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Effects on small-game hunt of reindeer short-term behaviour

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Svensk sammanfattning

Småviltjakten har varit omdebatterad sedan den släpptes fri 1992. Osäkerheten om huruvida renarna störs i samband med jakten har varit ett problem. Den här studien har varit ett första steg i att uppskatta effekten av småviltsjakt på renarnas beteende i samband med ripjakten. Vi har studerat renarnas dygnsrytm och aktivitetsmönster under de första tio dagarna av småviltsjakten under 2007 i Vilhelmina Södra sameby. Data från 25 GPS-halsband som hängt på renar har relaterats till antal jägare inom respektive jaktområde och dag. Vi undersökte också om renarnas flockbeteende påverkades av jakten genom att göra flygobservationer under jaktens tre första dagar, där vi räknade antalet renar och jägare från luften inom 5 olika jaktområden (mellan 70-191 km^2). Analyserna visade att det under den studerade perioden, med ett totalt jakttryck på som mest 1.5 jaktmandagar/km^2, inte gick att se någon effekt av antalet jägare inom ett jaktområde på renarnas rörelsehastighet eller dygnsrytm. Vi kunde inte heller hitta något samband mellan renarna flockstorlek och avståndet till jägare. Vår slutsats är att jakten inte verkade störa renarnas dygnsrytm eller rörelsemönster. Vi kunde dock konstatera att det skulle behövas mer detaljerade uppgifter om jägarnas positioner i förhållande till renarnas för att kunna dra säkra slutsatser. Effekten på renarna är troligen kortvarig (högst några timmar) och den kan därför vara svår att upptäcka genom att bara ha kännedom om totala antalet jägare inom ett jaktområde.

Abstract

To estimate the effect of small-game hunting activity on reindeer short-term movements and diurnal pattern data from GPS-collars fitted on reindeer were analyzed in relation to hunting activity during the first ten days of the hunt (August 25th to September 3rd, 2007). The study was made within 7 hunting areas (each 70-191 km^2) in Vilhelmina Södra reindeer herding district in Västerbotten County in northern Sweden. Reindeer flock size during the first three days of the hunt in relation to hunters positions were also studied. We hypothesized the hunting activity to increase the reindeer movement rates, disrupt their diurnal pattern and to decrease the reindeer flock size. The results show that within the observed study period and hunting areas, with a total highest hunting pressure of 1.5 hunter days/km^2, we could not find any association between the number of hunters per day in an area and the reindeer short-term movement rate or diurnal pattern. We found that the reindeer were more affected by environmental variables such as temperature and elevation. However, this might be due to different resolution in the reindeer observations compared to the hunting activity observations. Our recommendations from this study are that a detailed GPS dataset with reindeer positions also should be accompanied by a detailed dataset from conspecifics. In the case of this study, a new policy that records the exact whereabouts of hunters will provide more insights of the exact interactions between reindeer and the hunters.

Introduction

A new possible source of disturbance for the semi-domestic reindeer *Rangifer tarandus tarandus* in the Swedish mountain region may be the increased number of willow grouse (*Lagopus lagopus*) hunters in the early autumn. The willow grouse live in the willow thickets and the birch forest vegetation, where the reindeer preferably eat mushrooms during the late summer. In some mountain regions the hunt is carried out over a large part of the reindeer autumn range. For female reindeer this period is important because they try to compensate the energy lost due to the demands of lactation (Russell et al. 1993). Mårell et al. (2002) also showed that in this period reindeer search for sites with optimum resources, therefore any disturbance, which may affect this behaviour, could result in severe consequences for the upcoming winter.

Animal decision making can be considered a hierarchical process where selection occurs at different scales including: (1) the landscape at the regional level; (2) feeding sites or communities at the landscape level; and (3) feeding stations or plants at the patch level (Johnson 1980; Senft et al. 1987). Different factors also affect the animals' decisions or selections at different scales and analyses of animal movements can aid our understanding of animal responses to the environment at these different scales (Ager et al. 2003). Understanding movement patterns is vital in studies of highly mobile species, such as reindeer. In recent years the GPS-telemetry facilitates such an understanding.

The aim of this study was to evaluate the effect of small-game hunting on reindeer, studying reindeer diurnal pattern and short-term movements before and during the first two weeks of the small game hunt, i.e. their behavior at the landscape level. For this we used GPS-location fixes with 30 min time intervals, number of hunters within each hunting area, along with environmental variables such as temperature, wind speed, vegetation types and topographic factors. We also evaluated the reindeer herd behavior in relation to hunting activity. Here, we expected the hunters to split up the reindeer in smaller groups and to displace them from the hunting area. To gather information about the reindeer herd behavior in the area we performed aerial observations in five hunting areas during the first three days of the hunt, counting reindeer and hunters.

