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Master thesis

Spatiotemporal patterns of area use by humans and wild reindeer in a Norwegian National Park.

Master in applied ecology

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Contents

Abstract

Human impacts have for several decades led to fragmentation of habitats for wild reindeer across Norway. In Dovrefjell – Sunndalsfjella National Park there is a complexity of human activity that threatens the seasonal migration pattern for wild reindeer around the central mountain range *Snøhettamassivet*. This may affect time spent in foraging and avoidance of areas, which may force the reindeer to leave territories with better quality resources and provide long-time effects as reduced body condition and reproduction. The aim of my research is to uncover the wild reindeer-human co-existence during summer in an important migration corridor by describing the spatiotemporal patterns of area use by humans and wild reindeer in the Stroplesjødalen valley. Additionally I want to discuss management implications. I observed human activity in Stroplesjødalen during the peak summer season for hikers in 2010 to map the human use of the valley and used GPS plots to describe the area use and movement patterns for wild reindeer in the same area. My findings regarding human use revealed that 80% of hikers in the area use marked trails, while 94% of hunters used areas outside the marked trails. The human traffic along the main hiking trail differed in time and space throughout the day with a peak of density in the eastern part of the valley between 12:00 – 14:00. The tourist cabin Reinheim (36 beds) had a central function in the western part of the area and caused high densities of humans in its surroundings. The reindeer seems to avoid the valley and particularly the areas in the west. The movement pattern of reindeer measured as speed and path straightness varied with distance to the hiking trails and daylight conditions. During daylight, their speed was highest within 1 km to the hiking trails, and straightness gradually increased with increasing distance to the hiking trails. My conclusion is that the cabin Reinheim and the hiking trail from Kongsvoll to Reinheim had a negative effect on reindeer area use and caused impacts on the reindeer movement rates. Stroplesjødalen might evolve to an absolute barrier if the density of visitors increases. My somewhat radical recommendation for future management of Stroplsjødalen is to close down the Reinheim cabin if the number of visitor increase, and remove infrastructure of marked trails in relation to the cabin. However, it requires development off attractions close to Snøheim and continuity of the shuttle bus at the Snøheim road. To maintain the migration pattern around the *Snøhettamassivet,* further development of recreational infrastructure in Stroplesjødalen and trails towards the area *Kolla* should be avoided.

Keywords: Human disturbance, wild reindeer, avoidance, movement pattern, hiking-trail, cabins, barrier

Sammendrag

Menneskelige forstyrrelser har i flere tiår ført til fragmentering av leveområder for villrein i Norge. I Dovrefjell - Sunndalsfjella Nasjonalpark er det et komplekst bilde av menneskelig aktivitet som truer det sesongbaserte trekkmønsteret for villrein rundt det sentrale fjellområdet Snøhettamassivet. Dette kan påvirke reinens tid brukt til beiting og unnvikelse fra viktige områder for villreinen som igjen kan gi langtidseffekter som redusert kondisjon og reproduksjon. Målet med min oppgave er å forklare sameksistensen mellom villrein og folk om sommeren i en viktig trekkorridor ved å beskrive den rommelige og tidsmessige bruken mennesker og villrein har i Stroplesjødalen. I tillegg vil jeg diskutere forvaltningsutfordringer. Jeg har observert menneskelig aktivitet i Stroplesjødalen i høysesongen for besøkende i 2010 for å kartlegge menneskets bruk av dalen og brukt GPS-lokasjoner for å beskrive arealbruk og bevegelsesmønstre for villrein i det samme område. Mine funn om menneskelig bruk viste at 80% av turgåere i området bruker merkede stier, mens 94% av jegerne brukte områder utenfor de merkede stiene. Den menneskelige trafikken langs hoved-stiene varierte i tid og rom gjennom dagen med en topp i den østlige delen av dalen mellom kl. 12.00 - 14.00. Turisthytta Reinheim (36 senger) hadde en sentral funksjon i den vestlige delen av området og forårsaket høy tetthet av mennesker i nærheten til hytta. Reinen synes å unngå dalen og spesielt områdene i vest. Reinens bevegelsesmønster målt som hastighet og linearitet varierte med avstand til turstier og lysforhold. I dagslys var hastigheten høyest innen 1 km til turstiene, og linearitet økte gradvis med økende avstand til turstiene. Min konklusjon er at hytta Reinheim og turstien fra Kongsvoll til Reinheim hadde en negativ effekt på reinens bruk av området og forårsaket endringer i reinens bevegelsesmønster. Stroplesjødalen kan utvikle seg til en absolutt barriere dersom antall besøkende øker. Min litt radikale anbefaling for fremtidig forvaltning av Stroplsjødalen er å stenge Reinheim og avslutte videre merking stier i tilknytning til hytta hvis antall besøkende til området øker. Det krever imidlertid utvikling av attraksjoner nær Snøheim og videreføring av skyttelbussen langs Snøheimveien. For å opprettholde trekkmønsteret rundt Snøhettamassivet, bør utvikling av infrastruktur i Stroplesjødalen og stier mot området i og rundt Kolla unngås.

Nøkkelord: menneskelig forstyrrelser, unnvikelse, villrein, bevegelsesmønster, tursti, hytter, barriere

1. Introduction

Human impact has in the past few generations led to an increasing fragmentation of habitats that ultimately could threaten the livelihoods of species, including wild mountain reindeer. In order to make the right management decisions for the future it will require more precise knowledge about the relationship between different types of human activity and habitat fragmentation mechanisms as avoidance and migration barriers (Manor & Saltz 2005). Fragmentation of habitats to wildlife is of major concern for many species (Gill, Sutherland & Watkinson 1996). Wild reindeer *Rangifer tarandus tarandus* live in large herds and require large continuous areas due to its migration patterns and herd/population structure (Panzacchi *et al.* 2013; Panzacchi, Van Moorter & Strand 2013; Panzacchi *et al.* 2015; Panzacchi *et al.* 2016). In Norway, the home range to the historical 2-3 populations used to be much more continuous where they could migrate between various seasonal habitats (Skogland & Mølmen 1980; Jordhøy, Strand & Landa 1997). Over the past century continuous habitats for wild reindeer has been fragmented across Norway (Klein 1971; Iuell & Strand 2005b) and fragmentation is still ongoing (Panzacchi, Van Moorter & Strand 2013; Nilsen & Strand 2017). Today there are specified 23 wild reindeer areas in Norway and total population size during winter is approximately 25 000 animals (Villrein.no s.a.). The fragmentation is essentially caused by human infrastructure (Reimers *et al.* 1979) and has led to isolation of subpopulations into smaller areas with less opportunities to migrate between summer and winter habitats (Vistnes *et al.* 2004b; Nilsen & Strand 2017).

It is well known that human disturbance to wildlife in general and reindeer in special is a challenge for management to make decisions (Harris *et al.* 2009; Festa-Bianchet *et al.* 2011). The implementation of effective management strategies and conservation efforts on wildlife species requires an understanding of their ecology, type and intensity of the disturbance activities and how disturbance is affecting the population (Bennett *et al.* 2009). Wild reindeer are sensitive to human activities (Wolfe, Griffith & Wolfe 2000; Nellemann *et al.* 2003; Vistnes *et al.* 2004a; Iuell & Strand 2005a), and at the landscape level the reindeer's habitat selection during the snow-free periods depends mostly on forage resources (Klein 1990), insect harassment (Mörschel & Klein 1997), infrastructure development and diverse human activities (Nellemann & Cameron 1996; Nellemann *et al.* 2000; Vistnes & Nellemann 2001). The effects may have immediate or long time effects on the population. Immediate effects are alert and flight distances (Reimers *et al.* 2000), and even though the effect of a single disturbance is relatively small (Reimers & Colman 2006), it still affects time spent foraging and thereby the energy balance (Strand 2010). Repeated disturbances cause partial or fully

avoidance of areas. Furthermore, human activity may alter the foraging patterns and habitat use of animals, the latter forcing the animals to leave territories with better quality resources or to over-graze certain intensively used core areas (Nicholson, Bowyer & Kie 1997; Vistnes & Nellemann 2001; Manor & Saltz 2005). Recurring disturbance could then provide long-time effects such as reduced body condition and reproduction (Knight & Temple 1995; Gill, Norris & Sutherland 2001).

