth or vegetation, especially since the same trend is not found in all three areas. To investigate this further, these other factors should be included in future analyses.

Key words: Avoidance, power line, *Rangifer tarandus tarandus,* reindeer, UV-vision

SAMMENDRAG

Utbygging av infrastruktur har økt de siste tiår i Skandinavia og utviklingen av vind- og vannkraft, hytter, veier og kraftledninger kommer i konflikt med bevaring av villreinens (*Rangifer tarandus tarandus*) habitat. Høyspentledninger produserer corona-effekter som støy og UV-utladninger under spesielle værforhold. En ny hypotese antyder at unngåelse av kraftlinjer hos villrein kan ha en sammenheng med deres UV-sensitive syn om vinteren, kombinert med uforutsigbare UV-utladninger fra høyspentledninger. Studier basert på GPS-data fra flere norske bestander av reinsdyr har funnet begrensede negative effekter av kraftledninger under eller etter utbygging. Målet med studie var å teste "UV-hypotesen" i Setesdal Vest-Ryfylke og Setesdal Austhei ved å bruke data fra GPS-merkede villrein for årene 2007 - 2014. Tre test-områder med 420 kV og 300 kV kraftledninger ble valgt ut, i tillegg til flere kontroll-linjer i lignende landskap i nærliggende områder. Studiet testet forskjell i villreinens bruk av områdene mellom natt og dag for høst, vinter og vår innenfor en sone på 1 km, 500 m, 200 m og 100 m. "UV" – hypotesen kunne ikke støttes ut i fra mine resultater. For alle eksisterende kraftlinjer som ble testet var det ingen signifikant forskjell i villreinens bruk av område mellom natt og dag. Dette gjald for alle sonene (1 km, 500 m, 200 m og 100 m). Disse resultatene indikerer at villrein i Setesdal Vest-Ryfylke og Setesdal Austhei ikke er negativt påvirket av UV-utladninger, eller viser unngåelse av høyspentledninger nattestid. Villreinen i området kan ha tilvennet seg til UV-utladninger fordi det ikke er noe faremoment relatert til det elektriske fenomenet. Corona-effekten er mest dominerende under spesifikke værforhold (for eksempel ved vind, høy luftfuktighet og nedbør), derfor anbefales det å inkludere værdata i videre studier om emnet. I tillegg, på grunn av klassisk betinging, kan negative effekter om natten også føre til negative effekter om dagen. Dette kan være grunnen til at vi ser en økende tetthet av GPS-punkter ved økende avstand fra kraftlinjene i Setesdal Austhei Nord og Setesdal Vest-Ryfylke Sør. Trenden kan også være forårsaket av andre faktorer som moh., snødybde eller vegetasjon, spesielt siden man ikke ser den samme trenden i alle tre områdene. For å undersøke dette videre, bør disse andre faktorene tas med i analysene.

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1. INTRODUCTION

Development of human-made structures has increased in arctic regions the last decades, especially in Scandinavia, with development of wind-power plants, cabins, roads, hydroelectric dams and power lines (Colman et al. 2012). Norway has the highest rate of development of infrastructure in northern alpine ecosystems and the ecological effect has been a focus of concern (Nellemann et al. 2003). Many species including wild reindeer (*Rangifer tarandus tarandus*) have experienced increased disturbance and potential fragmentation of their habitat in these areas.

Studies on reindeer and their relation to power lines has become an important subject of knowledge. Although power lines do not directly hinder local movements or migrations, as reindeer are able to pass under, or facilitate human use after development such as roads, cabin resorts and hiking trails, they may still act as a disturbance. Norway has almost 200 000 km of power lines crossing the country and some of these power lines is interacting with important habitat for the reindeer (Bevanger et al. 2014).

Hearing, smell and vision are relevant in reindeer-human interactions, and there is reason to believe that reindeer have very good day and night vision (Reimers & Colman 2006). A study done by Hogg et al. (2011) demonstrated that the lens and cornea of the eye in *Rangifer* transmit ultraviolet (UV) light, and that this might be an adaption to a life in higher latitudes (Tyler et al. 2014a). Reindeer experience extreme photic conditions during winter. In addition, there are high levels of environmental UV-light in the polar regions during winter due to a high degree of atmosphere (Rayleigh) scatter and reflections from the ground covered in snow and ice (Hogg et al. 2011). Potential advantages for why reindeer extend their visual range into the UV is because their key food source during winter months, lichens, strongly absorb UV-light, making it more visible and thus easier to find when foraging. Another advantage could be that the wolf, their main predator, has a coat that reflects UV poorly, making them more visible against a white background in winter. It has been suggested that reindeer can also benefit from UV-sensitivity by the UV-reflecting properties of snow, that change with the quality of its surface. This could benefit the reindeer while foraging and moving (Hogg et al. 2011). Tyler et al. (2014a) concluded that UV vision might not have much functional significance for reindeer during the day. However, at low luminance, i.e. before dawn, after sunset, and during the extended UV enriched twilight of the polar winter day, UV vision might be valuable.

High voltage power lines produce corona, a type of electrical discharge (Bjerke 2015). This technical phenomenon leads to noise and UV-discharges under particular weather conditions, e.g. wind, high humidity and precipitation (Berlijn 2015; Bjerke 2015). A new hypothesis about ultraviolet vision and avoidance of power lines in birds and mammals was published in a letter in 2014 (Tyler et al. 2014b). The letter explains that mammals and ground – nesting birds avoid habitats up to several kilometers from high-voltage power lines, indicating some type of behavioral enhancement. New information about vision in reindeer, in addition to information about characteristics of power lines has led to the hypothesis that avoidance may be linked to the reindeer's ability to see ultraviolet light (UV). However, studies based on GPS data from several Norwegian reindeer populations have found limited negative effects of power lines alone or after the period of construction (Colman et al. 2014).

There have been numerous studies conducted on reindeer and their potential avoidance towards power lines (Bartzke et al. 2014). Nevertheless, the UV-hypothesis has not been tested. Thus, the objective of this study was to test the "UV-hypothesis" for wild reindeer in Setesdal Vest-Ryfylke and Setesdal Austhei using data from GPS-collared reindeer for the years 2007 - 2014. Area use was studied within three test areas with 420 kV and 300 kV power lines and numerous fictive control lines throughout the landscape. Differences in area use between nighttime and daytime within a 1 km corridor from real power lines and fictive control lines for autumn, winter and spring were tested. Based on the study of Tyler et al. (2014b), I predict that there is difference in reindeer's area use between nighttime and daytime within the tested corridors along the real power lines, but no difference within the tested corridors by the fictive control lines. I looked at difference in reindeer's area use between nighttime and daytime when testing the "UV-hypothesis" because an effect is expected at hours of low luminance. The autumn, winter and spring seasons were chosen for testing the hypothesis because of clear difference in natural light between nighttime and daytime. I chose the longest corridor distance to be within 1 km corridor because this is within reindeer's range of senses. I used corridors of high-voltage power lines at 300 and 420 kV, which produce UV-light and discharges (Bjerke 2015). If my first prediction is supported, UV-light from high-voltage power lines can act as a disturbance on reindeer during months and hours of low luminance in alpine areas.

2. MATERIALS AND METHODS

2.1. *Study species*

The wild reindeer is a nomadic, boreal to super-boreal species that is dependent on large areas for foraging (Andersen & Hustad 2004; Tyler et al. 2014a). Reindeer are adapted to a life on unproductive tundra and has physical as well as physiological adaptions to an extreme environment, especially during winter (Punsvik & Jaren 2006). They live in large herds to protect themselves from predators and tend to avoid humans and human made infrastructure as an anti-predator strategy (Andersen & Hustad 2004; Panzacchi et al. 2013; Punsvik & Jaren 2006; Vistnes & Nellemann 2008). Historically (for many hundred years ago), seasonal migration routes in Norway were over a much broader scale with fewer, larger populations (2-3 populations) compared with today's several meta-populations (ca. 23 meta-populations) (Panzacchi et al. 2013). Different herds of reindeer can vary in their response towards human disturbances (Reimers & Colman 2006). Their response can depend on population density, availability for habitat and whether they are wild, semi-domesticated or domesticated (Reimers et al. 2012).The type of disturbance is also important for how strongly reindeer react towards human activities and infrastructure (Reimers & Colman 2006).

2.2 *Study area*

The mountains in Setesdal Vest-Ryfylke has the second largest and Europe's southernmost wild reindeer area and is dominated by a landscape of rocky mountains and many lakes and rivers (Bevanger & Jordhøy 2015a). The area covers 6154 km^2 and has a winter population estimated at approximately 2400 individuals (Figure 1) (Bevanger & Jordhøy 2015a). Most of the landscape is mountainous, whereas 43 % of the area is unproductive land. Hydroelectric development, power lines, roads and extensive trail networks has been developed in Setesdal Vest-Ryfylke (Bevanger & Jordhøy 2015a).

Setesdal Austhei was defined as a wild reindeer area in 1980, after it previously had been a location for reindeer husbandry (Bevanger & Jordhøy 2015b). The area covers 2370 km^2 and has a winter population estimated at approximately 1500 individuals (Figure 1) (Bevanger & Jordhøy 2015b; Mossing & Heggenes 2010). The area north of Rv45 has many mountain ranges and covers 770 km^2, while the area south of the road is more characterized with forest and covers approximately 1600 km^2 (Mossing & Heggenes 2010). Most of the wild reindeer population in Setesdal Austhei has their winter ranges in the northern area and calving areas and summer ranges in the south (Bevanger & Jordhøy 2015b).

