Comparative movement behaviour and habitat selection of semi-domestic herbivore: Central-place grazing versus free-range grazing in Reindeer (*Rangifer t. tarandus*)

Habitatval och rörelsemönster hos ren (Rangifer t. tarandus): en jämförelse mellan fritt bete och stödutfodring

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Abstract

Reindeer (*Rangifer tarandus tarandus*) husbandry mainly relies on natural pastures to ensure a sustainable animal production. In Sweden, coniferous forest areas are most commonly utilized as grazing grounds during winter. Additionally, supplementary feeding is sometimes provided for free-ranging animals to ensure their survival. The main reasons for the provision of supplementary feeding are loss of lichen pastures due to modern forestry practices and climate change. It is important to understand habitat selection of reindeer and how this selection differs when supplementary food is provided during winter. To answer these questions, GPS collared reindeer data was analyzed for winters between years 2007 – 2010 and 2014 – 2016, comparing time periods when animals relied on natural pasture with periods when animals were provided with supplementary feeding. The study area is situated within Malå herding district in Västerbotten County in northern Sweden. The aim of this project was to investigate 1) habitat selection and space use pattern, 2) differences in home range size between supplementary fed and naturally grazing reindeer, 3) to what extent reindeer move during the winter period when they are not supplementary fed, and 4) how often they re-visit and stay close to the feeding stations when they are supplementary fed. The results clearly showed that reindeer select for lichen-rich forests, open areas and clear cuts both when freely ranging or supplementary fed. The choice of lichen-rich forest habitat becomes stronger when animal were not supplementary fed. The results also showed that reindeer avoided roads during winter. In addition, utility distribution covered a larger geographical area when they were feeding on natural pastures as reindeer covered large geographical area. The frequency of re-visitations and time spent around the feeding stations varied between years. The findings of this research can be useful to face the future challenges associated with reindeer husbandry management in different areas with respect to their home range size, habitat selectivity, re-visitation frequency and time spend inside the feeding stations. The study results could be compared with the herders' knowledge and shared with them for coordination and dialogue between different sectors.

Keywords: supplementary feeding, habitat selection, lichen-rich forests, home range size, *Rangifer tarandus tarandus*, reindeer husbandry management, Sámi, recursive movements, clear cuts, brownian bridge movement model.

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3. Abbreviations

WF's	Wind Farms
SMHI	Swedish Metrological and Hydrological Institute
BBMM	Brownian Bridge Movement Model
UD	Utilization Distribution
SSFs	Step Selection Functions
AMT	Animal Movement Tools
SL	Step Length
HRS	Home Range Size
BACI	Before and After Control Impact

4. Introduction

4.1. Background

Reindeer (*Rangifer tarandus tarandus*) play an important ecological and cultural role in Swedish mountain ecosystem (Bråthen et al., 2007). Reindeer exploit the spatial environment which is mostly dependent upon the availability of the resources throughout the landscape (Danell et al., 2006). During spring, they graze in the mountain areas, where they feed on meadows, snow-beds and heath lands while in winter they usually move to lower elevations or lichen rich grounds which are considered to be the ideal winter habitat for the reindeer (Sandström et al., 2003).

Movement of reindeer largely dependent upon the kind of the habitat they prefer. However, it remains unresolved if habitat selection and space use pattern differ between free-ranging reindeer as compared to those who are close to feeding sites. According to Beest et al., (2010), habitat selection of female GPS-collared moose changed in the presence of diversionary forage, as they concentrated their space use around the feeding sites. The space uses around the feeding sites are in accordance with the assumptions of central-place foraging (Beest et al., 2010). The result also showed that moose close to feeding sites and free rangers both used young pine stands to the same degree. There are two different types of movement behaviour depending on if reindeer use supplementary feeding sites or not. Animals return to the same site for foraging, when they go out to find a food are called central place foragers. All the species that have an attribute of central place foraging share one common instinct that they find their way back to central place after foraging away from central place. The activities of the central-place foragers include the outbound journey, a time spent in searching of food and back from journey (Bell, 1990).

The availability of resources during the winter and summer depend upon the weather conditions most of the time. No one other than indigenous Sami people has a right of reindeer husbandry. The total number of reindeer in Sweden is

260,000 animals approximately. For indigenous Sami people the socio-cultural and economic impacts of reindeer husbandry are highly important (Jernsletten and Klokov, 2002; Sandström et al., 2003).

The reindeer husbandry relies on undisturbed natural forage grazing grounds. During the winter period the population of reindeer mostly relies on ground lichen which they dig up through the snow. Snow is the main decisive factor regarding the accessibility of winter forage and it can cause low feeding rate among reindeer herds (Rominger et al., 2000). Reindeer can smell lichen patches through at least 90 cm of snow the time and energy consumption of digging increase with the hardness of the snow (Collins et al, 1991). When the lichens are present in the abundance they can constitute up to 80% of winter diet. Despite the variation in the winter diet, it is predicted that more animals and higher productivity can be achieved on lichen-rich grazing grounds as compare to lichen-poor grazing grounds (Helle et al., 1982; Kojola et al., 1995). They use the lichen as the energy source but if it is not available they use vascular plants and grasses or move to arboreal lichens which are found old growth coniferous forest (Heggberget et al, 2002).

In reindeer husbandry, herders provide supplementary feeding specifically in winters when forest floor is covered with the ice crust or deep snow (Nieminen, 2010) and thus to fulfil the nutritional requirement of the reindeer and keep the numbers stable (Åhman et al., 2006). Supplementary feeding can act as an attraction point and I predict that central place foraging takes place in response to supplementary feeding (Mathisen et al., 2014; Rozen-Rechels et al., 2015). This may change, at least temporarily, the behaviour from free range to central place foraging around the feeding site (Turunen et al., 2016). Extra feeding may or may not have certain elements in the food that fulfils the nutritional requirement (Felton et al., 2016). Therefore, reindeer tends to go in the forest areas where they have a forage area to bridge that gap, this response distance may vary according to landscape (Nieminen, 2013).

Besides weather effects on forage accessibility, forestry has contributed to a decrease in forage availability (Sandström et al., 2016). Young forests stands with high stem density are darker compared to old growth forest with more open canopies. Therefore, old growth forest of Scots pine can be an important habitat for ground lichens (Santaniello et al., 2017). However, less is known about the reindeers' habitat preferences with regard to forest species composition. Percentage of the ground cover with the vegetation/snow is also a key parameter for the habitat selection (Ihl et al., 2001). Land fragmentation is a clear threat or one of the main stressor to the traditional reindeer husbandry according to Sami culture preferences (Löfmarck et al., 2019). Both the forestry sector and reindeer herders use the forest resources in northern Sweden (Horstkotte et al., 2014). During the winter, reindeer mostly tend to avoid human settlements, main roads, forest roads, snowmobile tracks, skiing trails and gold digging areas when selecting home range area and within the home range area (Leblond et al., 2013). The strongest avoidances of infrastructure were observed during later winter, whereas(?) in the early winter there was a weaker avoidance (Anttonen et al., 2011). Recreation cabins, trails also act as hurdles for the reindeer movement (Anttonen et al., 2011). The phenomenon of climate change especially in the context of the movement of reindeer have a potential impact from their autumn ranges to winter grazing grounds and also at the end of the winter for their spring migration into summer grazing grounds (Furberg et al., 2011). According to the future projections there will be more frequent occurrence of ground ice that persists through the winter and ice layers in the clear cut forest areas will be thicker in the future (Turunen et al., 2016). The frequent occurrence of ice can be problematic for the movement of the reindeer (Riseth et al., 2011).

4.2. Study Aims

The main purpose of this study is to analyse the movement of reindeer within landscapes during winter and to see how habitat selection differs with movement behaviour.
More specifically, my research questions are:

1) Does the habitat selection differ if reindeer are naturally grazing compared to when they receive supplementary feeding?

2) Do reindeer avoid roads or other infrastructure between winters when receiving supplementary feeding or relying on natural pasture?

3) Does the space use pattern and home range size vary across the population between winters when receiving supplementary feeding or relying on natural pasture?

4) How often do supplementary fed animals return to feeding sites, and how long do they stay at the feeding sites?

5. Material and Methods

5.1. Study Site Description

The study area is situated within the Malå herding district in Västerbotten County, northern of Sweden (Figure. 1). The total winter grazing area before 2011 was 280322 hectares, while after 2011 the winter grazing area was reduced to 209762 hectares. A 15 km buffer zone is also included in the study area, as free-ranging animals usually moved beyond the borders of the district. The summer season lasts from May to September with an average daily high temperature above 13 degree Celsius, while the winter season last from November to March or April with average low -15 and high -9 degree Celsius (SMHI). The snow depth varies from 75-100 cm per year.

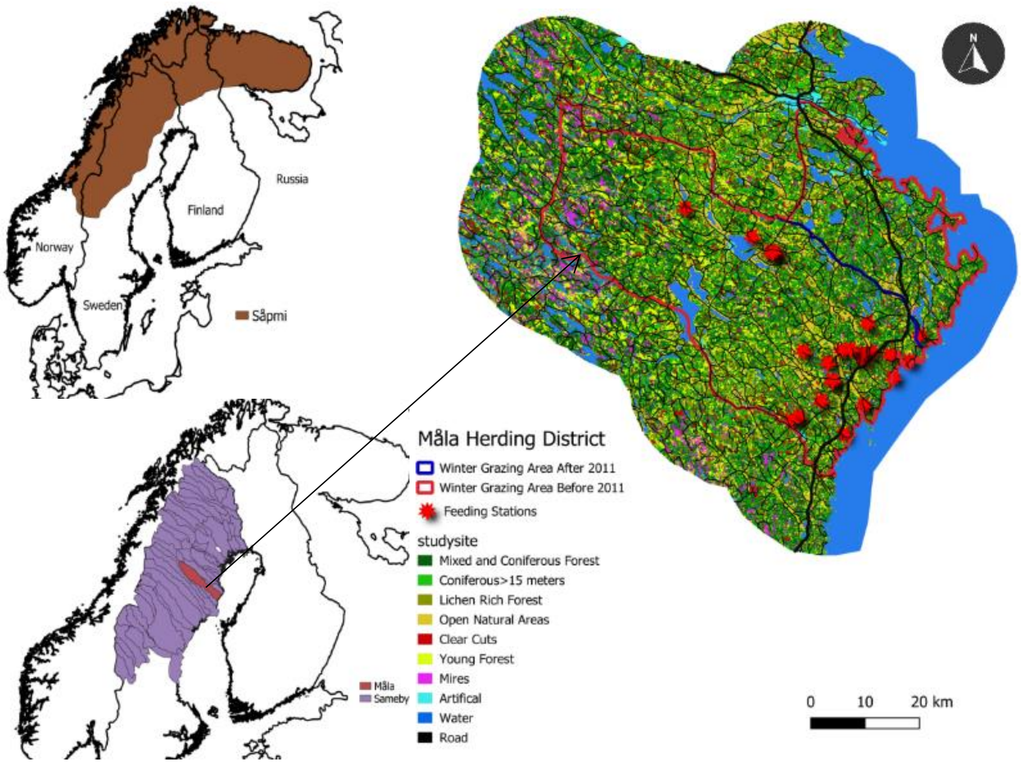

Figure 1; The winter grazing area of Malå herding district outlined in red. Note the change in borders (black) after year 2011, reducing the grazing area. A 15 km buffer was chosen around these borders, as reindeer moved beyond the borders. Upper left: Sápmi, the traditional homeland of the Sámi. Lower left: Reindeer herding districts in Sweden, Målå highlighted in red.

