Reindeer fidelity to high quality winter pastures outcompete power line barrier effects

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Abstract: We investigated barrier effects of a 66 kV power line established in 1966 before and after the line was upgraded to 132 kV in 2004 over a period of 44 years (1974-2017) in the North Ottadalen wild reindeer area (3245 km^2) of which 1038 km^2 are in use as winter pastures. The power line transects a peninsula (135 km^2) with high quality winter pastures in the southeast periphery. The reindeer population originated from a nucleus herd of 402 animals of domestic origin released in the area in 1964-1965 and 100 resident wild animals. Yearly winter survey started in 1974 and reindeer were first surveyed south of the 66 kV power line in 1982. Comparing the number of animals recorded in the peninsula vs. the number of individuals expected relative to available grazing area during the three periods (1974-2004, 1982-2004 and 2005-2017), the number of animals recorded in the peninsula was 3.6–4.9 times higher than expected. Since the upgrade of the power line, a substantial part of the reindeer population grazed in the peninsula every year. We therefore conclude that there was no long-term barrier effect from the original power line and no barrier effects at all from the upgrade. However, during the first 5 surveys of this study, there were no animals in the peninsula. Therefore, even if there are several possible reasons for this, we cannot exclude the possibility of short-term barrier effects resulting from the construction of the original power line. Our results support recent studies that report no effects from existing power lines and contrast some previous findings that have reported strong long-term barrier and avoidance effects of such infrastructure for *Rangifer* migration and grazing behaviour.

Key words: Area use; avoidance; disturbance; power lines; *Rangifer tarandus tarandus*; winter grazing.

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Introduction

Reindeer and caribou (*Rangifer* sp.) is a model species for a variety of population ecology questions, including those relating to human activities and infrastructure and scaling effects, because of their variation in genetics genetics (Flagstad & Røed, 2003; Røed, 2005), behaviour (Reimers *et al.,* 2012), body condition (Reimers, 1983), large population ranges (Reimers *et al.,* 1980), and circumpolar distribution (Banfield, 1961; Flydal *et al.,* 2019). Changes in area use of ungulates may be linked to resource selection responses in a changing environment or the fidelity to areas that confer benefits such as familiarity with resources and topography, access to seasonal food resources, and predator avoidance (Greenwood, 1980; Barraquand & Benhamou, 2008; Bergerud *et al.*, 2008). Even if site fidelity varies in time and space, and affected by multiple factors, human infrastructures among others, it is well documented for both reindeer e.g. (Panzacchi *et al.*, 2013a; Panzacchi *et al.*, 2013b; Colman *et al.*, 2015) and caribou (e.g. Schaefer *et al.*, 2000; Wittmer *et al.*, 2006). Giuggioli and Bartumeus (2012) defined site fidelity as the recurrent visit of an animal to a previously occupied area. Although the same areas are used over many years, some changes in preferred areas occur in timespans of several decades (Courtois *et al.*, 2003) as grazing conditions, environmental factors and anthropogenic disturbance are elements that may vary within or between years.

In Norway, thousands of kilometres of power lines exist in wildlife habitats and more are in the planning. Many of these lines cross mountain ranges that are favoured by tourists in general and specifically mountain hikers who are uncomfortable with such installations in otherwise unspoiled nature. In particular, according to mainstream public opinion, power lines were thought to influence reindeer movement through barrier and avoidance effects as a result of behavioural responses induced by the sight, sound, or smell of humans or human artifacts, either directly perceived or associated through learning (Nellemann & Jordhøy, 2000).

Follow up studies reported serious barrier and avoidance effects from power lines and associated human infrastructure ranging from predicted significant population size reduction (Nellemann & Jordhøy, 2000), reproduction failure (Nellemann *et al.*, 2003), loss of available winter ranges (Nellemann *et al.*, 2001; Vistnes *et al.*, 2001) and finally, substantial reduction in available ranges and traditional migration routes (Vistnes *et al.*, 2004; Vistnes, 2008).

