Moose winter home range

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ABSTRACT

Moose populations in Norway are managed by the municipalities according to regulations set by the county and central government. The main tool used to manage the moose population is harvesting, but also supplemental feeding in winter is getting more common. This is done to provide better nutrition in winter to enhance winter survival or to divert moose away from vulnerable habitats, roads and railways. There is however not much known about how the use of feeding stations effect the winter home range of moose. I expected that moose feeding on feeding stations would have smaller home ranges than moose that don't use the feeding stations. Data was used from 20 adult female collared moose in the Evenstad area to find out if this was true and secondly I looked at the amount of time moose spent in a certain distance from a feeding station to assess the space use. There was no relation between the size of the winter home range and the time spent on a feeding station for all moose, this relation was present for moose that use the feeding stations. The feeding station users also form core areas of their winter home range around the feeding stations. And spent most of their time (87%) within 1.5 km of a feeding station. Feeding stations can not prevent moose from taking in natural browse but feeding stations could be placed in sacrifice areas preferably > 1.5 km away from vulnerable habitats such as young Scots pine (*Pinus sylvestris*) stands.

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1. INTRODUCTION

Cervid populations in North America, Canada and Europe have been increasing the last 50 years (Karns, 2007; Milner, et al., 2006). With the increase of these populations conflicts also arise. The moose (*Alces alces*) population in Norway is no exception to this trend (Lavsund, et al., 2003; Statistik sentralbyrå).

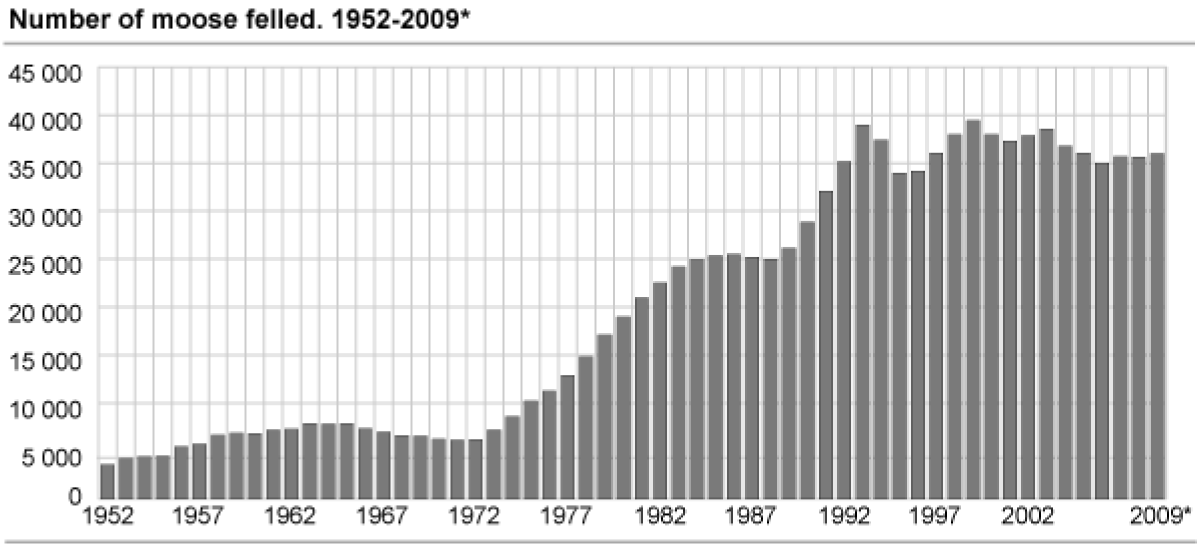

Figure 1: Total number of moose felled during hunting seasons in Norway from 1952 up to 2009

The increase in the moose population is probably caused by reduced predation, changes in forestry and sex and age-specific harvesting starting in the early 1970s (Gundersen, 2003; Lavsund, et al., 2003). Also large-scale climate patterns have an influence on the increase of cervid populations (Stenseth, et al., 2003). The population increase has led to an increase in moose vehicle accidents (Andreassen, et al., 2005; Storaas, et al., 2001), browsing damage mainly on forestry stands but also on agricultural crops (Gundersen, et al., 2004) and reduction in growth and fecundity (Danielsen, 2001; Gundersen, 2003).

1.1 Moose management

Norway has a land area of 323,782 sq km (Statistik sentralbyrå). The latitude ranges from approximately 57 degrees to 72 degrees North, and the longitude ranges from approximately 5 degrees to 31 degrees East. As a result moose management is conducted in a wide range of vegetation zones as well as geographical conditions (Moen, 1999; Danielsen, 2001). There is also a variation in landownership, from governmental land, church land to private owners. Property sizes can vary from one hectare up to thousands of hectares (Danielsen, 2001).

Wildlife management in Norway is based on the precautionary principle that is included in “The Wildlife Act” (1981). Moose populations are managed according to the “Cervid Regulations” (Miljøverndepartementet) (Danielsen, 2001). The general objectives for cervid management are:

- Moose, red deer, and wild reindeer populations should be stabilized at a sustainable level regarding the viability of the populations and other interests, such as forestry and traffic safety;
- Cervid populations should have an acceptable sex and age ratio and maintain their genetic variability;

- Cervid populations should not threaten biodiversity through too heavy browsing and grazing pressure;
- Cervid populations should yield a harvest that is as stable as possible;
- Land management should ensure long term survival of viable cervid populations;
- Management should ensure healthy cervid populations; and,
- Management should facilitate a harvest with both recreational and economical benefits.

(Milijøstatus i Norge; Danielsen, 2001)

The Norwegian municipalities are the local public wildlife management authority. They issue hunting licences to the landowners, based on a minimum area set by the County Governor. The fees for the licenses remain in the municipality. The municipalities also have full responsibility for ungulates killed out of hunting season, mainly by train and traffic collisions, and for crop damage (Danielsen, 2001).

The Ministry for Environment, the Directorate For Nature Management and the County Governor are responsible for legislation, setting national and regional goals and guidelines, and supervising the municipalities. The Directorate for Nature Management is also responsible for national monitoring programs and funding of research. They also issue management regulations under which the local and regional management operate (Danielsen, 2001).

In several municipalities landowners take the responsibility for cervid management plans and in return the have access to longer hunting seasons. They have full responsibility for sex and age ratio of their harvest and get financial support for regional management through landowners organizations (Danielsen, 2001).

Harvesting moose is the main management tool used to execute the management goals set in the “Cervid Regulation”. A total of 35,971 moose were harvested during the hunting season in 2008/2009. In that same year 2373 moose were killed by collisions either with a train or a car (Statistik sentralbyrå). In 1952 a little less than 5000 moose were harvested, this is an increase of more than 700% in almost 60 years (Fig. 1). Supplemental winter feeding at feeding stations is another management tool that is used in Norway. Supplemental feeding in winter is normally used to maintain or increase body weight over winter, improve fertility, increase winter survival, control animal movements and reduce damage caused to forest stands and agricultural crops (Putman & Staines, 2004).