5.2. Data Analysis

The GPS-collared reindeer data during different winter period was analyzed at population level (Table 1). Each feeding period during one winter was treated separately, i.e. if an animal was found to visit two different feeding sites during one winter separated by several weeks or days' time that animal's selection process was investigated separately (Appendix. 1).

Table 1; GPS-Collared data of Free Ranging and Supplementary Feeding reindeer for different years during winter.

Winter Feeding Year	No. of Reindeers on Free-ranging			No. of Reindeers on Supplementary Feeding			No. of Feeding Stations
	No.	Start Date	End Date	No.	Start Date	End Date	
2007-08	51	2007-11-09	2008-04-19	19	2008-03-19	2008-04-19	2(Hakatjärnen, Lappvattsheden C)
2008-09	30	2008-11-04	2009-04-16	3	2009-03-26	2009-04-14	3(Ånäset norra, Fongnesberget, Hakatjärnen)
2009-10	31	2009-11-01	2010-04-16	0	-	-	0
2014-15	38	2014-12-04	2015-04-09	6	2015-01-30	2015-03-21	2(Båtsjöliden, Klöstjärn)
2015-16	37	2015-11-01	2016-04-13	11	2016-02-15	2016-03-12	3(Fongnesberget, Snotterblommyran, Grimsmark)

5.3. Home Range Size and Utility Distribution

The Package "BBMM" (Nielson et al., 2013) in R was used to calculate the spatial extent of animal home range area, intensity of occurrence within the home range area and motion variance. The motion variance is an estimate of animal's mobility (Horne et al., 2007). The model also takes into account the GPS location error, as well as time and distance between the successive locations. The model calculates the relative probability of animal occurrence for each defined cell across the whole area, estimating the utilization distribution (UD). The GPS error was 20 m, while the time gap between two successive locations were two hours. Due to varying scale of movement the cell size varied among the free-ranging and supplementary feeding animals. Cell size was 200 m x 200 m (2007-08, 2008-09, 2009-10, 2014-15) and 250 m x 250 m (2015-16) for free-ranging animals. For animals on supplementary feeding, the cell size was set to 25 m x 25 m due to the smaller spatial extent of their movements.

The UD was calculated for the common time frame of the different winters (Table 1, Appendix. 1). During the whole year reindeer in Malö herding district stayed within the forest. To test my hypothesis, I analyzed reindeer positions during winter between the months November to April. To calculate the home range area and UD, two contour levels were set: the 50 % level (core area), 95 % level (home range). As compared to the other home range estimators, the BBMM recalculates the multiple statistics at multiple contours (Walter et al., 2011). This method therefore gives a detailed visualization of how the space use pattern varies between different winters for both animals on supplementary feeding and free-ranging animals. To visualize the utility distribution, the animals were separated into different feeding groups of the same winters, depending on the feeding sites that they used. These feeding sites during the different between years were identified earlier. The movement pattern of reindeer and their concentration at a single location was used to identify the location of the feeding site. The probability grid and contour level at 50 %, 95 % was exported to QGIS for each individual animal. The area was calculated at the 50 % and 95 % level for each animal.

For each winter, I tested the difference in home range size between the two feeding groups (i.e. free-range and supplementary fed), using a linear mixed model (R-package nlme). For each year I used group and home range size at the 95 % core area as fixed effect, and reindeer ID random factor.

5.4. Habitat Selection

The package “AMT” (Signer et al. 2019) was used to calculate the Step Selection Function (SSF) for both feeding types. For each winter, the data was divided into free-ranging and supplementary feeding behavior, depending on the movement pattern. The first and last position at an identified feeding site was used to set the time frame for using supplementary feeding.

The feeding sites were spread all over the area. To understand habitat selection and movement behavior, SSF are considered to be more powerful tool (Thurfjell et al., 2014). These functions analyse the how animals are moving through the landscape and can assess the effect of human disturbance on movement behavior.

SSFs links each consecutive animal location by regular time intervals, defined as steps (Thurfjell et al., 2014). It can be defined as the lines between two consecutive locations. The model calculates the habitats along the steps, or the proportion of habitat along the steps. In my case, the regular time interval was two hours. Step length and turning angel are two parameters that play an important role in modelling. It particularly depends upon the species and duration of the movement relative to fix rate. The numbers of random steps were set to 10 to compare the habitat at each random step to the environmental attribute of the actual observed step. Random steps are taken from the same starting point where the observed step was present. In my model, I assumed that all the individual in the population show the similar behavior and reindeer movements are made according to the forage availability within the reach of one step length. In the SSF, I used "mixed and coniferous forest" as the reference category, i.e. the reindeers' preference or avoidance of all other land cover classes are estimated relative to that class. In some cases, the lack of GPS positions in certain habitat types did not allow the model to estimate coefficients for these habitats. In these cases, the respective habitat class was excluded from the model.

SSFs can be used from second order of selection (i.e. at the landscape scale) to third order (at the feeding site within the home range) or fourth order of selection (procurement of food resources at some specific patch). I used the SSFs for second order of selection. I divided the habitat types into ten different classes (Table. 2, Figure. 1) by reclassification the original raster image (Swedish land cover data, SMD 2003). "Lichen rich forest" includes the original class of this type, but also "forests on open rocks". I combined these classes due to their habitat suitability for lichens, as well as a preliminary analysis that showed a preference of reindeer for "forest on rocks". Roads were added to the raster, with a 20 m buffer on either side. I created a new map for each winter, by updating the clear-cuts using the data from Skogsstyrelsen (Swedish Forest Agency) and changing previous clear cuts into young forest, if the clear cut in the original 2003 data had become older than 10 years.

Table 2; Habitat type by reclassification and updating of original raster image.

Land Class	Habitat Type
1	mixed & coniferous forest
2	Coniferous > 15 meters
3	Lichen rich forest
4	Open natural areas
5	Clear cuts
6	Young forest
7	Mires
8	Artificial
9	Water
10	Roads

5.5. Recursive Movements

The recursive movement pattern can be described as an activity to return to previously visited areas. Animals may visit again such sites that are rich in food resources, based on their spatial memory (Boyer and Walsh 2010). The reindeer show this behavior when they are on the supplementary feeding, i.e. they return repeatedly to the feeding site where herders provide them with food. One of the key elements of recursive movement is patch recursion (Riotte-Lambert et al., 2020). Patch recursion is used in analysis of larger spatial scales or animals with large home ranges. It can be described as regular appearance of the animal at the resource site. In my case, the resource sites are supplementary feeding sites.

I used the package “Recurse” (Bracis et al., 2018) only for animals belonging to the supplementary feeding group. It is used to analyse how often they move away from feeding sites to find other forage resources other than supplementary feeding, how long they stay in a certain radius around the feeding site, and how often they revisit the different places. I also analyzed if reindeer avoid the roads, if they receive supplementary feeding.

The radius for the recursion circle around each feeding site is taken according to the step length’s median for all animals using that particular feeding site. The number of segments of the trajectories passing through the circle is counted; this is the number of revisits. To calculate the time spent inside and outside that circle, the animal’s movement is assumed at a constant speed between inside and outside the circle. In my study, the minimum radius was 50 m, while the location error was 20 m. The radius also depends on the movement of the animals: the radius should increase if animals move a lot.

There was a high variation in the median of step length between winters (Appendix. 2). The median of step length for each population was calculated in the "AMT" package during the process of step selection function. I used two different radii around the feeding site to calculate the revisitation rate (Table. 3). The "core radii" is defined as the approximately equal to median of step length for the whole population, while the "buffer radii" is approximately triple to median value of step lengths. In general, increasing in the size of radius means increases the mean revisitation. Data for those four winters was used for the recursion analysis when animal were on the supplementary feeding (Table 3). To understand if reindeer return to roads, for road re-visits buffer radii were chosen while core radii were chosen to know about how much time they spend inside the feeding stations and for re-visitations frequency.

Table 3; Radii chosen for recursion analysis for each winter feeding year.

Winter Feeding Year	Radii for Recursion Revisitation analysis (m)	Radii for Road Revisits (m)	Radii for time inside the circle (m)
2007-08	90	300	90
2008-09	60	200	60
2014-15	80	300	80
2015-16	50	120	50

6. Results

6.1. Home Range Size and Utility Distribution

The home range size of free-ranging animals at 95 % contour level was largest in winter 2007-08 (Figure. 2).The smallest home rang sizes for the population was also recorded in winter 2008-09. As compare to other winters, the median value for the home range size in winter 2014-15 was larger where it was around 2500 hectares. The smallest median was recorded for the winter 2008-09 and winter 2009-10 where it was around 1800 hectares for both the winters.

At 50 % contour level (Figure. 2), the median value was largest for free-ranging animals in winter 2007-08 as compared to other winters. For the winter 2008/09, home range size was approximately 400 hectares, and smaller for the winter 2008-09 which was around 200 hectares.