Effects of human disturbance on wild reindeer behaviour may vary with the degree of hybridization with domestic reindeer. The wild reindeer populations of Dovre-Rondane, which include my study population Snøhetta (Figure 1), have only minor levels of hybridization (Flagstad & Røed 2003; Andersen 2004; Røed et al. 2008; Røed et al. 2014). Studies of alert and flight distances (Reimers et al. 2000; Colman, Jacobsen & Reimers 2001; Reimers & Colman 2006) have shown that the populations in the Dovre-Rondane region are more vigilant and have longer detection- and flight distances compared to populations that are more inferenced by domesticated reindeer (Reimers & Colman 2006). Reimers et al. (2000) estimated the alert distance for reindeer approached by a person on foot in Snøhetta to be 400 meters in the summer season. Other studies have shown the reindeer response to infrastructure and human activity with reduced frequency of use up to 10-15 km from the infrastructure (Kjørstad *et al.* 2017). In relation to long-time effects, tourist cabins have a direct effect on the habitat use of the surrounding area, and an effect of totally cease to use the area within 1 km radius (Panzacchi *et al.* 2013).

Human disturbance towards reindeer is diverse and complex, and varies with the spatiotemporal pattern of area use, the intensity of use and the type of activity. In general, recreation in the mountains is a part of the Nordic outdoor leisure tradition, including public rights of common access and simple activities like hiking, biking and skiing. In an international term, Norwegian National Parks are more like a wilderness area than the IUCN definition includes. In my study area Snøhetta (Figure 1), hiking is the overwhelming most important activity, including multiple additional reasons, such as nature experience, photographing, fishing, hunting and wildlife watching. Increased popularity of outdoor recreational activities is important for human health, but the growing popularity of outdoor recreation in protected areas has brought certain problems (Miller, Knight & Miller 2001; Taylor & Knight 2003a; Taylor & Knight 2003b; Manor & Saltz 2005; Stankowich 2008), such as: “1) loss of habitat due to technical interventions, 2) short-term physiological and behavioural responses to single animals that are exposed to disturbances, 3) barrier effects or 4) cumulative effects from different disturbances and interventions” (Jordhøy 2001).

Mapping of historic trapping systems in the Snøhetta area suggests that the reindeer used large continuous habitats and migrated between summer and winter pastures (Mølmen 1978; Jordhøy 2008). Now, the wild reindeer population at Snøhetta has been obstructed from its historic migrating routes after the development of infrastructure such as railways, main roads as E6 for a long time (Skogland 1986; Jordhøy 2008; Strand *et al.* 2013) and hydropower dams in Aursjøen and Torbudalen (Bevanger *et al.* 2007). This has led to a limitation in habitat use, due to the lack of migrating opportunity (Skogland 1986; Strand *et al.* 2013). In the remaining area there has been disturbance from different human activities. Already in 1925, the Norwegian army started to use parts of the areas in Snøhetta as a shooting range for artillery, including a dense network of gravel roads. During last century, the activity put severe limitations on the recreational use of the areas. Along with hiking trails, the shooting range has been a major disturbance on the eastern part of the area (Jordhøy 2001; Jordhøy *et al.* 2003). In 1998, the government of Norway decided to close down the shooting range and started a large restoration program. This has led to one of the greatest ecological restorations in Norway, and 165 square kilometers are returned to its natural state (Forsvarsbygg 2017), and a large part became a National Park in 2018 (Klima- og Miljødepartementet 2018a).

The aim of my research is to uncover the wild reindeer-human co-existence during summer in an important migration corridor in the Snøhetta wild reindeer range:

- Describe the spatiotemporal human use of the Stroplsjødalen valley
- Describe the wild reindeer spatial use of the valley, with focus on density of GPS plots in distance from human presence
- Discuss management implications for the observed wild reindeer- human use pattern

I want to give more precise knowledge of how people are distributed in the valley throughout the day in the peak season for hikers, and how distribution and movements of reindeer are in the same period. Hence, I will use observations of people's movements along hiking trails according to time of day and density to describe potential human impacts, and use GPS collars on reindeer to find differences in animal movements related to different distances from the trails. Based on reindeer disturbance literature I predict the reindeer to use areas close to the hiking trails less often, especially during times of day with high densities of humans. I also expect the reindeer to move faster and have straighter flight movements closer to the hiking trails.

2. Method

2.1 Study area

The study was conducted in the Snøhetta wild reindeer area in central Norway in Trøndelag, Oppland and Møre og Romsdal counties (Figure 1). Most of the wild reindeer area is protected as part of the Dovrefjell - Sunndalsfjella National Park. As a result of the development of Aura hydropower dam in Aursjøen in the early 50^{ies} the reindeer population is functionally separated into an eastern and western herd, where the eastern herd is located in the Dovrefjell – Sunndalsfjella National Park (Løkken & Skotvedt s.a.). The Dovrefjell – Sundalfjella National Park is one of the largest continuous protected areas on the main land in Norway (1830 km^2) with the main purpose to protect an alpine ecosystem with the natural biological diversity, which include securing the wild reindeer and its habitat (Klima- og Miljødepartementet 2018a). The management area for reindeer includes the National Park (the eastern herd) and several other protected areas and mountain areas around (including the western herd), in total ca. 3400 km^2 (Punsvik & Frøstrup 2016). The topography consists of gentle mountain areas in the east and more rocky mountains in the west. The study area encompasses a valley (Stoplesjødalen) in the eastern part of the National Park (Figure 2).

At Dovrefjell - Sunndalsfjella National Park there are few technical interventions and disturbance towards reindeer is most likely to be humans on foot along hiking trails. During summer time there are between 23-31 000 visitors to the National Park (Gundersen *et al.* 2013b). The eastern part of the National Park (Hjerkinn plateau) covers about 10 % of the park but 70 % of the visitors. There are two main entrances to the park, the Snøheim road and Stroplesjødalen, and with easy access from the main road E6 and parking places at Kongsvoll and Grønnbakken, Stroplesjødalen is one of the most visited areas (Gundersen *et al.* 2013b). The study area is more than one-hour walk from any roads in the area, and the only infrastructure is hiking trails, a tourist cabin (Reinheim) own by the Norwegian Trekking Association (NTA) and a few private owned very small cabins. The NTA has several cabins in the area and the only provider of accommodation in the National Park. Reinheim (1952) was initially a cabin located at the foot of Snøhetta at the end of the Snøheim road. In 1958, the shooting range expanded and the Ministry of defence acquired Reinheim, whereupon the NTA built a new cabin (Reinheim) in Stroplesjødalen. This established new movement patterns for hikers and increased traffic in Stroplesjødalen (Jordhøy *et al.* 2003), ultimately this has led to one of the most used entrances to the National Park (Wold 2009), where the hiking-trail form Kongsvoll/Gønnbakken to Reinheim is the busiest trail throughout the area

(Gundersen *et al.* 2013b). When the government decided to close down the shooting range the initial cabin Reinheim was returned to NTA now with the new name Snøheim. Snøheim is situated at the end of the controversial Snøheim road, which is the second main entrance to the National Park. The cabin was restored and reopened in 2012, and has more than 5000 overnight stay visitors during the summer season (Strand *et al.* 2013).

The study area is above the treeline in an alpine area with elevations ranging from 1100 to 1700 m.a.s.l. The musk-ox population in the area is an introduced for more than 70 years ago, and still defined as an exotic species in the fauna, However, it is a popular species for wildlife safaris, and more than 70% of the visitors to the area have musk-ox as the main reason for visiting the area (Pettersen 2011). Predation for ungulates have been at very low level the last century, but in the last decades the wolverine has brought it back to the area (Landa *et al.* 1997). The reindeer population is therefore mainly regulated through hunting (season 20.August - 15.September). Winter population is approximately 2700 individuals (Punsvik & Frøstrup 2016; Løkken & Skotvedt s.a.).