1.2 Home range

Burt (1943) described home range as the area traversed by an individual during normal activities of food gathering, mating, and caring for young. Animals establish a home range to ensure survival in critical biological periods (Lindstedt, et al., 1986). Body size is the main determinant between home range sizes of species in similar habitats (Mysterud, et al., 2001). McNab (1963) stated that the ultimate factor determining home range size seems to be energetics. For moose it is shown that the distance moved over a given period of time, which is related to home range size, directly relates to forage biomass (Lynch & Morgantini, 1984). Therefore moose that live in high productive habitats should have smaller home ranges that moose that live in habitats characterized by poor productivity.

1.3 Research question

The relationship between the home range size and the use of feeding stations for moose in the study area has not been researched yet. I expect that moose feeding on feeding stations have a smaller home range than the moose that don’t, because of the higher and better food availability. The following question will therefore be investigated; with the use of feeding stations, can we influence the home range size of moose, and therefore prevent, reduce or relocate browsing damage on forest stands? This question can be divided into 3 sub questions;

1. What is the winter home range size of collared moose in the study area?
2. Do moose feeding on feeding stations have a smaller winter home range than moose not feeding on feeding stations?
3. How can we use feeding stations to prevent, reduce or relocate browsing damage on forest stands?

2. METHODS

2.1 Study area

The study area is located in eastern Norway, within the Evenstad area, Østerdalen, Hedmark county see figure 2.

The vegetation zone is a combination of southern and middle boreal forest characterized by coniferous woodland with a mixture of deciduous species (Moen, 1999). The study area is dominated by forests with Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) which are managed for timber production. Mature forests are harvested by clear cutting with the exception of seed trees. Deciduous species include alder *(Alnus glutinosa)*, ash *(Fraxinus excelsior)*, birch *(Betula spp)*, willow *(Salix spp)*, rowan (*Sorbus aucuparia)* and aspen (*Populus tremula).* Of these only the birch species are used commercially, mainly as fire wood and in the paper industry. Abundant understory species found in the stands include blueberry (*Vaccinium myrtillus*) and cowberry (*Vaccinium vitis-idaea*).

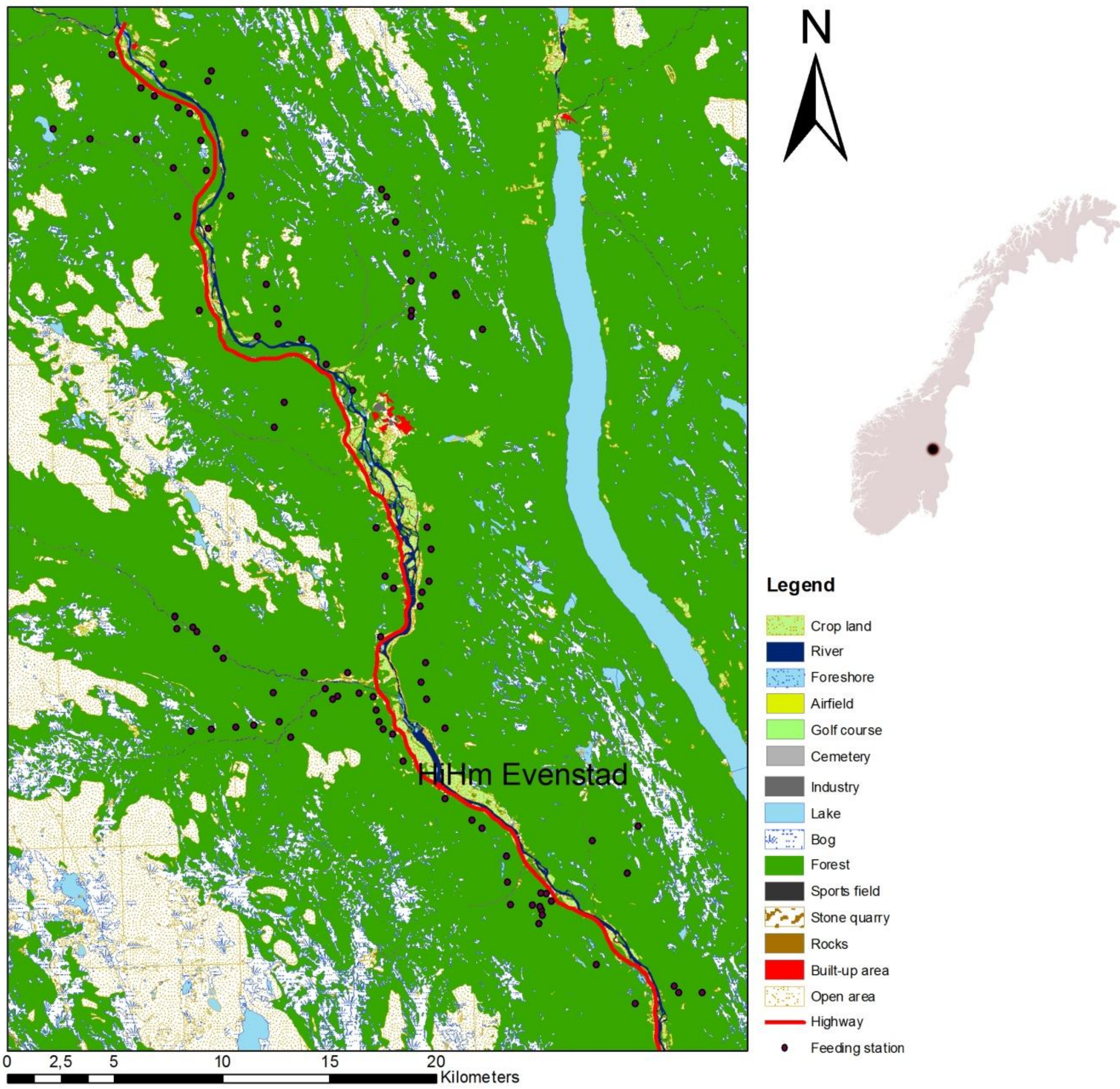

Figure 2: Map of the study area

Data used in the study is from January 2009 till April 2009. Mean winter temperatures varied from – 7.9° C in January till 5.2° C in April. And snow depth varied from 41.6 cm in January, up to 74.4 cm in March and 26.5 cm in April (Norwegian Meteorological Institute)

Potential natural predators in the area are the wolf (*Canis lupus*) and the brown bear (*Ursus actros*). But hunting is still the most important cause of moose mortality. For the year 2009, 44,369 licences were issued and 35,3971 moose were felled, 2373 moose were killed in a collision accident, 3648 were felled as nuisance, 30 were felled illegally, and 1233 moose were felled or killed for other reasons such as predation by large carnivores (Statistik sentralbyrå)

Supplemental winter feeding of moose was initiated by the landowners around the winter of 1990. The food consists of silaged graminoids and herbs, each bale weighing approximately 600 kg (van Beest, et al., 2010). The feeding starts when snow accumulates on the hillsides (usually in early December) and stops when the snow begins to melt (April/May). All feeding stations are placed along snow cleared roads with low human activity (Gundersen, et al., 2004).