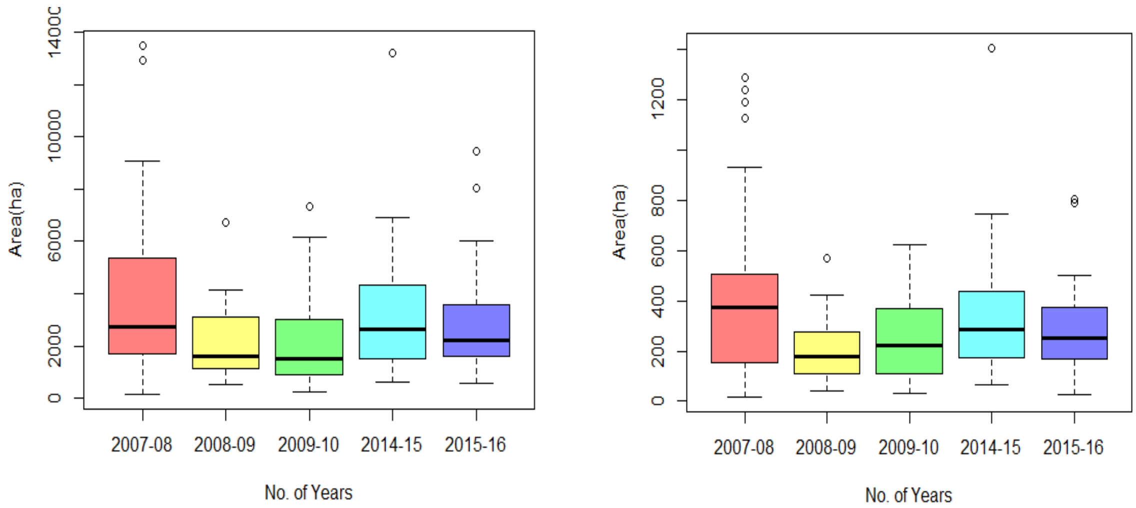

Figure 2; Home range size of the free-ranging reindeer at 95% (left) and 50% (right) contour levels.

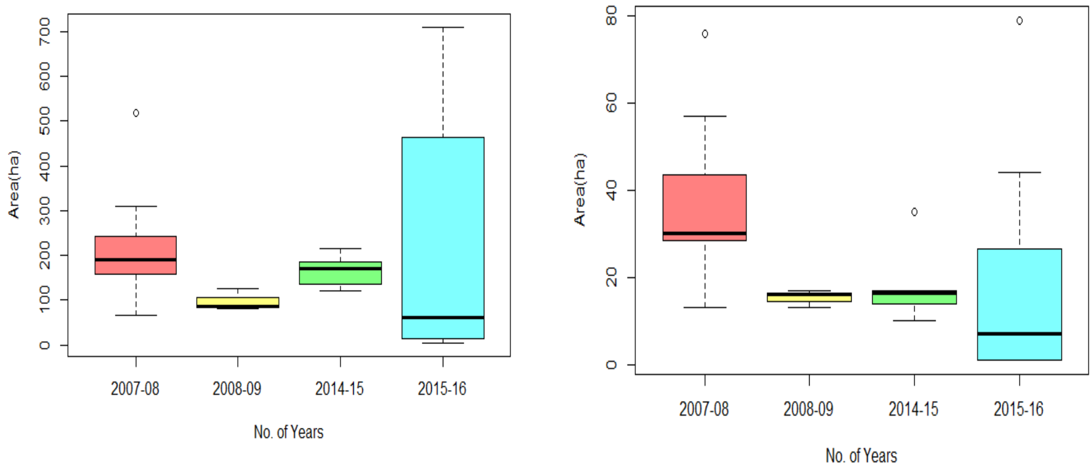

Figure 3; Home range size of the supplementary feeding reindeer at 95% (left) and 50%(right) contour levels.

The home range size distribution of animals receiving supplementary feeding at 90 % and 50 % contour levels shows the largest median value for the winter 2007-08 which was around 200 hectare at 90% contour level and around 30 hectare at 50% contour level as compare to other winters (Figure. 3). This is the same pattern as observed for free-ranging animals (see above). Comparatively large variation in home range sizes were recorded in the winter 2015-16, which was around 500 hectare at 90 % contour level. The reason for this is that some reindeer made long detours from the feeding sites, including crossing the sea ice. At the same time, the smallest median was recorded for the winter 2015-16 at 50 % and 90 % contour level.

Reindeer grazing on natural pasture have utilized a larger area as compare to those who were on supplementary feeding (e.g., Figure. 4, 5; Appendix. 3). The motion variance was higher for favourite grazing sites. Reindeer selected those forest types that are good lichen habitat as indicated by classification of raster image (Figure. 1; Appendix. 4).

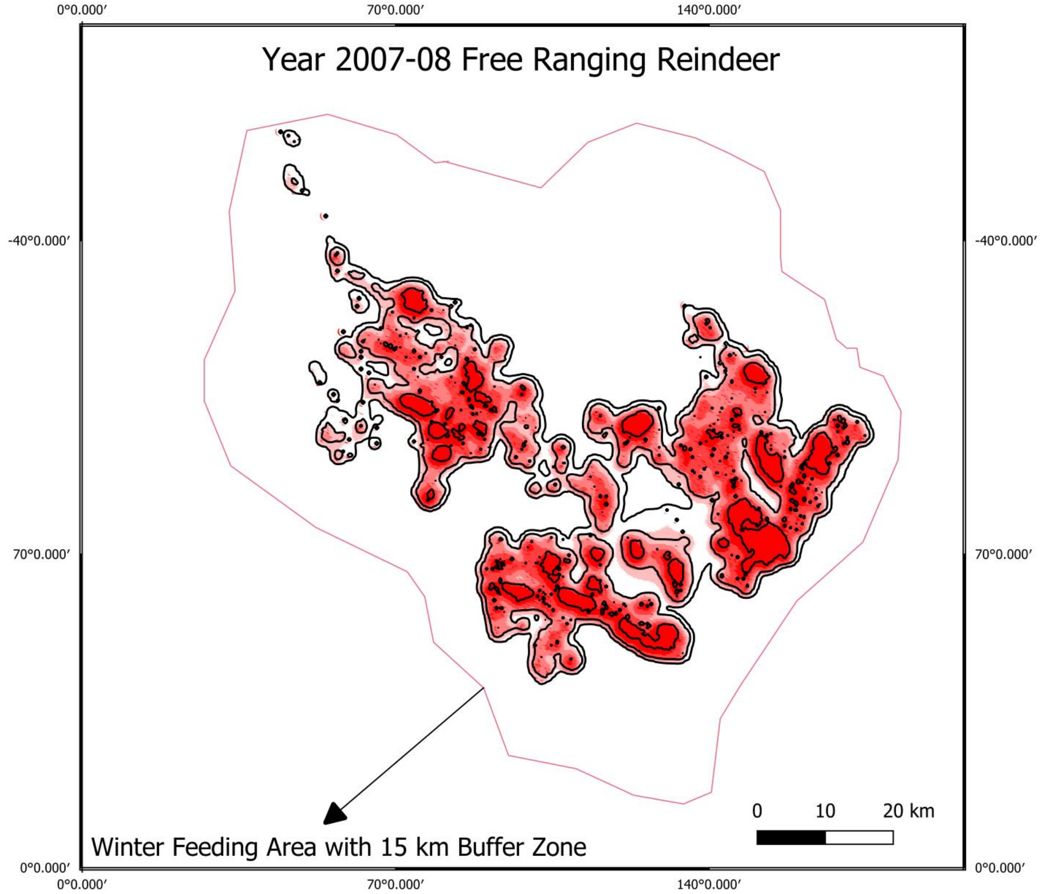

Figure 4; Utility distribution map of free ranging reindeer at 50%, 95% and 99% contour levels for the winter 2007-08, A 15 km buffer zone on the left side while on the right side is a coastal line.

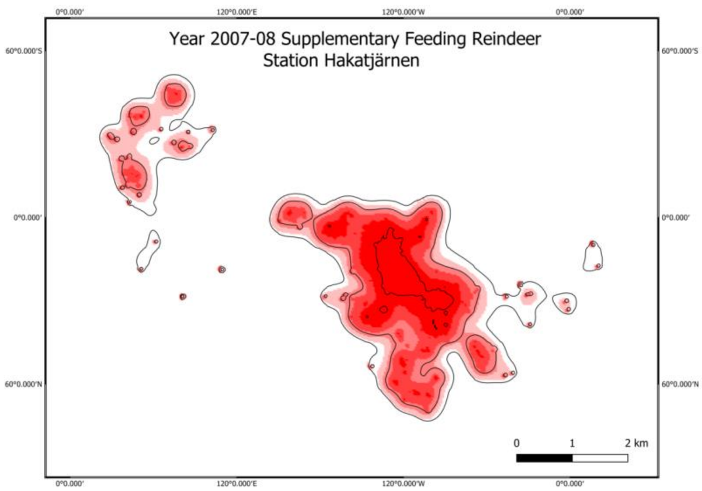

Figure 5; Utility distribution map of supplementary feeding reindeer at 50%, 95% and 99% contour levels for the winter 2007-08 with two different feeding stations.

The linear mixed model showed that home range size at the 95 % level was significantly higher for free ranging reindeer in all winters (Table. 4).

Table 4; Results of the Linear mixed model for different winters to test for differences in home range (95 % core area) size between free-ranging animals and animals on supplementary feeding. Reindeer ID is as a random effect, while home range size, and groups were used as fixed effect, and free-ranging reindeer was used as an intercept).

Winter		Value	Std.Error	DF	t-value	p-value
Winter 2007/08	Intercept	7313.59	973.31	50	7.468	< 0.001
	Group	3552.12	727.08	18	-4.885	< 0.001
Winter 2008/09	Intercept	4117.13	899.38	31	4.578	< 0.001
	Group	2009.40	797.21	31	-2.521	0.017
Winter 2014/15	Intercept	4477.22	426.38	37	10.501	< 0.001
	Group	1278.01	188.11	5	-6.794	< 0.001
Winter 2015/16	Intercept	5332.25	805.48	44	6.620	< 0.001
	Group	2561.74	639.40	44	-4.006	< 0.001
All Winters	Intercept	5950.09	508.18.48	173	11.708	< 0.001
	Group	2878.64	404.92	18	-7.109	< 0.001

6.2. Habitat Selection

The SSF function clearly showed that reindeer either on supplementary feeding or free-ranging preferred habitat where lichen cover was high (Figure. 6, Appendix 4). Even when receiving supplementary feeding, reindeer selected these areas, most probably because supplementary food they receive is not enough to fulfil their nutritional requirements.

The second most preferred habitat types were clear cuts in case of free-ranging animals. When receiving supplementary feeding, habitat selection of reindeer differed. In some winters, clear cuts were selected, but young forest and mires are also considered to be the second most preferred habitat (Figure.7, Appendix. 4)
The third most preferred habitat by free-ranging animals was open area, young forests or coniferous forests less than 15 meters in height. These patterns differed between the winters (Appendix. 4).

The habitat types avoided by free-ranging reindeer were roads, artificial infrastructure (Houses, construction sites etc.) and water bodies. In supplementary feeding animals, there was some variation in regard to which classes are less preferred, but open areas, roads, mires were avoided (Appendix. 4).