The topography in the National Park has a central mountain range *Snøhettamassivet* with its high altitudes that are less attractive for the reindeer. Through late summer and autumn the reindeer has a rotational movement pattern around the alpine mountain range (Jordhøy *et al.* 2012). When closing down the shooting range these rotational patterns where crucial for the area use of the reindeer, and concerns about barriers that would prevent these patterns has been some of the background for the decisions to restore the shooting range back to its origin (Jordhøy *et al.* 2012).

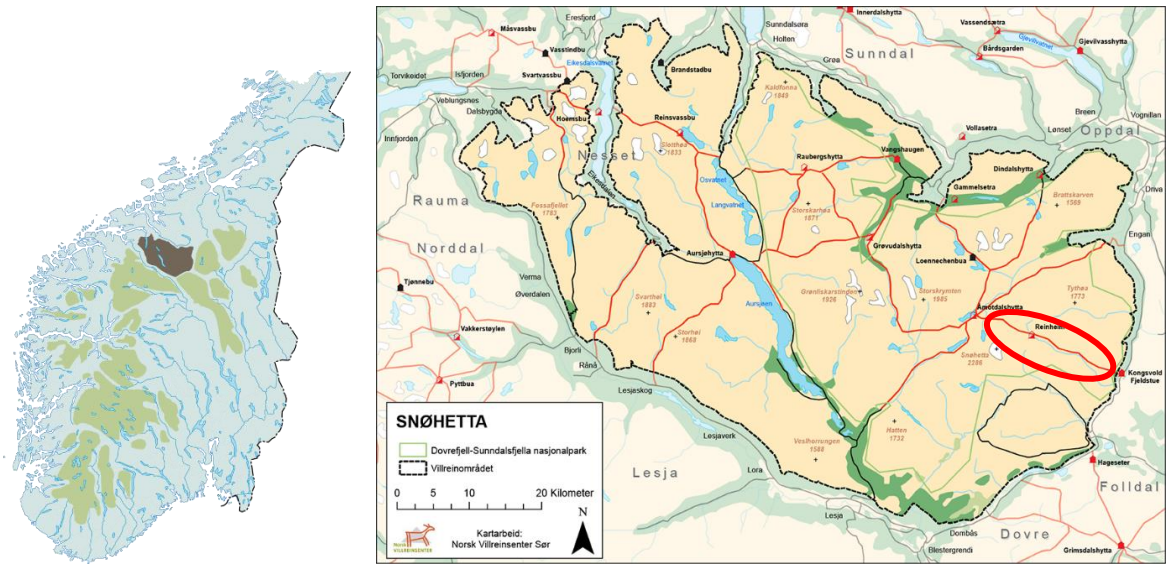


Figure 1: Snøhetta wild reindeer area including the Dovrefjell-Sunndalsfjella National Park (Klima- og Miljødepartementet 2018a), red circle study area.

2.2 Data collection

2.2.1 Human activity

Data was collected during the peak season for visitors in 2010. We collected data on human activity during six periods: 30. July - 2.August, 6.August - 9.August, 20.August - 22.August, 27.August - 28.August, 10.September - 12.September and 17.September -19.September, to get an adequate representation of the season. Those periods included both the peak season of visitors and the hunting season for reindeer. Direct observations where used to estimate density and movements of humans in the area. The area was covered visually from 8:00 to 20:00 from three locations (Figure 2). Each observation period had a minimum of 36 hours of observation. However, one period was limited by bad weather, and had a lower number of observed hours (15 h. in total). At each location, the observer used binoculars and telescopes to observe the area. Human activity was recorded at time of observation, numbers of people and where the observation occurred in the valley. Additionally, they were categorized as: daytrip or overnight tourists (small or big backpack), hunters (carrying rifle or shotgun) and if they occurred on or off trails.

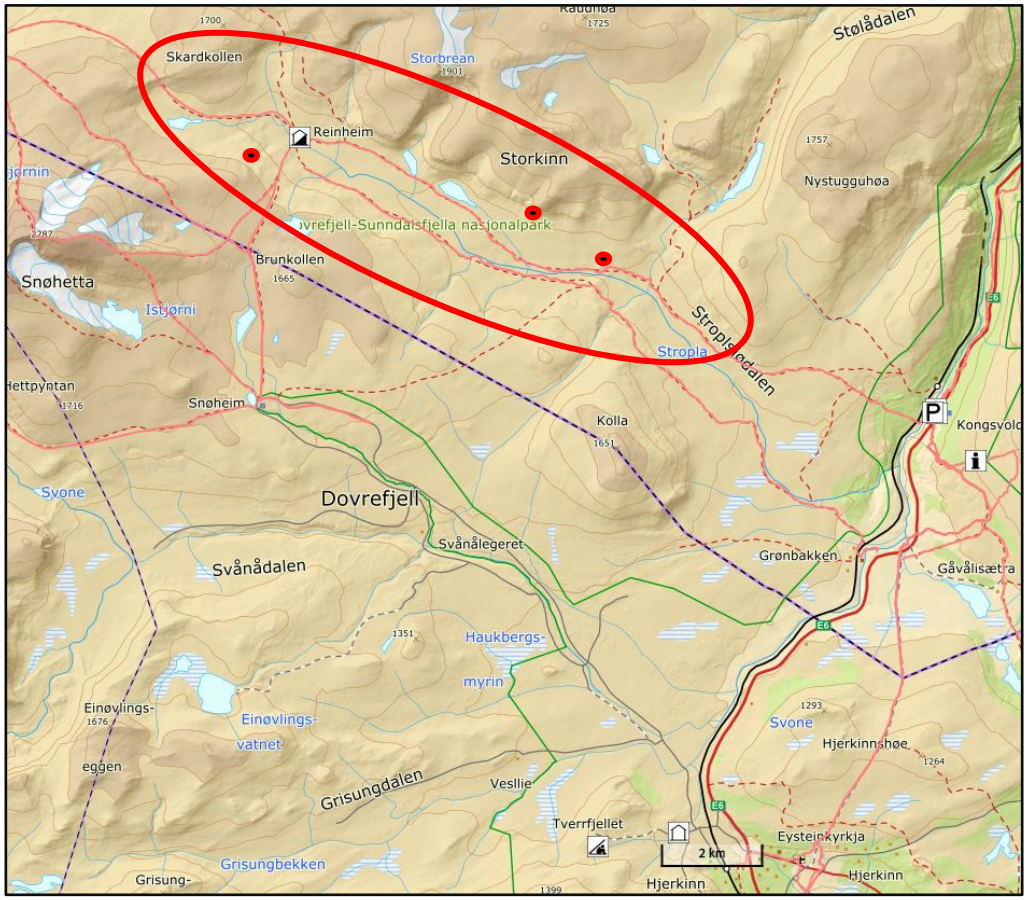


Figure 2: Study area with observation locations (red dots). The two main entrances to the National Park is hiking trails from Kongsvoll towards cabin Reinheim through Stoplesjødalen and the Snøheim road from Hjerkinn towards Snøheim. Green line: National Park border.

2.2.2 Reindeer data

Data of reindeer movements were collected from GPS collars from 27 July - 31 August 2010. The collar data is available from (NINA s.a.). To measure differences in animal movement I used GPS positions from the R&D project *"FoU Snøhetta"* where 9 female reindeer were marked with GPS collars in March 2009, and 3 male reindeer marked in March 2010 (Jordhøy *et al.* 2012). One female and one male were shot during the hunting season 2010 (Strand 2010; Jordhøy *et al.* 2012). The GPS collars recorded positions every half hour, and daylight conditions (day or night) were given for each position. I used all data within 5 km away from the closest hiking trails to analyse reindeer movements (N = 4931).

2.3 Data analysis

Human density along trails

To estimate densities of humans along trails I used ArcMap 10.1, to plot all observations of human activities in a grid (500x500m.). A spatial join of the point observations to the grid resulted in a number of people per grid cell, as a proxy of human density. Human density was mapped for 2-hours time periods throughout the day (08:00-09:59, 10:00-11:59, 12:00-13:59, 14:00-15:59, 16:00-17:59 and 18:00-20:00).

