Microhabitat characteristics of kill and rest sites of Eurasian lynx (*Lynx lynx*) in northern Norway

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Abstract

The human population on earth has increased from 3 billion to 6 billion since 1960 and nearly 25% of the earth's terrestrial surface is now cultivated. The human pressure causes habitat fragmentation and has reduced populations of large carnivores throughout the world. Livestock depredation is the most significant conflict between people and large carnivores. In the county of Finnmark in northern Norway, where this research took place, especially Eurasian lynx are causing many livestock depredation conflicts, mainly with semi-domestic reindeer. In 2011 the Norwegian government paid about US$ 4.16 million in compensation for the depredation losses by lynx. Due to the low-intensity reindeer herding that is in practise, most carcasses of missing animals are never recovered. This provides uncertain and limited information concerning lynx depredation although the current level of compensation, paid for by the Norwegian government, is based on this information. Because of the uncertain and limited information the Norwegian government wants to change the current compensation system into a compensation system based on the presence of carnivores instead. A so-called risk based compensation system requires reliable estimates of lynx density, data on individual kill rates and habitat use of lynx are essential. The aim of this research was to provide insights into the habitat use of the Eurasian lynx in northern Norway by measuring microhabitat variables associated with kill and rest sites of lynx, which can contribute to the creation of a new compensation system. Data on lynx positions in the county of Finnmark was obtained in the summer period of 2011 and 2012 and were available from three collared lynx individuals. In total 90 kill sites of reindeer and 116 rest sites were sampled during a 3-months of data collection (June – August 2012). In addition, for each lynx site sampled, a control site was sampled within a 100m radius from the sampled lynx site. Microhabitat variables collected in the field were: habitat type, elevation, ruggedness, slope, aspect, presence of an edge, substrate structure, visibility, vegetation height and presence of a rock wall. A paired logistic regression was carried out with SPSS v. 19.0 to find out to what extent the microhabitat characteristics influence the presence or absence of lynx sites. Results showed that the probability of lynx selecting kill sites in a habitat type with trees was higher than in a habitat type without trees when compared to kill control sites. In addition, the probability of lynx selecting a kill site increased with a decrease in rock substrate and increased with a decrease in elevation. Characteristics found for lynx kill sites could be explained by the habitat selection of their prey, the reindeer. The probability of lynx selecting their rest sites in a habitat type with trees was higher than in a habitat type without trees compared to rest control sites. With steeper slope, a higher percentage of moss substrate and more uneven terrain, the probability of lynx selecting their rest sites increased compared to control sites. Characteristics found in this research for rest sites could be explained by the fact, that lynx selected a reduced visibility that provides shelter and security from being seen. On the other hand, a higher slope could indicate a better view for the lynx over the surrounding area.

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1. Introduction

The human population on earth has increased from 3 billion to 6 billion since 1960 and nearly 25% of the earth's terrestrial surface is now cultivated (Macdonald & Loveridge, 2010). The human pressure causes habitat fragmentation and has reduced populations of large carnivores throughout the world (Woodroffe 2000; Sunquist & Sunquist 2002). Large carnivores are among the most challenging taxonomic groups to conserve (Mech, 1995), because of their massive area requirements and predatory behavior, on both wild prey and livestock (Nowell & Jackson, 1996; Breitenmoser & Breitenmoser-Würsten, 2008). In Europe five large carnivore species are still present, namely the Eurasian lynx (*Lynx lynx*), Iberian lynx (*Lynx pardina*), brown bear (*Ursus arctos*), wolf (*Canis lupus*) and wolverine (*Gulo gulo*) (Linnell et al., 2010). We as humans do our best to conserve nature in national parks and protected areas, although the ability to conserve them is limited (Linnell et al., 2001). However, numbers have expanded in the last 30 years, either through natural expansion or reintroduction of these large carnivores (Linnell et al., 2010). This expansion into the mulltiuse landscapes results in conflicts with human land-use activities (Linnell et al., 2010; Pedersen et al., 1999; Odden et al., 2002). Livestock depredation is the most significant conflict between people and large carnivores (Sunde et al., 1998; Basille et al., 2009; Moa et al., 2006). There are many methods of mitigating carnivore depredation on livestock, ranging from traditional systems of shepherds, nighttime enclosures, to modern systems with electric fences (Herfindal et al., 2005; Woodroffe et al., 2005; Kalb, 2007). However, these methods are not possible to use in Norway where the per capita losses of livestock due to bears, wolves and lynx are the highest observed in Europe (Kaczensky, 1999). Since the parliament in Norway has accepted to maintain viable populations of the four species of large carnivores (wolf, wolverine, brown bear and Eurasian lynx) and stated that predator-killed livestock should be fully compensated (Andren, 2007), an ex post compensation policy is in effect (Schwerdtner and Gruber, 2007). Ex post compensation is based on an estimation of losses and is paid directly to the owners (Mattisson et al., 2011).