Contrary to these reports, Reimers et al. (2007) and Flydal et al. (2009) found neither behavioural nor aversion/barrier effects from power lines on reindeer area use or migration habits. Furthermore, recent GPS-studies did not find negative effects during the operational period for power lines alone either (Panzacchi *et al.*, 2013a; Eftestøl *et al.*, 2016; Colman *et al.*, 2017). This dichotomy may reflect that *Rangifer* habitat use and feeding preferences in response to human activities and infrastructure are governed by a complexity of natural interacting factors. Domestication, habituation and sensitization are essential in shaping *Rangifer*'s adaptability, and should be included in discussions of reindeer and caribou responses towards various anthropogenic activities. The lack of consistency between results from these studies on reindeer reactions towards infrastructure in general and power lines in particular leads to management challenges (Pape & Loeffler, 2012; Flydal *et al.*, 2019). Here we contribute to this issue by presenting extended data and analysis from a long-term survey on reindeer population size and spatial distribution.

The power line study in North Ottadalen (Reimers *et al.*, 2007) evaluated the effect of a 66 kV from 1974 until it was upgraded to 132 kV in 2004, concluding there were no effects from the power line before the upgrade. Here, we follow up reindeer area use on the peninsula transected by the upgraded 132 kV line from 2005 to 2017, test the prediction by Reimers et al. (2007) of no barrier-impact from the established and upgraded power line, and discuss possible reasons for our results. To avoid similar misinterpretation as done by Tyler et al. (2016) who used Reimers et al. (2007) in support of strong barrier effects (see (Haukos, 2016), we also include additional use-availability analyses of the data material presented in Reimers *et al.* (2007).

Study area

The North Ottadalen wild reindeer management area (3245 km^2) is located in the Ottadalen mountain range at approximately 62°N, 8-9°E (Fig. 1); see Reimers et al. (2007) for a more detailed area description. The reindeer population originates from a nucleus herd of 402 animals of domestic origin released in the area in 1964-1965 in Brøstdalen and Ulvådalen in the northwestern corner south of Bjorli at the Ottadalen wild reindeer range (Fig. 1). The nucleus herd mixed with some 100 resident wild animals giving a total population of 502 animals in 1965. Reindeer hunting started in 1967. According to air surveys the herd had increased to 3358 animals in the winter of 1974 at a time when the animals expanded their grazing to include most of the North Ottadalen mountain range. By then, the local management authorities (Villreinutvalget) decided to limit the herd size between 2000 and 3000 animals in order to prevent overgrazing of the winter pastures.

Three power lines, mostly in the sub- and low alpine region, intersect the study area. Two lines, 132 kV and 300 kV, put into operation