Density of reindeer

To map the distribution of reindeer in the study area I used all locations in ArcMap. Then I used number of locations per grid cell to estimate density of positions in the same grid as above (500x500).

Time and distance from trail for GPS locations

To investigate the locations of reindeer at different time intervals and distances from the hiking-trails, each reindeer location was grouped in five distance categories; 1 km, 2 km, 3 km, 4 km and 5 km from the hiking-trails and in 2 hourly time intervals. I estimated the expected time of location at different distances from track in 2 hourly intervals with Chi-squared test in Excel 2016.

Reindeer behavioural metrics

To describe reindeer movement, I estimated speed and straightness index from GPS locations. A common method to describe movements path is its tortuosity and how twisted a path is in a given time and space (Almeida *et al.* 2010). To estimate the tortuosity of an animal's path I

used a straightness index (ST) (Batschelet 1981). Benhamou (2004) found ST to be a reliable estimate of tortuosity when there were an oriented path. The ST measures how straight (linear) the animals path is according to the beginning and end locations on a path and varies from 0 – 1, the closer to 1 the more straight is the animals path. I calculated ST for each 2-hour segment consisting of five half-hourly, consecutive positions p1, p2, p3, p4 and p5 by using the following method: I first calculated the Euclidean distance between all consecutive locations. I then calculated the Euclidean distance between p1-p3, p2-p4 and p3-p5. For each of these three 1-hour steps, I calculated the linearity index as the sum of the two half-hourly step distances divided by the hourly distance. I then calculated ST as the mean of the three linearity indices.

Similar to the straightness index, I estimated speed using the four half-hourly steps making up the 2-hours interval. For each half-hourly step, I calculated the speed (m/h) as the Euclidean distance (m) between two consecutive half-hourly positions divided by 0.5 hours. I then calculated the average speed S of the 2-hours segment as the mean speed of the four steps

I fitted linear mixed-effects model with the package lme4 (Bates *et al.* 2014) in R (R Core Team R 2018) to analyse factors affecting the reindeer movement indices. I developed two sets of models, one for each movement index; *speed and straightness*. I used reindeer individual as random factor in all models and tested for the effect of distance from trail and light conditions on speed or straightness, respectively. To achieve normal distribution of response variables, I transformed variables before analysis using log(*speed*) and arcsine√(*straightness).* Model selection was based on Akaike`s information criterion (AIC) using the package AICcmodavg (Mazeroll 2019).

3. Results

3.1.1 Human activity

Total hours of observation from three locations was 581. There were 804 observations and 2044 people observed with an average group of size 2.5 people per observation. People in the valley were mainly distributed in connection to the marked hiking trails (Figure 3). In total, 74% of the observed people were on the marked trail and 26% were off, either partly by leaving the trail or off trail during the entire observation time. Hunters were observed 94% off and 6% on trails, while hikers were 20% off and 80% on trails. The density of people along the marked hiking trails were highest along the trail from east following the north side of the valley towards Reinheim. Among the user groups, overnight visitors were 59%, daytime visitors 23%, hunters 8% and 10% were not categorized.

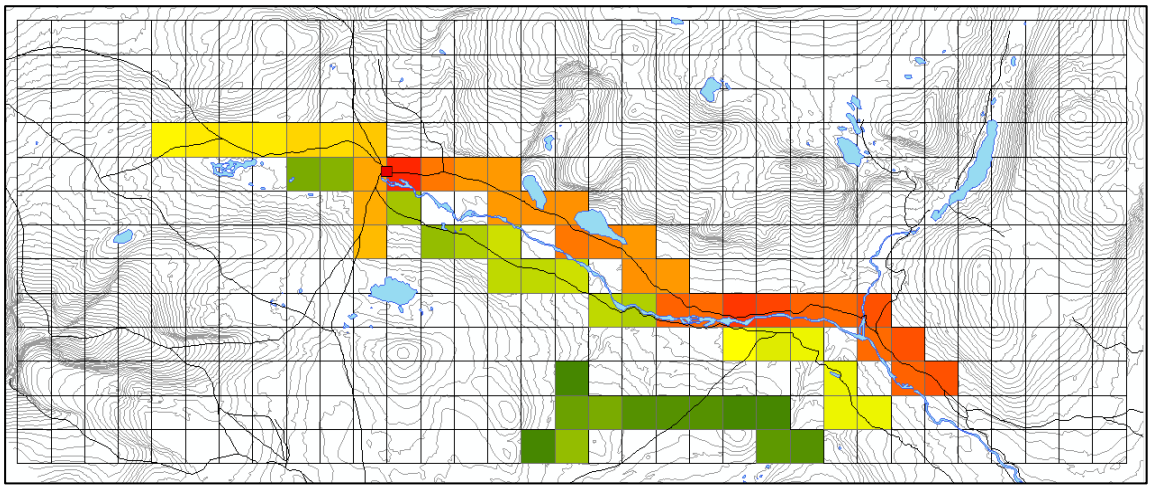
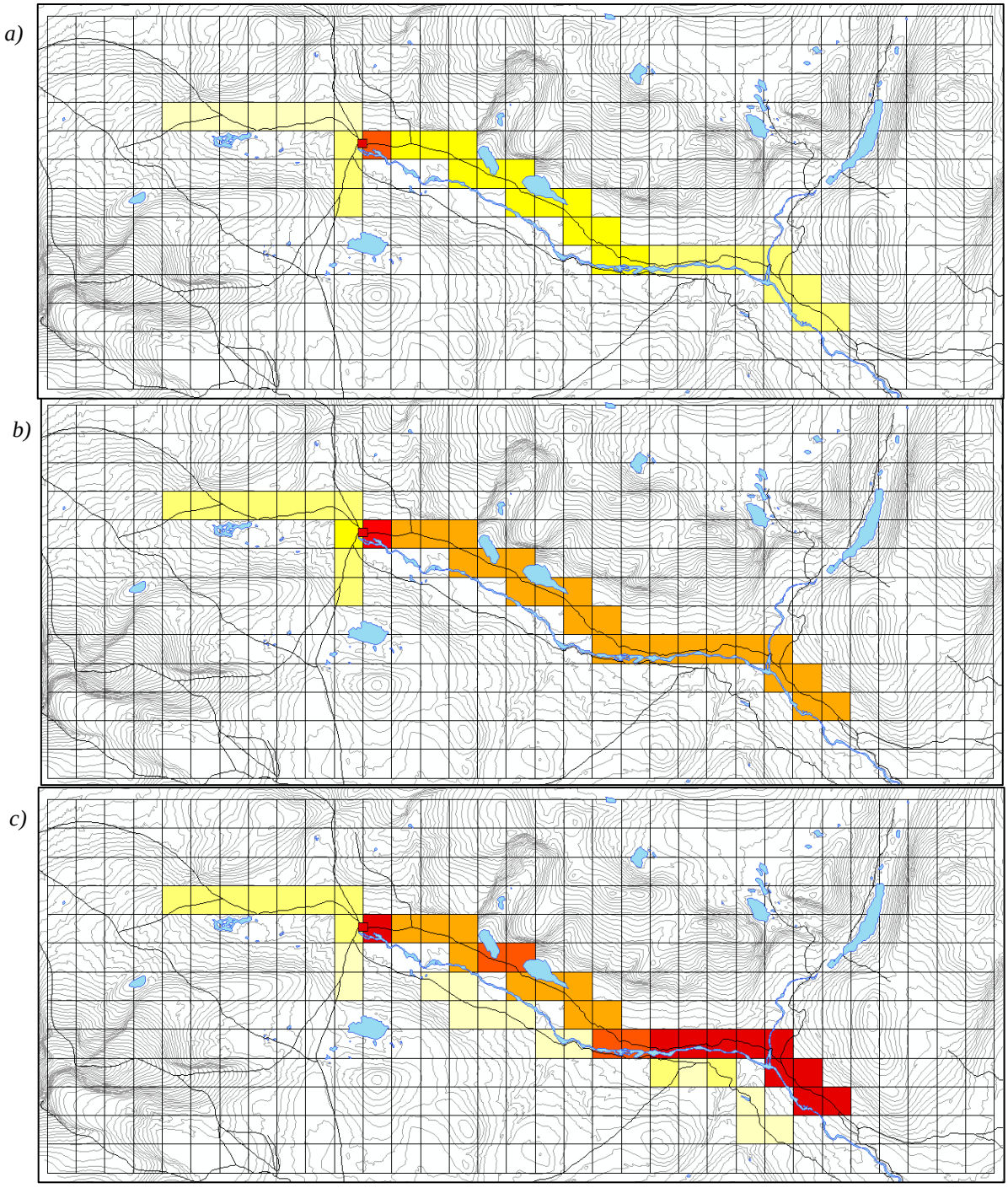


Figure 3: Density of people for all observations during summer peak season for hikers in 2010 (n=2044) Red; high density - green; low density

Along the hiking trails the density increases throughout the day and peaks in the eastern part of the area between 12:00-14:00 (Figure 4). Reinheim is a crossroad and has the highest density of people at all time periods.