In northern Norway, lynx are predating semi-domestic reindeer and therefore causing many livestock depredation conflicts with the indigenous people, the Sámi (Pedersen et al., 1999). In 2011 the Norwegian government paid about US$ 4,16 million for the depredation losses, estimated to be caused by lynx (Mattisson et al., 2011). The government is required to do so since they have signed the Sámi Act of 12 June 1987. The purpose of this Act is to enable the Sámi people in Norway to safeguard and develop their language, culture and way of life (Government Administration Services, 2012). In addition, Norway signed the UN´s International Covenant on Civil and Political Rights (Mattisson et al., 2011), which protects minorities and indigenous peoples against discrimination. Furthermore, Norway signed the International Labor Organization (ILO) convention on Indigenous and Tribal Peoples in Independent Countries (Roy & Henriksen, 2010), that states that rights for the indigenous peoples to land and natural resources are recognized as central for their material and cultural survival.

However, the Norwegian government also has to conform with national and international commitments concerning the Eurasian lynx in Norway. In 1860 the Norwegian government implemented a premium payment for the kill of lynx, so that the species was almost exterminated there in 1930. Fortunately, the lynx in Sweden was already protected in 1928. Thus lynx migrated from Sweden to Norway and the distribution of the lynx in (northern) Norway increased rapidly from 1970s (Fig. 1).

In 1980, the Norwegian government ceased the premium payment on shot lynx and the hunting season was limited. In 1994, a quota hunting system was introduced. (Breitenmoser & Breitenmoser-Würsten, 2008). In 1996, IUCN listed the lynx as lower risk/least concern and in 2002 it was listed as near threatened (Breitenmoser et al., 2008). Moreover, Norway is member of the Council of Europe and they agreed up on the Bern Convention (Council of Europe, 2012) under which the Eurasian lynx is protected on Appendix III (Breitenmoser et al., 2008).

After all of this the Eurasian lynx became the most abundant large carnivore species in northern Scandinavia (Hayward & Somers, 2009). The total population size was estimated at 436 adult lynx in 2011 in Norway (Fig. 2), which include 74 family groups (females with dependent kittens) (Brøseth & Tovmo, 2011). In the counties of Troms and Finnmark the number of family groups is estimated at 11,5 (Brøseth & Tovmo, 2011), which is about 68 adult lynx individuals.

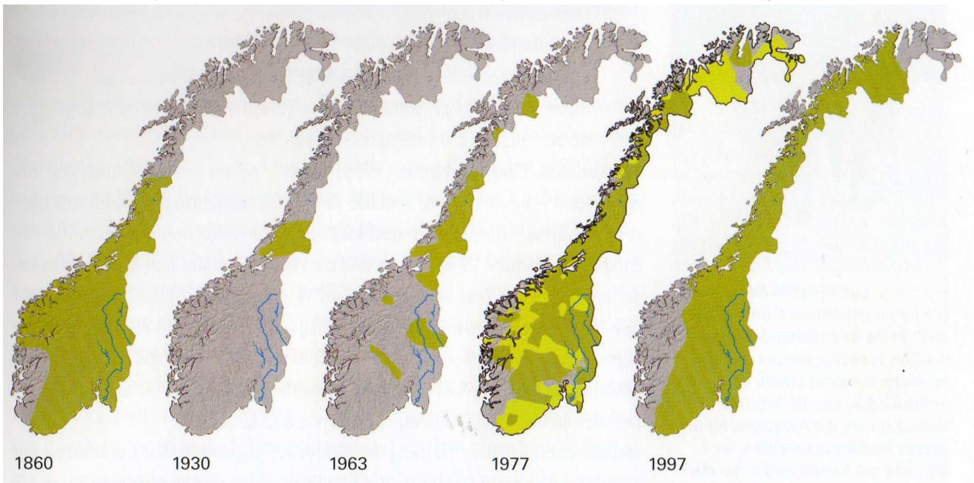

Figure 1: The distribution of the Eurasian lynx (*Lynx lynx*) in Norway since 1860 (Breitenmoser & Breitenmoser-Würsten, 2008)
The dark green parts indicate the permanent occupied areas by lynx. The light green parts in 1977 indicate the sporadic occupied regions by lynx.