2.2 Moose

From 8 till 12 January 2009 20 adult female moose were tranquilized with a dart gun from a helicopter using established techniques (Arnemo, et al., 2003). The cows were fitted with Tellus GPS collars (Followit Wildlife). These collars give hourly positions which are stored in the collar, but the collars also send the position to a server by SMS. Not every hourly position is recorded as GPS collars can fail to connect to the satellites which are needed to make out the coordinates. On average 91.6 % of the hourly positions were recorded by the GPS collars.

Three moose cows were excluded from further analysis. Cow 2209 died in January 2009 and cow 1809 died during re-capturing in March. The data from cow 4109 is missing because the data was stored in the calf's collar and this collar hasn't been retrieved yet.

2.3 Migratory versus resident moose

Moose can migrate between summer and winter home ranges. These movement patterns have a large influence on the size and shape of the home range. To exclude the migration movements between the summer and winter home range it is important to determine if the individuals are migrating or not. For this net displacement graphs (Bunnefeld, et al., 2009) were made in ArcGIS 9.3.1, with an extension called Hawth's Analysis Tools version 3.27. This extension contains modelling and analysis tools. Some of the analysis tools are driven by R, an open source statistical analysis program. The net displacement is the distance from point zero to each other point. The tool automatically calculates these distances and adds a column in the table of the layer file. This column was then used to make graphs which display the net displacement. The shape of the graph indicates whether an individual migrates or not. Migratory moose will travel greater distances from point zero than residential moose, therefore migratory moose will show a 'table' like line as to resident moose will show a more horizontal line as seen in figure 3.

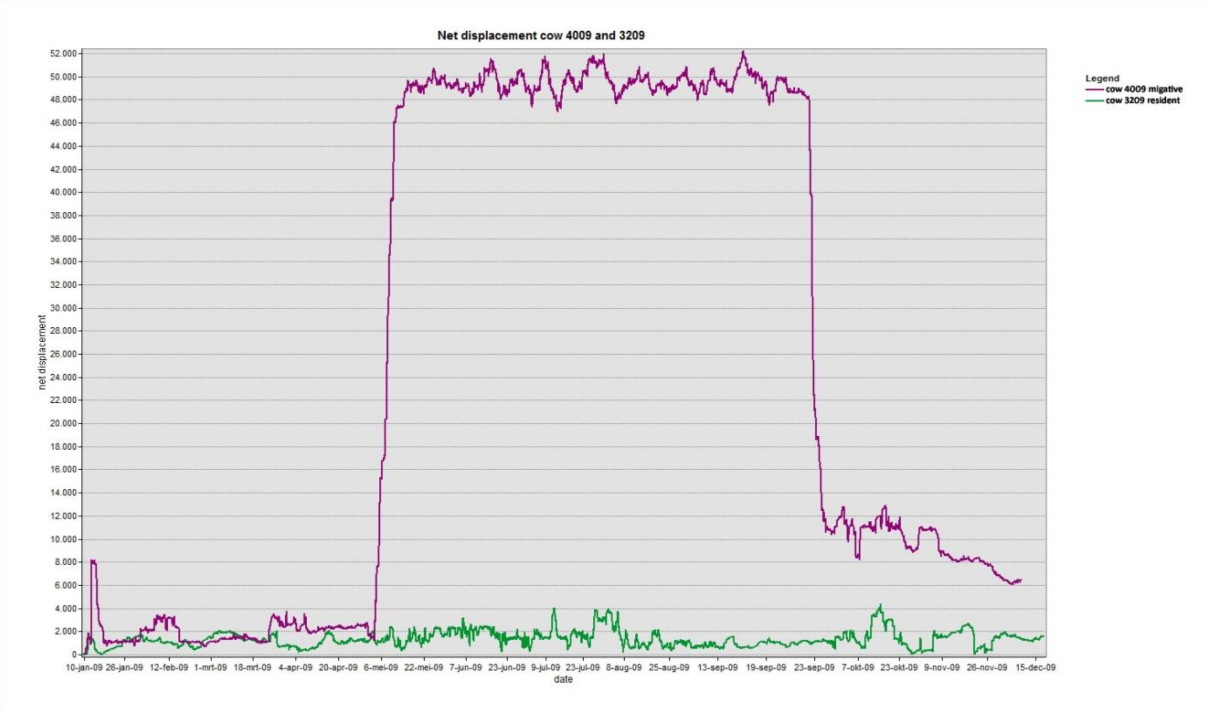

Figure 3: Net displacement graphs for to individual moose cows. Cow 4009 is a migratory cow, shown by the 'table' shape purple line, and cow 3209 is a resident with a more horizontal line (green).

2.4 Winter home ranges

In winter moose select parts within their annual range were there are less mires, clear cuts and fields, these might be avoided because snow covers the ground vegetation. Migratory moose also depend more on young pine as winter food . For migratory moose the beginning of winter was defined as the ending of the migration. When they start migrating snow has accumulated in the higher summer ranges and they come down to the valleys were there is less snow and more available forage. Previous studies have shown that migration usually starts and ends around a snow depth of 30 cm (Gundersen, 2003). All migratory collared moose in the study area were either captured during or after the migration. Therefore the beginning of winter was defined as the day of collaring or the day the migration ended whichever is latest. The end of winter was defined as the start of migration towards summer areas (cow 2109 and 3009) or 14 April 2009 whichever was earliest. This is the day that the snow depth went below 30 cm (Norwegian Meteorological Institute). Beginning of winter for non-migrating moose was the day of collaring. The ending of winter was the 14th of April.

All GPS location points were loaded into ArcGIS 9.3.1, and by use of the dates defining the beginning and ending of winter, the winter points for each individual were saved in layer files. By use of these layers files, two different methods for calculating home ranges were used. The first was a fixed Kernel Density Estimator (KDE) with a likelihood cross validation (CVh) smoothing factor. The smoothing factor determines how smooth the density estimator is. This smoothing factor was chosen because it seems to outperform any of the other smoothing factors commonly used (Horne & Garton 2006). KDE home ranges are based on a continuous probability distribution (Gaussian distribution) which gives a description of data that cluster around the mean. At first KDE home ranges were calculated with ArcView GIS 3.2, by use of an extension called Animal movement SA v2.04 beta, but this proved very slow and the output of home ranges were consistently too small. Therefore I decided to calculate the home ranges in ArcGIS 9.3.1, with Hawth's Analysis Tools version 3.27. The CVh smoothing factors for each individual were calculated by use of Animal Space Use 1.3 Beta. This program calculates different smoothing factors by using the X and Y coordinates in the point layer files from ArcGIS. For each home range two isopleths were used, 90 and 50 %. The isopleths show the amount of time the moose cow spent within this area. The 50% isopleths or 50% time spent in that area is the core area of the moose home range (Fig. 4 and 5) According to Börger et al. (2006) using isopleths in this range produces area estimates less biased by sample size than using isopleths above 90% or below 50% (Börger, et al., 2006; Getz, et al., 2007)