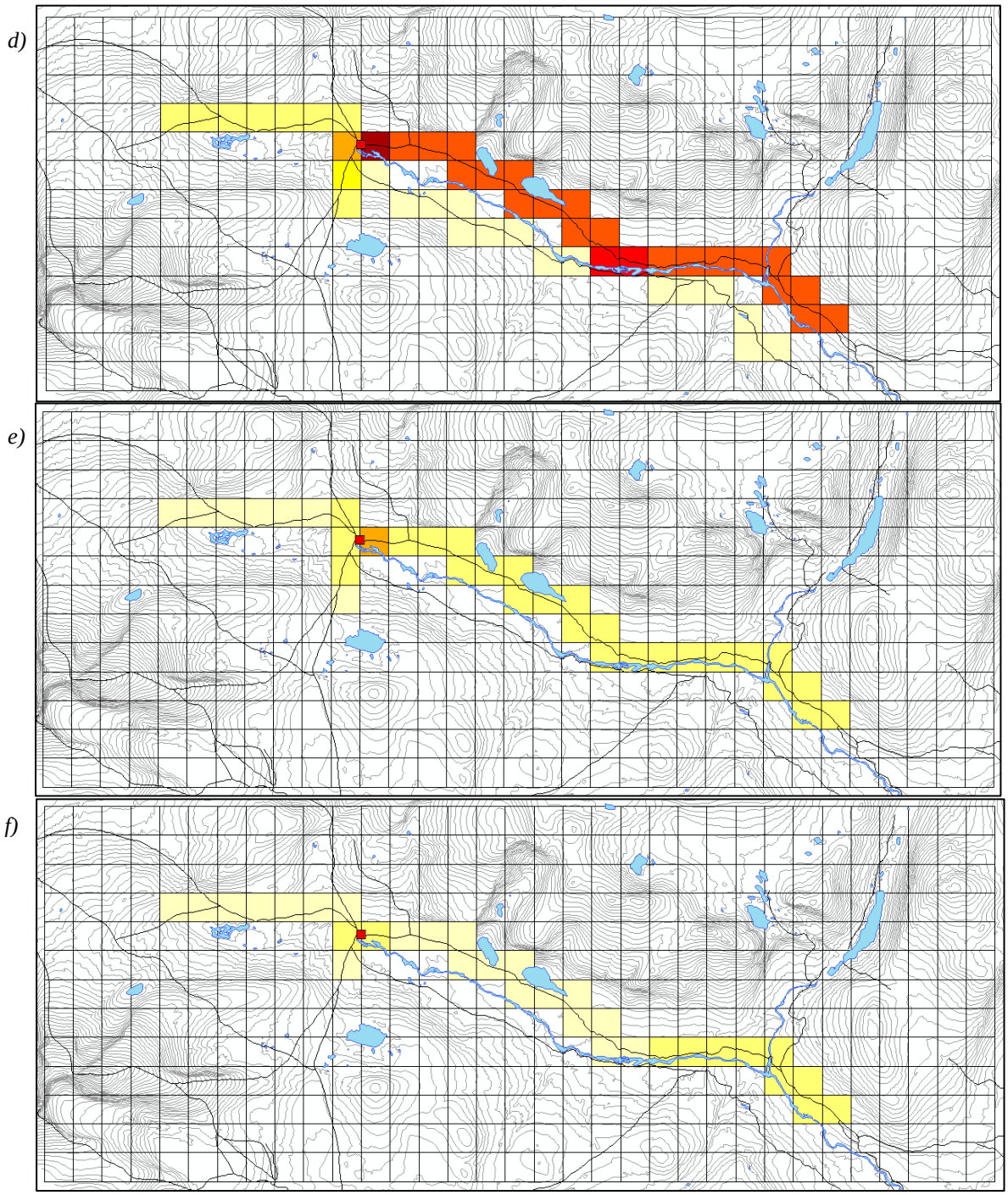


Figure 4: Density of people along the main hiking trails in Stroplesjødalen at different time periods throughout the day in the summer peak season for hikers in 2010. a) 8:00-9:59, b) 10:00-11:59, c) 12:00-13:59, d) 14:00-15:59 e) 16:00-17:59 and f) 18:00-20:00. Red; high density - yellow; low density- white; 0 observations. All cells down in the valley were visible to the observers, but cells occurred at a distances were less visible due to the shape of the terrain and sometimes weather conditions.

3.1.2 Reindeer

Density

When plotting all locations for the period there is an open gap with less locations in the valley. The density map (Figure 6), also has higher densities north east in the area.

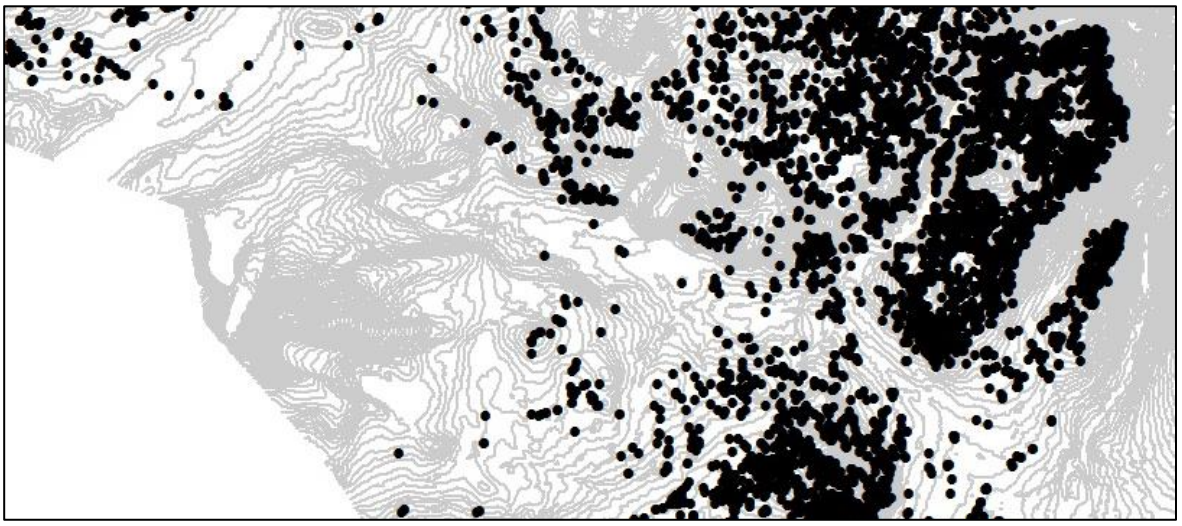


Figure 5: Half-hourly GPS locations of wild reindeer between 27 July to 31 August 2010.