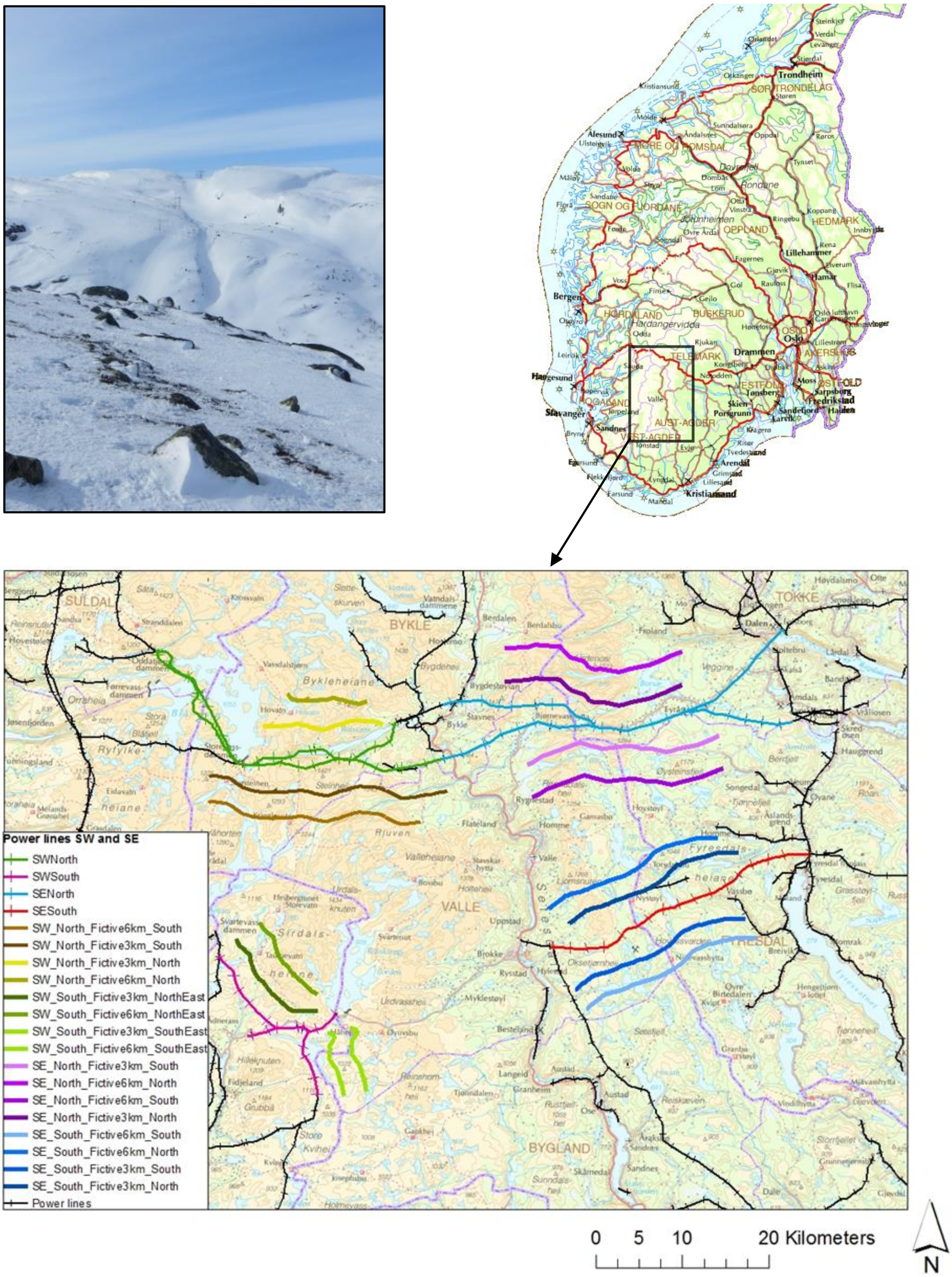


Figure 1: The location of the tested areas were Setesdal Vest-Ryfylke and Setesdal Austhei in southern Norway. Area use was tested within three test areas with 420 kV and 300 kV power lines and 12 control lines throughout the landscape.

In this study, three power lines at 420 and 300 kV were selected for the analysis. Two of them were located in Setesdal Vest-Ryfylke; one close to Blåsjø (59°21'50" N, 06°56'20" E, approx. 1055 MAMSL) in the north and Øyarvatn (58°56'23" N, 06°39'52" E, approx. 904 MAMSL) in the south (Figure 1). Both power lines were located in rugged mountain landscape, with sharp contrast between lowlands in the valleys and high mountains. The tested areas included rivers and lakes, and hydroelectric developments has been carried out in both Blåsjø and Øyarvatn (Bevanger & Jordhøy 2015a). The selected power line in Setesdal Austhei was located north of Store Bjørnevatn (59°20'42" N, 07°31'53" E, approx. 803 MAMSL). The northern region of Setesdal Austhei included many contiguous mountain sections. In the eastern and western part of the northern area, the landscape transforms into valleys with forested landscape. The vegetation in the north consisted of pronounced mountain plant communities. Food availability may also vary from east-west due to climate differences (e.g. snowfall) (Jordhøy 2005). This applies also for Setesdal Vest-Ryfylke. There are many variations in the landscape, from high mountains to valleys at lower elevations with numerous rivers and lakes on both sides of the valley, and fictive lines was used as control for variation.

2.3 *Data collection*

The GPS-data used in this study were obtained from Norwegian Institute for Nature Research (NINA). The GPS-transmitters used were from GPS-GSM type (Strand et al. 2011). One position is collected every three hours, in addition to more frequent registrations during certain periods of the year, or when the animals have stayed in particularly interesting areas (Strand et al. 2011), but I only used data with three hour intervals. The potential dataset for an animal that has been GPS-collared for one year is 365 days * 24 hours / 3 hour intervals = 2920 positions / animal / year.

The real power lines selected for this study were chosen based on the number of GPS positions within the tested areas, e.g. enough data to perform analyses. In this study, reindeer's area use was tested within a 1 km distance of three power lines. Then intervals of 100 m, 200 m, and 500 m within the 1 km distance corridor were selected. This was done to test the first prediction, i.e. difference in reindeer's area use between nighttime and daytime within the tested corridors by the real power line. The same was done to test the second prediction, i.e. no difference in area use between nighttime and daytime within the tested corridors by the fictive control lines. For each of the three real power lines included in this study, four fictive control lines were located within a distance of approximately 3 km and 6 km from the real power lines, avoiding overlap of the different test corridors. Fictive control lines were used as control for the real power lines that were tested. For the real power line in Setesdal Vest-Ryfylke North and Setesdal Austhei, two were located north of the real power lines and two were located south. In Setesdal Vest-Ryfylke South, two fictive lines were located north and two located east of the real power line. Habitat and elevation were also taken into consideration during placement of the fictive control lines, choosing habitat and elevation as similar as possible to the real power lines.

To test "true" nighttime versus daytime, months with few dark hours over a 24-hour period and hours during twilight were excluded from the analysis. The months selected for the analyses were September to April (8 months). The hours included in the analysis were 11:00 a.m. to 1:00 p.m. (daytime) and 11: 00 p.m. to 1:00 a.m. (nighttime).

Measurement of distance between each GPS point and the selected power lines were obtained using GIS, ArcMap (version 10.2.2) through generating a NEAR analysis table. ArcMap was also used to map the study area, select the power lines and to insert the corresponding fictive control lines.

2.4 *Data analyses*

Statistical analyses were performed in the statistical software R 3.1.1 (R CoreTeam, 2014). I analyzed the effects of daytime (categorical predictor: daytime vs. nighttime) in relation to distance (i.e. within 1 km and the intervals of 500 m, 200 and 100 m) to each of the selected real or parallel fictive power lines by fitting a linear mixed effect model using the library nlme package in R (Crawley 2007). Vegetation (forest vs. non-forest) and elevation were also included as predictors. Animal id, year, and month were included as random effects to account for variations among individuals as well as repeated measures (Bates 2013). The continuous variables (i.e. distance to power line and elevation) were scaled to standardize the variables. I kept the most parsimonious models, using Akaike's Information Criterion adjusted for small sample sizes [AICc]; (Burnham & Anderson 2002). The least significant variables were removed in backward elimination procedure until only statistically significant terms were left in the model, but the daylight predictor variable was retained even if it was not significant.

3. RESULTS

For all real power lines, there were no significant difference in reindeer's area use within 1 km, 500 m, 200 m and 100 m zones between daytime and nighttime in relation to distance to power line ($p > 0.05$) (Tables 1, 2, 3 and 4; Figures 4, 9 and 14). The results were the same for both Setesdal Vest-Ryfylke and Setesdal Austhei (Table 1, 2 and 3; Figures 4, 9 and 14). The boxplots (Figures 4-18) show the overall patterns of responses for each real power line and fictive control lines; a clear overlap between daytime and nighttime was evident in all the panels. The figures in the Appendices depict the number of GPS locations across distance zones. There was no significant difference amongst any of the zones that were tested, although some variation occurred. This indicates that my first prediction, i.e. difference in reindeer's area use between nighttime and daytime within the tested corridors by the real power lines, was not supported.

My second prediction, i.e. no difference in reindeer's area use between nighttime and daytime within the tested corridors by the fictive power lines, was mostly supported. However, there were significant differences in reindeer's area use between nighttime and daytime within three of the twelve fictive lines. These were in Setesdal Austhei 6 km south within the 500 m and 200 m zones, and the fictive power line in Setesdal Vest-Ryfylke North, 3 km south within the 500 m zone ($p < 0.05$) (Tables 2 and 3; Figures 8 and 12).

There were significant differences in reindeer's area use between non-forest and forest habitat within 200 m, 500 m and 1 km zone for some fictive control lines (Tables 1, 2 and 3). There were also some differences in reindeer's area use in elevation within 200 m, 500 m, 1 km zone for some fictive control lines (Tables 1, 2 and 3). For real power lines, there was only significant difference in reindeer's area use in elevation within the 200 m, 500 m and 1 km zones (Tables 1, 2 and 3).

In Setesdal Austhei North and Setesdal Vest-Ryfylke South there is a trend for higher densities of reindeer with increasing distance from the power lines, but not in Setesdal Vest-Ryfylke North (Figure A1, A6 and A11 in appendices).

Figure 2: 420 kV power line located in the study area in Setesdal Austhei, Kleivstjørn (north of Store Bjørnevatn). Tracks and places of foraging of approximately 20-30 individuals were observed on March 24, 2015.

Figure 3: 420 kV power line located at Kleivstjørn, north of Store Bjørnevatn, going west towards the Valley. Pellets and tracks can be seen close by the power line. Photo taken March 24, 2015.

Table 1: Parameter estimates of a linear mixed effect model predicting reindeer preference to areas within 1 km zone of different real and fictive parallel power lines in relation to daytime (11:00 a.m. to 1:00 p.m) and nighttime (11: 00 p.m. to 1:00 a.m.) in two wild populations of Setesdal Vest-Ryfylke and Setesdal Austhei in southern Norway. In addition to the timing factor, vegetation (non-forest vs. forest) and elevation were included as predictors. Animal id, year and month were included as random factors. Reference levels for time and vegetation categorical variables were "nighttime" and "forest", respectively.