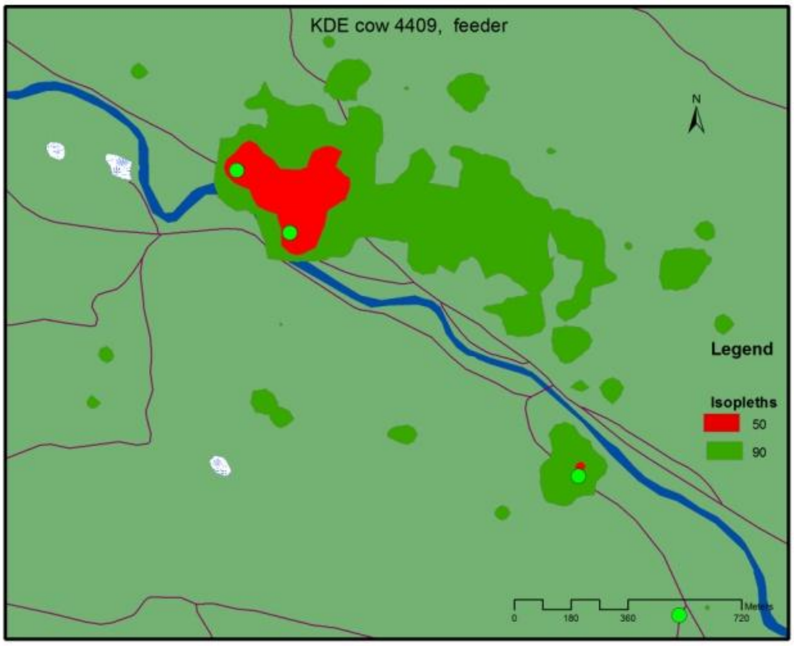

Figure 4: Winter KDE HR of cow 4409, feeding station user with the 90% isopleth and a 50% isopleth. The core areas are formed around the feeding stations.

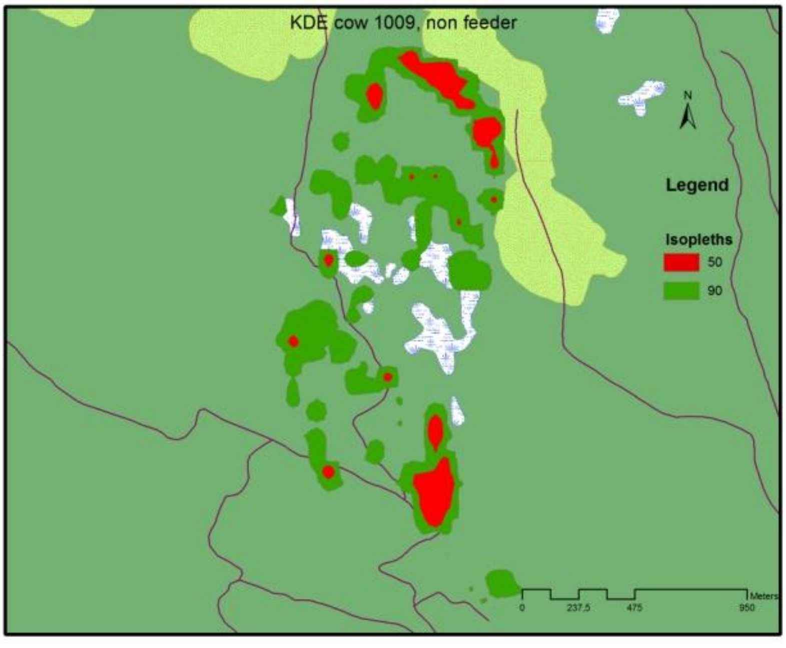

Figure 5: Winter KDE HR of cow 1009, a non-user, with the 90 and 50% isopleths.

The second method used was a Local Convex Hull (LoCoH), a non parametric kernel method which generalizes the minimum convex polygon (MCP) method (Getz, Fortmann-Roe, Cross, Lyons, Ryan, & Wilmers, 2007). The LoCoH basically makes a MCP but with holes in it, this is because it recognizes hard boundaries, such as rivers and roads. These home ranges were calculated in Arcview GIS 3.2 by the use of an extension called LoCoH v2.1. To calculate a LoCoH home range with this extension a k-value is needed, which is the square root of the number of points within the layer file. When k is, for example, 43 the method will construct a convex hull associating each point and its 43 nearest neighbours. These hulls combined represents the home range for the individual (Getz, et al., 2007). Isopleths are automatically created ranging from 100% down to 10%, so for this study the area of the 90% and 50% isopleths were used for further analysis (Fig 6 and 7).

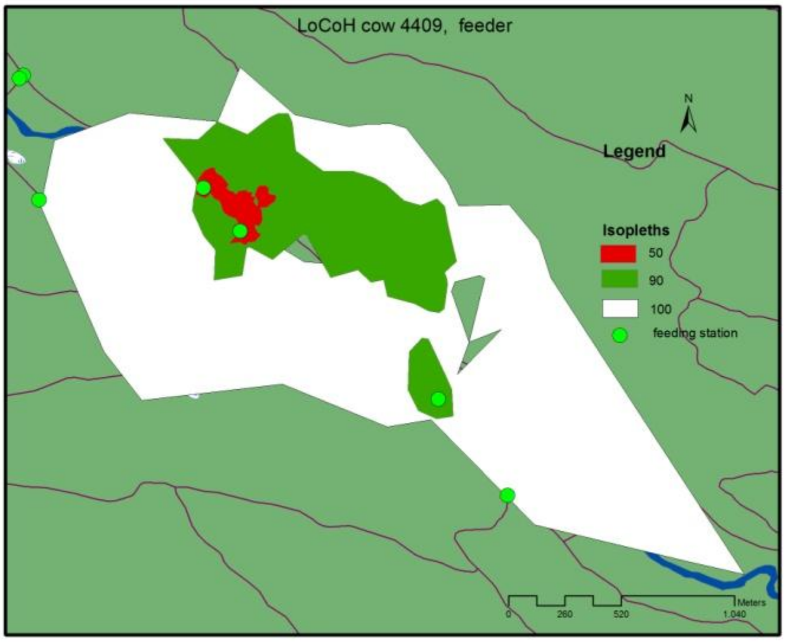

Figure 6: Winter LoCoH HR of cow 4409, feeding station user with the 90% isopleth and a 50% isopleth. The 100% isopleths is also added to show the holes in the HR. The core areas are formed around the feeding stations.