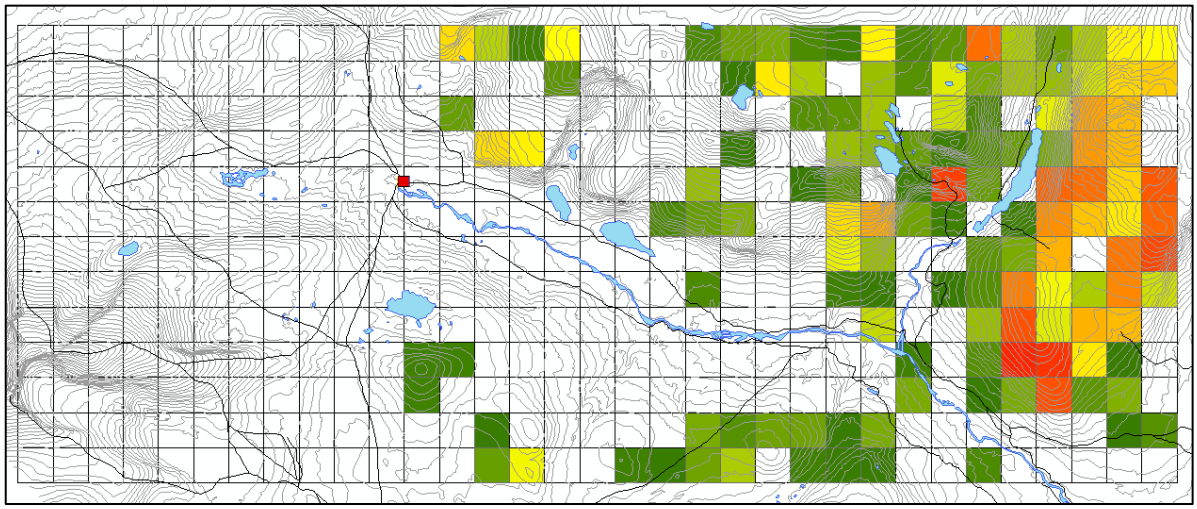


Figure 6: Density of GPS locations taken every half hour from reindeer from 27 July to 31 August in 2010. Red; high density - green; low density

Time of location

I found that number of locations at different distances from the trail were dependent on time of day (χ^2 = 295.34, *df*=44, p<0.001). The groups that differed most was within 1 km away from the trail between 6:00 - 7:59 and 2 km between 8:00 - 9:59, the number of locations was in both groups higher than expected (Figure 7, χ^2 = 62.6 / χ^2 = 4.98).

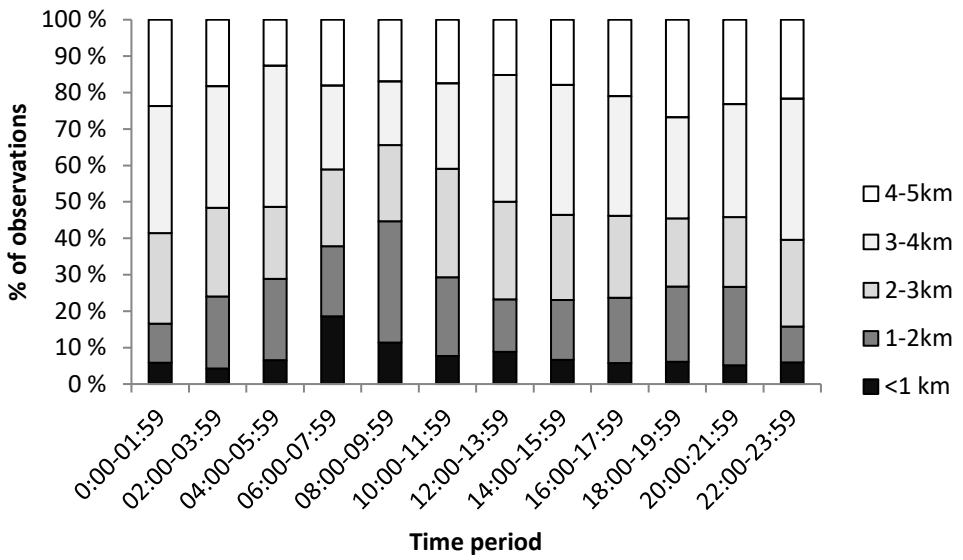


Figure 7: Percentage of positions (N=4931) in distance categories within 5 km. from trails at different time periods

Reindeer behavioural metrics

The best models to explain variation in speed and straightness of paths included distance to hiking trail in interaction with daylight conditions (Table 1). This implies that that the effect of distance from hiking trail on speed and straightness of paths depend on daylight conditions. The second ranked model for both indices included distance to trail and the additive effect of daylight conditions.

Table 1: Model selection tables based on AICc selection criteria for speed (a) and straightness index (b).

a) Speed

Variables	*df*	*LL*	*AICc*	*ΔAICc*	*AICc Weight*
distance_group * daylight conditions	12	-7548.00	15120.06	0.00	1
distance_group + daylight conditions	8	-7557.88	15131.80	11.73	0
daylight conditions	4	-7576.94	15161.89	41.83	0
distance_group	7	-7860.71	15735.44	615.37	0
null-model	3	-7893.66	15793.33	673.27	0

b) Straightness index
(linearity of path)

Variables	*df*	*LL*	*AICc*	*ΔAICc*	*AICc Weight*
distance_group * daylight conditions	12	1540.84	-3057.62	0.00	0.99
distance_group + daylight conditions	8	1532.21	-3048.40	9.22	0.01
daylight conditions	4	1519.21	-3030.41	27.21	0.00
distance_group	7	1502.28	-2990.54	67.09	0.00
null-model	3	1491.77	-2977.53	80.09	0.00

The reindeer were generally moving at higher speed during daylight than at night and the speed decreased with increasing distance from the hiking trail at daylight hours. There was no change in speed with increasing distance from hiking trail during night. The average speed of GPS marked reindeer within 1 km of the trails was 731 m/h (95% confidence interval 631-847 m/h) for daylight and 223 m/h (171-290 m/h) during night. At 4-5 km of the trails, the mean speed was 506 m/h (452-568) during daylight and 177 m/h (153-205) during night.

Path straightness ST increased with distance to trails during daylight. Although confidence intervals are overlapping between neighbouring distance groups, there was a significant difference in straightness between <1km (mean ST = 0.928, 0.920-0.935) and 4-5km (mean ST = 0.945, 0.940-0.949) distance groups at daylight. The straightness of paths is generally lower at night and it is somewhat very low at <1km from hiking trail, whereas there is overlapping CI for all other distance groups at night.

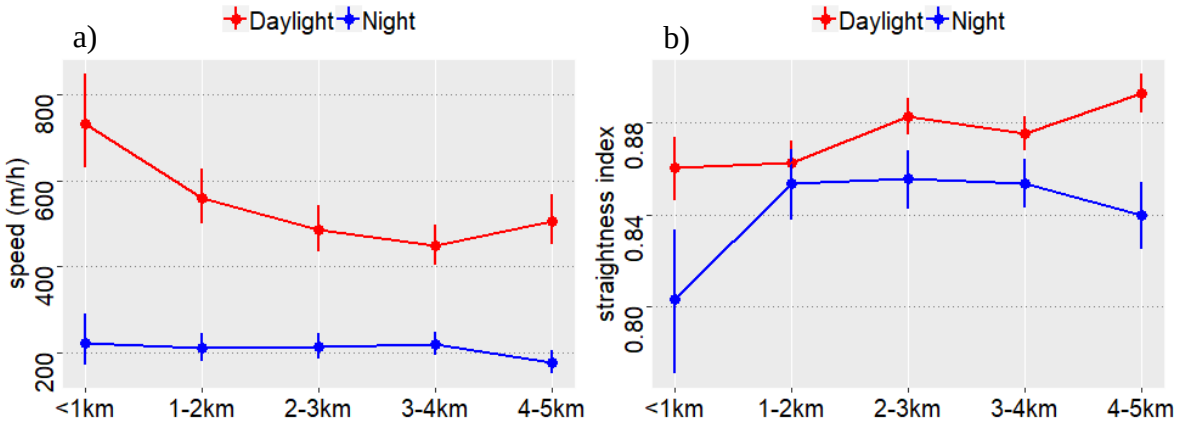


Figure 8: Mean (±SE) of (a) Speed and (b) straightness index (ST) of reindeer from 27.July – 31.August 2010 at different distances to trails and daylight conditions, backtransformed estimates.