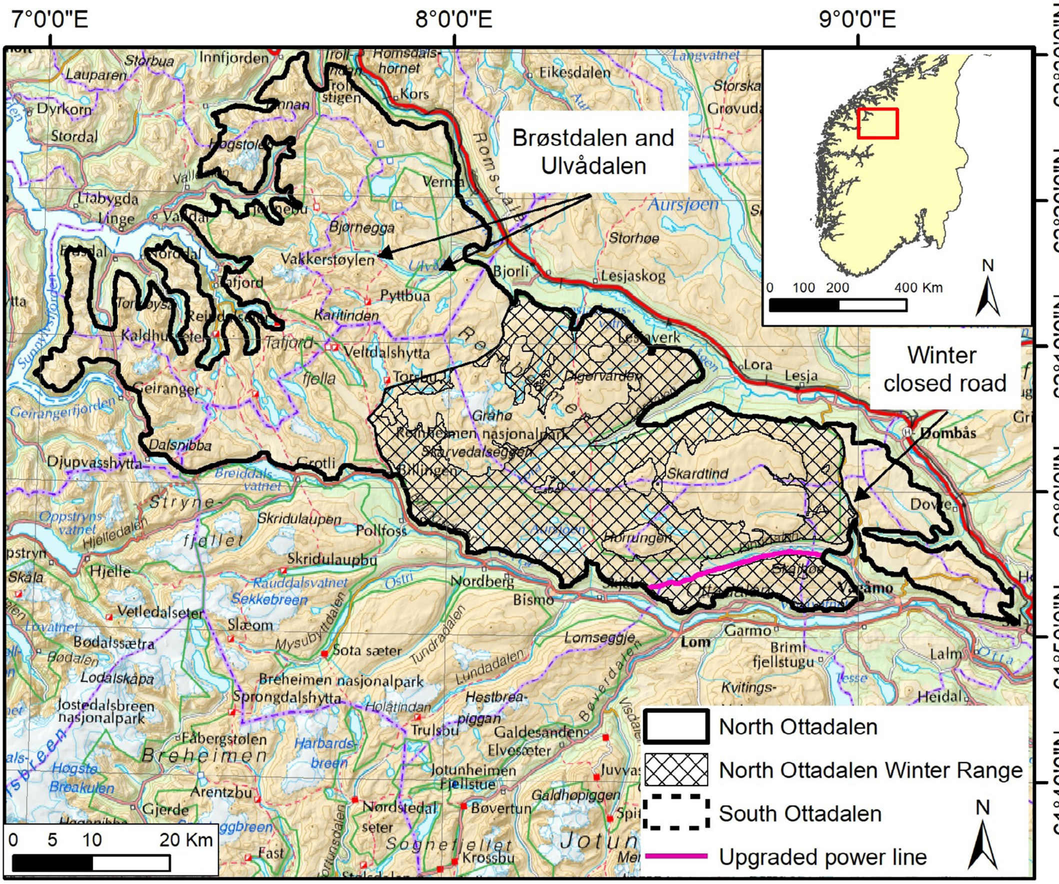

Figure 1. The 66 kV power line, upgraded in 2004 to 132 kV (purple line), that transect a peripheral peninsula (135 km^2) of North Ottadalen wild reindeer area (3245 km^2). Hatched areas (1038 km^2) indicate available winter pastures between 1000 and 1500 m.a.s.l within the peninsula (99 km^2) and the rest of the area (939 km^2). The two parallel power lines (132 and 400 kV) and the winter closed road run north-south at the eastern border of the North Ottadalen winter range. The nucleus herd was introduced to the areas in Brøstdalen and Ulvådalen in the north-western part of the mountain range.

in 1963 and 1974, respectively, run parallel to a winter closed road north-south along the eastern border of the area. The 66 kV power line established in 1966 and upgraded to 132 kV in summer 2004, the one we focus here as a possible barrier, crosses the area in the south-eastern part of the range (Fig. 1). The south-eastern power line has no other infrastructure associated with it. A summer hiking trail intersects the central part of the North Ottadalen range but is of minor use as there are no tourist facilities available in this central and eastern part of the area. We define the total available winter pastures in current use as all areas between 1000 and 1500 m.a.s.l. as described by Vistnes et al. (2004), located west of the winter closed road between the municipalities of Lesja and Vågå and east of Asbjørnsdalen/Torsvatnet (Fig. 1) (K. Granum, unpublished data). This is a conservative estimate since animals were also observed outside this area during winter (see the result and discussion sections). Based on this estimate, the total winter range size available to reindeer use in North Ottadalen is approximately 1038 km^2, of which 99 km^2 are within the peninsula cut off by the power line in question (Fig. 1).