Material and Methods

Study area

The study was conducted in the mountain summer ranges of Vilhelmina södra reindeer herding district (65^0 8'N, 14^0 9'E, Fig. 1.). The studied area is 5204 km^2. Within the summer ranges, reindeer graze freely from May to October with interruption of the calf marking in beginning of July. Vilhelmina södra summer range hosts approximately 10000 reindeer.

Table 1. Percentage of the total area and where the GPS reindeer positions were present within each vegetation type cell (Swedish CORINE Land Cover map (50 m cell size)) in Vilhelmina södra reindeer herding district

	Total area		**GPS reindeer presence**	
Classes	Km^2	%	Km^2	%
Broad-leaved forest	915.5	17.6	7.6	17.0
Forest	846.4	16.3	0.1	0.2
Moors and heathland	1808.6	34.8	28.1	62.9
Thickets	30.9	0.6	0.5	1.1
Grasslands	311.7	6.0	2.8	6.3
Bare rock	89.9	1.7	0.3	0.6
Mires	601.8	11.6	4.1	9.1
Water courses	0.6	0.0	0.0	0.0
Lakes and ponds, open surface	394.3	7.6	0.4	0.8
Lakes and ponds, surface being grown over	8.5	0.2	0.0	0.0
Not Available	196.5	3.8	0.9	2.1
Total	5204.4	100	44.6	100

The elevation in Vilhelmina södra ranges between 353 and 1566 m above mean sea level (AMSL), it is an alpine ecosystem with deep and long valleys. The landscape is dominated by moors and heathland (Table 1) with broad-leaved forest representing timberline at 800 m AMSL. The area has low road density, to access the area hunters can use the two major roads.

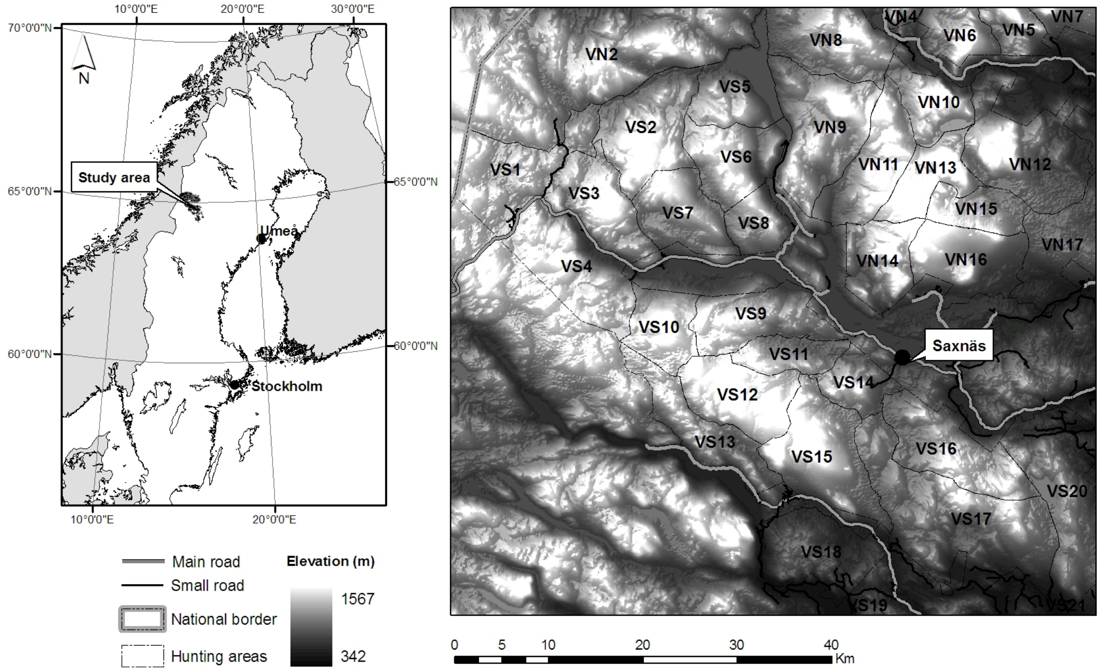

Figure 1. The study area, with hunting areas in Vilhelmina södra reindeer herding district.

Weather records of temperature and wind speed (observed every third hour), from Saxnäs Meteorological station (Swedish Metrological and Hydrological Institute) were considered to be representative for the season. The overall weather conditions trend for the study was that the temperature progressively dropped from average 12.5 ^{0}C in the period before hunting to 6.1 ^{0}C after hunting and the wind speed increased from average 1.8 m/s before hunting to average 2.9 m/s after hunting.