4. Discussion

4.1 Human activity

People tend to follow trails (Bayfield 1973). The hikers did so also in my study with the exception of the hunters who were off-trail in the majority of the observations. This is not surprising since hunters are seeking out for areas where they expect to find their prey. Among all other user-groups, 80% are on the trails without leaving it. Other studies in the same area concluded that more than 80% of visitors were following trails (Strand *et al.* 2013), and for 34 National Parks in Norway with similar surveys, between 80-95% of the hikers followed marked trails (Selvaag *et al.* 2018). However, in the neighbour reindeer area, Knutshø, very few of the visitors followed trails. This is mainly because of lack of marked trails in the Knutshø area, and because most of the users are locals and well-known regular visiting the area doing fishing, hunting or herding (Strand *et al.* 2015a).

In Stroplesjødalen, people are distributed throughout the valley (Figure 3), with the highest densities at the tourist cabin Reinheim (36 beds). The high densities around the cabin in the morning is most likely people preparing for their daytrip. There are two marked trails going from Reinheim and east towards Kongsvoll, at both side (south and north) of the river Stropla, but the northern one is the far most used. This trail has increased density of people throughout the day and peaks in the eastern part between 12:00-14:00 (Figure 4). This is probably at the time when people that started from Reinheim in the morning, on their way out of the valley, meets people that started from Kongsvoll. As mentioned earlier, most of the people are following the two marked trails in Stoplesjødalen valley, and the other trails starting from Reinheim going west towards Åmotdalshytta and south towards Snøheim are less used. The trail going south connects the area with the other of the two main entrances to the National Park, the Snøheim road towards Snøheim cabin. Since 2012 there has been established a shuttle bus regime at the Snøheim road and the new tourist lodge Snøheim (80 beds) at the end of the Snøheim road 14 km from Hjerkinn and 5.5 km south of Reinheim (Figure 2). The shuttle bus was established to gain control of traffic to avoid conflicts between people and reindeer along the Snøheim road. Regardless of the establishment of a new Snøheim cabin (approximately 5000 visitor stay overnight during summer) and the shuttlebus regime (approximately 10 000 users), it seems that this has had little influence on the human activity in Stroplesjødalen (Gundersen *et al.* 2017). But, even though access to the area is easier using

the path from Snøheim towards Reinheim, it is surprising that most of the hikers in Stroplesjødalen use the long-distance path from Kongsvoll. There seems that these two parallel main entrances to the park, the trails from Kongsvoll to Reinheim and the shuttlebus to Snøheim, has limited exchange of people in the matrix between. As Nerhoel (2011) describes there are only one marked trail and several minor used unmarked trails between these areas and the traffic through Stroplesjødalen has little influence of the traffic along the Snøheim road.

Nerhoel (2011) also found that 88% of the visitors using the Snøheim road as entrance were daytime tourists. In Stroplesjødalen, the cabin Reinheim has a central function that could indicate that there are overnight tourists visiting the area. Wold (2009) found differences in the composition of the visitor's origin and residence time between the two entrances. Visitors using Kongsvoll as starting point had higher proportion of foreigners choosing to stay overnight in the area than visitors using Snøheim that were mostly daytrip visitors hiking to the summit of Snøhetta. According to my study, 59% were overnight tourists. This means that visitors in Stroplesjødalen were multiple-day hikers and spent more time in the area than visitors using the shuttle bus along the Snøheim road to Snøheim cabin.

The general intensity of use in the National Park is relatively low compared to other international National Parks (Gundersen *et al.* 2011). During summer there is estimated 17 visitors / km² within the park (Gundersen *et al.* 2013a). But, since people are not evenly distributed, certain areas have more visitors than others. A trail tends to be treated as a "constant", but ultimately it shows spatiotemporal variation during a day, a week or seasonal variation throughout a year and also between years (Flemsæter *et al.* 2018). My descriptive study of humans with different densities on site and time of day provides a more subtle picture of the human activity in the valley. By knowing the spatial composition of humans along the trails, it provides useful information which gives the management an opportunity to facilitate an appropriate monitoring. Research projects have annually since 2006 used approximately 20 automatic counters in the area (Eco-Counter, infrared sensor). These estimates vary throughout the season, but during the peak season for hikers there is an average of 50 people entering the area per day (Strand *et al.* 2013). I had 17 days of observation and counted 2044 = 120 people per day. Taken into account that I also covered two other trails into the area and that my observation periods were at weekends (Friday-Sunday), there seems to be a certain similarity consistent between the two surveys. Monitoring the path from east using automatic

counters along with overnight statistics form the Reinheim would be an appropriate way to monitor the human activity in the area.

To change the intensity and distribution of people there is an option to remove trails and cabins in vulnerable areas and establish recreational infrastructure inn less vulnerable areas. This has been a success in other areas and has reduced the level of conflict (Nellemann *et al.* 2010). Canalizing the traffic to other areas, often areas outside or in the fringe of wild reindeer ranges, seem as an efficient action to implement, however, this is also depending on the users respond to changes in the infrastructure. Gundersen *et al.* (2015) found differences between local users and non-local visitors according to approval of legitimacy of management solutions. Non-locals and foreign visitors tend to be more positive to area restrictions and less positive to path restrictions, though they adapts easily to changes in trail systems. Local communities were more sceptic to area restrictions, as they are regular well-known users that went off marked trails. Considering the fact that majority of visitors using the entrance from Kongsvoll is foreigners with little connection to the area (Wold 2009), it would get more effect and easier to implement a change in the trail system than giving area restrictions.

To a certain extent, there has been established changes in the trail system to prevent daytime visitors to not entering the vulnerable reindeer areas in the valley. This is done by facilitating a musk-ox trail in 2017 (Dovrefjell nasjonalparkstyre 2017) visiting main attractions and important musk-ox habitat in the fringe. This will most likely canalize daytime visitors that are interested in musk-ox safari, and my data indicate that a part of the daytime visitors interrupt important reindeer areas in the most eastern part of my study areas. However, since a majority of the visitors using inner part of the Stroplesjødalen valley are overnight visitors, the musk-ox trails might not cause huge effects on the human activity in this part of the valley. Hopefully this initiative to reduce the human impact in a critical corridor for the reindeer will be monitored and evaluated throughout the years to come. My data have stated that automatic counters measuring the marked trails in the area will represent the majority of the human use of the valley, and thus be representative for the changing use of the valley caused by development of infrastructure outside my study area.

4.2 Reindeer

Reindeer are distributed mostly north of the valley and in the area *Kolla* south of Stoplesjødalen in the eastern part of the study area (Figure 5), in the density map (Figure 6)

there is an accumulation of GPS locations in the north - eastern part of the valley. As both maps indicate, the reindeer seems to avoid the valley and particularly the areas in the west. Reinheim is situated in this area and as other studies has shown (Panzacchi *et al.* 2013) that presence of tourist cabins has a dramatic negative effects on the reindeers use of the areas within 1 km radius. The densities of reindeer north - east of the valley is most likely reindeer waiting on the edge down towards the valley before the cross the valley on their migration south. When they have crossed the valley, they tend to stay in the area *Kolla* before they cross the Snøheim road heading further south. *Kolla* seems to be an important refugee area for reindeer movement in the area, strategically placed between the two main axes of intensively human use. Therefor it is crucial that the crossing area in the eastern part of Stroplesjødalen is maintained.

Locations of reindeer according to time and distance from the hiking trails was higher close to the trails in the early morning (Figure 7). This is in the time period before the human activity evolves throughout the day. Most likely this is the time period the reindeer attempts to cross the valley. Based on other studies (Panzacchi, Van Moorter & Strand 2013) I expected the reindeer to have a straighter flight and higher speed closer to the hiking trail. Though I found that they had a straighter flight at daylight, it was not expected that they had less straightness closer to the trails. However, an explanation may be that they are more vigilant and therefore have a more twisted path or they have been disrupted and stopped their attempt to cross the valley. As predicted, the reindeer were moving faster closer to the trails. They had more than 700 m/h speed within 1 km from the trails. Average speed per day during summer and late summer is 9-10 km, approximately 400 m/h (Pape & Löffler 2016). This is more or less the same speed that I found 2-5 km away from the trail.

