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Research paper

Reindeer spatial use before, during and after construction of a wind farm

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ABSTRACT

The Fakken Wind farm (WF) was built in 2010–12 on the Fakken peninsula on the south-east corner of the island of Vannøy. Field and GPS sampling was conducted to test the interaction between reindeer spatial use and the WF with associated infrastructure for the period 2007–2015. “Before data” for both direct observations and GPS-positions confirmed that the site where the WF was built was an important winter grazing area for reindeer. Testing data from before, during and after construction of the WF showed that the overall use on the island and for the WF area did not change during the study period. The reindeer density did not vary significantly among the periods, both for the WF and power line areas. We found no avoidance responses on reindeer spatial use towards the WF during the operation periods for direct observation data. However, we found some significant changes in reindeer area use that may be related to disturbance from human activities for the calving period during construction in WF zone 1 and road zone 1 (GPS-data), and for the power line area during construction in summer and autumn (direct observational data). Our study site represents an area where coexistence of reindeer husbandry and wind energy development is possible, with negligible effects on reindeer spatial use during and after WF development. We recommend that new WFs should be built close to existing infrastructure and limit an increase in human accessibility to remote areas where reindeer are less accustomed to human activity.

1. Introduction

The amount of infrastructure has increased in Arctic regions over the last 50 years (Klein, 2000; Forbes, 2006), especially in Scandinavia (Bartzke et al., 2014). The demand for renewable energy is growing, and construction of wind power, hydro power and solar power plants affects the habitats of many cervid species (e.g., Mahoney and Schaefer, 2002; Bartzke et al., 2014). Because of their extensive land use and social behaviour of forming groups (Skogland, 1984; Reimers et al., 2014), *Rangifer* sp. are vulnerable towards anthropogenic development that reduce movement patterns or pasture utilization (Reimers and Colman, 2006; Panzacchi et al., 2013; Beyer et al., 2016). In Norway, five wind farms (WF) have been built within reindeer ranges along the northern coast, and by 2016, eight more WFs had achieved concession, but were not yet built (https://www.nve.no/konsesjonssaker/, accessed 28 Oct 2016).

Reindeer herdsmen and their management authorities fear detrimental effects from WFs and their associated roads and power lines on movements and spatial use of reindeer (Colman et al., 2012a; 2013; Skarin et al., 2015). Recent studies have found minimal avoidance in situations when human activity is less prevalent in connection with infrastructure (Panzacchi et al., 2013; Colman et al., 2015; Eftestøl et al., 2016). These studies revealed how construction of infrastructure induce a temporary shift in use of areas away from construction activities, but with no avoidance response in the operation period. Increased human presence, transportation and construction activities during the construction period likely frightens the animals, resulting in reduced use of the surrounding areas. Supporting this, Skarin et al. (2015) found reduced movement rates for reindeers' use of migration corridors during construction of a WF, mostly in relation to the access road.

Since WFs cover large areas, need access roads and power lines, they may induce large-scale shifts in spatial use for reindeer. Studies need to sample at an appropriate spatial and temporal scale in order to identify real effects of the disturbance (Bartzke et al., 2014; Colman et al., 2017). Moreover, reindeer congregate into large herds, move through expansive landscapes, and fluctuate their use of pastures within their home range over time (e.g., Bergerud et al., 1984; Hinkes et al., 2005;

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Reimers et al., 2014). This signals a need for more long-term studies in several areas with different environmental conditions (Colman et al., 2013; Bartzke et al., 2014; Johnson and Russell, 2014) to make sound generalizations about effects of WFs on reindeer spatial use. Most studies on the effects of infrastructure on reindeer have been conducted post-construction with only correlative evidence backing conclusions (Reimers and Colman, 2006; Colman et al., 2017). Colman et al. (2017) and Bartzke et al. (2014) highlight the importance of before and after studies to better understand measured effects and aid in the proper interpretation of observed patterns.

We studied free ranging, semi-domesticated reindeer inhabiting the island Vannøy in Troms, Northern Norway, where a WF containing 18 wind turbines was built between 2010 and 2012. The island maintains year-round pasture for the reindeer, with no long distance seasonal migrations. Previous studies of WF development and reindeer have focused mainly on the summer half of the year (Colman et al., 2012a, 2013) or only the migration period (Skarin et al., 2015), thus data for the winter, late autumn and calving seasons was pertinent. How effects on spatial use may vary between seasons and years were investigated by sampling reindeer use for a period of nine years of direct observation, and two and a half years of GPS-monitoring. Our data spans before, during and after construction of the WF, enabling us to test the reindeers' spatial use within and amongst these periods. The existing road system on the island and its use for access to and from the WF for all vehicles and equipment also allowed us to test possible effects of road traffic to and from the WF. Additionally, we field sampled a four year period along a power line area and tested the effects from construction of this power line during an upgrade in conjuncture with the WF on reindeer spatial use.

From a hypothesis of negative effects of WF, roads and power lines on reindeer spatial use, we tested both regional and local avoidance towards these stimuli, predicting the strongest negative effects during the construction period with a heightened amount of human activity in the area. We also predicted reduced use of the WF area during operational years as a consequence of the turbines themselves and increased human activities in the form of operational and maintenance activities.