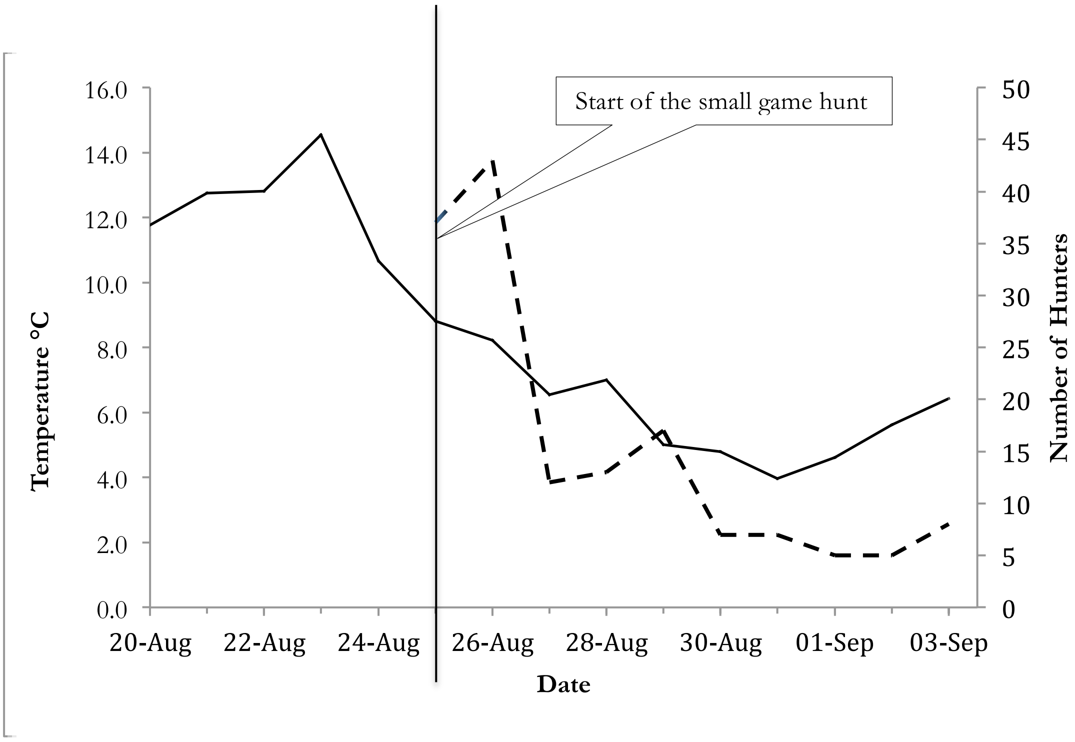

Figure 2. Average daily temperature (solid line) and the number of hunters in areas where the GPS-reindeer were positioned (dashed line).

Data collection

From July 18th until April 1th 2008, 26 randomly selected adult female reindeer were fitted with GPS transmitting collars (Posrec©, 650 gram, manufactured by TVP Positioning AB) providing a GPS fix every 30 minutes between 13th August until 9th September, otherwise positions were collected every third hour. Females were chosen as study animals as they represent the majority of the herd. Due to technical failure one collar was excluded from the analysis. For the study period starting August 20th until September 3rd, the total number of fixes from the 25 collars was 17998, with 163 missing fixes.

In August 25th the small-game hunting season opens in Sweden. In the reindeer herding area, small-game hunt is allowed within designated areas. In Vilhelmina södra reindeer herding district the total number of hunters from August 25th until September 3rd were 402, 152 of these hunted in areas (VS1, VS5, VS6, VS12 and VS13; Fig 1.), where 11 reindeer of the GPS-collared reindeer also were present. The first five days, hunting was more intense than the last five days of the study period (122 hunters compared to 32 hunters, Fig. 2). The number of hunters was provided from the County Board of Västerbotten.

In order to study the reindeer herd behavior during the hunt the area was systematically overflown with helicopter once every day during August 25th until August 27th. The search started at the earliest each day at 10:00 am in Saxnäs and finished at the latest at 16:00 am at the same spot. We flew over five of the hunting areas in Vilhelmina södra district (VS5, VS6, VS8, VS16 and VS17, Fig 1). In total one GPS equipped reindeer was in VS5 and one were in VS6 at the same time as the aerial observations was performed.