No extensive pasture quality study is carried out within the North Ottadalen winter range. In similar climatic and low alpine mountain areas, ridge communities with lichen usually compose 25–35% of the vegetation (Gaare *et al.*, 2001). However, due to its longitudinal expansion, its divided into an oceanic western part with heavy rainfall and mild winters and a drier continental part with colder winters (Reimers *et al.*, 2005). In the oceanic western part, where precipitation often exceeds 1800 mm annually, reindeer winter pasture (lichen growth) is largely replaced with summer pasture (graminoid fields) and large snow bed communities with dominant least willow *(Salix herbacea*). However, low precipitation, 400 mm annually in this eastern low alpine part of the study area, favour extensive lichen dominated plant communities with high biomass of the lichen species favoured by reindeer, *Cetraria nivalis* and *Cladonia stellaris,* making the eastern part of the range, including the peninsula in question, excellent winter pastures (Reimers *et al.*, 2007). Also, Vistnes *et al.* (2004) recorded lichen height/ biomass in the eastern part that adhere to the definition of high quality lichen pastures in this part of the range. Except from the geographical position (peripheral vs everything else) and the east-west gradient descripted above, there are no other clear differences between the areas within the winter range.

In general, the reindeer approach the peninsula in November and appear to remain in this area during December-March, and begin moving west and north towards the calving areas located in the interior in April (K. Granum, unpublished data), when the first females give birth (Flydal & Reimers, 2002).

Material and methods

We used official aerial surveys, carried out by the local wild reindeer authorities (Villreinutvalget supervised by coauthor K. Granum), of reindeer distribution during one or, if the first survey was incomplete, two consecutive day(s) in February-April (mostly February-March). The surveys were carried out in 33 out of 44 years when weather and snow condition were favourable, allowing a search of the whole area for the entire study period (1974-2017). During years with air surveys the population size was based on counts. For other years estimates are mainly interpolations using information on population size and harvest rates the year before. Based on a nucleus herd of 502 animals in 1965 and 3358 animals in 1974, the average growth rate in this period was 1.24 (502*1,2351^9=3358). In 1975 Villreinutvalget conducted aerial survey on February 26 and March 21 and recorded 3250 and 3280 animals, respectively, indicating that surveys are relatively reliable or at least capture trends. During 2012-2017, between November and April, we also conducted ground surveys, mostly with snowmobiles, to provide a better understanding of the area use throughout winter. For all surveys, groups were classified as mixed (females, calves, and young males) and male groups, and their positions were recorded on 1:50.000 maps. Generally, females and younger animals were found in two to three large groups (> 300 animals), while the males frequently appeared in groups smaller than 100 animals. The hunting quotas are based upon these surveys, and during the survey years, there has been a successful match between expected and documented population size. While we are confident that the big groups of females and younger animals were found, photographed, and accurately counted the different years, smaller groups of mostly males may have been overlooked some years.

Analyses

For the aerial survey data, we used descriptive statistics to evaluate the relative difference between the number of wild reindeer counted and expected south of the 66 kV power line before (1974-2004 or 1982-2004) and after its upgrade to 132 kV (2005-2017). According to the aerial survey data, 1982 was the first year reindeer were known to graze on the peninsula. We therefore excluded years before 1982 in one of the comparisons for the period before the upgrade. We did separate comparisons for each period. If there were no barrier effect from the power line, i.e. not selection of specific areas, we assumed the expected number of animals in a given site would be proportional to the relative size of that site. Based on that, we calculated the expected number of animals south of the power line based on the relative size of the area and compared it to the actual number of individuals. The winter range was 99 km^2 within, and 939 km^2 outside the peninsula. Thus, if used in a homogeneous way, and in the absence of a barrier effect, the expected number of animals within the peninsula would be approximately 9.5 % of the population each year.

Similarly, we used descriptive statistics to illustrate difference between observed vs. expected number of reindeer during 2012-2017 for the direct observation data. During ground surveys in this period, 17 out of 157 groups were observed outside the estimated winter range. We excluded these groups from the calculations (5 groups within the peninsula and 12 groups outside the peninsula). Out of the 17 groups counted outside the estimated winter range, 11 were observed during November or April, i.e. very early or late in the season (see also Fig. 5 and results below). For both the aerial survey and direct observation, we used figures to illustrate the relative differences. All descriptive statistics and figures were done in R version 3.5.1 (R Core Team, 2018) or Excel spreadsheet (Microsoft, 2016).