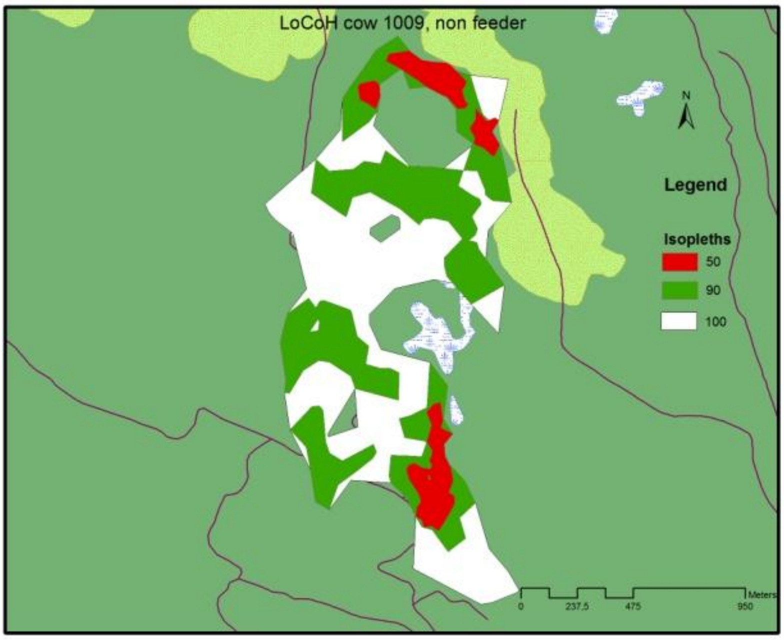

Figure 7: Winter LoCoH HR of cow 1009, a non-user, with the 90 and 50% isopleths. The 100% isopleths is also added to show the holes in the HR.

2.5 Users versus non-users

Feeding station users were defined as moose having hour points within 250 meters of a feeding station. The 250 meter buffer was decided because of inconsistency in the GPS and because positions were taken hourly.

All feeding station users had distinctive star patterns between the points in the winter period, this suggests a feeding station or station. Some of these star patterns occurred on stations were there was no feeding station in the layer file. These locations were checked in the field, and pin pointed with a handheld GPS, to add them later in the feeding station layer file. The hour points within the buffer were clipped and saved in a separate layer file.

Feeding station users were defined as moose having hourly points within 250 meters of a feeding station. The 250 meter buffer was decided because of the GPS location error and because positions were only taken hourly.

All feeders had distinctive star patterns between the points in the winter period, with the centre of the star at a feeding station. Some of these star patterns occurred on stations were there was no feeding station in the layer file. These locations were checked in the field, and pin pointed with a handheld GPS. The layer file was subsequently up-dated if a new feeding station was found. The hourly points within the buffer were clipped and saved in a separate layer file.

Cow 5309 was qualified as a low user. This is because although she feeds on a feeding site, 8,79% of the winter period, she spent most of her time in little ‘super’ habitats, typical for non feeders. One of these ‘super’ habitats gave a weak star pattern that could suggest a feeding station (Fig. 8). This site was checked in the field and it was confirmed that this was a ‘super’ habitat, a clear cut with a large amount of deciduous species and not a feeding station. To visualize the comparison 2 extra figures have been added, number 9 a typical user pattern on a feeding station and 10 a non-user pattern.

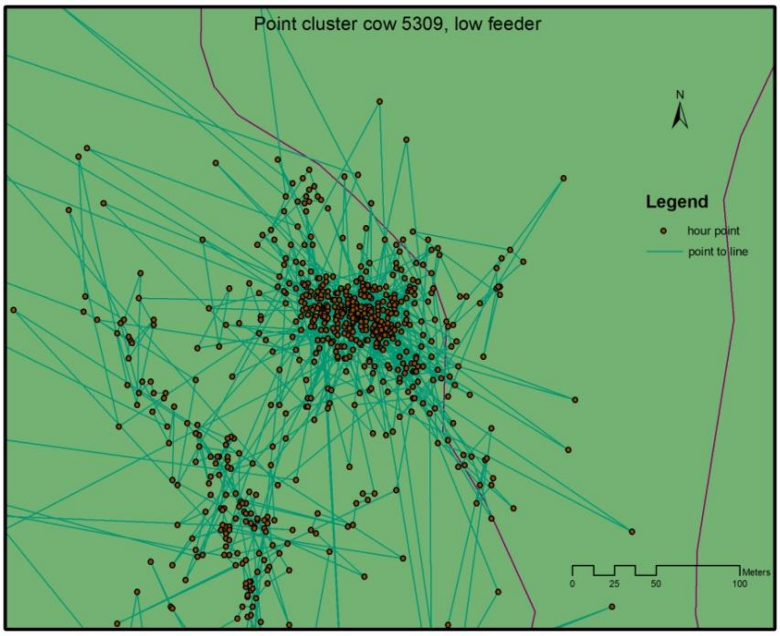

Figure 6: Movement pattern of cow 5309, low user, on a feeding area.

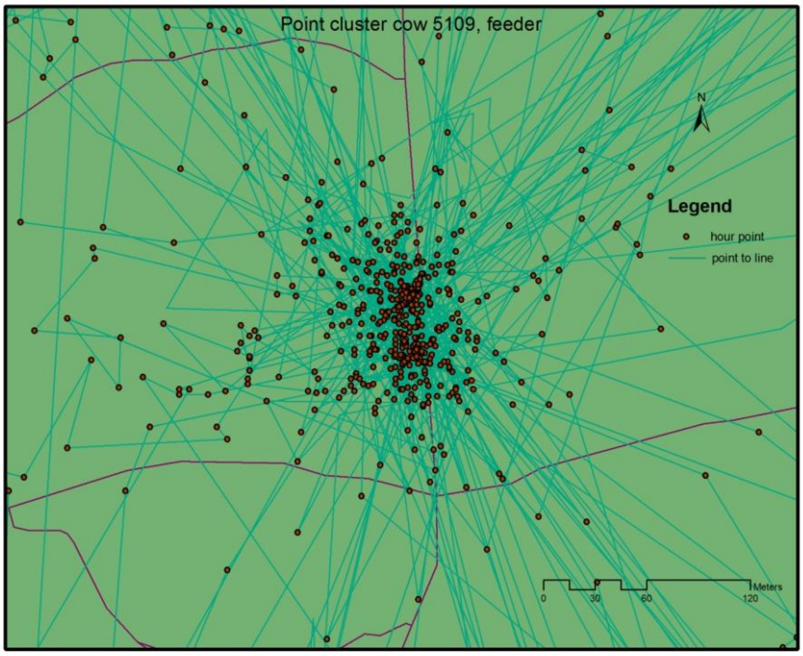

Figure 8: Movement pattern of cow 5109, a feeding station user, on a feeding station.