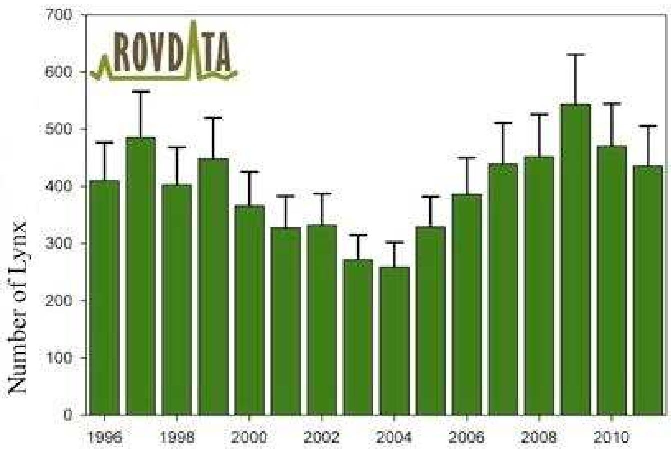

Figure 2: Estimated number (with the 95% confidence level) of lynx individuals in Norway from 1996-2011 with an estimated population size of 436 adult lynx in 2011 (Brøseth & Tovmo, 2011).

In southeast Norway lynx mainly prey upon roe deer (Odden et al., 2006) but in the northern parts 90% of the lynx diet consists out of semi-domestic reindeer (Danell et al., 2006; Pedersen et al., 1999; Mattisson et al, 2011). The Sámi manage their reindeer in an extensive manner by migrating with them year round (Pedersen et al., 1999). In Norway there are estimated to be about 230,000 free ranging domestic reindeer in winterherd (Linnell et al., 2010). Especially in Finnmark the density of reindeer is very high. With approximantly two reindeer per km^2, reindeer density is roughly four times greater than for example the density of reindeer in Russia. (International Arctic Science Committee, 2012)

Due to the low-intensity herding system of the Sámi, most carcasses of missing animals are never recovered (Pederson et al., 1999), which provides uncertain and limited information concerning lynx kill rates although the current level of compensation is based on this information (Mattisson et al., 2011).

In Figure 3, lynx kill rates are given per social status group (Mattisson et al., 2011). As shown, males kill more reindeer than solitary females or family groups during summer, but when calculating the average kill rate of lynx in summer it confirms the results described above of 1 reindeer per 5 days. However, this study also showed that the number of killed reindeer varies with the seasons, depending on reindeer migration.

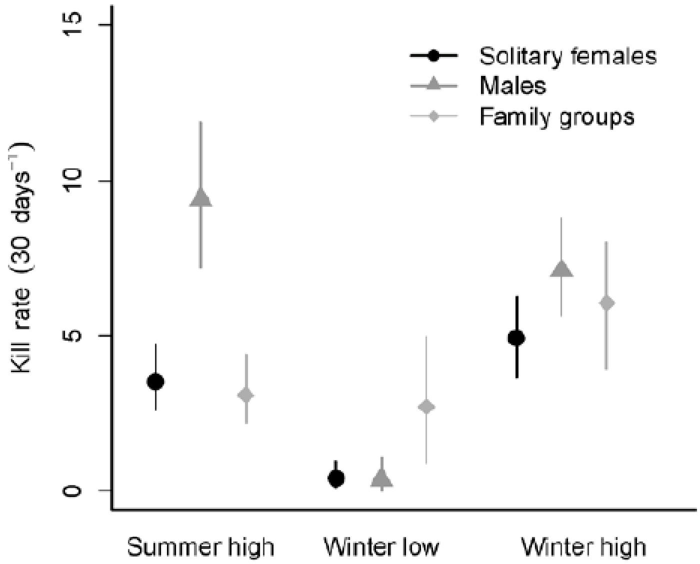

Figure 3: Predicted lynx kill rate on reindeer with 95% bootstrap confidence interval based on 128 kill rate periods from 35 lynx in northern Sweden and Norway, separated by lynx social status. High-low indicates presence-absence of reindeer pasture within the lynx home range at the time of the kill rate period (Mattisson et al., 2011).