Power line	Variable	Setesdal Austhei				Setesdal Vest-Ryfylke			
		Estimate	SE	t-value	P-value	Estimate	SE	t-value	P-value
Real 420 kV north	Intercept	0.031	0.079	0.392	0.695	0.003	0.131	0.020	0.984
	Daytime vs. Nighttime	-0.063	0.063	-0.999	0.318	-0.110	0.098	-1.123	0.263
Fictive 3-km north from 300-420 kV	Intercept	0.0373	0.089	0.4196	0.675	< 0.001	0.100	0.006	0.996
	Daytime vs. Nighttime	0.0417	0.096	0.433	0.666	-0.059	0.121	-0.488	0.626
Fictive 6-km north from 300-420 kV	Intercept	-0.048	0.098	-0.486	0.627	-1.113	0.899	-1.239	0.217
	Daytime vs. Nighttime	0.160	0.096	1.666	0.097	0.062	0.120	0.516	0.607
	Non-forest vs. Forest					1.162	0.895	1.298	0.196
Fictive 3-km south from 300-420 kV	Intercept	0.589	0.216	2.724	0.007	-0.474	0.222	-2.135	0.033
	Daytime vs. Nighttime	-0.008	0.135	-0.059	0.953	0.084	0.086	0.980	0.328
	Non-forest vs. Forest	-0.722	0.184	-3.925	< 0.001	0.519	0.215	2.410	0.016
	Elevation					-0.271	0.079	-3.418	< 0.001
Fictive 6-km south from 300-420 kV	Intercept	-0.894	0.216	-4.145	< 0.001	0.027	0.091	0.300	0.765
	Daytime vs. Nighttime	0.244	0.126	1.931	0.055	-0.034	0.098	-0.352	0.725
	Non-forest vs. Forest	1.022	0.250	4.096	< 0.001				
	Elevation	-0.321	0.110	-2.911	0.004	0.197	0.052	3.761	< 0.001
Real 300-420 kV south	Intercept					-0.750	0.545	-1.376	0.172
	Daytime vs. Nighttime					-0.044	0.166	-0.272	0.785
	Non-forest vs. Forest					0.818	0.542	1.509	0.135
	Elevation					0.429	0.086	4.997	0.000
Fictive 3-km north from 300-420 kV	Intercept					0.076	0.174	0.437	0.663
	Daytime vs. Nighttime					-0.127	0.146	-0.866	0.388
Fictive 6-km north from 300-420 kV	Intercept					0.041	0.128	0.318	0.751
	Daytime vs. Nighttime					-0.008	0.149	-0.050	0.960
Fictive 3-km east from 300-420 kV	Intercept					0.019	0.192	0.097	0.923
	Daytime vs. Nighttime					0.118	0.175	0.675	0.502
	Elevation					-0.502	0.093	-5.410	0.000
Fictive 6-km east from 300-420 kV	Intercept					0.078	0.127	0.613	0.541
	Daytime vs. Nighttime					-0.145	0.120	-1.211	0.228
	Elevation					0.249	0.074	3.357	0.001

Table 2: Parameter estimates of a linear mixed effect model predicting reindeer preference to areas within 500 m zone of different real and fictive parallel power lines in relation to daytime (11:00 a.m. to 1:00 p.m) and nighttime (11: 00 p.m. to 1:00 a.m.) in two wild populations of Setesdal Vest-Ryfylke and Setesdal Austhei in southern Norway. In addition to the timing factor, vegetation (non-forest vs. forest) and elevation were included as predictors. Animal id, year and month were included as random factors. Reference levels for time and vegetation categorical variables were "nighttime" and "forest", respectively.

Power line	Variable	Setesdal Austhei				Setesdal Vest-Ryfylke			
		Estimate	SE	t-value	P-value	Estimate	SE	t-value	P-value
Real 300-420 kV north	Intercept	0.321	0.232	1.385	0.167	0.020	0.185	0.106	0.916
	Daytime vs. Nighttime	0.005	0.097	0.048	0.962	-0.0470	0.163	-0.289	0.773
	Non-forest vs. Forest	-0.355	0.222	-1.601	0.110				
	Elevation	0.148	0.064	2.320	0.021				
Fictive 3-km north from 300-420 kV	Intercept	0.181	0.157	1.153	0.251	-0.568	0.430	-1.322	0.189
	Daytime vs. Nighttime	0.194	0.120	1.610	0.110	-0.174	0.174	-1.003	0.318
	Non-forest vs. Forest					0.666	0.418	1.594	0.114
Fictive 6-km north from 300-420 kV	Intercept	-0.073	0.154	-0.473	0.637	0.984	0.988	0.997	0.322
	Daytime vs. Nighttime	0.020	0.139	0.140	0.889	0.371	0.198	1.875	0.065
	Non-forest vs. Forest					-1.165	0.997	-1.169	0.246
Fictive 3-km south from 300-420 kV	Intercept	0.124	0.173	0.717	0.476	-0.157	0.126	-1.244	0.215
	Daytime vs. Nighttime	-0.3307	0.196	-1.687	0.097	0.284	0.119	2.391	0.018
Fictive 6-km south from 300-420 kV	Intercept	-0.696	0.275	-2.530	0.014	-0.017	0.111	-0.155	0.877
	Daytime vs. Nighttime	0.507	0.184	2.751	0.008	0.053	0.136	0.391	0.696
	Non-forest vs. Forest	0.906	0.204	4.443	0.000				
Real 300-420 kV south	Intercept					0.084	0.245	0.342	0.736
	Daytime vs. Nighttime					-0.163	0.342	-0.477	0.639
Fictive 3-km north from 300-420 kV	Intercept					1.507	0.725	2.080	0.042
	Daytime vs. Nighttime					-0.271	0.204	-1.332	0.188
	Non-forest vs. Forest					-1.333	0.708	-1.884	0.064
Fictive 6-km north from 300-420 kV	Intercept					-0.194	0.158	-1.225	0.226
	Daytime vs. Nighttime					0.387	0.224	1.732	0.089
Fictive 3-km east from 300-420 kV	Intercept					-0.058	0.216	-0.267	0.791
	Daytime vs. Nighttime					0.268	0.262	1.021	0.314
Fictive 6-km east from 300-420 kV	Intercept					0.859	0.584	1.470	0.147
	Daytime vs. Nighttime					-0.102	0.199	-0.515	0.609
	Non-forest vs. Forest					-0.837	0.590	-1.419	0.161
	Elevation					0.247	0.108	2.288	0.026

Table 3: Parameter estimates of a linear mixed effect model predicting reindeer preference to areas within 200 m zone of different real and fictive parallel power lines in relation to daytime (11:00 a.m. to 1:00 p.m) and nighttime (11: 00 p.m. to 1:00 a.m.) in two wild populations of Setesdal Vest-Ryfylke and Setesdal Austhei in southern Norway. In addition to the timing factor, vegetation (non-forest vs. forest) and elevation were included as predictors. Animal id, year and month were included as random factors. Reference levels for time and vegetation categorical variables were "nighttime" and "forest", respectively.

Power line	Variable	Setesdal Austhei				Setesdal Vest-Ryfylke			
		Estimate	SE	t-value	P-value	Estimate	SE	t-value	P-value
Real 300-420 kV north	Intercept	-0.068	0.199	-0.339	0.736	-0.200	0.252	-0.793	0.435
	Daytime vs. Nighttime	0.053	0.153	0.345	0.731	0.150	0.294	0.508	0.615
	Elevation	0.234	0.079	2.966	0.004				
Fictive 3-km north from 300-420 kV	Intercept	-0.486	0.100	-0.486	0.629	-0.864	0.596	-1.450	0.161
	Daytime vs. Nighttime	0.297	0.207	1.435	0.157	-0.254	0.304	-0.836	0.412
	Non-forest vs. Forest	0.439	0.990	0.443	0.659	1.104	0.578	1.910	0.069
	Elevation	-0.236	0.106	-2.219	0.031				
Fictive 6-km north from 300-420 kV	Intercept	0.776	0.368	2.113	0.051	-0.077	0.199	-0.388	0.701
	Daytime vs. Nighttime	0.147	0.288	0.509	0.617	0.191	0.303	0.629	0.534
	Non-forest vs. Forest	-0.919	0.385	-2.385	0.030				
Fictive 3-km south from 300-420 kV	Intercept	-0.029	0.307	-0.094	0.926	-0.061	0.172	-0.356	0.723
	Daytime vs. Nighttime	0.059	0.342	0.174	0.864	0.190	0.192	0.988	0.328
Fictive 6-km south from 300-420 kV	Intercept	-0.594	0.307	-1.933	0.068	-0.045	0.182	-0.250	0.804
	Daytime vs. Nighttime	0.623	0.282	2.207	0.040	0.066	0.222	0.296	0.769
	Non-forest vs. Forest	0.808	0.294	2.744	0.013				
	Elevation					-0.221	0.121	-1.824	0.077
Real 300-420 kV south	Intercept								
	Daytime vs. Nighttime								
Fictive 3-km north from 300-420 kV	Intercept					0.146	0.292	0.500	0.624
	Daytime vs. Nighttime					-0.238	0.372	-0.639	0.532
Fictive 6-km north from 300-420 kV	Intercept					-0.244	0.270	-0.903	0.401
	Daytime vs. Nighttime					0.640	0.437	1.463	0.194
Fictive 3-km east from 300-420 kV	Intercept					0.001	0.374	0.002	0.998
	Daytime vs. Nighttime					-0.279	0.465	-0.599	0.564
Fictive 6-km east from 300-420 kV	Intercept					0.048	0.346	0.138	0.893
	Daytime vs. Nighttime					-0.055	0.349	-0.159	0.877

Table 4: Parameter estimates of a linear mixed effect model predicting reindeer preference to areas within 100 m zone of different real and fictive parallel power lines in relation to daytime (11:00 a.m. to 1:00 p.m) and nighttime (11: 00 p.m. to 1:00 a.m.) in two wild populations of Setesdal Vest-Ryfylke and Setesdal Austhei in southern Norway. In addition to the timing factor, vegetation (non-forest vs. forest) and elevation were included as predictors. Animal id, year and month were included as random factors. Reference levels for time and vegetation categorical variables were "nighttime" and "forest", respectively.