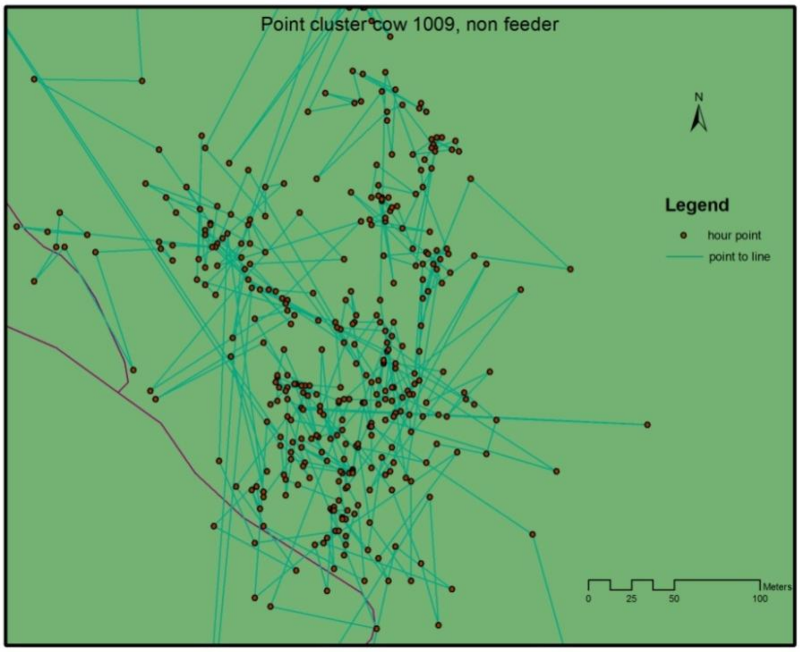

Figure 7: Movement pattern of cow 1009, a non-user, on a feeding area

2.6 Time spent in feeding station area

To see how much time moose spent in the area surrounding the feeding stations, buffers were created ranging from 250 up to 1500 meters. The number of points in the buffer zone were counted and compared to the total number of winter points to determine a percentage of time spent within that buffer. This was done for each individual in ArcGIS 9.3.1.

2.7 Data analysis

All home range areas from both methods were transformed by natural logarithms and saved in Microsoft Office Excel sheet together with covariates such as; time spent within 250 meter buffer, weight in March, new calves in June, weight in January, number of feeding stations used and categorical variables migratory y/n, feeder y/n, and calf present in March y/n. This sheet was then imported in R (R Development Core Team, 2009). A linear regression analysis was used to asses the relationship between the dependent variables, the different logarithms of the 50 and 90% areas from the home ranges, and the covariates. Many models were tried to explain the variation in the size of the home range in terms of the explanatory covariates.

3. RESULTS

Of the 17 collared moose cows 6 (35%) were classified as migratory moose. 11 (65%) Moose were classified as feeding site users and 5 (29%) were non-users. Cow 5309 was classified as a low user (see paragraph 2.5 Users versus non-users). No non-users had a feeding station within their winter home range.

Home range size for the KDE method varied from 0.55 to 4.24 square km (90% isopleth) and core areas from 0.08 to 0.7 square km (50% isopleths). For the LoCoH method the size varied from 0.62 to 6.35 square km (90% isopleths) and core areas from 0.05 to 0.68 square kilometres (50% isopleths). A summary of the winter home ranges sizes for all moose is given in table 1. Table 2 shows the summary data for the feeding station users, table 3 for the non-users and table 4 is cow 5309 the low feeder. All winter home range sizes are given in appendix 1, winter home range areas in km^2 for all moose.

All moose	KDE 90%	KDE 50%	LoCoH 90%	LoCoH 50%
Min	**0.55**	**0.08**	**0.62**	**0.05**
Median	1.37	0.23	1.61	0.26
Mean	1.60	0.27	2.11	0.27
Max	4.24	0.70	6.35	0.68
s	0.93	0.17	1.48	0.19

Table 1: Summary of the minimum , the maximum, the mean and median winter HR of the KDE and LoCoH method for all moose, all areas are in square km. Also added the standard deviation.

FS users	KDE 90%	KDE 50%	LoCoH 90%	LoCoH 50%
Min	0.55	0.08	0.67	0.05
Median	1.62	0.30	2.20	0.26
Mean	1.86	0.31	2.38	0.27
Max	4.24	0.70	6.35	0.67
s	1.05	0.19	1.66	0.18

Table 2: Summary of the minimum , the maximum, the mean and median winter HR of the KDE and LoCoH method for all feeding station users, all areas are in square km. Also added the standard deviation.

Non-users	KDE 90%	KDE 50%	LoCoH 90%	LoCoH 50%
Min	0.55	0.10	0.62	0.11
Median	1.03	0.23	1.00	0.26
Mean	1.11	0.21	1.38	0.32
Max	1.88	0.33	2.93	0.68
s	0.49	0.09	0.91	0.22

Table 3: Summary of the minimum , the maximum, the mean and median winter HR of the KDE and LoCoH method for all non-users, all areas are in square km. Also added the standard deviation.

Low FS user	KDE 90%	KDE 50%	LoCoH 90%	LoCoH 50%
	1,28	0,10	2,94	0,09

Table 4: Areas, in square km, of winter HR from KDE and LoCoH method for cow 5309, low feeder

There was no relation between the size of the winter home range and the time spent on the feeding station for all moose, $F_{1.15} = 0.000$, $p = 0.983$ (Fig. 11). But for feeding site users only, this relationship is significant ($F_{1.15} = 7.178$, $p = 0.0252$, $R^2 = 0.444$ (Fig. 11). The dotted line presents the linear relation between the size of the winter home range for the feeding station users and the time spent on the feeding station. The other line presents the linear relation between the size of the winter home range and all moose and the time spent within 250 m feeding station buffer. The R^2 of this line (R^2 = 3E-05) shows that there is hardly any relation between the winter HR size and the time spent on the FS.

Therefore it can be said that moose which spent a little time feeding on feeding stations had a larger home range than the ones that feed a lot on a feeding station.