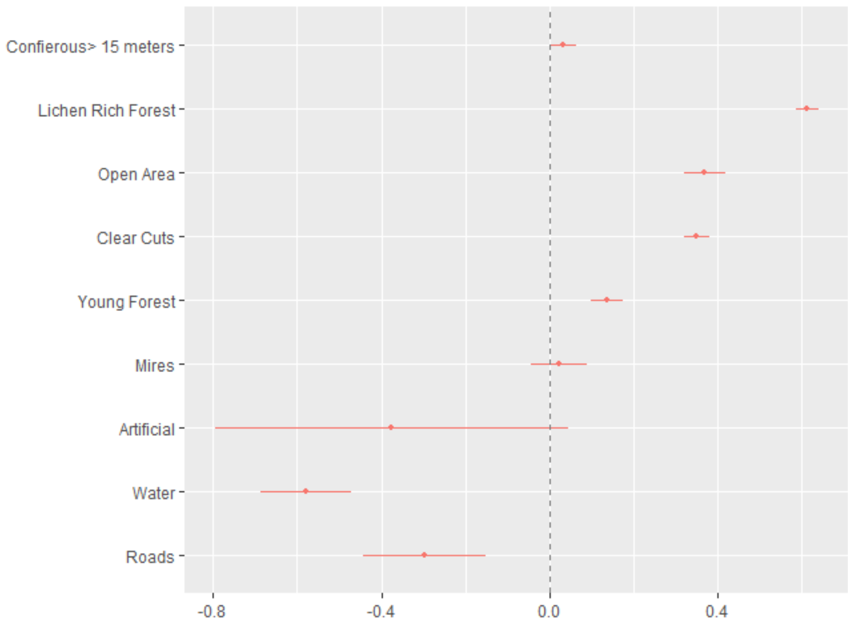

Figure 6; Winter 2007-08, Habitat selection by reindeer grazing on natural pasture

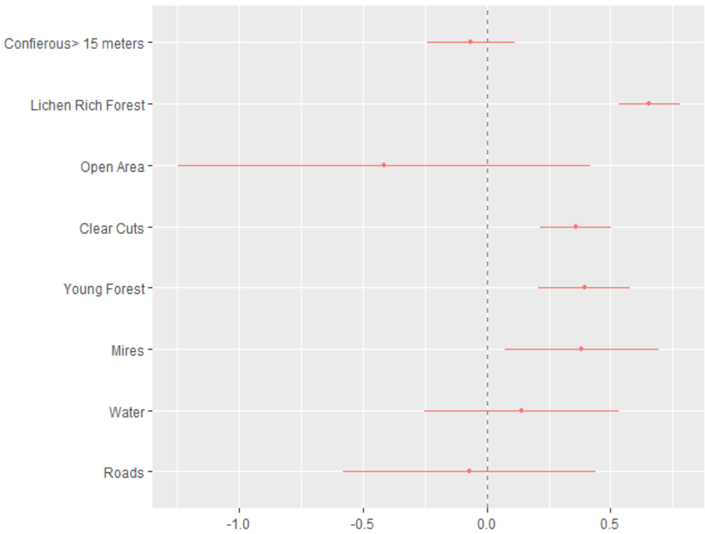

Figure 7; Winter 2007-08, Habitat selection by reindeer on Supplementary feeding.

6.3. Recursive Movements

The results from "Recurse" package showed similar behavioural and activity pattern as shown above by SSFs with respect to roads. The analysis is carried out for the supplementary feeding animals of a winter 2007-08, 2008-09, 2014-15, and 2015-16 with different feeding sites within the winter grazing area. They didn't return to the roads. The revisits were lower close to the roads during the analysis. The buffer radii were chosen to display the graphs (Figure. 8). The core radius was also taken into account during the analysis to see how the revisit changes with respect to radius size selection.

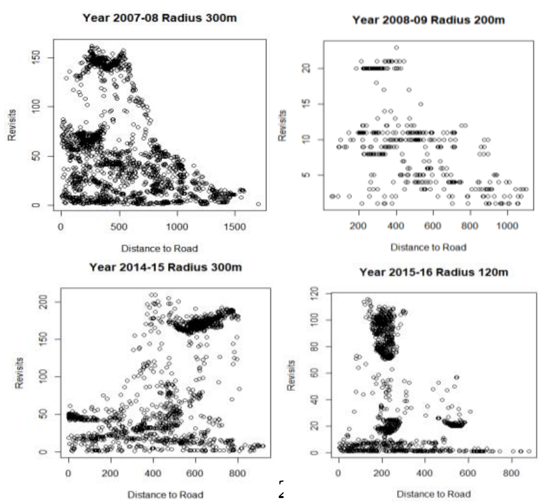

Figure 8; Re-visits and distance to road with buffer radii for different feeding winters.

The core radii of each winter which were chosen according to the median of step length for supplementary feeding animals was taken to analyse how much time reindeer spent time in close proximity to the feeding sites. For the winter 2007-08, most animals spent 0-2 hours close to feeding stations within radius of 90m, while some observations were recorded for very few individuals where they spent 15 hours close to the feeding site (Figure. 9). Frequencies were high for the individuals in winter 2014-15 where they spent most of the time inside the feeding site while the following winter 2015-16 reindeer spent 0-5 hours inside the feeding sites most of the time. The frequency of revisitation inside the core radii were higher as compare to winter 2007-08 even the number of individuals were lower. For the winter 2014-15 and 2015-16 a few individuals even spent 20 to 30 hours close to the feeding site.

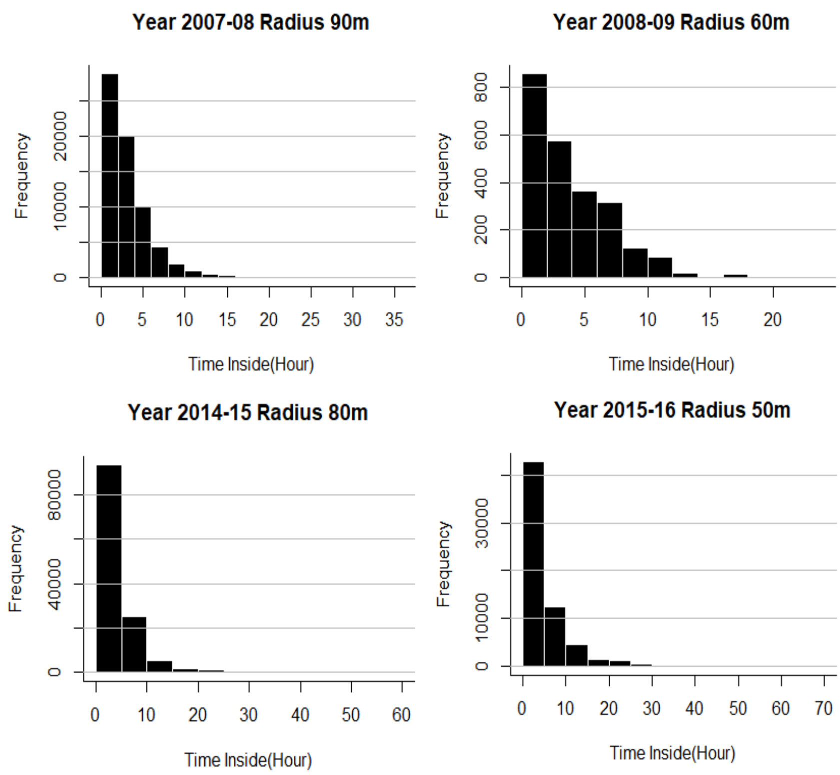

Figure 9; Time inside the feeding stations with core radii for different feeding winters.

The results showed (Figure. 10) the re-visitation within radii around the identified feeding stations. The number of re-visitations varied for different winters. The revisitation is how often reindeer enter the circle of a particular radius around each GPS-position again. Most locations are visited only once, i.e. reindeer do not come back to them at a later stage. This is why there is high frequency at low re-visitations because animals do not return to these sites.

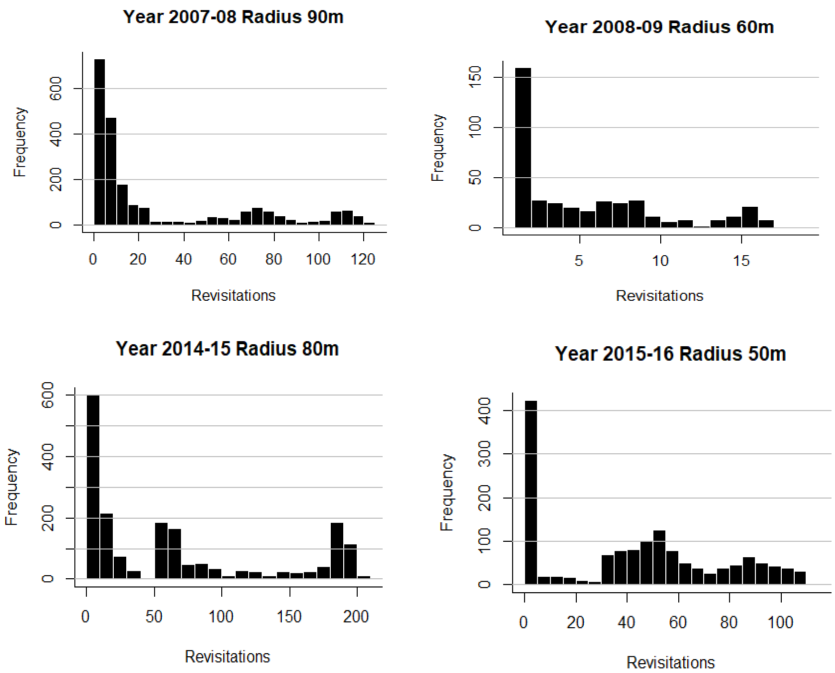

Figure 10; Frequency of Rev-visitation within the core radii for different feeding winters.

However, there are some few places to which reindeer return quite often. Figure 11 (Appendix.5) depicts blue points that have very low re-visitation rates, while the red sites are those where reindeer return more frequently to.