Power line	Variable	Setesdal Austhei				Setesdal Vest-Ryfylke			
		Estimate	SE	t-value	P-value	Estimate	SE	t-value	P-value
Real 300-420 kV north	Intercept	-0.067	0.226	-0.296	0.770	-0.325	0.294	-1.103	0.299
	Daytime vs. Nighttime	0.136	0.269	0.505	0.620	0.580	0.393	1.474	0.175
Fictive 3-km north from 300-420 kV	Intercept	0.268	0.367	0.728	0.474	0.122	0.452	0.269	0.797
	Daytime vs. Nighttime	0.286	0.287	0.996	0.330	-0.043	0.528	-0.082	0.937
Fictive 6-km north from 300-420 kV	Intercept	0.059	0.245	0.242	0.814	-0.049	0.301	-0.164	0.872
	Daytime vs. Nighttime	-0.078	0.377	-0.206	0.841	0.136	0.317	0.429	0.675
Fictive 3-km south from 300-420 kV	Intercept	-0.500	0.390	-1.284	0.240	0.227	0.188	1.209	0.241
	Daytime vs. Nighttime	0.548	0.350	1.564	0.162	-0.575	0.278	-2.072	0.054
Fictive 6-km south from 300-420 kV	Intercept	0.091	0.267	0.341	0.743	-0.050	0.256	-0.197	0.847
	Daytime vs. Nighttime	0.568	0.429	1.324	0.243	0.124	0.332	0.374	0.715
	Non-forest vs. Forest	-1.046	0.454	-2.302	0.055				
Real 300-420 kV south	Intercept								
	Daytime vs. Nighttime								
	Non-forest vs. Forest								
	Elevation								
Fictive 3-km north from 300-420 kV	Intercept					0.290	0.411	0.707	0.511
	Daytime vs. Nighttime					-0.465	0.520	-0.894	0.412
Fictive 6-km north from 300-420 kV	Intercept					-0.355	0.443	-0.800	0.482
	Daytime vs. Nighttime					1.291	1.000	1.295	0.419
Fictive 3-km east from 300-420 kV	Intercept					-0.205	0.762	-0.269	0.813
	Daytime vs. Nighttime					1.438	0.796	1.807	0.213
Fictive 6-km east from 300-420 kV	Intercept					0.757	0.628	1.205	0.263
	Daytime vs. Nighttime					-0.634	0.273	-2.320	0.259
	Elevation					0.471	0.164	2.877	0.213

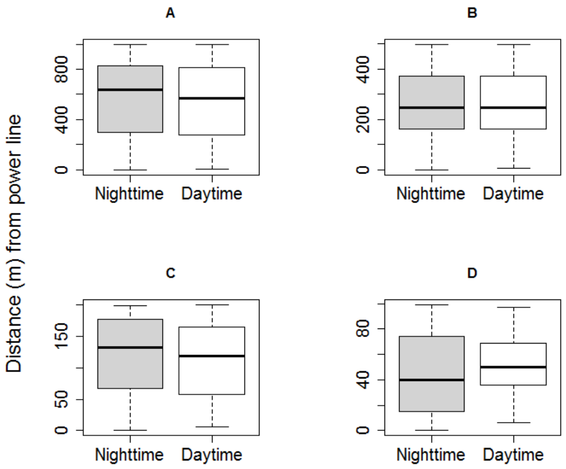


Figure 4: Reindeer preference to areas within four zones from real 420 KV power line in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Austhei in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

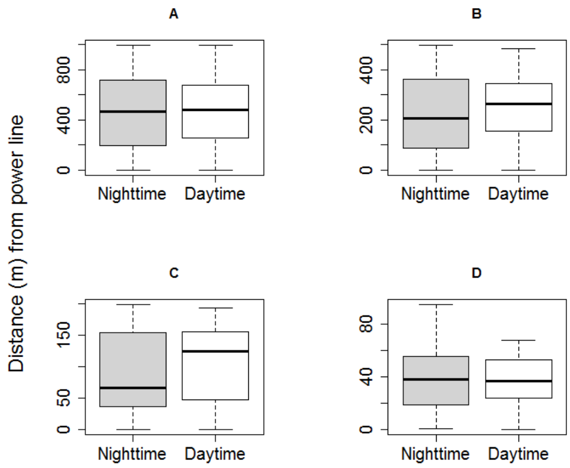


Figure 5: Reindeer preference to areas within four zones from control power line, 3 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Austhei in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

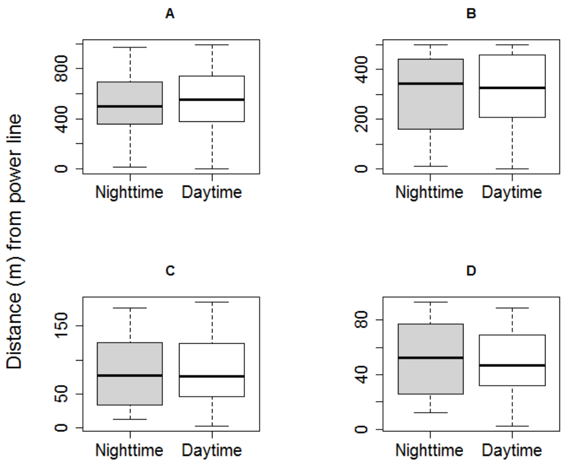


Figure 6: Reindeer preference to areas within four zones from control power line, 6 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Austhei in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

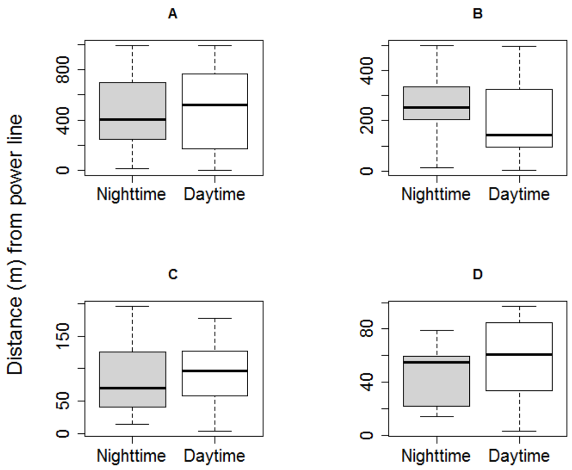


Figure 7: Reindeer preference to areas within four zones from control power line, 3 km south in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Austhei in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

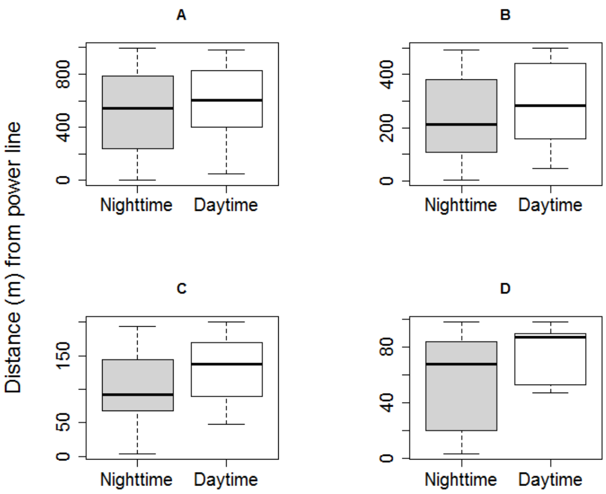


Figure 8: Reindeer preference to areas within four zones from control power line, 6 km south in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Austhei in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

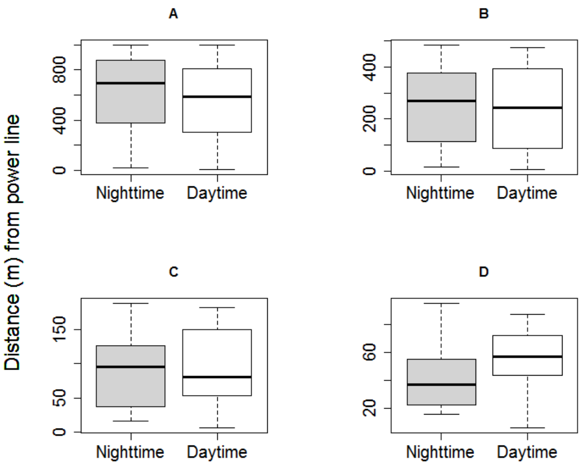


Figure 9: Reindeer preference to areas within four zones from real 420 KV power line in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke North in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

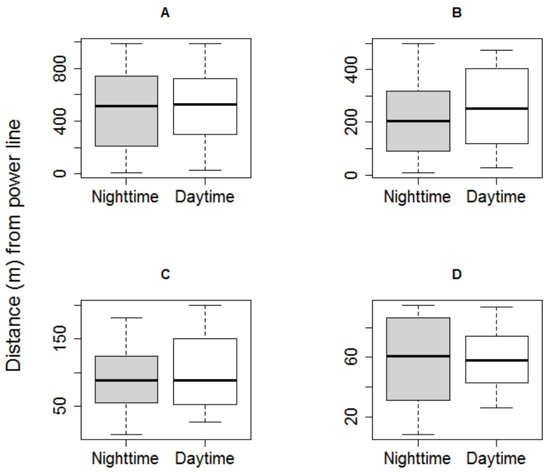
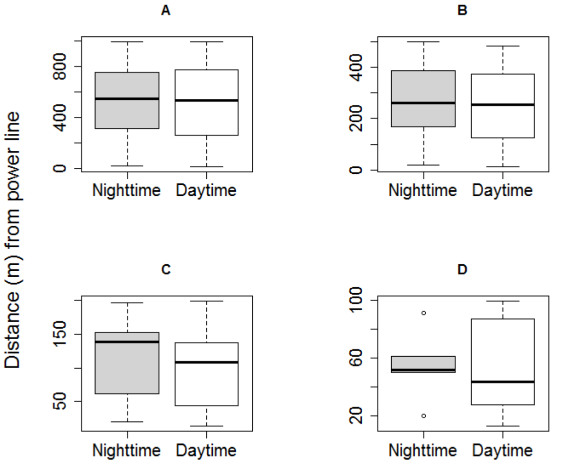


Figure 10: Reindeer preference to areas within four zones from control power line, 6 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke North in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.