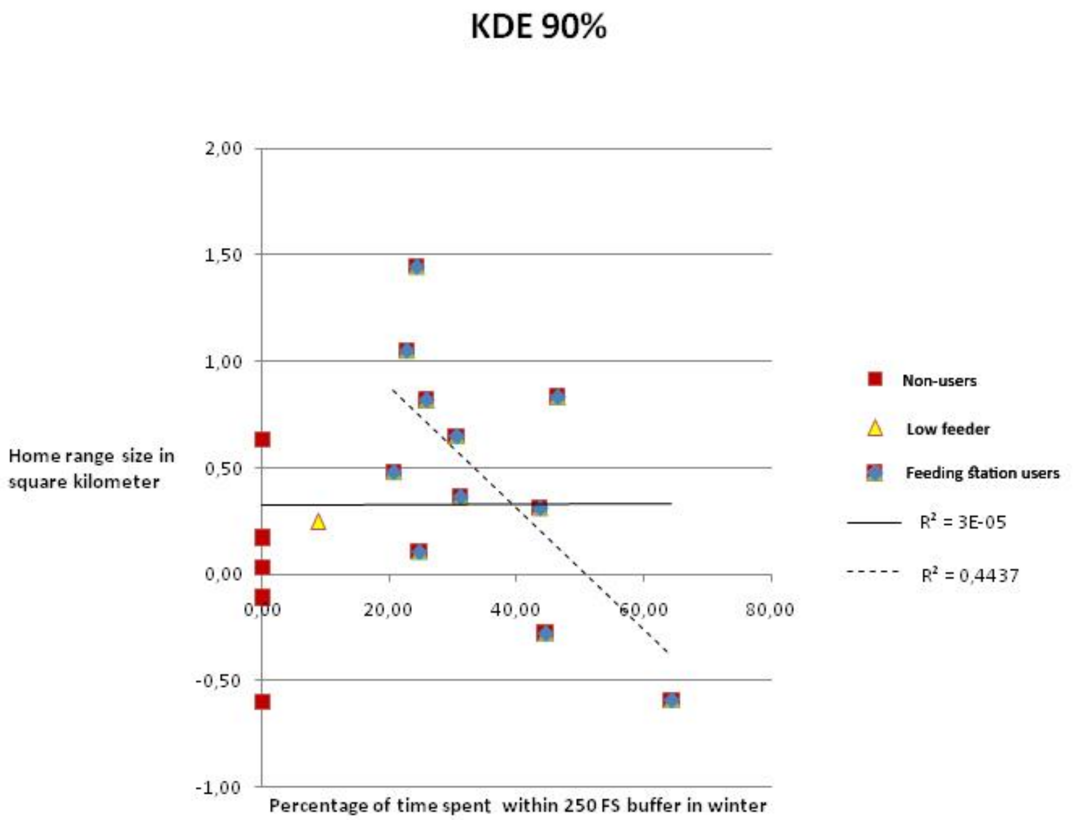

Figure 9: Graph of KDE 90% winter HR and percentage of time spent within the 250 m FS buffer for all collard moose used, divided by non-users, low feeder and feeding station user.

For the core areas, KDE 50%, the relation between the size of the winter home range and the time spent on the feeding stations was even stronger, $F_{1.15} = 11.07$, $p = 0.009$, $R^2 = 0.552$ (Fig. 12). Feeding site users formed core areas in their winter home range around the feeding stations.

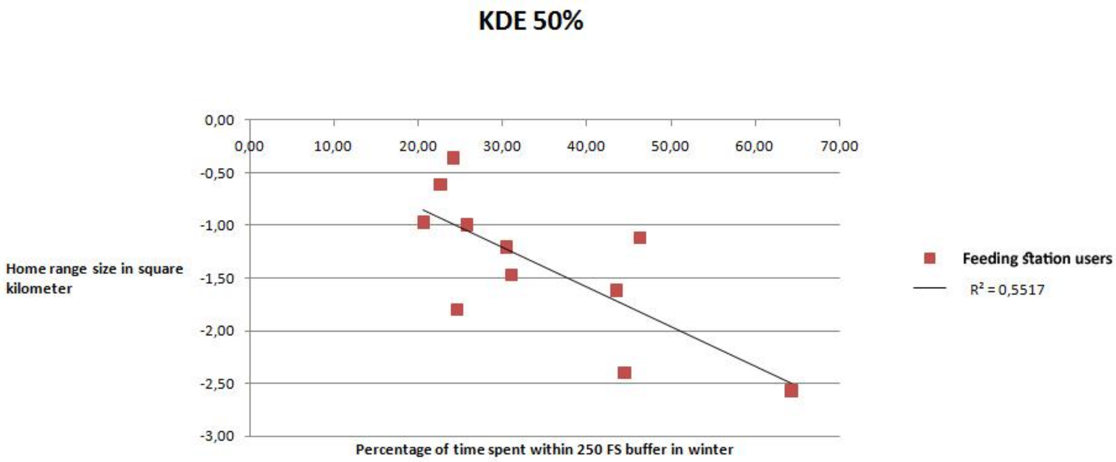

Figure 10: of KDE 50%, core areas, winter HR and percentage of time spent within the 250 m FS buffer for all feeding station users. The line through the point presents the linear relation between the winter HR core areas and the time spent within 250 m FS buffer.

The number of feeding stations used is a variable that also relates to the size of the winter home range. The more feeding stations a moose uses the larger the winter home range is. None of the other individual covariates had a significant influence on the size of the home range. For the non feeders other biological factors than body weight, calf present, number of calves, migratory y/n must determine winter home range size.

Feeding station users utilize the area surrounding the feeding stations intensively. The feeding station users (Fig. 13) spent 78.01% (mean) of their time within 1000 meters of feeding stations. At 1500 meters this is 87.05% (mean). All non users spent 0% of their time within the 1500 meter buffer and the low feeder spent 77.01% within 1000 meters and 94.91% within 1500 meters of a feeding station.

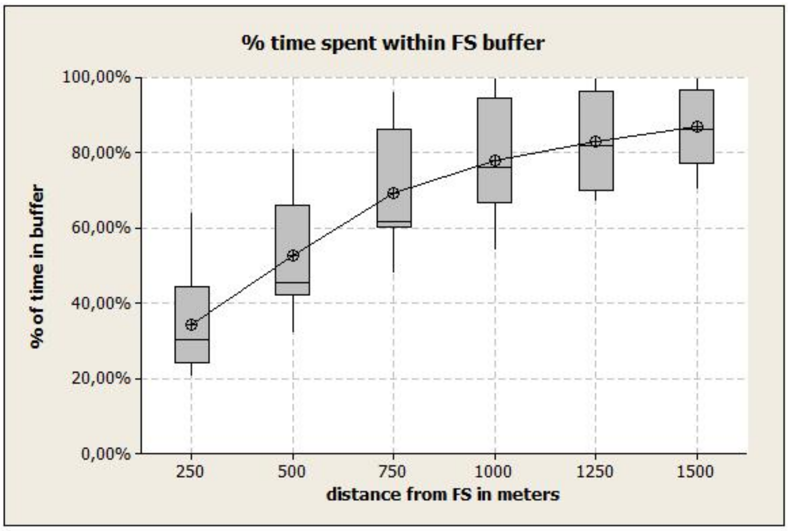

Figure 11: The amount of time feeding station users spent within a certain distance from a feeding station. The line presents the mean percentage of time.