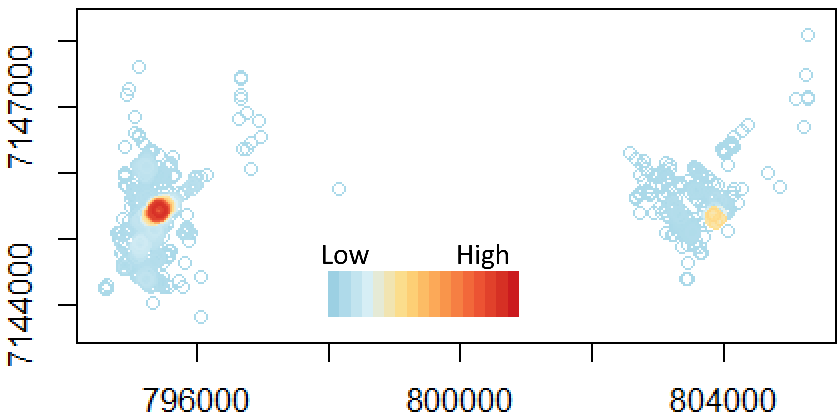

Figure 11; Frequency of Rev-visitation with core radii for year2014-15, radius 80m at two different feeding stations (Båtsjöliden, Klöstjärn).

7. Discussion

The result showed the space use pattern and home range size varied across the population between different winters for free-ranging and supplementary feeding animals. My results emphasize that both groups prefer lichen rich forest irrespective of supplementary feeding or totally relying on natural pasture. The reindeer on supplementary feeding clearly avoided the roads. During the recursive movement analysis it showed that it varied across the population between winters that how often they revisit the feeding sites or spent inside the feeding stations. This difference could be the availability of food resources around the feeding sites and weather conditions of different winters.

7.1. Habitat Selection and Road Avoidance

One thing which is clearly evident from the above results in relation to the habitat preference that reindeer would like to go to lichen-rich forest either they are on free-ranging or supplementary feeding during the winter period. The old and wide-crowned trees during winter create mechanical obstacles to accumulate the snow on the ground so the reindeer can do cratering easily (Riseth et al., 2011). These results also co-relates with interviews of reindeer herders where the informants described that reindeer started to feed on the lichen when the snow covered the ground (Inga, 2007). The role of lichen rich old growth forest with respect to reindeer husbandry during winter period can't be neglected. This result also resembled with the continuous use of natural forage case studies in white-tailed deer (Doenier et al., 1997) and moose (Gundersen et al., 2004, Felton et al., 2017) while being offered supplementary forage. The reasons could be shortage of essential nutrients or fibre in the supplementary feed. The reason of the supplementary feeding are maybe due to restrictions on the pasture resources, after rain-on-snow events because it create the ice-locked pastures, for protection against the predators, economic compensation when the reindeer pastures are being replaced by infrastructure (Tryland et al., 2019, Staaland et al., 1991, Turunen et al.2014, Åhman et al., 2018). In this case study, the main reason was non-availability of the food during the winter time period (pers. comm. by T. Horstkotte with herders in Malå herding district, winter 2019).

The study results showed the second most preferable class where reindeer would like to go was clear cuts specifically in the case of free-ranging reindeer. These results co-relates with the study by Kumpula, (2003) where the author described that growth of ground lichens, grasses and herbs increased with the time in the felled areas, sapling stands and thinned forest. It is due to increase availability of sunlight on the ground floor. The dwarf shrubs and grasses/sedges can comprise nearly half of the winter diet (Kojola et al., 1995) that’s why the second most preferred class in this study was clear cut. This statement is true, specifically for those areas where felling residue has already decomposed and where growth potential of lichen or other grasses has also increased (Colpaert et al., 2003; Kumpula 2003). The provision of supplementary feed by reindeer herder’s also gives energy which enables reindeer to dig and get access to vegetation other than lichen on the ground. One of the main reasons to go on the clear cut is the presence of dead grass names as *Deschampsia flexuosa* to use as forage. The other things which can be counted regarding preference of clear cut is accessibility and clear vision (Altendrof et al., 2001) for predator avoidance (Skarin et al., 2018).

They do avoid the roads and other infrastructure when the supplementary feed is given to them or either they rely on natural pasture as analysis shown during the habitat selection and recursive movements. It can be the result of feed or maybe their instinct behavior and they do not like to go close to the roads. This was similar to the study carried out in boreal forest environment in northern Finland using GPS tracking data of 29 female reindeer (Anttonen, 2011). Their study results showed the strongest avoidance of infrastructure in the late winter, similar to my results. The particular study in Finnish Lapland also found that weakest avoidance of infrastructure was found in early winter and in summer for within-home-range selection (Anttonen, 2011). The cumulative effects of different human activities should also take into consideration while formulation of land-use plans within the home range size of reindeer. Due to adaptive management approaches, the reindeer herders today are forced to adapt to infrastructure development, but suitable grazing grounds needs non-fragmented landscape and priority for reindeer herders will always be undisturbed grazing grounds (Kitti et al., 2006). But it has also been noted that in some case studies reindeer may adopt to infrastructure and human disturbances (Skarin et al., 2004). A study related to wild reindeer in Norway and impacts of infrastructure on their population concluded that further infrastructure development will put the remaining population at risk, as further habitat fragmentation will make the undisturbed patches too small to maintain a viable population (Nellemann et al., 2003). A review conducted by Flydal et al., 2019, which is related to understanding the effects of infrastructure to reindeer population in relation to spatiotemporal scales, showed that 53% of research results showed the negative impacts, 34% no effects and 14% positive effects on reindeer, but majority of the publications didn't include the before-after-control-impact (BACI) design. However, the authors propose to integrate the spatial-temporal variation for future studies. In general, it is suggested that reindeer may avoid infrastructure up to a distance of 4 km and they could potentially abandon areas once disturbance increase (Vistnes and Nellemann 2001).

7.2. Home Range Size, Re-visitations and Time spend inside the Feeding Stations

In general, the study result showed that home range size varied from 2000-6000 hectares when reindeer did not receive supplementary feeding, compared to 100-400 hectares when animals used supplementary feeding sites. The results showed home range size varied across different winters because it also depends on the available food resources throughout the landscape. The free-ranging animal's activity pattern was high as compare to supplementary feeding. During recent years, land-use changes in northern Sweden had a negative effect on movement pattern of reindeer (Widmark, 2006). As a result of these land-use practices, the home range size decreased and spatial distribution pattern changed (Chapin et al., 2004). The forest harvesting practices definitely decrease the size of old-growth forest and presence of arboreal lichen resources (Kivinen et al. 2012; Sandström et al. 2016). The deterioration of these winter ranges force reindeer herders to give them extra supplementary feed during the winter period and these practices reduced their profit margin (Kumpula 2001).

The result of recursive movement pattern showed that reindeer exhibit central foraging behavior during the winter time when supplementary feed is given to them. It is interesting to know about how often reindeer stay inside the feeding station when the supplementary food is provided to them and how often they do revisits the feeding sites and how often they avoid the roads. During the different years the time period and frequency varied when the animal stayed inside the feeding stations and scale of re-visitations varied too. The reason for this could be because of the severity of winter conditions, may be increase in snow depth is an important element influencing the use of feed by them (Doenier et al., 1997).

Different radii were chosen according to step length median. Sometimes they spent 0-2 hours and sometimes they spent 0-5 hours and can be 30 hours maximum inside the feeding sites. Furthermore, time spent close to the feeding site could also depend upon the available food resources in the surrounding forest or other habitat types. These results are first of their kinds and no one looked so far re-visitations and time spent inside the feeding stations.

One of the possible shortcomings of the study is the non-availability of the lichen map. An updated classified raster image of the lichen resources with relative to its abundance could show that the reindeer distribution was higher in those areas where lichen cover was high. The other thing could be the snow depth data with respect to different forest types could give the answer that how the movement of the reindeer is affected with respect to snow depth. To find an answer we have to go into details how the herders' management is also varies during the peak period of snow depth with respect to topography and available food resources. The results of the study is totally based on the GPS-collared data of reindeer, information from the herders who are living in that herding district, if incorporated during the analysis could give us a different perspective and more clear picture. The coordination and dialogue between reindeer husbandry and forestry sector in Sweden is quite old keeping in view the ecological, institutional economic, social, historical and political perspectives. This coordination needs to be further strengthened due to the detrimental effects of climate change and modern forestry practices on reindeer husbandry (Pape et al., 2012).

The results showed that the forest should be managed in a way that it shouldn't affect the reindeer husbandry management. Land fragmentation is a big issue due to modern forestry practices; forest areas should keep intact for continuous home range for free-ranging reindeer. Old growth forest should not cut down and not replace by young forest as they are the most important source of arboreal lichens for free-ranging animals. If lichen resources are sufficient there will be a less need of supplementary forage for supplementary feeding reindeer. Roads shouldn't be constructed within the forest areas as both free-ranging and supplementary feeding reindeer tends to avoid the roads.

8. Conclusion

During the winter period, it is concluded that lichen rich forest is a very important habitat for the reindeer either on the supplementary feeding or relying on natural forage. They like to go to clear cuts especially in the case of free-ranging reindeer it is second most preferred habitat type. They avoid the roads and other infrastructure. Construction of infrastructure such as roads, buildings may cause disturbance to reindeer herding and affects the home rang size for free-ranging reindeer, because it decreases the continuity of the landscape. The home range size varied differently throughout different winters. The re-visitation close to feeding sites, roads and time inside the feeding stations varied too. For the recursive movements the time and frequency of revisits could be used to further investigate the revisits at particular locations that the animals prefer relative to others. In the case of reindeer as results shown above it will be interesting to understand how often they go to lichen rich forest, clear cuts and open areas and how long they stay over there by selecting or identifying the time series GPS data of most preferred locations.

For future research, it is imperative to add the knowledge of reindeer herders and compare it with the research analysis, as they know more about on ground facts and realities and they are the only ones who holds the exclusive right of reindeer husbandry in Sweden.