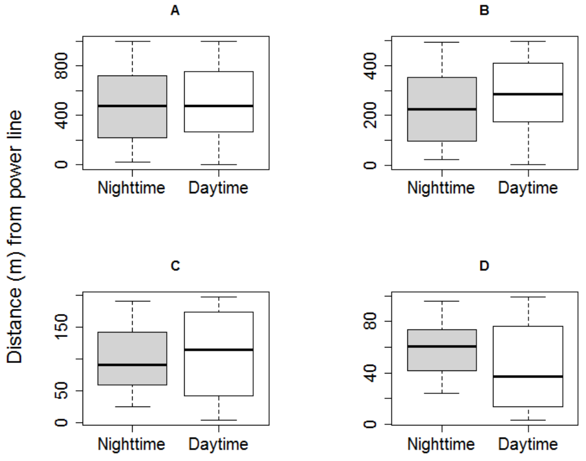


Figure 11: Reindeer preference to areas within four zones from control power line, 3 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke North in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

Figure 12: Reindeer preference to areas within four zones from control power line, 3 km south in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke North in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

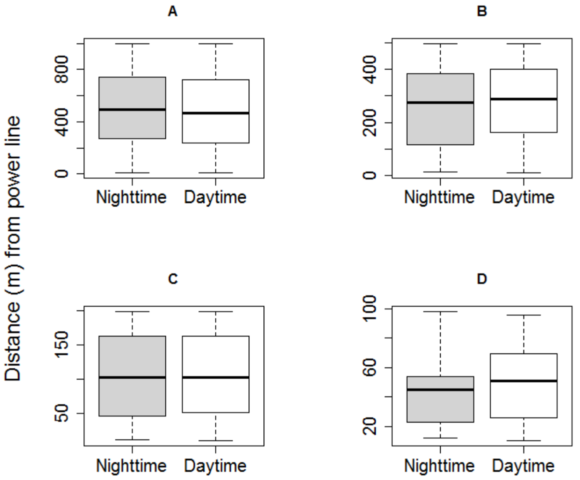


Figure 13: Reindeer preference to areas within four zones from control power line, 6 km south in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke North in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

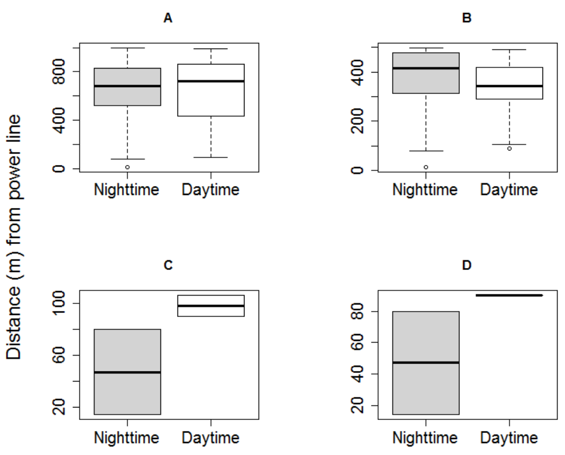


Figure 14: preference to areas within four zones from real 420 KV power line in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke south in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

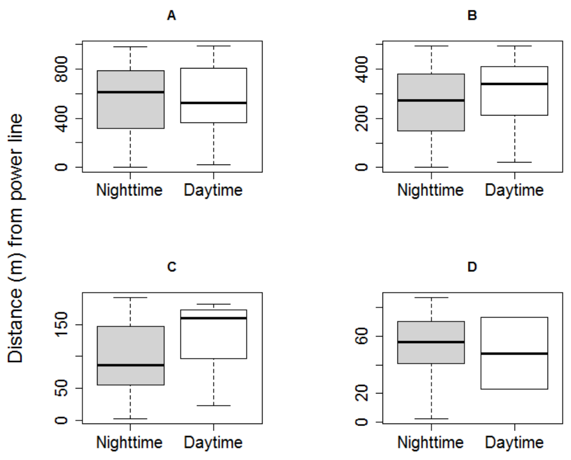


Figure 15: Reindeer preference to areas within four zones from control power line, 6 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke south in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

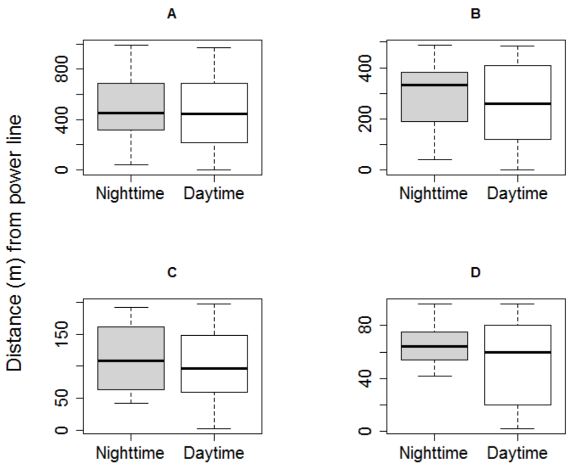


Figure 16: Reindeer preference to areas within four zones from control power line, 3 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke south in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

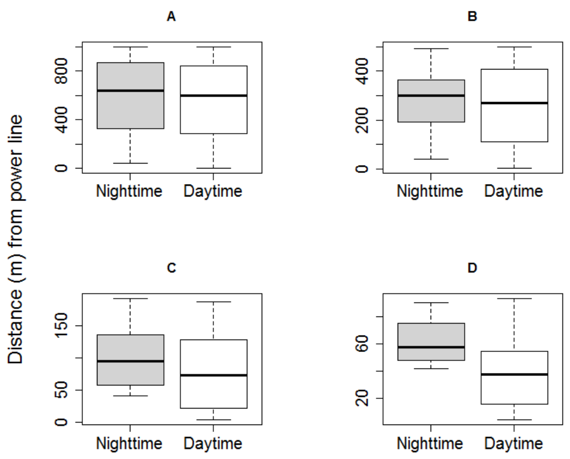


Figure 17: Reindeer preference to areas within four zones from control power line, 6 km east in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke south in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

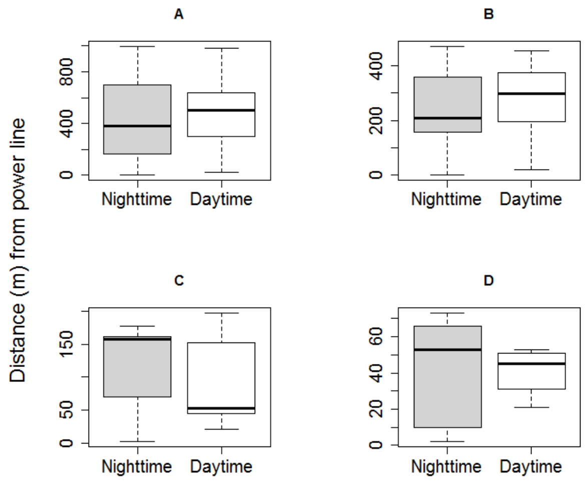


Figure 18: Reindeer preference to areas within four zones from control power line, 3 km east in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke south in southern Norway. A: 1 km zone; B: 500 m zone; C: 200 m zone; D: 100 m zone.

4. DISCUSSION

For all real power lines, there was no significant difference in reindeer's area use between nighttime and daytime in relation to distance to power line within 1 km, 500 m, 200 m or 100 m interval zones, indicating that the "UV"-hypothesis was not supported. The corona effect and UV-light from high voltage power lines did not appear to act as a significant disturbance on reindeer during months and hours of low luminance in both Setesdal Vest-Ryfylke and Setesdal Austhei. These results corresponds with other studies where power lines had little negative effect on reindeer's area use (Colman et al. 2014; Flydal et al. 2009; Reimers et al. 2007). I tested area use within 1 km of the chosen power lines. It is possible that reindeer's behavior response is at a larger scale. However, this is unlikely if the response is based on a sensory reaction from UV-discharges from high voltage power lines, as hypothesized by Tyler et al. (2014b). The prediction of difference in reindeer's area use between nighttime and daytime was based on UV-light from high-voltage power lines act as random flashes and UV-discharges is reflected and scattered by snow. This may increase the appearance of UV-light during months with snow-covered ground. If UV-discharges from high-voltage power lines disturb reindeer, this must occur during nighttime when UV-light is visible. If this is the case, then one would expect that reindeer has an increased aversion effect towards power lines during nighttime than daytime. However, the results from this study do not support this expectation.

My second prediction, i.e. no difference in reindeer's area use between nighttime and daytime within the tested corridors by the fictive power lines, was mostly supported. There were significant differences in reindeer's area use between nighttime and daytime within three of the twelve fictive lines, but this is a random effect (i.e. could be because of other environmental factors), as the "power lines" in question do not exist. It is possible to argue that reindeer's behavior and aversion effect can be transferred during daytime, and therefore not find difference in reindeer's area use between nighttime and daytime. However, the majority of the fictive control lines in this study indicates the same pattern as with the real power lines that were tested.

The corona effect is most dominant during specific climatic conditions, such as wind, high humidity and precipitation. The UV-discharge that comes from the corona effect is not a continuous source of light, but rather short, scattered glimpses of short duration (Bjerke 2015). It is known that reindeer can see UV-light (Hogg et al. 2011; Tyler et al. 2014a; Tyler et al. 2014b), although the results from my study show that reindeer do not avoid power lines more frequently during nighttime when their UV-vision is active (Tyler et al. 2014a). There is little knowledge about how far away such light or noise will be possible to perceive, and what carries furthest (Bjerke 2015). The power line south in Setesdal Vest-Ryfylke lacked data within the two closest distance intervals (100 m and 200 m). Lack of data may indicate that reindeer avoid this particular power line in general, or it may indicate that there is no suitable habitat for reindeer in this area. For the power line north in Setesdal Vest-Ryfylke, there was no significant difference in reindeer's area use between nighttime and daytime, but the box plot indicates that reindeer tend to stay closer to the power line within the 100 m zone during nighttime than daytime. Similar results were also found for the real power line in Setesdal Austhei. This may contradict what would be expected according to the predictions made, but makes sense if the reindeer are not affected more by the power lines at night, i.e. UV-light, compared to day.

The results from this study show no negative effect from the UV-discharge from high-voltage power lines. The reason for this might be reindeer's habituation towards UV-discharge, or simply a lack of fright towards such stimulus. Reindeer may perceive certain stimuli which do not incur any fright reactions. They may also respond to changes in their surroundings in a negative way, but then habituate (Reimers et al. 2000). Thus, if there was any initial negative behavioral reactions, the disturbance effect may decrease after some years (Algers & Hennichs 1983). Reindeer and other ungulates can habituate towards anthropogenic activities and structures (Reimers & Colman 2006). The animals eventually adapt to the stimuli after repetitive, non-negative exposure. In general, the explanation for reported large aversion distances and strong barrier effects has been that reindeer associate man-made structures with danger (Frid and Dill, 2002; Vistnes et al., 2004). Power lines do not facilitate human use after development and this could lead to a more rapid habituation, due to less moving objects, e.g. roads and human activity (Nellemann et al. 2001). Flashes of UV-discharge from power lines are random and it is believed that this might prevent habituation (Tyler et al. 2014b). Over time, reindeer might habituate to UV-discharge stimuli because there is no danger related to the electrical phenomenon. Domestication of reindeer will also influence the animal's behavioral response towards humans and infrastructure (Reimers et al. 2012). The reindeer population in Setesdal Vest-Ryfylke is considered wild, while the population in the Setesdal Austhei is a former domestic reindeer population that was classified as wild in the 1970's. The former domestic reindeer population could have a higher tolerance for human disturbances. However, I found no significant difference in reindeer's area use between nighttime and daytime in relation to distance to power line between the two different study areas.

Several factors may have an impact of whether ungulates choose to cross under power lines. Such factors can be topography, vegetation, important locations for foraging and calving, time of year, climate and the age, sex, physical and psychological condition of the animals and their earlier experience (Reimers et al. 2000). Differences in reindeer's area use between non-forest and forest habitat and in different elevation varied between the different power lines across distance zones. During the winter months, reindeer seek areas with uneven terrain and alpine ridges where they have access to lichens (Hjeljord 2008). This could explain why we found difference in elevation area use by some power lines. In addition, reindeer may be located in different areas of elevation between nighttime and daytime during the winter months, while searching for forage. For the fictive control lines, there were also significant differences in reindeer's area use between non-forest and forest habitat. This means that reindeer in these areas prefer either forest or non-forest habitat within the different intervals for each particular tested area. Often, these fictive control lines were located along routes with significant differences in elevation. Non-forest vegetation occurs at higher elevations and reindeer might prefer these types of habitat during the winter months.