My study reveals that human and reindeer in Stroplesjødalen to a small extent overlap, and that the reindeer has differently movement pattern at different distances from the hiking trails. Skarin *et al.* (2010) found that domestic reindeer movement rates were linked to differences in abundance of hikers and distance to trails. In areas where hikers were abundant, the movement rates of reindeer decreased closer to the trails whereas in areas where hikers were less abundant, the movement rates of reindeer increased closer to the trails. This indicates that the relation between human use of trails and reindeer use close by the trails is not straightforward, as other factors such as grazing resources and insect harassment in combination with habituation of human activity are important variables. In my study area, the human activity is likely to displace the reindeer from using the areas and affect the change in

movement patterns. There are different perceptions of habituation associated with reindeer and for instance (Reimers *et al.* 2010) concluded that the reindeer in Blefjell were habituated to frequent human encounters, while Nellemann *et al.* (2010) in their more spacious studies did not find signs of habituation. There is no evidence in my study that the reindeer habituated to the cabin and human activity in the area. It seems more likely that the reindeer use the area at time periods when there is less chances to be disrupted by humans.

My results are limited in time, but due to other studies, there is similar results according to reindeer avoidance and movement patterns. However, my study contributes with a better understanding of the spatiotemporal human activity in Stroplesjødalen. My study describes how reindeer and humans are distributed and movement patterns at one summer season. This gives a picture of reindeer avoiding the area and changes their behaviour relative to humans using the hiking trails and tourist cabin in the area, but further research is essential to give a more precise answer to the question why reindeer avoid and change behaviour. According to Skarin (2006), reindeers habitat selection at the landscape level seems to depend of interactions between vegetation, topography, weather, insect harassment and human disturbance. There would be useful to create Resource selection models as RSF (resource selection function) or RUF (resource utilization function) including all these variables. The area also hosts a population of musk-ox that wold be of interest to get more knowledge about. In the field period there was several observations of musk-ox every day, and observations of musk-ox chasing reindeers. Previous studies has concluded that reindeer and musk-ox co-exist (Vincent & Gunn 1981), but (Sheremetev *et al.* 2014) found trends that reindeer populations decreased while musk ox population increased in several areas and was determined by the food web structure.

Even though the visitor numbers to the National Park in general is low, results from GPS studies of wild reindeer shows an effect of avoidance of areas and barriers according to human activity along hiking trails (Gundersen *et al.* 2013a). In Stroplesjødalen, the tourist cabin Reinheim and the human activity may lead to more stagnation in the areas north of the valley and less time spent on foraging. Local disturbances may ultimately effect the reindeers energy-balance (Vistnes & Nellemann 2008). Along with other studies, it seems as a set of different disturbances that ultimately may have cumulative effects on the wild reindeer.

4.3 Management implications

Getting precise knowledge about how human activity occur in the area and visitors attitude toward management restrictions is essential for the management to implement the right management strategies. The Nordic right to have access to wilderness and freedom to roam may challenge the human acceptance of regulations (Klima- og Miljødepartementet 2018b). There might be management actions needed to secure the wild reindeers migration pattern in the area that could threaten the common access to the area. Visitors to Dovrefjell – Sundalsfjell National Park has different attitudes towards management restrictions where local users tend to have higher resistance towards area restrictions than non-local users (Gundersen *et al.* 2015). Because of the people's right to freely roam, there is not the same possibility to use zoning and restrictions on use as a management tool in the same way as in other countries (Gundersen *et al.* 2015). Actions has to be more facilitating the use to channelize people in less vulnerable areas rather than restrictions by law in sensitive areas.

When management actions regarding co-existence of wild reindeer and humans is taken there is essential for the management to make the most appropriate decisions for both human and reindeers. The habitat selection by reindeer can be seen in the concept of hierarchical decisions. Selections occur at different levels – patch, landscape and regional level (Skarin 2006). This could also be evaluated according to human activity at the same levels. The management could treat human impact at different scales. It might be that a count of people override the thresholds the management has set, but depending on the type of activity, intensity and time of day / month / year, it might be seen on a different scale. For the management to make the right decisions they need up-to-date knowledge and at what extent the effect of their choices performs. To balance the co-existence of human and wild reindeer in the National Park there is established visitor management measures to avoid conflicts (Strand *et al.* 2013). In Stroplesjødalen, the measure is to monitor the human traffic by using automatic counters with actions limiting the entrance to the valley to not exceed 20-30 persons per day during the peak season for visitors, as more people than this on a trail can reduce the probability for reindeer crossing. With more than 220 persons per day, no crossing have been observed in wild reindeer ranges in Norway (Strand *et al.* 2015b). Today the number of persons in the middle of my study area Stroplsjødalen may have equivalent numbers, the regular numbers during the peak season is from 20 to 60 persons per day (Gundersen *et al.* 2013b). Using carrying capacity for visitors and reindeer could possibly be used as a tool for management to

make decisions, and it is important to keep on monitoring the human use along the main trail in Stroplsjødalen. Simulation models are used as a tool to facilitate monitoring and managing social carrying capacity (Lawson *et al.* 2003) at daily bases. Simulation models could also be an attempt to be implemented including ecological carrying capacity. To prevent discussions about which management actions to implement it would give the management a choice to make the right decisions that supports the objectives of the National Park.

My somewhat radical and comprehensive conclusion is that the cabin Reinheim and the path from Kongsvoll to Reinheim has a negative effect on the reindeers use of the area and causes impacts on the animals movement rates, but it is today not an absolute barrier. Gundersen *et al.* (2013b) made assumptions that the number of visitors will increase in the future. The valley may then evolve into a barrier if the density of humans increases. Båtstad (2002) recommended to reduce the traffic from Kongsvoll by stop marking the hiking trail towards Reinheim and canalize the traffic using the Snøheim road. Today there is already an expansion of the capacity for visitors in the area. When the military closed the shooting-range, they gave the cabin Snøheim to the NTA. This caused more than 5000 additional overnight stay visitors at Snøheim cabin during the summer season (Strand *et al.* 2013). Along with the other cabins NTA runs in the area, they appear as the driving force for the human activity in the National Park.

Reinheim is the most important factor for the further development of human activity in Stoplesjødalen (Jordhøy *et al.* 2003). A closedown of the cabin would most likely be an effective management action to decrease the human activity. Since there is established a shuttle bus on the Snøheim and the reopening of the cabin Snøheim, there is an opportunity to remove the cabin Reinheim and quit marking the path from Kongsvoll for transmit of the traffic to Snøheim. Instead of two parallel human use axes that the reindeer need to cross, a strategy would then be to channel all traffic to one of them. Nellemann *et al.* (2010) found that removal of ski trails and an associated tourist cabin to restore access to historic habitat brought the reindeer back to the area. A removal of Reinheim and the trail will most likely have an impact on the multiple-day hikers and an effective action to implement to prevent the valley from becoming a permanent barrier. Decreasing the density of humans in Stroplesjødalen will increase the traffic to Snøheim and the surrounding areas, first of all to the summit of Snøhetta and towards Åmotsdalshytta from Snøheim. Those areas are closer to the central mountain range with high altitudes that are less attractive for the reindeer, but provide large attractions to the tourists. A continuation of the shuttle bus regime will, despite increased traffic be able

to control the human activity on the road. This is likely to be a controversial decision but the alternatives of not considering to reduce the traffic in Stroplesjødalen is to make it evolve into a barrier that might have major consequences for the reindeers rotational movement seasonal pattern around the mountain range.

To sum up, if the human activity increases during the peak season for hikers in Stroplesjødalen, I have the following overall recommendation for future management:

- Close down the Reinheim tourist cabin, and remove associated infrastructure of marked trails.
- Develop the Snøheim road access further, including attractions close by Snøheim and strengthen the connection to marked trails south and north of Snøhetta mountain range towards Åmotsdalshytta further west.
- Avoid all development of recreational infrastructure in Stroplsjødalen
- Avoid all development of recreational infrastructure towards the reindeer refuge area Kolla, and in the areas in between the main entrance Stroplsjødalen and the Snøheim road

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