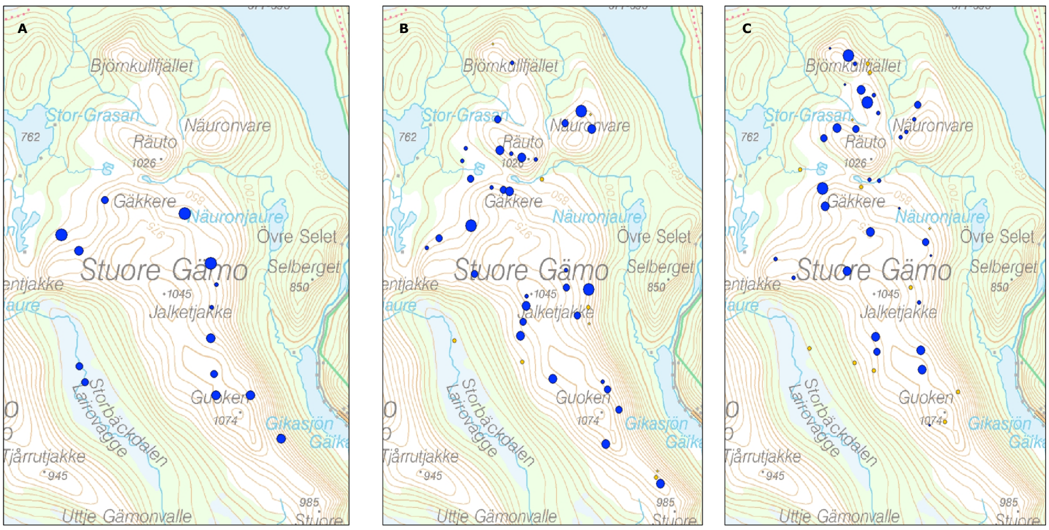

Figure 3. Reindeer locations as observed from air within VS5, VS6 and VS8 hunting areas in a) August 25th, b) August 26th and, c) August 27th. The blue dots are reindeer observations increasing in size with number of reindeer and the yellow dots are the observations of hunters. No hunters were observed in the area August 25th.

Data treatment

To study reindeer small-scale movements before and during hunting season a study period of 15 days was defined. The period before hunting consisted of five days from August 20th to August 24th of, the period during hunting was defined during August 25th –to September 3rd. The study period was selected to be as short as possible in order to decrease the uncertainty of other events that could possibly take place.

We used ArcGIS 9.3 (Environmental Systems Research Institute Inc., Redlands, CA) to assign the number of hunters to each hunting area and then we connected the number of hunters to the GPS fixes of each reindeer.

To correlate the reindeer behaviour with hunting, a categorical variable for hunting activity was created. The number of hunters was not the same throughout the whole period. A cut-off point (7 hunters) was calculated from the median of the number of hunters for the study period during hunting in order to define two categories of hunting activity, low (L) and high (H). The areas where hunting did not occur or were not permitted were considered as non-hunting (NH) areas.

The influence of landscape variables was estimated simultaneously with hunting activity. The variables used were the elevation, slope, aspect, ruggedness, vegetation type (Table 1), distance to lakes and road density. The available raster resolution of the digital elevation map (DEM) set the resolution of the analysis to 50 x 50 m. Slope, aspect and ruggedness were derived from DEM using ArcGIS 9.3. Ruggedness was calculated through the vector ruggedness measure (VRM; Sappington et al., 2007). The aspect was divided in 5 classes (Flat, Northeast, Southeast, Southwest and Northwest). Digitized vegetation data, (Swedish CORINE Land Cover; 25 x 25 m) were acquired from Lantmäteriet and further resampled to 50 x 50 m in order to match the rest of the layers. The vegetation types (Table 1) were Boolean variables of either 1 denoting presence or 0 denoting absence. For each 50 x 50 m cell the Euclidian distance to the nearest lake or water body was calculated. In the same way the road density was calculated with a 2 km search radius. The value of every landscape variable was assigned to all fixes through the `overlay` function in R-statistical Software (Gentleman and Ihaka, 2000).

Missing fixes in the GPS data due to bad satellite coverage as well as rounding of the time of the day was treated with R functions `setNA` and `sett0`. Note that a prerequisite of the programme is to erase the double entries that might occur while the data are downloaded from the collars. Where no-information was obtained from the collars a new full time series was created with equal time intervals of 30 minutes, where the missing time was inserted and the fix was left with no positioning. Finally, `ltraj` function package computed the distance between two consecutive fixes.

Data analysis

GPS-telemetry data is often correlated in time and space. In high resolved data (when the time span between relocations is small), the successive fixes (positions) are highly dependent in both space and time. Temporal autocorrelation is when the successive observations are influenced by the past observation and spatial autocorrelation when they are influenced by all directions. In statistical analysis autocorrelation is often conceived as a ‘thorn’ affecting the rules of classical statistical hypothesis testing, where sample independence of the successive fixes is a prerequisite (Legendre 1993). To tackle this problem, solutions as subsampling or variance inflation have been proposed (Turchin, 1998). However, animal movement behaviour is in general heavily autocorrelated, and by removing it relevant information on animal behaviour might be lost (Boyce et al., 2010; Dray et al., 2010). For example, relocations with temporal autocorrelations can be due to an internal process such as a diurnal or crepuscular activity and once it is identified the data can be detrended to further examine other reasons behind the variability of animal movements (Dray et al., 2006).

To assess the impact of hunting activity on reindeer step length the data was first tested for autocorrelation using the `acf` function in R. Furthermore, the periodicity of the autocorrelation values was estimated with a generalized linear model (GLM):

$$y(t) = \beta_0 + \beta_1 \cos(\frac{2\pi t}{24}) + \beta_2 \sin(\frac{2\pi t}{24}) + \beta_3 \cos(\frac{2\pi t}{12}) + \beta_4 \sin(\frac{2\pi t}{12}) + \beta_5 \cos(\frac{2\pi t}{8}) + \beta_6 \sin(\frac{2\pi t}{8}) + \beta_7 \cos(\frac{2\pi t}{6}) + \beta_8 \sin(\frac{2\pi t}{6}) + \varepsilon$$

where the response variable y(t) was an oscillating response, representing the calculated autocorrelation (r) for every lag (t). The period length was tested for 24, 12, 8 and 6 h, which denote the daily cycle, the activity every half of a day, every 8 hours and every 6 hours respectively.