The lynx-reindeer conflict is unique in the sense that semi-domestic reindeer are the main ungulate prey species available for the lynx within most of the reindeer husbandry area (Andersen et al., 1998). In addition, it is the predation by lynx on semi-domestic reindeer that is especially easy due to the fact that these animals, compared to roe deer, have a relatively poor developed anti-predator behaviour (Moa et al., 2006). However, lynx also feed on hares, birds and smaller carnivore species like red fox (*Vulpes vulpes*), pine martens (*Martes martes)* and domestic cat (*Felis catus*) (Mattisson et al., 2011).

Because a balance has to be found between maintaining a viable lynx population and sustainable reindeer husbandry (Mattisson et al., 2011), the Norwegian Institute for Nature Research (NINA) and Grimsö Wildlife Research Station in Sweden, started a collaborative research project in 2005 named Scandlynx. Although the Swedish side of Scandlynx had worked in the reindeerhusbandry area before, this was the first year for the Norwegian side. The major goal for Scandlynx is to gather and share knowledge about lynx. By doing so, it will contribute to knowledge-based management models that are accepted by different interest groups. Many projects in recent years have developed management tools to minimize the conflicts and improved the conditions for reindeer herding practices. (Scandlynx, 2011)
One of those tools includes the direct compensation system for reindeer owners for the losses by predators. However, the Norwegian government wants to change this compensation system by compensating reindeer losses based on the presence of carnivores. A compensation system like this is already in use in Sweden and has been implemented in a successful matter (Zabel & Holm-Müller, 2007).

Lynx knowledge such as reliable estimates of lynx density (Andrén et al., 2002), individual kill rates (Mattisson et al., 2011) and habitat use of lynx (J. Odden, pers. comm. 24th March 2012) are essential. Moreover, this information can be used to create a map of risk for reindeer to be killed by lynx. A map of risk is a tool to predict future sites of depredation and shouls distinguish low-risk from high-risk areas (Treves et al., 2011). It can inform reindeer owners about the risk of having their reindeer in certain habitat types. Lynx spend a significant time of their day resting (up to 70%), this requires sites that provide security for long time periods (Podgorski et al., 2008).

The aim of this research was to gain insight into the habitat use of the Eurasian lynx in northern Norway by measuring microhabitat characteristics associated with kill and rest sites. By doing this it can become clear whether lynx select certain characteristics and this could then contribute to the creation of a map of risk for reindeer to be predated on. Furthermore this could contribute to a greater ability to interpret their behaviour from remote data and potentially could require fewer visits of sites in the field.

The main research question of this study was:
To what extent do microhabitat characteristics influence the presence or absence of lynx sites?

To be able to answer the main question the following sub-questions are formulated:
- To what extent do microhabitat characteristics influence the presence or absence of lynx kill sites?
- To what extent do microhabitat characteristics influence the presence or absence of lynx rest sites?

2. Study area

This research was carried out in northern Norway in the county of Finnmark (Fig. 4). Latitudes are 69°37'N, longitudes are 23°57'E (Maps of world, 2012), which is above the Arctic circle. Finnmark measures about 48,617 km^2 (Northern Norway, 2012). On the south side Finland is the country that borders this northern part of Norway. On the eastside it borders to Russia and the North and West side are enclosed by the Barents Sea. This area is the least populated area of Norway with an average population density of 2 persons per km^2 (Arctic Stat, 2010).