2. Study area and methods

2.1. Study area

The study area encompasses the Fakken peninsula (i.e., WF area) in southeast, and the power line area in southern parts of Vannøy island, Troms county, Norway (Fig. 1). The island is approx. 223 km^2 with year-round reindeer husbandry, and the WF area is approximately 60 km^2. The winter population of reindeer on the island varied between 300 and 400 during the study period 2007–2015 (supplementary, Table S1), see also Reindriftsforvaltningen (2015). The island is characterized by low-lying areas along the coast, while the inland is mountainous. The vegetation in Vanøy changes gradually from grass and *Calluna* heaths in low altitude zones to more oroarctic types in higher altitudes (Virtanen et al., 1999). Average elevation for the entire island is 240 m.a.s.l., while the WF area is on average 89 m.a.s.l. Reindeer pasture is mostly (93.4%) below 600 m.a.s.l., with limited to no vegetation above this (Rapp and Røthe 2014 'Unpublished results'). Settlements, roads and other infrastructure on the island are mainly located within a 4–500 m band along the western, southern and southern part of the eastern coasts (Fig. 1). The only exceptions are two power lines, and an associated dirt road or trail transecting remote parts of the mid-section of the island (Fig. 1). On the north coast and along the northern part of the east coast there are no roads or other infrastructure (Fig. 1). The WF area on Fakken peninsula has existing roads and power lines along the southern and eastern coastline. The WF was constructed in the period from the middle of October 2010 to the end of September 2012, but there was no construction work from December 10, 2011 to the end of February 2012. The power line was constructed from February 2011 until August 2012. Importantly, as part of the compensation scheme from the reindeer management authorities, the reindeer district reported an increase in animals killed in traffic during the construction of the WF (Otto Asbjørn Hansen from the Vannøy reindeer district and Jan Gunnar Brattli from Reindriftsforvaltningen (the reindeer management authorities), 'Personal communication'), but with no confirmed road kills from the WF developer (Ronald Hardersen from Troms Kraft power company, 'Personal communication').

2.2. Data collection

The study combines data from direct observations in the study area and GPS-collared reindeer over the entire island (the reindeers' entire home range). Direct observations began in January 2007, and continued once each month until the end of February 2014, with three additional months from April-June 2015 (see supplementary, Table S1). Direct observations were performed by the same observer throughout the study period, except for March 2008, when they were conducted by two other people who walked together. A predetermined route maximized area covered within the WF area. The observer (s) used binoculars to scan the surroundings from all viewpoints/ridges providing maximal visibility (Downes et al., 1986; Colman et al., 2003) and registered all animals observed on a 1:30 000 topographic map, similar to Colman et al. (2013). Care was taken to avoid disturbing reindeer while in the field, but this did not influence the total area surveyed. When reindeer were located, the animal's position was marked using GPS in combination with compass direction and the map. When reindeer were in groups, the approximate position of the centre of the group was mapped. Female reindeer, especially accompanied by calves, are considered more sensitive towards human activities and infrastructure than males (Reimers and Colman 2006). Observations were divided into three periods in relation to the WF construction (before: August 2007–15 October 2010; during: 15 October 2010–30 September 2012; after: 1 October 2012–30 June 2015) and in five seasons (autumn: 1 August-30 October; winter: 1 November–30 April; calving: 1–31 May; summer: 1 June–31 July) (see supplementary, Table S1, S2). Direct observations were also conducted from 2009 to 2012 (before: January 2009–January 2011; during: February 2011–August 2012; see supplementary Table S2) along an existing power line corridor that was upgraded in conjuncture with the WF (Fig. 1).

In addition to direct observations, we used GPS-tagged females with positions recorded every 3 h from 19th September 2009 to 1st February 2012 (see supplementary, Table S2). The reindeer herdsmen were involved in all aspects of capturing and equipping the GPS collars on their reindeer. A total of 14 GPS-marked animals were used, but the number decreased in later periods due to life span of GPS batteries and some mortality unrelated to the GPS-collars (Otto Asbjørn Hansen, 'Personal communication'). We used the GPS Plus collars with double battery packs (2D, with position registering every 3rd hour the batteries last usually last between 2 and 3 years) from Vectronic's Aerospace GmbH (Berlin, Germany). The herd is free ranging over most of the year. To reduce potential influence from the herdsmen during drives and gatherings, we removed data during gatherings (see Skarin et al., 2008; Anttonen et al., 2011; Eftestøl et al., 2016). Because we did not continue the GPS-project after 2012, we have no GPS data for the "after" period. The presence of GPS marked animals varied in relation to seasons in the different parts of the island (see supplementary, Table S2). Out of the total 64594 GPS positions recorded from 14 marked animals throughout the study period, 7415 GPS positions (i.e. 10%) were in the WF area. The distribution in relation to season within the WF area were 63% (winter), 20% (autumn), 12% (calving) and 5% (summer).

Based on topography and location of the different infrastructure that might interact with reindeer spatial use, we divided the WF area into the following sub-zones (Fig. 1): (1) WF zone 1, areas lying within 500 m of the WF turbines and farther than 250 m from main roads; (2) WF zone 2, areas lying more than 500 m away from WF, and farther