Step length size was detrended from any autocorrelation pattern and the residuals (detrended step length - DSL) were used (instead of the real step length) to estimate the influence of hunting activity of reindeer short-term movement. The latter was examined using a mixed effect model (`lme` function; Pineiro and Bates 2007) with reindeer individuals as random effect and hunting activity, landscape variables, temperature, and wind as fixed effects. For hunting activity the NH class was considered as a default and compared with the rest two classes L and H hunting activity. For the aspect classes flat was considered as default and compared with the rest four classes.

To cover the large-scale habitat selection the reindeer daily-utilized areas (DUA) were estimated using minimum convex polygons (MCPs). MCPs were calculated using the 100% of the fixes per day (`mcp` function in R). Linear mixed effect models were developed of reindeer area used per day on hunting activity, temperature, and wind considering reindeer individuals as a random effect.

For both DSL and DUA, three models were constructed. In the first models (model 1) the data from the period during hunting was computed. In the second model (model 2) the data from the period before (5 days) and the first 5 days hunting period for only the individuals, exposed to hunting. The third model (model 3) treats data from the whole study period for all the individuals. For each model the best set of predictor variables was selected based on Akaike's Information Criterion (AIC).

To estimate reindeer group size on distance to hunters from the aerial observations, a generalized linear model of number of reindeer in each group on the logarithm of distance to nearest hunter (maximum distance 6990 m), number of hunters and day of observation.

Results

Step length

The mean step length for all animals during the study period was 205 m. There is also a significant diurnal pattern in the autocorrelation functions for 48 lags (i.e. the 24 hour-cycle; Fig. 4). The diurnal activity was verified with the cosine term for 24hrs ($p<0.01$, t-value=2.8) for the whole study period. For the period before the hunt there was also a significant diurnal pattern ($p<0.001$, t-value=4.7), however for the period during the hunt the pattern was not significant, even though reindeer were divided into two groups with 11 reindeer within the hunting area, and 14 reindeer outside the hunting area. The autocorrelation was then removed in order to test for the effect of hunting (Fig. 5).

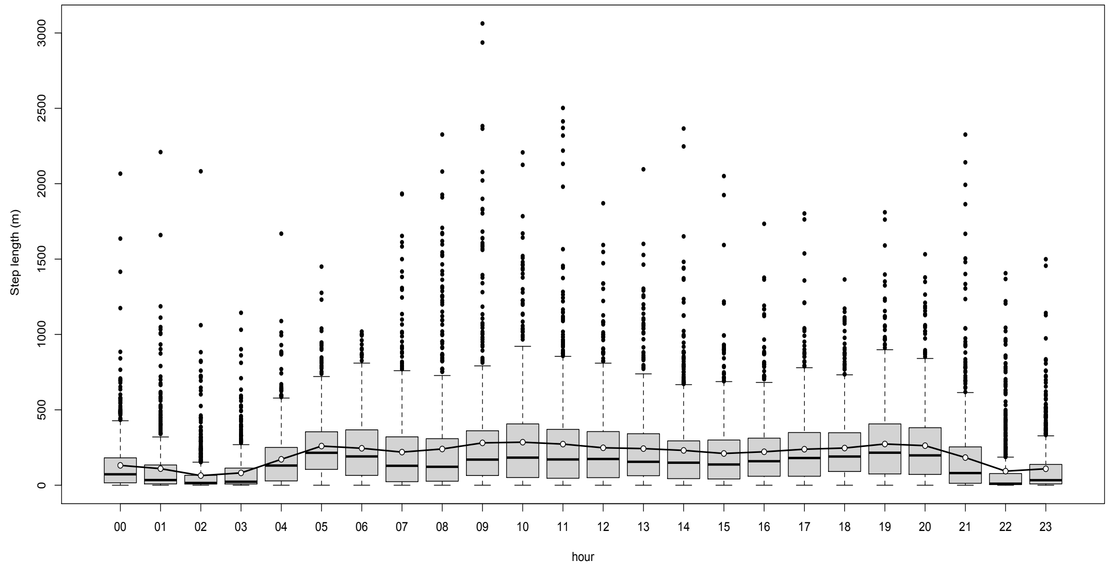

Figure 4 Boxplots of the step lengths for 25 reindeer for every hour for the whole study period.