9. References

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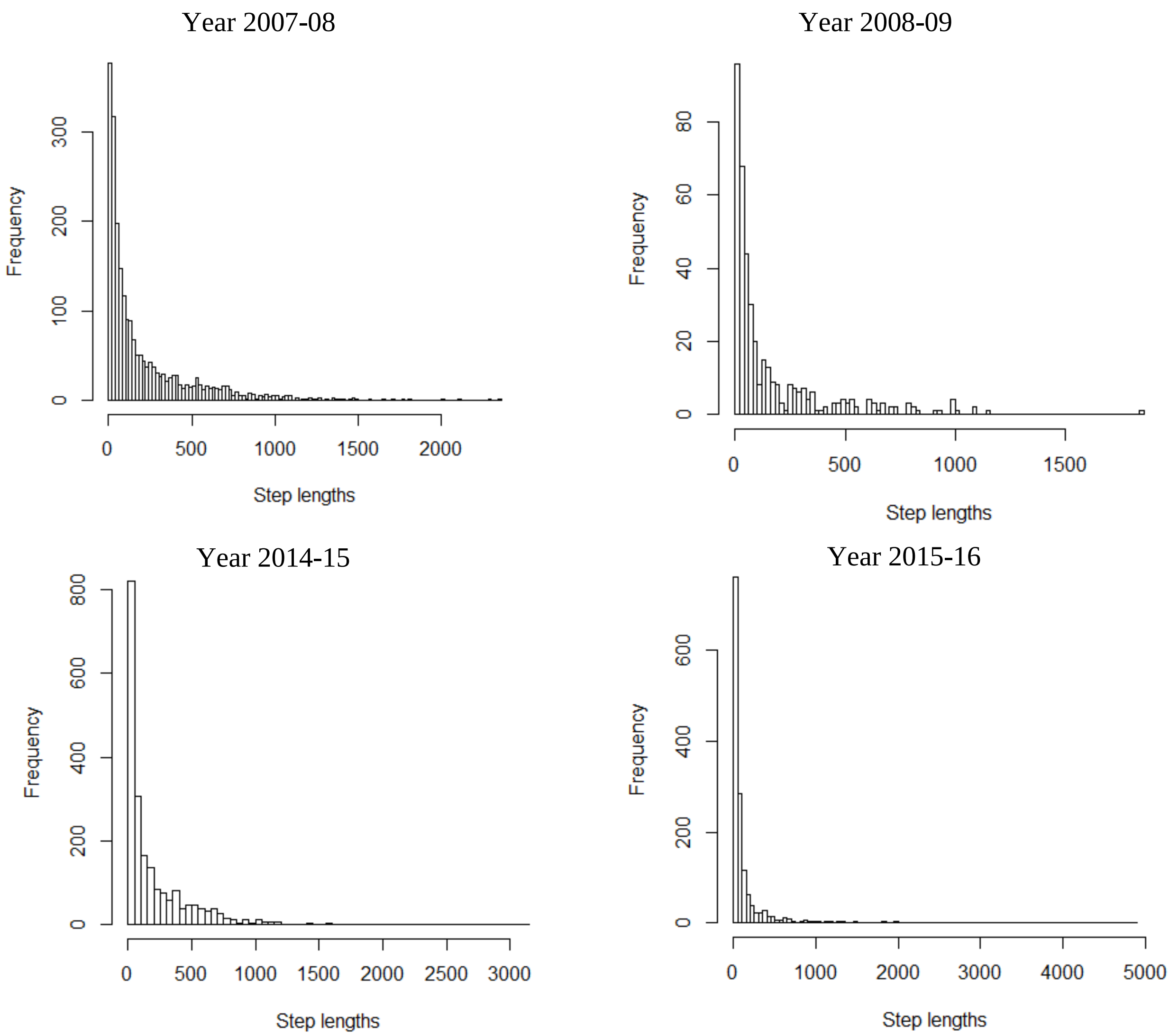
Appendix 1

Winter Feeding Year, 2007-08, Supplementary Feeding Animals				
Animal ID	**Start date**	**End date**	**Feeding Station**	**Approx. days on Feeding**
r_RG_08_010	2008/03/21 09:17:00	2008/04/06 14:17:00	Hakatjärnen	16
r_RG_08_011	2008/03/20 21:36:00	2008/04/03 02:36:00	Hakatjärnen	13
r_RG_08_015	2008/03/19 16:54:00	2008/03/28 10:54:00	Hakatjärnen	9
r_RG_08_015	2008/04/03 07:54:00	2008/04/06 11:54:00	Hakatjärnen	3
r_RG_08_016	2008/04/10 14:38:00	2008/04/13 10:38:00	Hakatjärnen	3
r_RG_08_021	2008/03/19 17:00:00	2008/03/28 11:00:00	Hakatjärnen	9
r_RG_08_021	2008/03/31 10:00:00	2008/04/04 22:00:00	Hakatjärnen	5
r_RG_08_94	2008/04/03 12:02:00	2008/04/19 12:02:00	Lappvattsheden C	16
r_RG_08_024	2008/04/11 10:52:00	2008/04/13 10:52:00	Hakatjärnen	2
r_RG_08_029	2008/03/20 16:52:00	2008/03/28 10:52:00	Hakatjärnen	8
r_RG_08_030	2008/03/20 13:16:00	2008/03/24 11:16:00	Hakatjärnen	4
r_RG_08_035	2008/03/20 12:40:00	2008/04/06 13:40:00	Hakatjärnen	17
r_RG_08_92	2008/04/03 12:02:00	2008-04-19 08:02:00	Lappvattsheden C	16
r_RG_08_91	2008/03/20 13:38:00	2008/04/06 16:38:00	Hakatjärnen	17
r_RG_08_066	2008/03/20 14:01:00	2008/03/28 14:01:00	Hakatjärnen	8
r_RG_08_075	2008/03/21 14:53:00	2008/04/19 11:53:00	Lappvattsheden C	29
r_RG_08_085	2008/03/20 12:52:00	2008/03/27 10:52:00	Hakatjärnen	7
r_RG_08_085	2008/04/01 23:52:00	2008/04/06 21:52:00	Hakatjärnen	5
r_RG_08_087	2008/03/20 12:09:00	2008/04/06 09:09:00	Hakatjärnen	17
Winter Feeding Year, 2008-09, Supplementary Feeding Animals				
r_RG_09_030	2009/03/26 15:33:00	2009/04/14 10:33:00	Fongnesberget	19
r_RG_09_033	2009/03/28 22:10:00	2009/04/13 09:10:00	Ånäset norra	15
r_RG_09_034	2009/04/03 10:01:00	2009/04/13 10:01:00	Ånäset norra	10
r_RG_09_082	2009/04/04 10:03:00	2009/04/12 13:03:00	Hakatjärnen	8
Winter Feeding Year, 2014-15, Supplementary Feeding Animals				
r_RG_15_020	2015/02/15 11:24:00	2015/03/17 11:24:00	Båtsjöliden	30
r_RG_15_021	2015/02/17 07:00:45	2015/03/17 15:00:45	Båtsjöliden	28
r_RG_15_023	2015/02/02 15:00:53	2015/02/27 11:00:53	Klöstjärn	25
r_RG_15_025	2015/01/30 11:01:15	2015/02/27 11:01:15	Klöstjärn	28

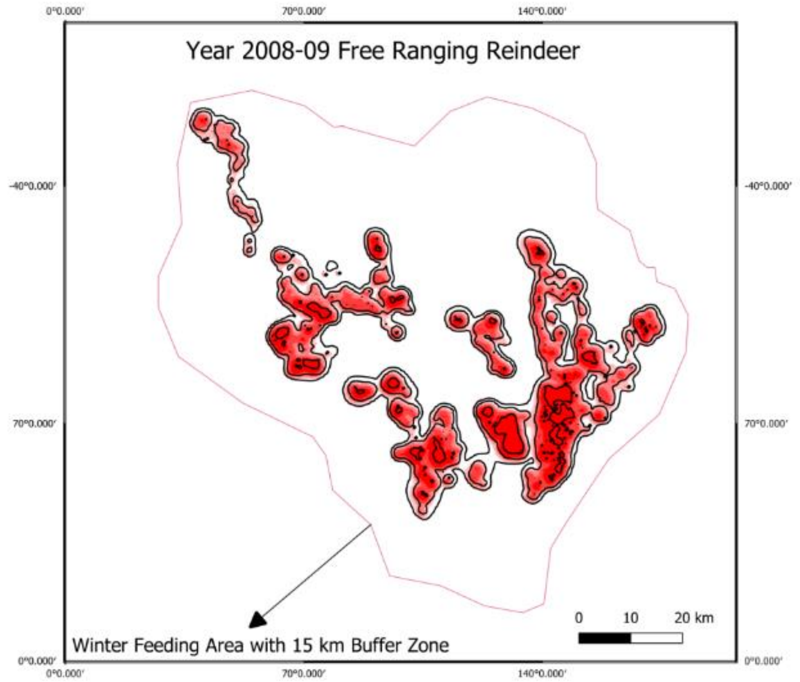
rt_RG_14_019	2015/02/11 10:30:00	2015/03/01 08:30:00	Skarberget	18
rt_RG_14_023	2015/02/14 09:00:43	2015/03/15 09:00:43	Båtsjöliden	29
rt_RG_15_001	2015/02/19 13:01:10	2015/03/17 15:01:10	Båtsjöliden	26
rt_RG_15_007	2015/02/16 15:00:30	2015/03/21 09:00:30	Hampmyrberget	33
Winter Feeding Year, 2015-16, Supplementary Feeding Animals				
rt_RG_14_032	2016/02/23 15:00:00	2016-03-07 07:00:00	Fongnesberget	13
rt_RG_14_042	2016-02-28 17:00:00	2016-03-12 07:00:00	Snotterblommyran	13
rt_RG_14_056	2016/02/29 19:00:00	2016/03/12 11:00:43	Snotterblommyran	12
rt_RG_15_013	2016-02-29 17:00:00	2016-03-08 11:00:00	Snotterblommyran	8
rt_RG_15_033	2016-02-27 17:00:00	2016-03-12 11:00:00	Snotterblommyran	14
rt_RG_15_039	2016-02-29 15:00:00	2016-03-07 11:00:00	Fongnesberget	7
rt_RG_16_028	2016/02/15 13:00:00	2016/03/09 09:00:00	Grimsmark	23
rt_RG_16_029	2016/02/27 15:00:00	2016/03/12 11:00:00	Snotterblommyran	14
rt_RG_16_030	2016/02/28 15:00:41	2016/03/12 11:00:00	Snotterblommyran	13
rt_RG_16_038	2016-03-05 13:00:00	2016-03-09 09:00:00	Grimsmark	4
rt_RG_16_039	2016-02-26 13:00:00	2016-03-07 11:00:00	Fongnesberget	10