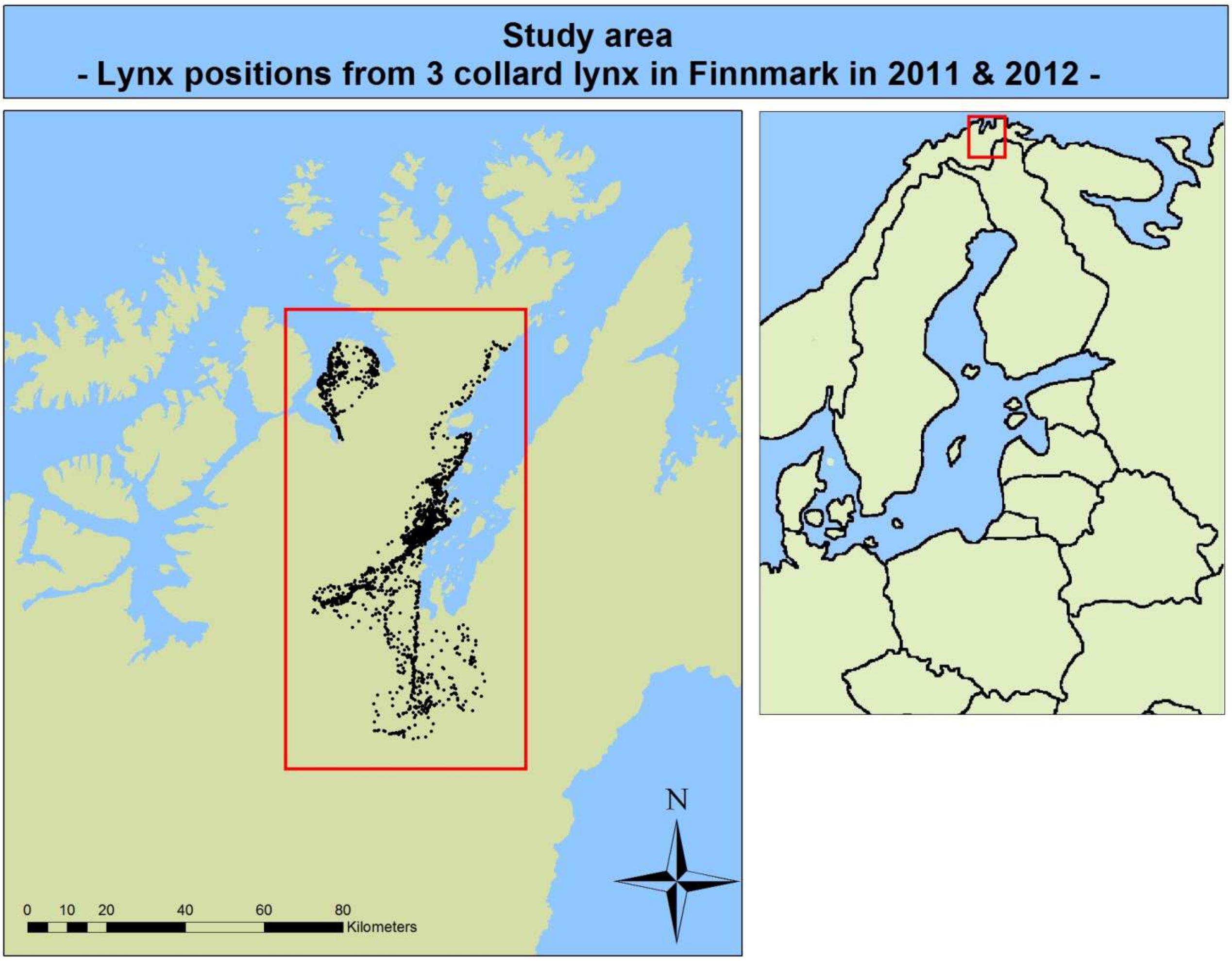

Figure 4: Study area in northern Norway. The red square indicates the study area of this research.

Alpine tundra dominated the study area followed by mountain birch forest (*Betula pubescens*) and small patches of pine forest (*Pinus sylvestris*) along the coast and in some of the valleys (Oksanen & Virtanen, 1995). Norway's climate is temperate although it shows large variations due to the fact that from its southernmost point, to its northernmost point, there is a span of 13 degrees of latitude. In northern Norway a coastal alpine climate is applicable, one of the largest climate differences are found here. Having midnight sun in the summer months and no sunshine at all during winter, northern Norway can enjoy temperatures above 30 °C in summer and during winter the Finnmark Plateau will reach mean monthly temperatures of -15°C. (Meteorologisk Institutt, 2012)

3. Eurasian Lynx Ecology

After the brown bear (*Ursus arctos*) and the wolf (*Canis lupus*), the Eurasian Lynx (*Lynx lynx*) is the third biggest carnivore occurring in Europe with one of the widest distributions of felids in the world (Breitenmoser et al., 2000). Its range reaches from Western Europe through the boreal forests of Russia, and down into central Asia and the Tibetan plateau (Sunquist & Sunquist, 2002) (Fig. 5). Populations in the southeast of its range (Europe and southwest Asia) are generally small and widely separated, whereas the bulk of its historic range from Scandinavia through Russia and Central Asia is largely intact (IUCN / SSC Cat Specialist Group, 2011). The European lynx population (excluding Russia) was estimated in 2012 at 8000 individuals (Macdonald & Loveridge, 2010).