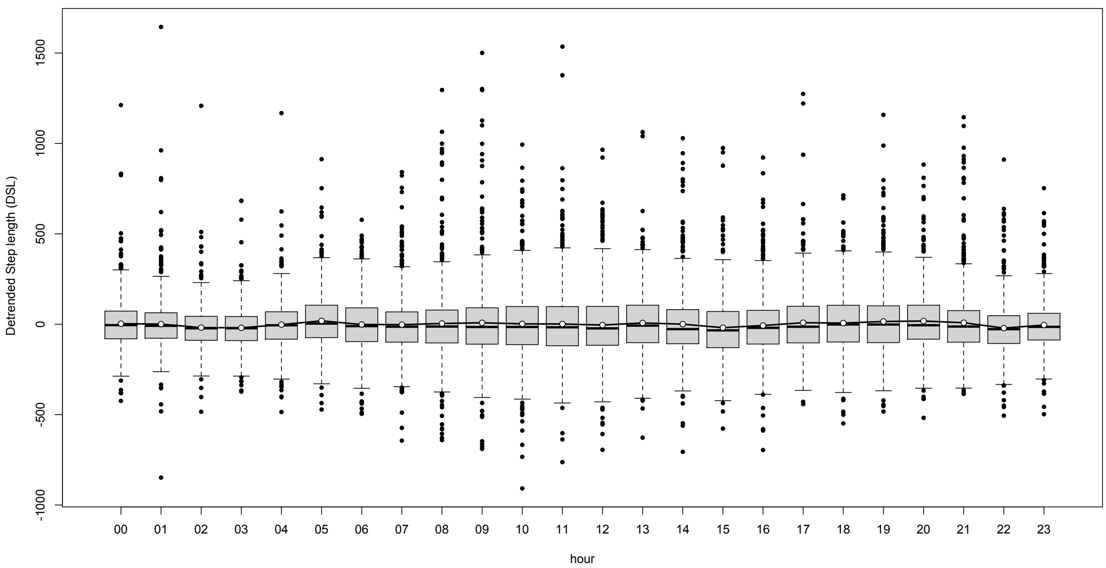

Figure 5. Detrended step length for 25 reindeer for every hour for the whole study period.

The linear mixed effects models on DSL revealed that there is no effect of hunting on reindeer DSL (Table 3), and in the first model none of the predictors explains the DSL trends. Furthermore, the second model showed that the reindeer step length decreased within the vegetation types bare rocks and mires. In the third model, estimating the effect of the environmental factors on reindeer DSL over the whole study period there is a significant effect of temperature (p-value=0.004), were the step length increased with temperature. Moreover the step length decrease with elevation, ruggedness and in the vegetation type bare rocks. For all three models the most parsimonious model according to the AIC-value was the full model.

Table 3. Results of the three linear mixed effects for the detrended step lengths (DSL). DSL10 (model 1) studies DSL for only the period of hunting, DSL 5-5 (model 2) studies DSL only for the reindeer that occurred in areas with hunters and DSL15 (model 3) studies DSL for all the individuals for the whole study period.

	DSL10 (1)				**DSL5-5 (2)**				**DSL15 (3)**			
	LMM		**ANOVA**		**LMM**		**ANOVA**		**LMM**		**ANOVA**	
	coef	**SE**	**F-value**	**p-value**	**coef**	**SE**	**F-value**	**p-value**	**coef**	**SE**	**F-value**	**p-value**
Intercept	10.929	16.054	0	1	-10.265	36.872	0	1	28.846	12.639	0	1
Categorical variables												
Hunting activity			1.869	0.154			0.183	0.833			0.010	0.990
Low Hunting	-8.890	5.028			5.347	9.798			0.704	5.162		
High Hunting	8.733	12.842			5.061	14.936			0.501	13.294		
Aspect			1.024	0.393			0.791	0.531			0.173	0.952
Aspect NE	-0.924	8.969			17.012	15.236			-5.873	7.712		
Aspect SE	3.779	9.233			22.657	16.050			-3.885	7.884		
Aspect SW	5.001	9.048			23.601	15.839			-4.582	7.731		
Aspect NW	7.091	9.119			21.727	15.583			-4.168	7.816		
Vegetation types												
Moors and Heathlands	1.130	4.157	0.079	0.779	5.182	13.311	1.015	0.314	0.121	3.808	0.059	0.809
Willow thickets	17.698	15.048	0.995	0.319	53.019	37.263	1.216	0.270	13.940	12.659	1.370	0.242
Bare rocks	31.452	35.200	0.386	0.534	-38.831	33.560	3.104	0.078	-27.498	17.883	3.802	**0.051**
Forests	17.996	32.874	0.502	0.479	93.219	184.082	0.234	0.628	40.272	34.234	1.935	0.164
Mires	-3.026	6.052	0.030	0.863	12.008	15.529	0.386	0.534	-7.484	5.434	0.000	1.000
Grasslands/ Open areas	1.051	7.952	0.299	0.585	22.454	20.217	0.888	0.346	-2.955	6.386	1.590	0.207
Continous variables												
Distance to lakes	0.002	0.002	0.518	0.472	0.000	0.003	0.072	0.789	0.000	0.001	0.007	0.934
Road density	15.453	11.955	1.858	0.173	30.488	18.619	2.072	0.150	11.797	11.192	0.643	0.423
Temperature	0.285	0.760	0.211	0.646	1.710	0.940	2.972	0.085	1.010	0.351	8.412	**0.004**
Elevation	-0.018	0.016	1.617	0.204	-0.036	0.042	0.179	0.672	-0.034	0.014	6.357	**0.012**
Ruggedness	-0.127	0.133	1.023	0.312	0.360	0.406	1.078	0.299	-0.276	0.096	7.352	**0.007**
Slope	-0.462	0.392	1.270	0.260	-1.132	0.835	1.995	0.158	-0.454	0.331	5.774	**0.016**