Results

Aerial surveys

During 1974-2004, the period when the 66 kV power line was a potential movement barrier, the entire North Ottadalen mountain range was surveyed for 20 years. In 13 of these years, an average of 61.9 % ± 31.0 (SD) of the reindeer herd had crossed the line and was found on the 99 km^2 (9.5 % of the whole winter range) south-eastern peninsula transected by the power line (Fig. 2). In the remaining 7 years, all within the period of 1974-80 and 1990-91, no animals were located on the peninsula on the survey day(s). If we include these 7 years with no animals on the peninsula, the average proportion of the population on the peninsula each year was 40.2 % ± 39.0 (SD). During the follow-up study in 2005-2017, reindeer crossed the upgraded 132 kV power line all years (Figs. 2, 3). During these 13 years, an average of 77.5 % ± 17.1 (SD) of the total herd was found grazing on the peninsula on the survey day(s). For all three periods (1974-2014, 1982-2004 and 2005-2017), we found that the number of animals recorded on the peninsula was higher than expected relative to available grazing area (Fig 4).

Ground surveys

During 32 surveys in winter (November-April) in the period 2012-2017, a total number of 63

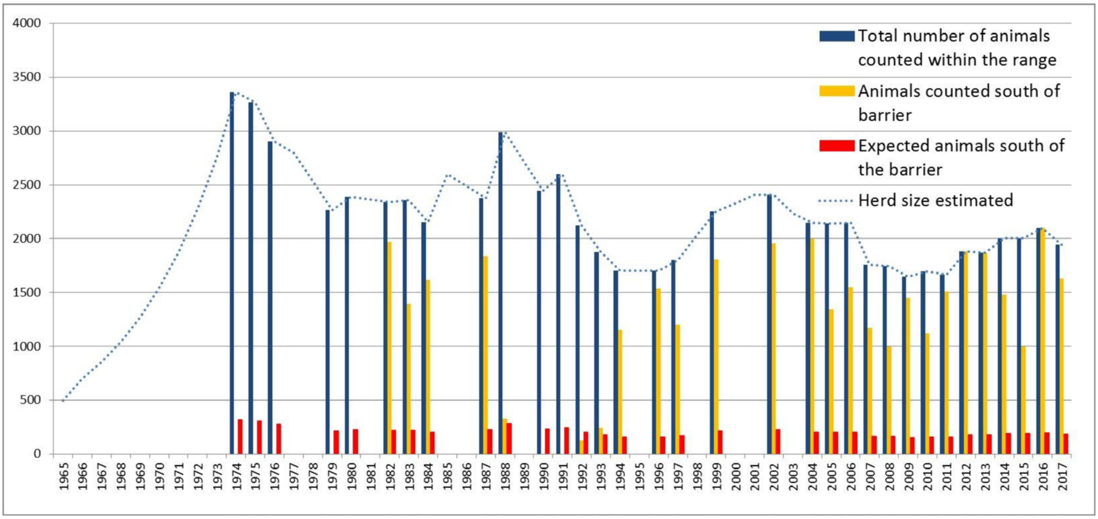

Figure 2. Wild reindeer winter herd size counted or estimated (dotted line) and the number of reindeer recorded and expected on the peninsula (bars) during air reconnaissance and animal surveys in the period 1974-2017 in North Ottadalen. Between 1965 and 1974 the yearly average growth rate was calculated as 1.24. No animals were recorded on the peninsula on the survey day in 1974-76, 1979-80 and 1990-91. The other years with no animals recorded are years when conditions prohibited air reconnaissance. The first year reindeer were found grazing on the peninsula was in 1982.

Figure 3. Wild reindeer movements/grazing under the 132 kV power line 31 March 2015 one year after the upgrading on their migration to their calving grounds in the central part of North Ottadalen. (Photo: Cecilie Vordal).