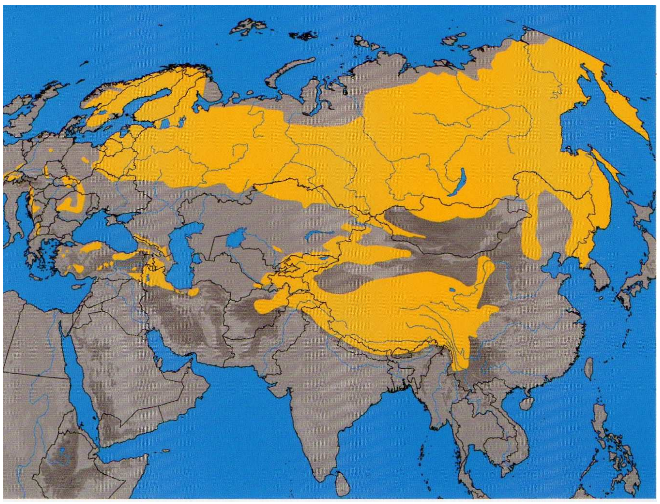

Figure 5: Distribution of the Eurasian lynx (*Lynx lynx*) (Breitenmoser & Breitenmoser-Würsten, 2008)

Lynx are adapted to a life in northern latitudes where snow covers the ground during most of the year (Scandlynx, 2012). Their long, thick and silky fur, which is densest on the back, insulates against the winter cold (Sunquist & Sunquist, 2002). Their summer coat is thin and smooth and their fur is reddish-brown colored, which changes during winter into a grayish-white, giving them a good camouflage (Scandlynx, 2012; Kalb, 2007). Other typical characteristics of the lynx are its short back, stubby tail and ear tufts (Fig. 6). Furthermore they are longer-legged and have larger feet in comparison to some of the other felids like bobcats (*Lynx rufus*) (Sunquist & Sunquist, 2002). Body mass of adult individuals ranges between 14-36,5 kg and total body length varies between 85-110 cm with a shoulder height of around 50-75 cm (Kalb, 2007). Although the Eurasian Lynx shows the least amount of sexual dimorphism, males are usually larger than females (Weingarth et al., 2011). In nature, lynx were reported to live up to 17 years, whereas in captivity, they can reach an age of 25 years. The medium age of resident animals in a population is however much lower, about 4-5 years. (Breitenmoser et al., 2000)

Figure 6: Picture of a male collared Eurasian lynx (*Lynx lynx*) taken in Northern Norway (© Mosini, A. 2012). Clearly visible are the black spots of the Eurasian lynx that differ per individual.

Although there is little evidence, lynx appear to have a social organization that is similar to that of other solitary felids, in which males occupy large home ranges and one or more females reside within each male's area (Sunquist & Sunquist, 2002, Mattisson et al., 2011). After mating in February/March (Jędrzejewska & Wójcik, 2004), parturition occurs in late May and early June with a normal litter size of 2 to 3 young (Kvam, 1990). When lynx are around 10 months old, they normally leave their mothers, which is during the months March-April (Kalb, 2007, Samelius et al., 2011). In the first months these young lynx stay close to their mother's home range. Most young

individuals survive their first spring and summer alone, and all move away from their natal area after a few months. (Scandlynx, 2012)
The home range size (MCP100) of lynx in northern Norway was estimated to be between 919 and 4941 km^2 for adult males and between 255 and 3468 km^2 for adult females (Odden et al., 2012). When comparing these numbers with home range sizes of lynx in other European countries (Poland: m: 248 km^2, f: 133 km^2 (MCP100) (Schmidt, 1997); Switzerland: m: 159 km^2, f: 106 km^2 (MCP100) (Breitenmoser et al., 1993) it turns out that their home range in northern Norway is relatively large (Linnell et al., 2001).