Setesdal Vest-Ryfylke is highly affected by a coastal climate (Mossing & Heggenes 2010). In the west of the heathland the annual precipitation is 2500 mm or more. Going further east, the annual precipitation declines and northeast of Bossvatn in Bykle the annual precipitation is approx. 1000 mm. The climate in Setesdal Austhei is a mixture of coastal and inland climate. Annual precipitation ranges from 750 mm in Bykle to 1250 mm in Åmli (Strand et al. 2011). The corona effect is most dominant during climatic conditions with wind, high humidity and precipitation (Bjerke 2015). The results from this study had no significant difference between the two areas (Setesdal Vest-Ryfylke and Setesdal Austhei) in reindeer's area use between nighttime and daytime, and thus, climate might not be related to avoidance of power lines at all.

5. CONCLUSION AND MANAGEMENT IMPLICATIONS

No difference was found in reindeer's area use between daytime and nighttime within intervals of 1 km, 500 m, 200 m and 100 from power lines in Setesdal Austhei and Setesdal Vest-Ryfylke during the fall, winter and spring months of 2007-2014. These results imply that UV-discharge from high-voltage power lines are not perceived as a danger for the reindeer within the tested areas and do not act as an aversion effect. Reindeer may perceive UV-discharge, but not react towards this stimulus in any negative manner. They might also have habituated towards UV-discharge stimuli over time because there is no danger related to the electrical phenomenon. UV-discharge might be more dominant under particular weather conditions, thus, future studies should include weather data. Also, due to classical conditioning, (or even large time scale autocorrelation) negative effects during night may also lead to negative effects during day. This may be the reason for why we see an increase in the density of GPS-points further away the power line in Setesdal Austhei North and Setesdal Vest-Ryfylke South, but it may also be caused by other factors like elevation, snow depth, or vegetation, especially since we do not see the same trend in all three areas. To investigate this further, these other factors should be included in the analyses. Reindeer's selection of area use close to high-voltage power lines during daytime and nighttime in winter months can be more dependent on forage quality and quantity rather than potential disturbing effects from the power lines. With increasing development of power lines in reindeer habitat, it is important to have knowledge about possible impacts this can have on reindeer and their area use for future developments. This study provides important information about possible consequences from power lines in areas where reindeer can be affected.

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7. APPENDICES

Setesdal Austhei North power line and control line

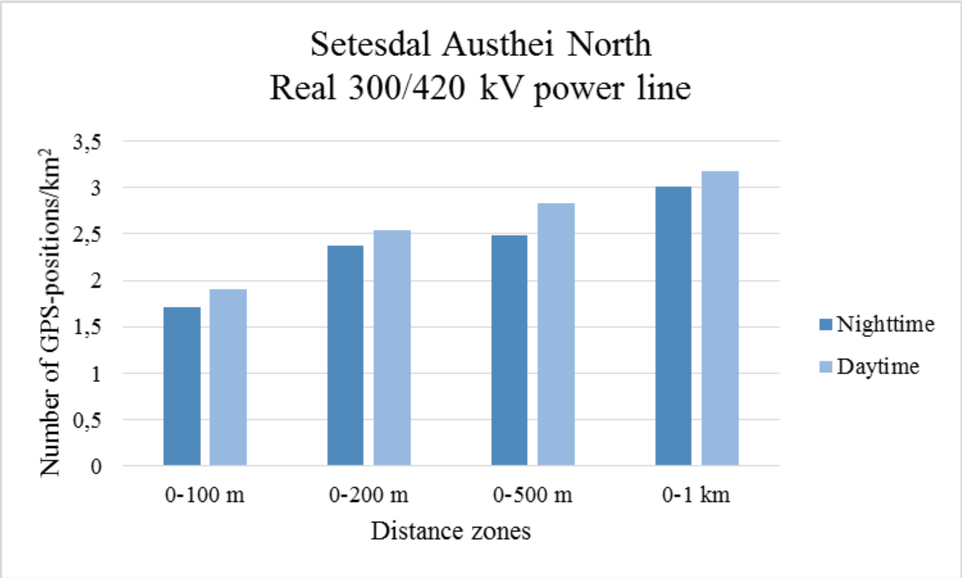

Figure A1: Number of GPS positions/km² within each of the four distance zones from real 420 kV power line in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Austhei in southern Norway.

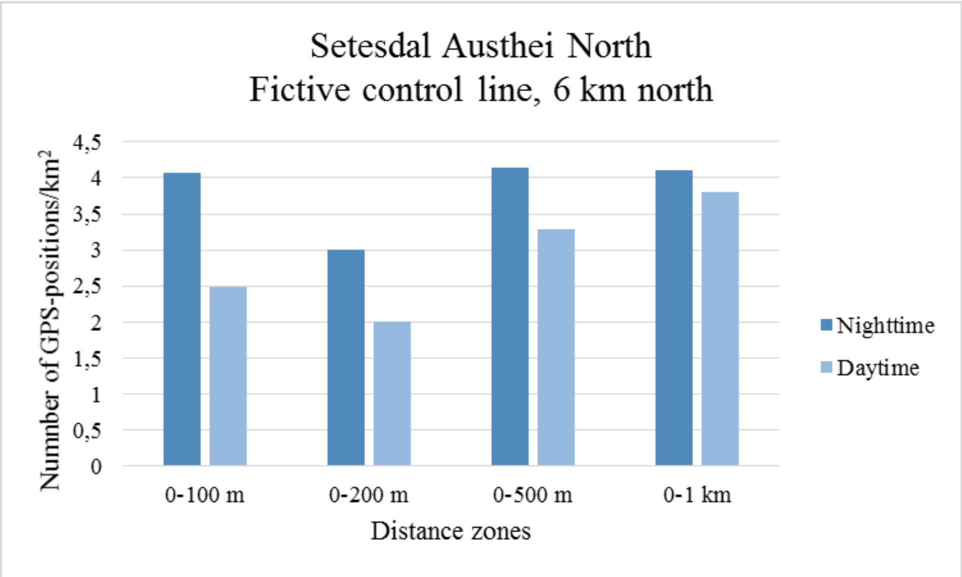

Figure A2: Number of GPS positions/km2 within each of the four distance zones from control power line, 6 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Austhei in southern Norway.

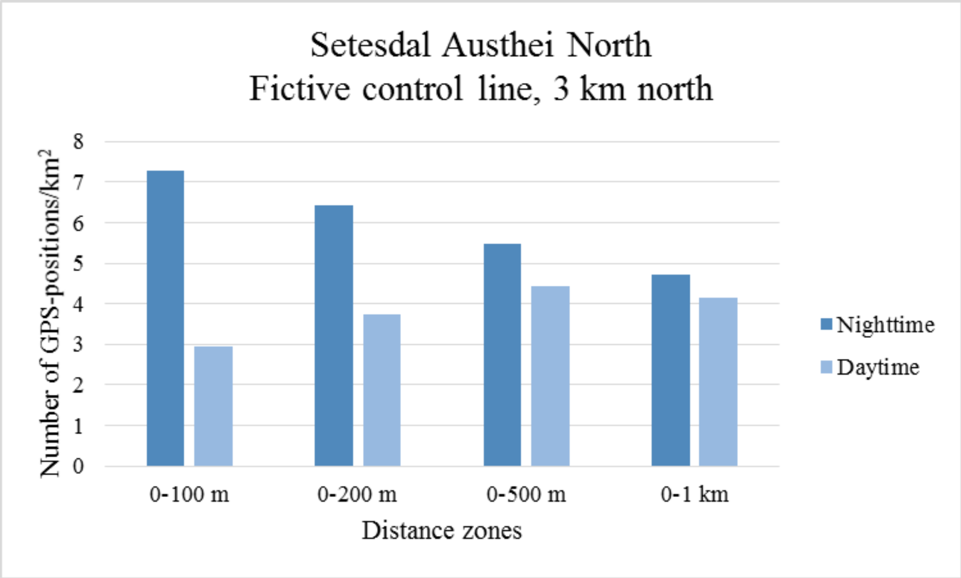

Figure A3: Number of GPS positions/km^2 within each of the four distance zones from control power line, 3 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Austhei in southern Norway.

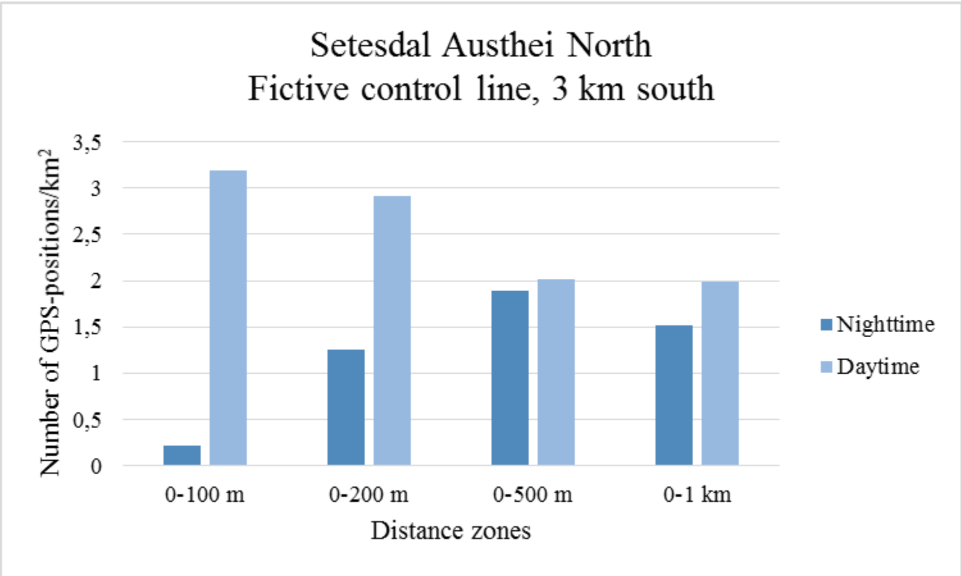

Figure A4: Number of GPS positions/km^2 within each of the four distance zones from control power line, 3 km south in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Austhei in southern Norway.