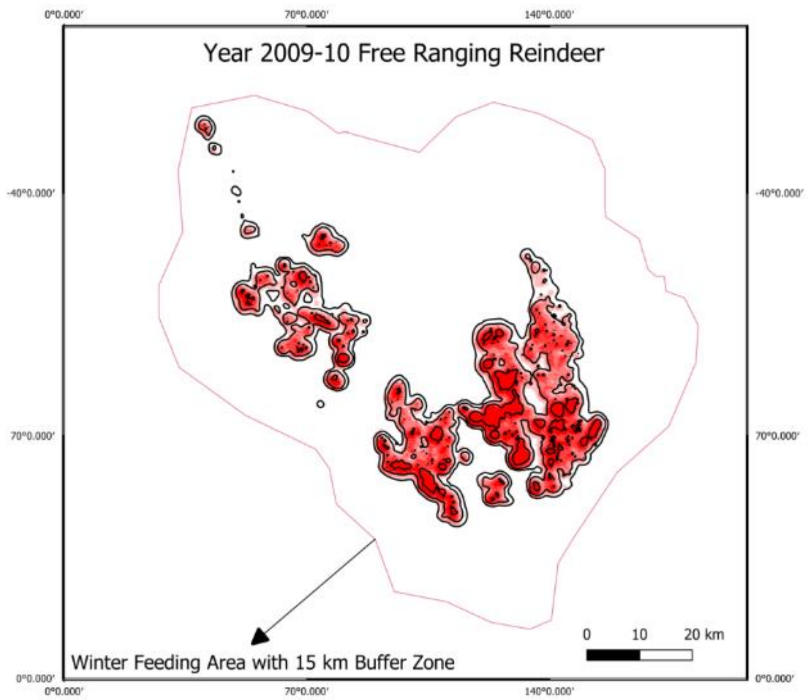
Appendix 2

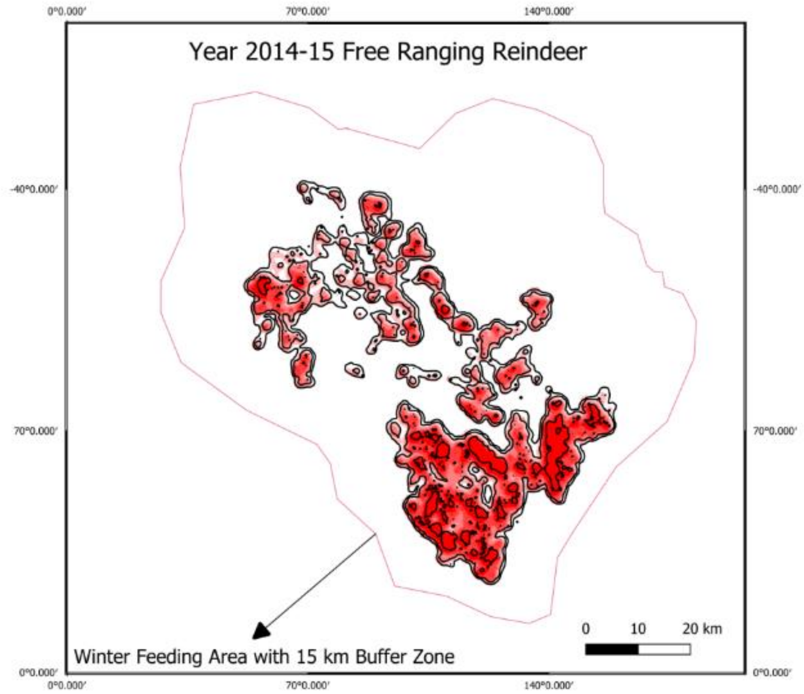


Histograms of step lengths of different years when reindeer were on supplementary feeding.

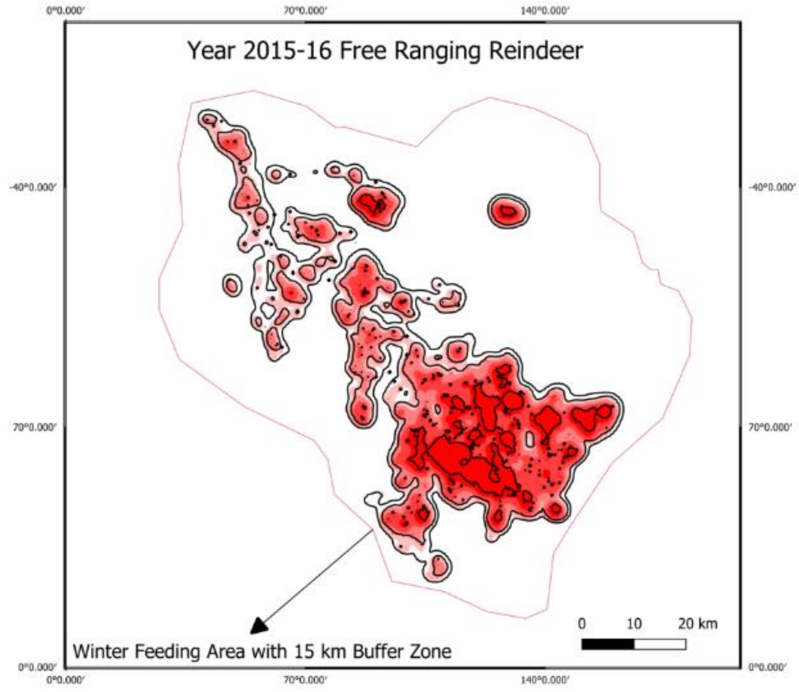
Appendix 3- Utility Distribution Maps



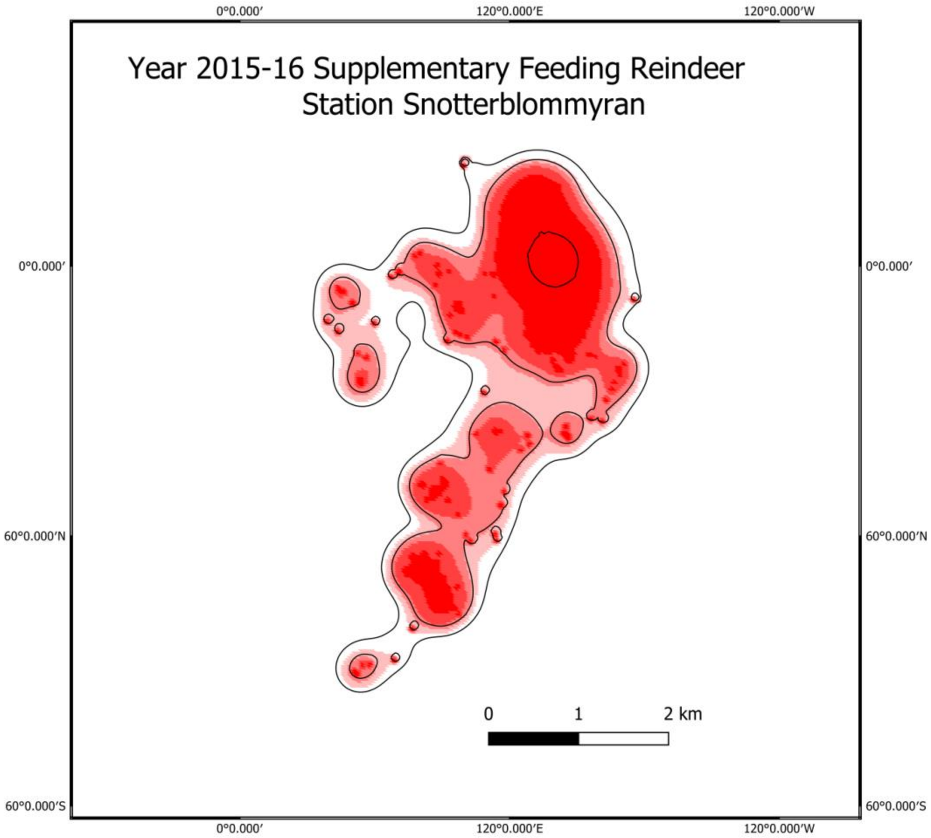


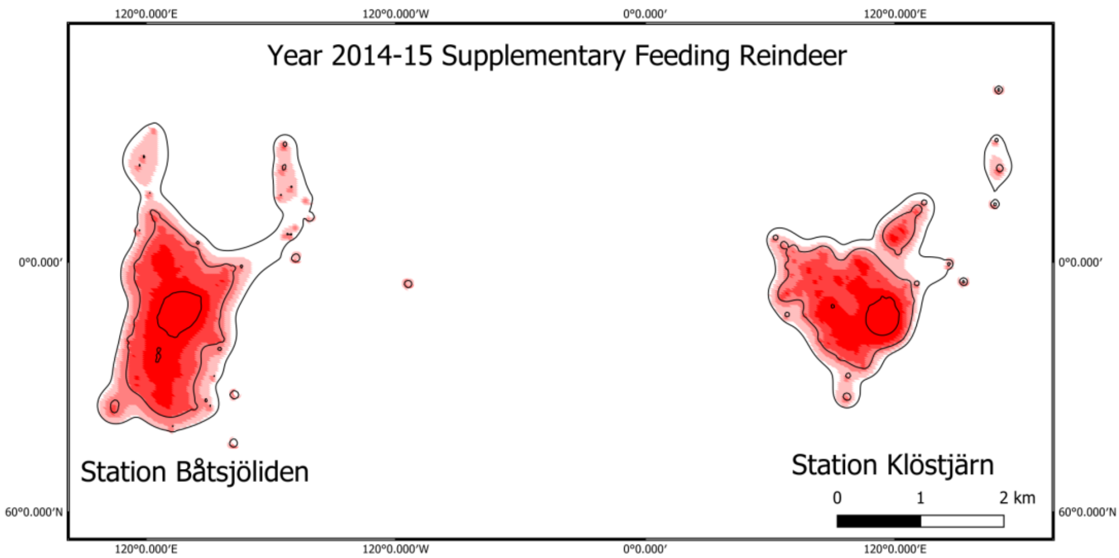


0°0.000′
70°0.000′
140°0.000′
Year 2014-15 Free Ranging Reindeer
-40°0.000′
70°0.000′
0 10 20 km
Winter Feeding Area with 15 km Buffer Zone



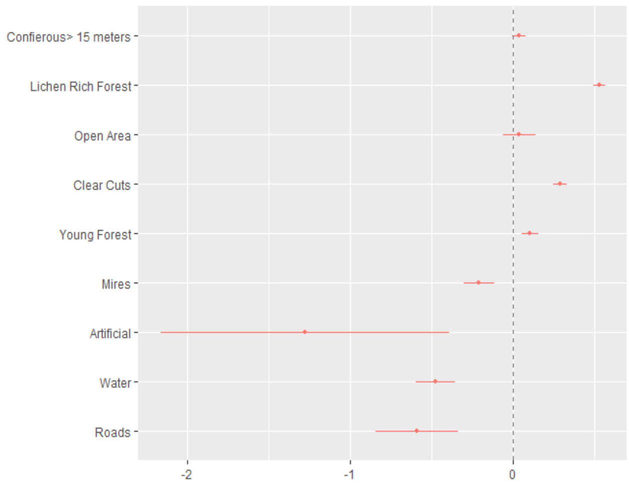
0°0.000′
70°0.000′
140°0.000′
Year 2015-16 Free Ranging Reindeer
-40°0.000′
70°0.000′
0 10 20 km
Winter Feeding Area with 15 km Buffer Zone