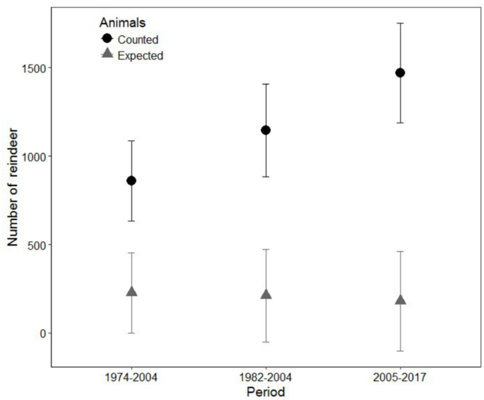

Figure 4. Mean annual number ± SE of wild reindeer counted vs. expected during air surveys south of the 66 kV power line before (1974-2004, 1982-2004) and after the upgrade to 132 kV (2005-2017). The year 1982 was the first year reindeer were known to graze on the peninsula.

out of 140 groups observed within the winter range were located within the winter pastures on the peninsula. Because the majority of groups within the peninsula had more than 200 animals (predominantly females, calves and young males), the total number of animals on the peninsula these years make up approx. 47% (26 163 vs. 56 038) of the animals counted, representing a monthly average of 818 ± 910 SD vs. 1751 ± 1241 SD, respectively. Furthermore, it seems clear that it is during midwinter (December-March), the animals prefer the peninsula (Fig. 5).

Discussion

Despite the fact that the peninsula in question is located in the periphery and only constitutes less than 10 % of the North Ottadalen available winter pasture, air surveys showed that the majority of the reindeer herd travelled back and forth under the power line in 26 of the 33 years surveyed. Approximately half of the population was within the peninsula for the entire 44 year period. During the first five years of surveys (1974-76 and 1979-80), no reindeer were found on the peninsula on the survey days. This period is 9-16 years after the herd was established in 1964 with a nucleus herd of only ca. 500 animals, of which 402 animals were newcomers to the area (Reimers, 1972). Hence, the absence of animals within the peninsula for those first 5 survey years may be attributed to barrier effects but may also be related to time needed for the herd to explore and familiarize themselves with the 3245 km^2 large range. Taken into account the small size of the nucleus herd and therefor a lack of need to explore for pasture and thus probably strong site fidelity, it is fair to believe that it must have taken the animals at least some years (5-10 years) before they knew about the pastures on the peninsula in question. The distance between the points of introduction of the nucleus herd in northwest to the peninsula in southeast adds to this. Furthermore, given that reindeer use large areas and shift their range use in a larger time perspective (Thomson, 1977), and animals were counted once a year during 1 (2) days, natural variation in area use between years or periods of year will be large for such a small part of the total winter range. Therefore, it is expected that there will be shorter periods of years with no animals counted within the peninsula. We do not know if there were animals, or how many, on the peninsula before 1974 or between 1976 and 1979, and cannot exclude that a lack of animals on the peninsula before 1982 could partly be due to a short term (< 5-10 years) effect of the original power line. However, there is no support of long term (> 5-10 years) barrier effects from this power line, or short- or long-term barrier effects of the upgrade in 2004. The preference for using the peninsula in most years is probably related to the high quality winter pastures in this area (Reimers *et al.*, 2007). Apparently, the peripheral location of the peninsula does not override this preference. The intensive use of the peninsula may also reflect part of a long-term cyclic use that characterizes most *Rangifer*