Daily-utilized area size

Similar results were also revealed testing the effect of hunting on the DUA size for every reindeer (Fig. 6). There is no effect of hunting on the size of the area for all three models (p-value: 0.57, 0.47, 0.35), however the size of the area increased with temperature in model 3 (p-value= 0.01).

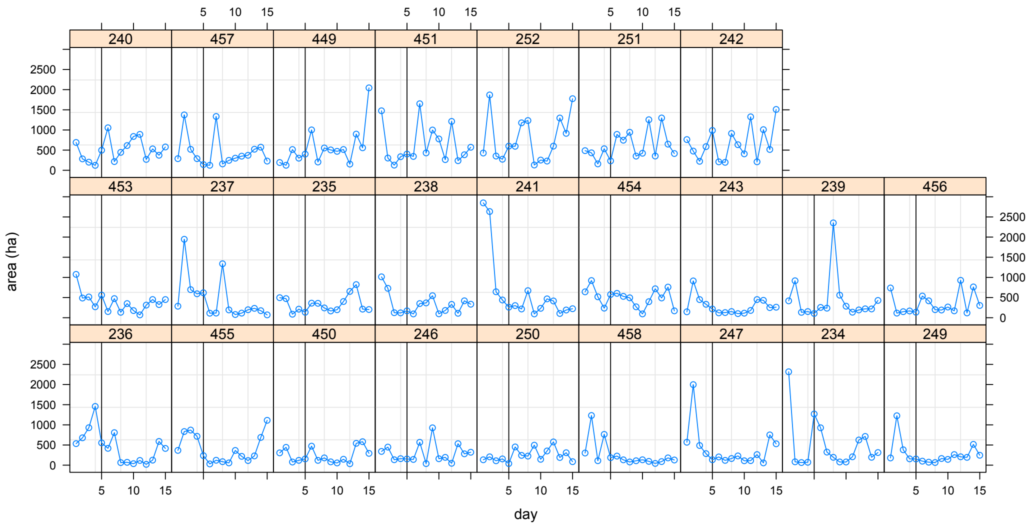

Figure 6. Utilized area of each reindeer per day for the whole studied period. The vertical line (x=5) separates the days before and after hunting.

Aerial observations

The mean group size of the number of reindeer in each observation varied between 17-14 reindeer over the three days. The GLM analysis of the aerial observations over the five hunting areas show that the hunters there is a difference in the number of reindeer in each group between the day of observation. There is a tendency to be more reindeer (however non-significant) in each group the closer they are to the hunters (Fig. 7).

Table 2. The average group size of reindeer per day, the average number of hunters and the average distance between hunters and reindeer.

Date	Reindeer		Hunters		Distance	
	Mean	SD	Mean	SD	Mean	SD
25-aug	16.7	16.6	2.0	1.6	4122.2	1644.9
26-aug	16.9	17.8	3.9	1.3	2394.1	1662.9
27-aug	14.5	15.8	2.5	1.0	1885.5	1445.5

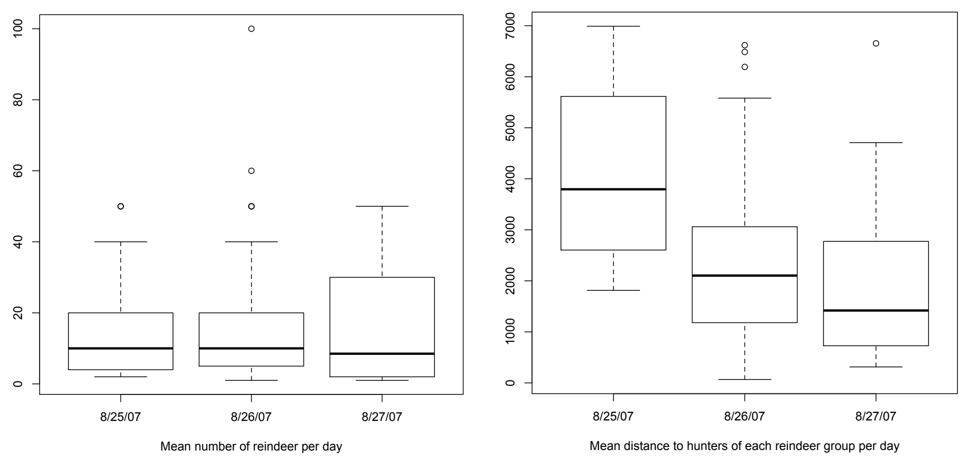

Figure 7. The mean number of reindeer within each reindeer group and the distance to the nearest hunter(s) per day.