4. DISCUSSION

I expected that moose feeding on feeding stations had a smaller home range than the moose that don't. For the collared moose in the study area this wasn't true. No relation was found between the size of the winter home range and the amount of time spent on a feeding station, this relation was present for the feeding station users just as for roe deer (*Capreolus capreolus*) (Guillet, et al.,1996) and alpine red deer (*Cervus elaphus hippelaphus*) (Schmidt, 1993). A study in Sweden on seasonal home range size without the use of feeding stations shows a far higher mean, 4.9 km^2, winter home range area (Cederlund & Okarma, 1988) than this study, mean 1.6 km^2 (KDE 90% for all moose). The feeding station users formed core areas within their winter home range around the feeding stations they used, just as white tailed deer (*Odocoileus virginianus*) (Kilpatrick & Stober, 2002) and the size of the winter home range increased by the number of feeding stations used. The reason why non-users don't have bigger winter home ranges than feeding station users in the study area couldn't be explained by the covariates used in the data analysis and must therefore have different reasons. A reason for this could be that the non users form winter home ranges or have access to what I like to call 'super' habitats. These habitats have all a moose needs to eat, rest, and shelter from predators in a small area. These 'super' habitats were in earlier times created by forest fires (Peek, 2007), now logging industry in the form of clear cuts has taken that place (Peek, 2007). It is most likely that moose pick out such a clear cut area with a high availability of forage even in mid winter when snow depths are high. This forage would consist of a high density of deciduous tree species, which moose prefer (Renecker & Scwartz, 2007), and Scots pine. Moose in winter will naturally use areas of high forage biomass, this until snow depth hinders movements and access to plants (Peek, 2007). So as snow accumulates during winter moose gradually shift to closed canopy stands, were there is less snow, because winter habitats that favour conservation of energy are the ones used (Peek, 2007). Because clear cuts in Norway are relatively small (Larsson & Hylen, 2007) an ideal winter habitat can be created on a small area. High quality winter forage, and canopy cover to reduce movement, thus save energy, within a small area would create a 'super' winter habitat. Feeding station users have access to high quality forage in a very small area, therefore it is logical that the more time a feeding station user spends on a feeding station the smaller the winter home range is, because home range size will depend on spatial arrangements of food hot spots, in this case the feeding stations.

The number of feeding stations used relates to the home range size in winter. Movement in winter for moose is limited by snow (van Ballenberghe & Ballard, 2007). Feeding stations are located near cleared forest roads and they use these roads to move from feeding station to feeding station. There are also 'moose highways' between feeding stations, small paths which are frequently used by moose between feeding stations. Therefore moose can easily move between feeding stations without spending a lot of energy doing so and by doing this the home range size can increase.

Feeding stations can't be used to prevent moose from browsing on natural browse or divert them away from vulnerable young stands (Gundersen, et al., 2004; van Beest, et al., 2010). Areas surrounding feeding stations are heavily browsed (van Beest, et al., 2010). This is due to the fact that moose spent most of their time within the feeding station area. In this study the feeders spent on average 78% of their time within a 1000 meters of a feeding station. This was also seen in southern Norway, were moose feeding on feeding stations continued to select young pine stands as much as moose that didn't use the feeding stations (van Beest, et al., 2010). But this is probably partly because feeding station users in southern Norway did not use the feeding stations as much as feeding station users in the Evenstad area (van Beest, et al., 2010). Also moose might need other food resources than silage, such as natural browse, and will use sources available close to feeding stations (Gundersen,et al., 2004). Additionally, damage to forest adjacent to supplementary feeding sites may increase, due to the increased density of animals within an area leading to increasing browsing pressure (Gundersen, et al., 2004). A recent not yet published paper (van Beest[2], et al., 2010) shows that when feeding stations are maintained in the same area over a long period of time will increase the risk of excessive browsing close to feeding stations (<1 km). And that browsing on economical valuable Norway spruce increases after 15-20 years of supplemental feeding (van Beest[2], et al., 2010). It might be possible to relocate browsing pressure on young forest stands, but moose need to learn the location of the feeding sites (Gundersen, et al., 2004). This could be the case for the low feeder, she is learning to use the feeding station, what would explain the amount of time she spends within feeding station areas. Or it is that she prefers her 'super' habitat above the feeding stations. Gundersen, Andreassen, & Storaas (2004) suggest that feeding stations may intercept migratory moose, this could not be seen within this study because the winter home ranges were determined after the migration ended and there is no data from migratory routes before. Sahlsten, et al. (2010) states that feeding stations at the ending of the migration are more likely to be used than at the beginning of migration.

5. CONCLUSION/MANAGEMENT IMPLICATIONS

Supplemental feeding in winter by using feeding stations has an effect on the winter home range size of moose using those feeding stations. The more time moose spent on feeding stations the smaller the winter home range is. It is difficult to compare this study to any other study relating to areas with no feeding stations because most surveys nowadays are conducted in areas were there is supplemental feeding. There are some older studies that describe the winter home range size of moose in areas without feeding stations, but the methods used to calculate the home range size differ from the ones I used. Also a lot of these studies were conducted in the United States and not Scandinavia, and therefore will be less suited for comparison. The core winter home range areas are formed around the feeding stations. This leads to increased browsing pressure on forest stands adjacent to the feeding stations. So browsing on forest stands can not be prevented by supplemental winter feeding moose. It is however possible to redistribute moose, but moose have to learn the location of the feeding stations and with feeding stations placed at the end of the migration route used more often it is very important to know the migration routes of the moose. This makes the location were to place the feeding station very important. I suggest to place feeding stations in sacrifice areas at least 1 km (van Beest, et al., 2010) and preferably 1.5 km away from the area that should be protected. This because 78% of the movement of moose feeding on feeding stations is within 1 km of the feeding station and at 1.5 km this is 87%. But managers should keep in mind that with long term supplemental winter feeding the sacrifice areas should be increased (van Beest, et al., 2010; Börger, et al., 2006). This same principle could also be used for other purposes such as the prevention or lowering moose vehicle collisions. Feeding stations should be placed at the end of migration routes and at least 1.5 km away from a main traffic artery. But managers should be aware that feeding stations do attract moose and other animals (Peek, et al., 2002) therefore local population densities could increase which could result in similair or higher collision rates.

It would be interesting to see how the results presented in this paper would develop when the data from the collared moose cows from this winter (2010) is added but I suspect that the linear relationship will be even stronger. It would be more interesting to find out what exactly determines winter home range size for moose that don’t feed on feeding stations, also to see if my ‘super’ habitat theory is correct. From a economical side it would be interesting to compare the cost of the browsing damage, cost of silage and hunting revenues to see if feeding stations are necessary at all.

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APPENDIX 1: WINTER HOME RANGE AREAS IN KM^2 FOR ALL MOOSE

FS using status	ID	KDE 90% area in km^2	KDE 50% area in km^2	LoCoH 90% area in km^2	LoCoH 50% area in km^2
non-user	1009	0,55	0,10	0,62	0,11
non-user	1209	1,03	0,23	1,00	0,26
non-user	1309	1,88	0,33	2,93	0,68
non-user	3209	1,19	0,23	1,38	0,33
non-user	3609	0,90	0,17	0,95	0,22
FS user	1409	4,24	0,70	6,35	0,67
FS user	1709	2,86	0,54	3,76	0,47
FS user	2109	2,30	0,33	3,63	0,29
FS user	3009	0,76	0,09	1,07	0,06
FS user	3309	1,92	0,30	2,20	0,33
FS user	3909	1,44	0,23	1,61	0,31
FS user	4009	1,37	0,20	2,24	0,16
FS user	4309	1,11	0,17	1,18	0,15
FS user	4409	0,55	0,08	0,67	0,05
FS user	5109	2,27	0,37	2,30	0,26
FS user	5509	1,62	0,38	1,11	0,18
Low FS user	5309	1,28	0,10	2,94	0,09