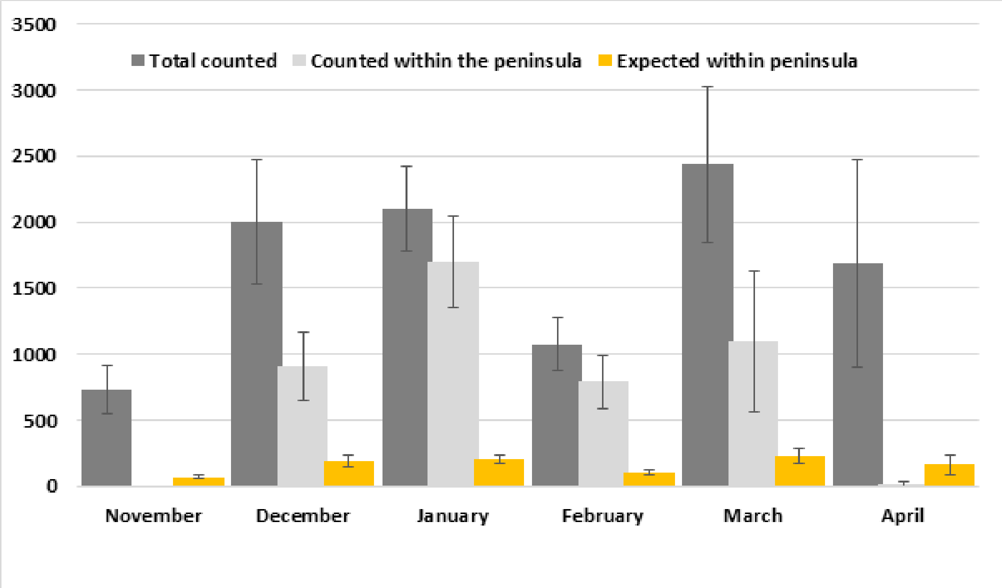

Figure 5. Mean monthly number ± SE of wild reindeer observed vs expected during ground surveys in 2012-2017.

herds. In total this 44 year observation series strengthen our previous conclusion (Reimers *et al.*, 2007). Furthermore, it also supports more recent research (Panzacchi *et al.*, 2013a; Bartzke *et al.*, 2014; Colman *et al.*, 2015; Eftestøl *et al.*, 2016; Plante *et al.*, 2018; Skarin *et al.*, 2018) that power lines transecting reindeer habitats have limited effects on reindeer area use.

This is contradictory to findings that linear structures such as power lines act as long-term barriers for both wild and domestic reindeer (Nellemann *et al.*, 2001; Vistnes & Nellemann, 2001; Nellemann *et al.*, 2003; Vistnes *et al.*, 2004; Vistnes *et al.*, 2008). This possible barrier and avoidance behaviour beg the question: why should reindeer avoid operational power lines, especially above the tree line, unless the lines are accompanied by additional infrastructure in terms of recreational activities or roads with traffic? It is well established that humans and predators trigger fright and flight in reindeer/caribou and other mammals (Borkowski, 2001; Frid & Dill, 2002; Donadio & Buskirk, 2006; Stankowich & Coss, 2006; Stankowich & Reimers, 2015). This also applies, however more moderately, to motorized traffic (Tyler, 1991; Burson *et al.*, 2000; Dyer *et al.*, 2001; Reimers *et al.*, 2003). Power lines may represent a disturbance for reindeer through electromagnetic fields (Algers & Hennichs, 1983), corona noise from electrical discharges in moist weather and wind turbulent noise (Busnel & Fletcher, 1978). However, even though the noise associated with power lines can be heard by reindeer, reindeer showed no clear behavioural effects of noise from two parallel power lines (132 and 300 kV) in strong winds up to 18.7 m/sec in an experimental study of reindeer and power lines (Flydal *et al.*, 2009).