Discussion

We found that the reindeer had a diurnal pattern during our whole study period investigated (before and during hunting). However, dividing the data to before and during hunting we found a diurnal pattern in the period before the hunt and no diurnal pattern in the period during the hunt. This could be explained by the hunters disturbing the reindeer in this period however, when we divided the data once again between reindeer within hunting areas and reindeer outside hunting areas we saw no difference in the diurnal pattern between the two groups. This suggests that the reindeer were more affected by other environmental factors such as weather parameters than by hunters. During the study period, the weather conditions changed from high temperature and low wind before hunting, to low temperature and high wind speed during the hunt. Thus, in the period before the hunt there was larger difference between day and night temperatures, most likely causing the strong diurnal pattern. The number of hunters within each hunting area was also rather low, and varied between 0.3 and 1.5 hunting-days/km^2.

Further, our analyses on reindeer step length suggest that hunting activity had no impact on reindeer in our study area. The variance of the recorded step lengths was merely due to the temperature fluctuation. The results from the analysis of the daily-utilized area show that decreased temperature lead to smaller utilized areas. The reindeer response to insect harassment might be an explanation for the pattern we report. In summer and early autumn, insect activity has been found to increase with temperature (Anderson et al. 1994; Hagemoen and Reimers 2002). Therefore, reindeer decreased step length with elevation is most likely correlated with finding insects relief at higher altitudes when temperature is high (Skarin et al. 2004; Skarin et al. 2010). Thus, the results from the first and the second model where temperature had no effect, is explained by the stable weather patterns. The temperature alteration as an environmental factor may also play an important role in the decision making process for reindeer. The trade-offs between disturbance of hunting and compensation from insect harassment may override the disturbance from hunters. A similar idea proposed by Skarin et al. (2004) where hiking activity was obscured by the insect harassment.

There was a tendency in the aerial observations that the reindeer groups were smaller the last observation day (Table 2), implying that the hunters split the reindeer in smaller groups (Fig. 3). A personal observation during the aerial observations was also that at some occasion reindeer were about to run of from the mountain as the hunters approached. However, our analysis of the aerial observations, estimating the number of reindeer in each group on the distance to hunter and day of observation, showed that there was a non-significant negative dependence between the number of reindeer and distance to hunters, but that the number of reindeer per group changed between the observation days. Thus, the patterns were unclear which also implies that the environmental variables had a larger effect on the reindeer group size than the hunters.

In general comparable results indicating no impact of hunting activity have been reported in other studies, for example hunting activity on non-hunted moose had no effect on their movements rates (Neumann et al. 2009). Further, the effects of hunting on other ungulate species (moose, red deer, feral pigs and roe deer) have shown to have a temporary effect on the animal, which last less than day, then the animals returned to their initial grounds, or is some extreme cases they returned within days (Jeppesen 1987a; Jeppesen 1987b; McIllroy and Saillard 1989; Cederlund and Kjellander 1991; Ericsson 1993).

In some cases hunting have shown to play an important role on the physical condition of the animals (Skogland and Grøvan; 1988). For example, in wild reindeer, hunting had an effect on reindeer movement activity especially when the animals were already in poor condition (Skogland and Grøvan; 1988). However, Skogland and Grøvan (1988) studied the immediate response of wild reindeer to hunting disturbance with ground observations and following them for a short period. Other studies show little or no disturbance at all on reindeer (both wild and semi-domestic) from recreational activities during winter (skiers, snowmobiles; Reimers et al. 2003; Reimers et al. 2006) or summer (hiking; Skarin et al. 2008; Skarin et al. 2010). The decreased flight response of the direct disturbance from human activities in wild reindeer has been suggested to be a result of a habituation response to frequent human encounters (Reimers et al., 2010). However, one should bear in mind that the reindeer in these cases had little chance of selecting another area available for foraging.

In conclusion, we did not find that the hunters, during this study period at this density of hunting, disrupted the reindeer diurnal pattern neither did we see any effect on the reindeer short-term movements. The reindeer during this period are said to focus on the foraging intake, which probably override a possible disturbance from a hunter. The reindeer we studied did not have any disrupted behavior pattern due to the presence of hunters during this short time period of ten days. Nevertheless, the registrations of the reindeer positions was very detailed with fixes every half hour, whereas the available hunting data were not as detailed, despite the fact that the number of hunters per day and hunting area is known, their exact positions within the hunting areas remain unknown. We highly recommend that a detailed GPS dataset should be also accompanied by a detailed dataset from conspecifics. In the case of this study, a new policy that records the exact whereabouts of hunters will provide more insights of the exact interactions between reindeer and hunters.

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