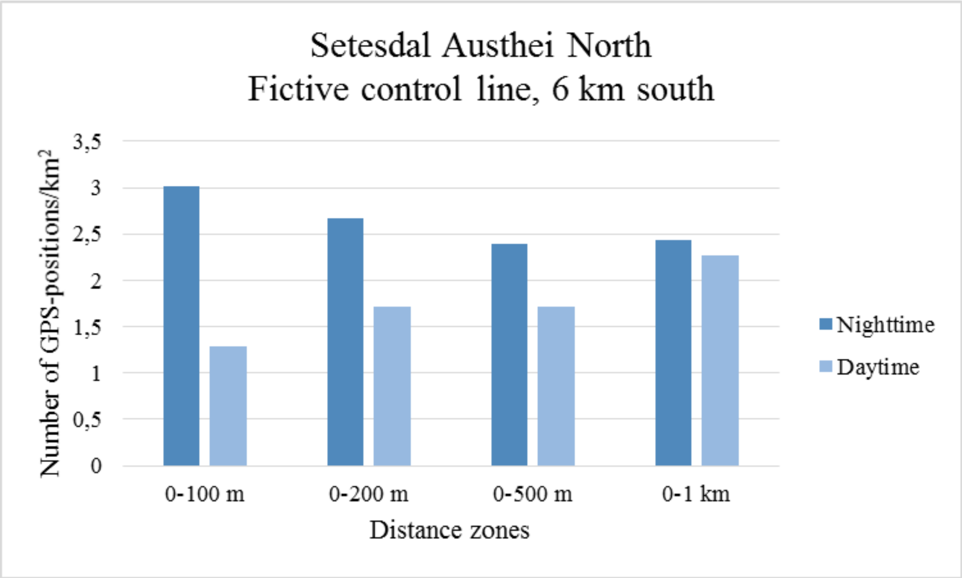

Figure A5: Number of GPS positions/km^2 within each of the four distance zones from control power line, 6 km south in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Austhei in southern Norway.

Setesdal Vest-Ryfylke North power line and control line

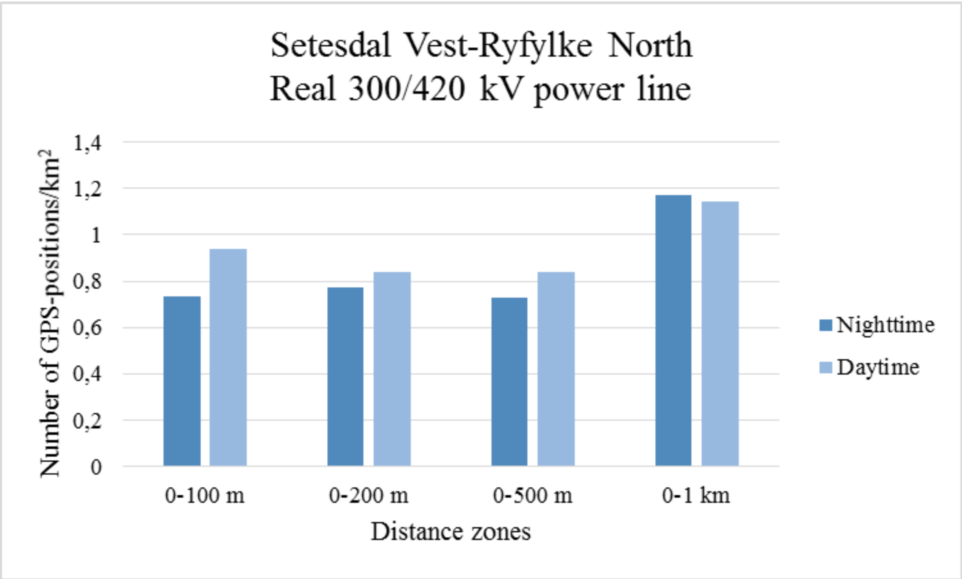

Figure A6: Number of GPS positions/km^2 within each of the four distance zones from real 300/420 kV power line in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke North in southern Norway.

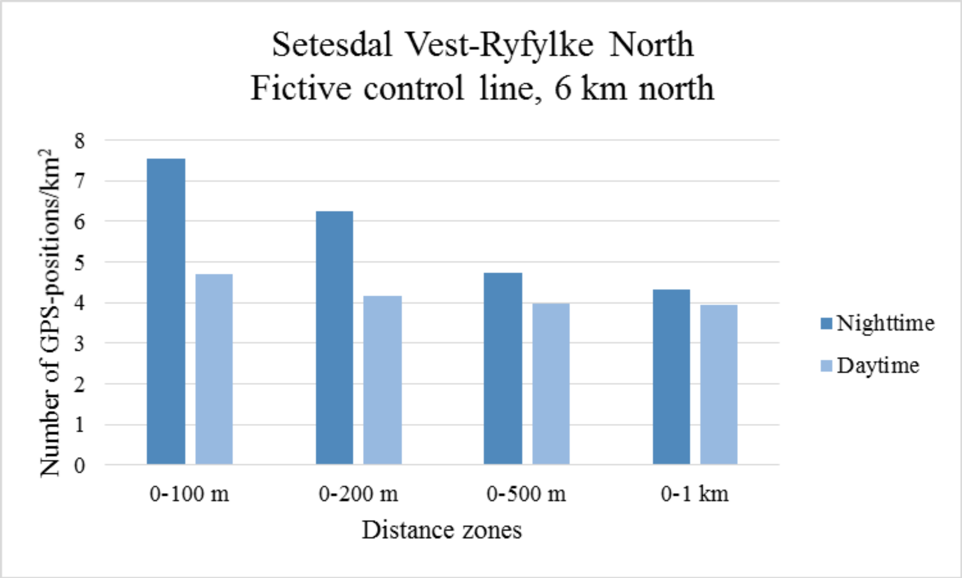

Figure A7: Number of GPS positions/km^2 within each of the four distance zones from control power line, 6 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke North in southern Norway.

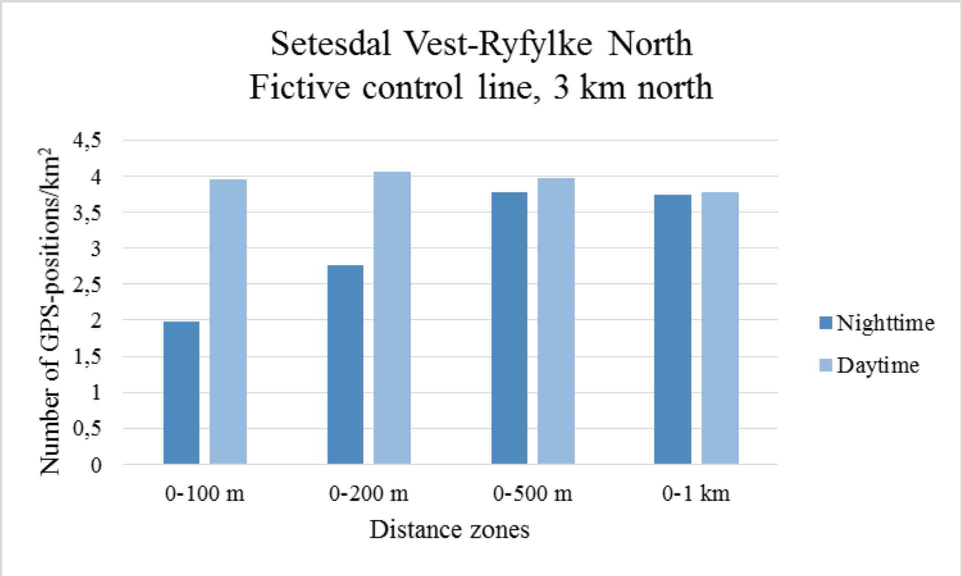

Figure A8: Number of GPS positions/km^2 within each of the four distance zones from control power line, 3 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke North in southern Norway.

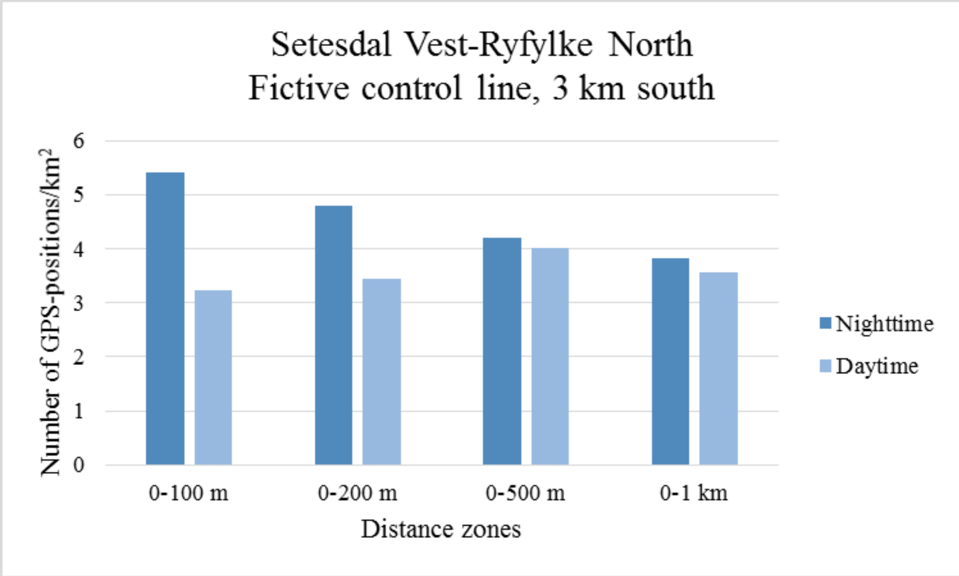

Figure A9: Number of GPS positions/km^2 within each of the four distance zones from control power line, 3 km south in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke North in southern Norway.

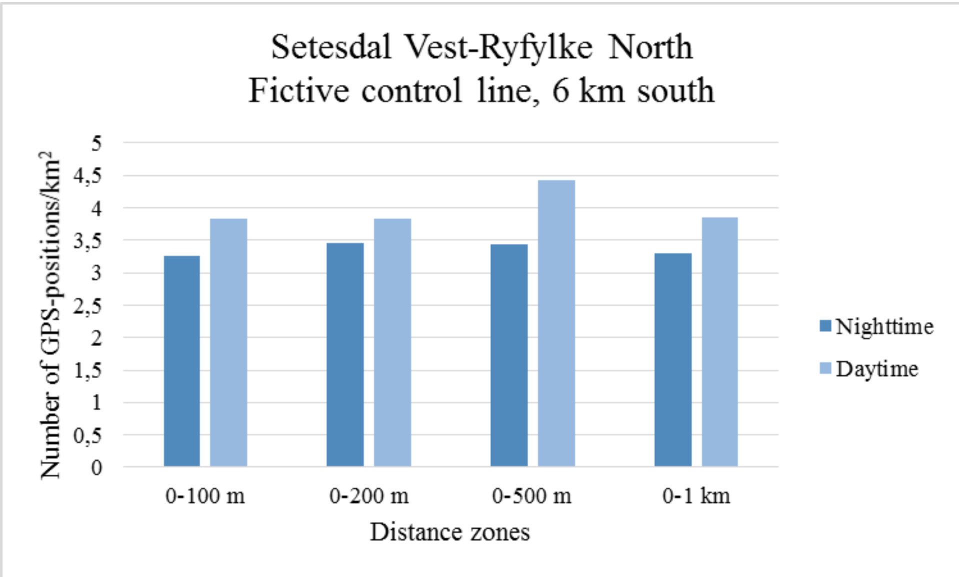

Figure A10: Number of GPS positions/km^2 within each of the four distance zones from control power line, 6 km south in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke North in southern Norway.