Recently, Tyler *et al.* (2016) integrated established information on visual function of ultraviolet (UV) light for reindeer (*Rangifer tarandus*) with the characteristics of power line function. They suggested their findings provide "compelling evidence" that previously reported avoidance/barrier effects behaviour in reindeer (Nellemann *et al.*, 2003; Vistnes *et al.*, 2004) may be linked with the ability of reindeer to detect UV light. Tyler et al. repeat their corona light hypothesis and review 6 studies supposedly supporting their hypothesis (Nellemann *et al.*, 2001; Vistnes & Nellemann, 2001; Nellemann *et al.*, 2003; Vistnes *et al.*, 2004; Reimers *et al.*, 2007; Vistnes *et al.*, 2008). However, in addition to Reimers et al. being wrongly cited (Haukos, 2016), several of the studies may have alternative explanations, i.e. the power lines correlate with other infrastructure/factors (Reimers & Colman, 2006; Reimers *et al.*, 2007; Flydal *et al.*, 2019). Furthermore, more recent studies like Plante *et al.* (2018), Skarin *et al.* (2018), Colman et al. (2015), (Panzacchi *et al.*, 2013a), Eftestøl *et al.* (2016) and this study, do not find separate effects from power lines in their operational period. To our knowledge, no studies published the last 10 years have found negative effects from power lines alone. To establish a causal relationship between the construction of power lines and potential avoidance and barrier effects, Bartzke *et al.* (2015) and Colman *et al.* (2017) recommend before-after-impact control studies which now appear to be a commonly used method. Many of the studies concluding with strong negative effects from power lines lack this and thus may have interpreted the negative correlation between power lines and distribution of reindeer wrongly (e.g. Nellemann *et al.*, 2001; Vistnes & Nellemann, 2001). Even if corona/UV-light may affect reindeer on a smaller scale and should be investigated further, avoidance distances of several km seem unlikely causal effects from UV-light, which may be seen by reindeer under certain weather/power line conditions only at much shorter distances during dark hours.

In general, the explanation for the large aversion distances and the strong barrier effects of power lines above the tree line emanates from the assumption that reindeer associate man-made structures with danger (Frid & Dill, 2002; Vistnes *et al.*, 2004), even though most of these power lines are not associated with increased levels of human presence after their construction period (Nellemann *et al.*, 2001). On basis of this study and other recent studies (see review by Flydal *et al.*, 2019) we question the validity of reindeer evasive behaviour towards power lines themselves.

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Villreinens bruk av vinterbeite av høy kvalitet overstyrer barriereeffekter av kraftlinjer

Abstract in Norwegian/Sammendrag: Vi undersøkte barriereeffekter av en 66 kV kraftledning som ble opprettet i 1966 før og etter at linjen ble oppgradert til 132 kV i 2004 over en periode på 44 år (1974-2017) i Nord-Ottadalen villreinområde (3245 km^2) hvorav 1038 km^2 er i bruk som vinterbeite. Kraftledningen avskjærer en halvøy (135 km^2) med vinterbeite av høy kvalitet i den sørøstlige utkanten av området. Reinsdyrbestanden stammet fra en kjernebestand av 402 tamrein som ble sluppet fri i området i 1964-1965 og 100 villrein som fantes der fra før. Årlig flytellinger startet i 1974 og reinsdyr ble for første gang fotografert sør for 66 kV kraftledningen i 1982. En sammenligning av antall rein som ble registrert på halvøya i de tre periodene (1974-2004 1982-2004 og 2005-2017) med antall forventet relativt til tilgjengelig vinterbeiteareal var 3.6–4.9 ganger høyere. I årene etter oppgraderingen av kraftledningen i 2004 beitet en betydelig del av reinbestanden på halvøya hvert år. Vi konkluderer derfor med at det ikke var langsiktige barriereeffekter fra den opprinnelige kraftledningen og ingen barriereeffekter i det hele tatt fra oppgraderingen. I løpet av de første 5 flytellingsårene var det imidlertid ingen dyr på halvøya. Selv om det er flere mulige årsaker til dette, kan vi derfor ikke utelukke muligheten for kortsiktige barriereeffekter fra den opprinnelige kraftledningen. Resultatene støtter nyere studier som rapporterer ingen effekt på rein fra eksisterende kraftlinjer, og støtter følgelig ikke tidligere funn som har rapportert om sterk langsiktig barriere- og unngåelseseffekt av slik infrastruktur.