0°0.000′
120°0.000′E
120°0.000′W
Year 2015-16 Supplementary Feeding Reindeer
Station Snotterblommyran
0°0.000′
0°0.000′
60°0.000′N
60°0.000′N
0 1 2 km
60°0.000′S
60°0.000′S
0°0.000′
120°0.000′E
120°0.000′W

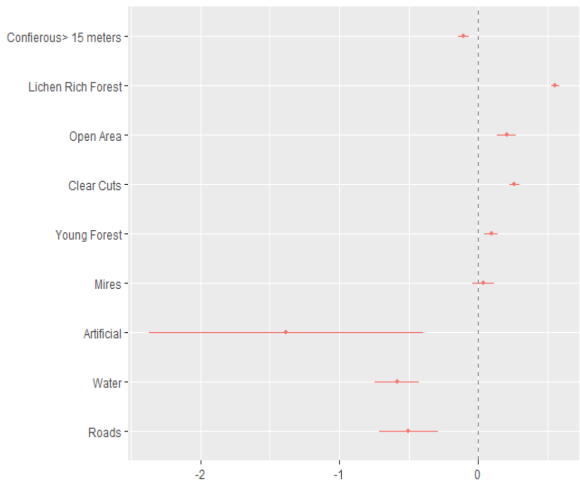

120°0.000′E
120°0.000′W
0°0.000′
120°0.000′E
Year 2014-15 Supplementary Feeding Reindeer
0°0.000′
0°0.000′
Station Båtsjöliden
Station Klöstjärn
0 1 2 km
60°0.000′N
60°0.000′N
120°0.000′E
120°0.000′W
0°0.000′
120°0.000′E

Appendix 4- Habitat Selectivity

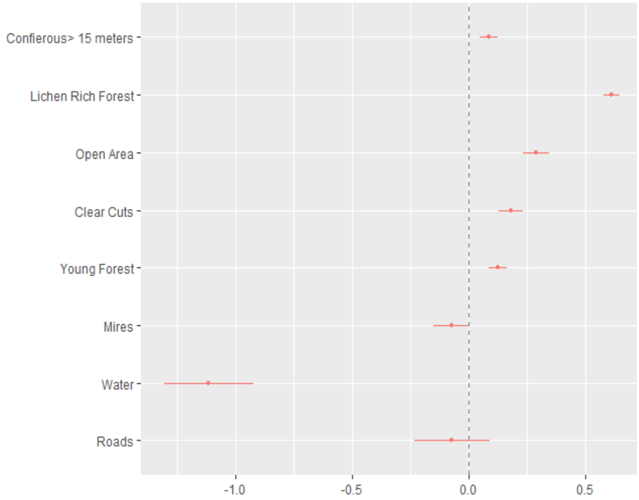
Year 2008-09 Free Ranging Reindeer



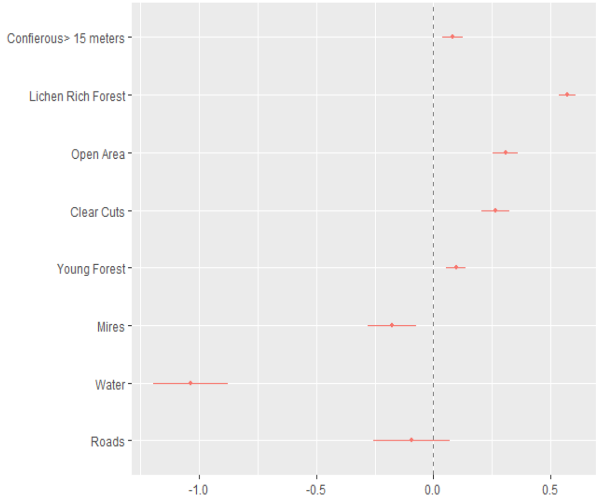
Year 2009-10 Free Ranging Reindeer



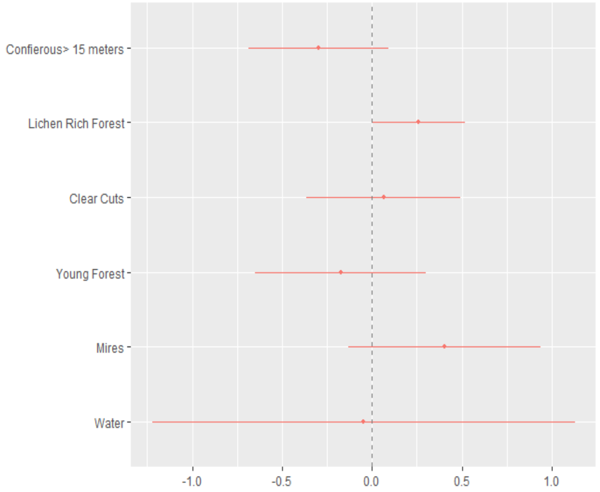
Year 2014-15 Free Ranging Reindeer



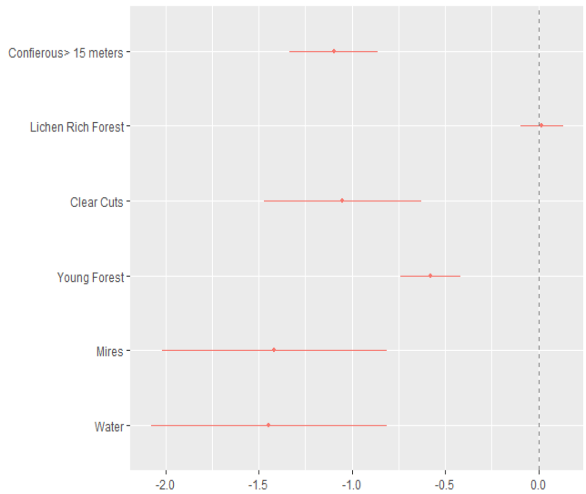
Year 2015-16 Free Ranging Reindeer



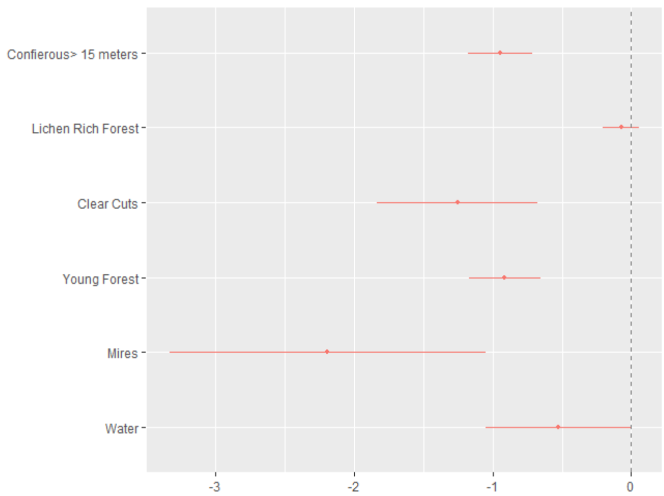
Year 2008-09 Reindeer on Supplementary Feeding



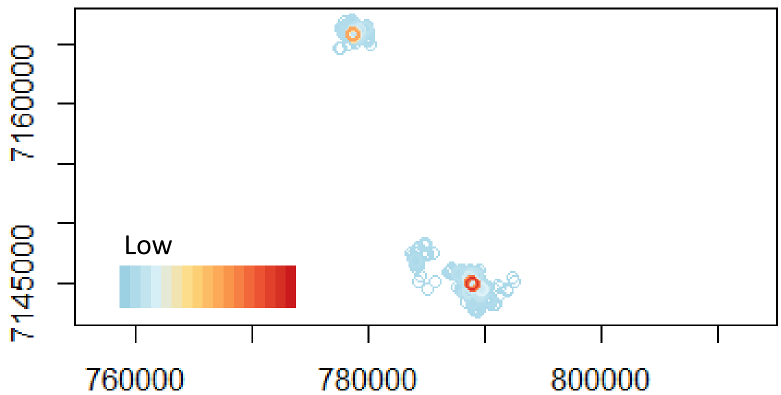
Year 2014-15 Reindeer on Supplementary Feeding



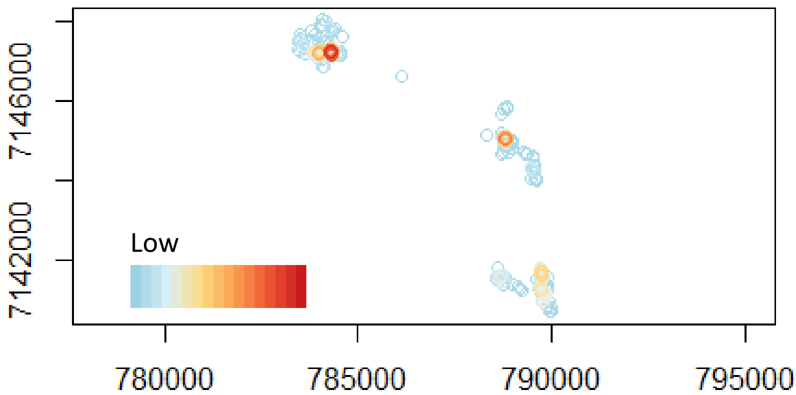
Year 2015-16 Reindeer on Supplementary Feeding



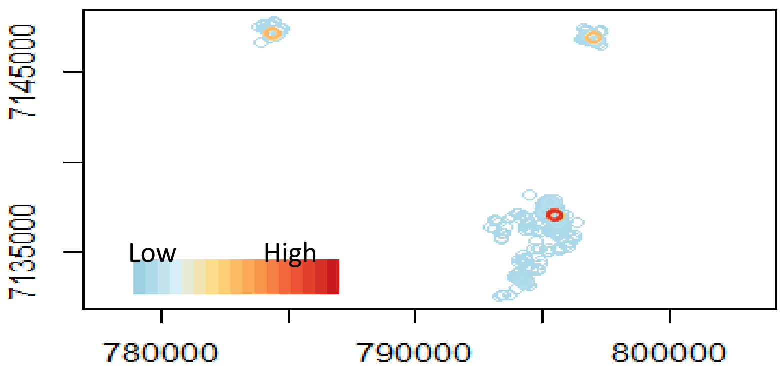
Appendix 5- Revisitation Analysis



Frequency of Rev-visitation with core radii for year2007-08, radius 90m at two different feeding stations (Hakatjärnen, Lappvattsheden C).



Frequency of Rev-visitation with core radii for year2008-09, radius 60m at three different feeding stations (Ånäset norra, Fongnesberget, Hakatjärnen).



Frequency of Rev-visitation with core radii for year2015-16, radius 50m at three different feeding stations (Fongnesberget, Snotterblommyran, Grimsmark).

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