Setesdal Vest-Ryfylke South power line and control line

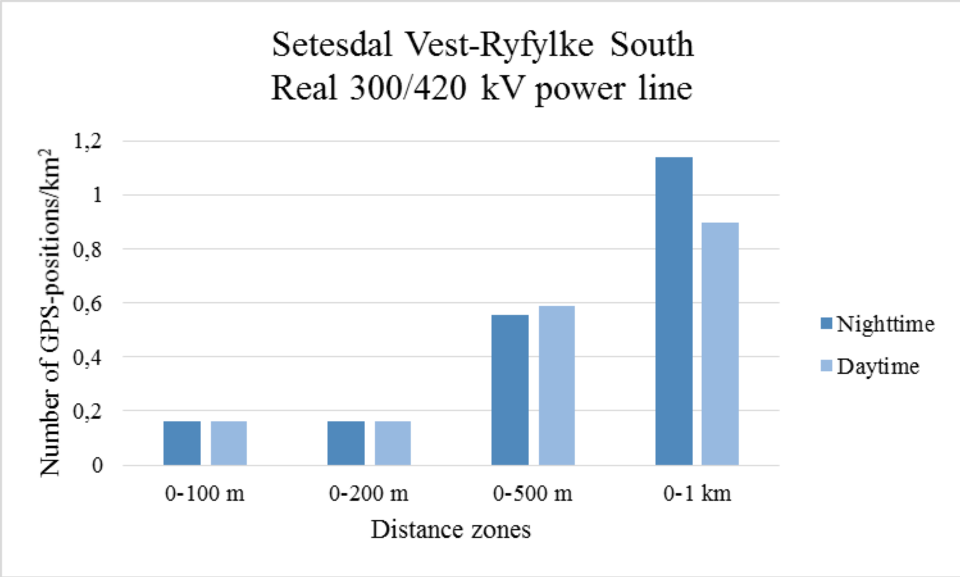

Figure A11: Number of GPS positions/km^2 within each of the four distance zones from real 300/420 kV power line in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke South in southern Norway.

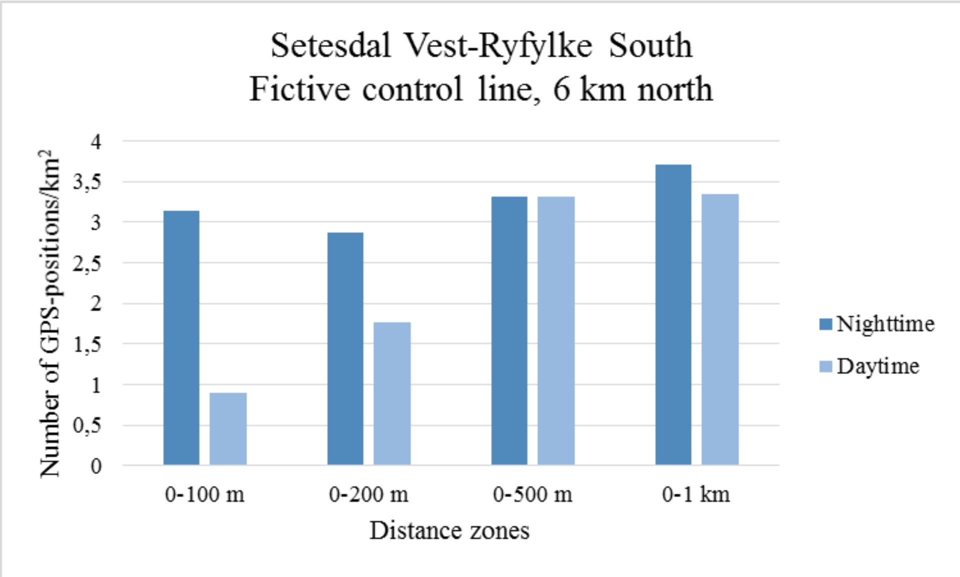

Figure A12: Number of GPS positions/km^2 within each of the four distance zones from control power line, 6 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke South in southern Norway.

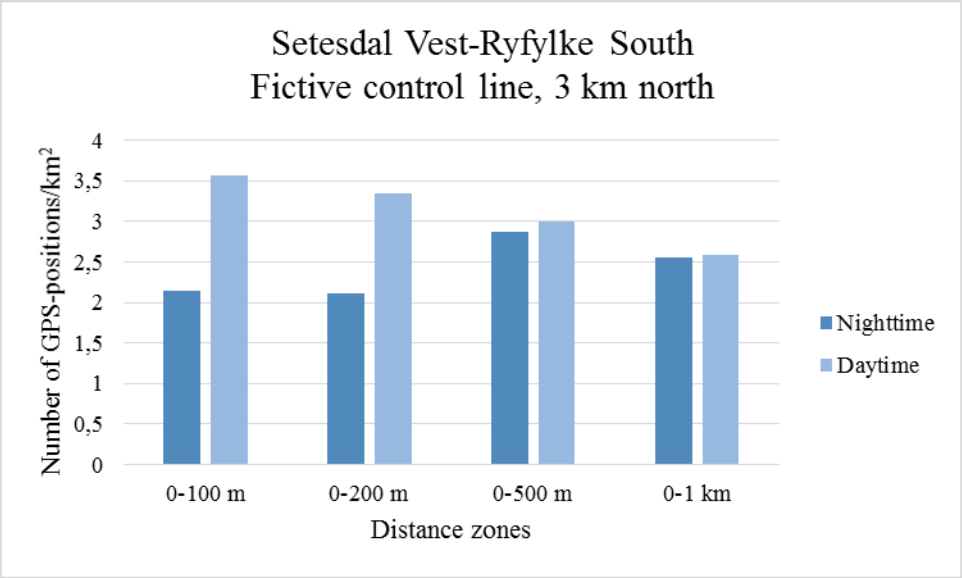

Figure A13: Number of GPS positions/km^2 within each of the four distance zones from control power line, 3 km north in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke South in southern Norway.

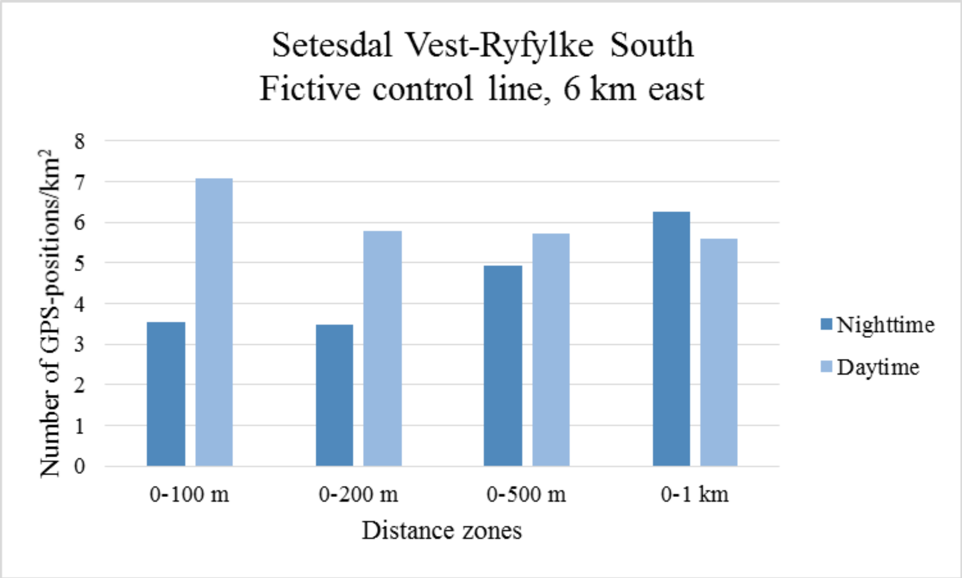

Figure A14: Number of GPS positions/km2 within each of the four distance zones from control power line, 6 km east in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke South in southern Norway.

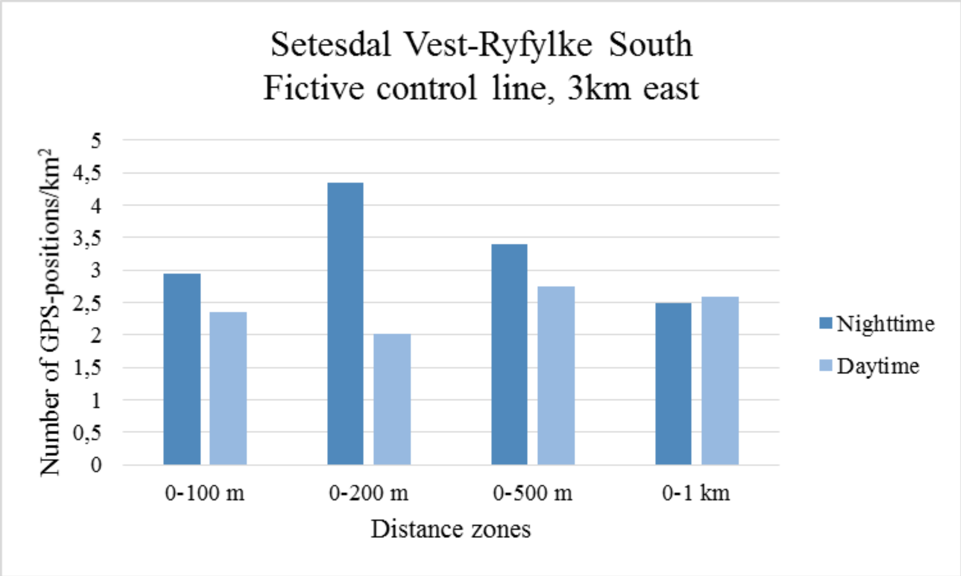

Figure A15: Number of GPS positions/km^2 within each of the four distance zones from control power line, 3 km east in relation to daytime (11:00 a.m. to 1:00 p.m.) and nighttime (11: 00 p.m. to 1:00 a.m.) in Setesdal Vest-Ryfylke South in southern Norway.

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