Main prey of the Eurasian lynx is wild ungulates; semi-domestic reindeer dominates the ungulate community in northern Norway. In the year 2011, about 162 300 reindeer (Reindeer Husbandry Administration in Norway, 2011) lived next to about 66 adult lynx individuals in the counties of Finnmark and Troms (Brøseth & Tovmo, 2011). Free ranging sheep (no exact numbers found) are present in most areas during summer and Moose (*Alces alces*) occure in significant numbers throughout the study area. Although Moose are the only wild ungulate species there, they are not being predated by lynx. Roe deer (*Capreolus capreolus*) only exist sporadically at low altitude or coastal areas. Furthermore, Mountain hare (*Lepus timidus*), tetranoids (*Lagopus lagopus, Lagopus muta, Tetrao urogallus, Tetrao tetrix*), red fox (*Vulpes vulpes*), and small rodents (*Clethrionomys spp., Microtus spp. and Lemmus lemmus*) are potential alternative prey species for lynx. (Mattisson et al., 2011)

Like other felids, lynx are stalk-and-ambush hunters: they creep up slowly on their prey and wait for the opportune moment to leap and pounce on the victim (Sunquist & Sunquist, 2002). Hunting usually takes place in the first night half, when their prey is also active and foraging. Small ungulates such as roe deer are often dragged away from the kill site into dense undergrowth. However, heavier prey is consumed at the kill site (Breitenmoser & Breitenmoser-Würsten, 2008).

Lynx come back to their prey for several nights to consume it (Kalb, 2007). They eat of the flesh and internal organs (lung, kidney, heart and liver). Remains of the kill are usually the digestive tract, legs and head (Breitenmoser & Breitenmoser-Würsten, 2008). A lynx consumption rate averages from 1 to 2,4 kg of meat per day (Kalb, 2007). According to Pedersen et al. (1999), lynx family groups kill on average 0,2 reindeer per night, which results in 1 reindeer per 5 days. Lynx are especially active to kill and consume in the evening and in the early mornings (Fig. 7). Figure 7 shows that lynx are least active at late morning, midday and afternoon.

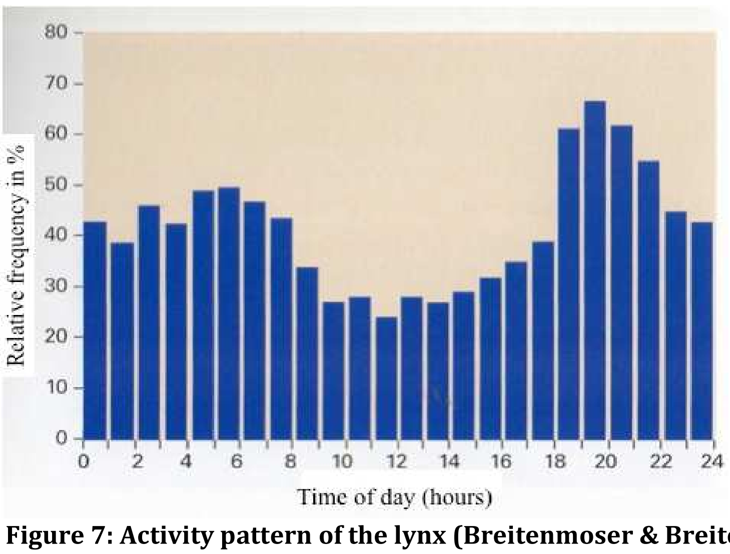

Figure 7: Activity pattern of the lynx (Breitenmoser & Breitenmoser-Würsten, 2008).

4. Data Sampling

Data on lynx positions were available from three collared individuals in Finnmark. One individual was the female F248 (Ella), collared since 28.02.2009, which had one kitten in 2011 and one in 2012. One was a male with ID-number M269 (Mattis), collared since 23.02.2010. Data of these two individuals were collected in 2011 during June and July and in 2012 during June and August. From individual number three, M296 (Joe), only data of 2011 were used. In 2012 only F248 and M269 had working collars that sent usable data during June and August. In these two months the collars transmitted 24 positions a day. In July, the collars transmitted only one position a day, this was done to spare battery life for August so a broader impression could be obtained throughout the summer season. In Fig. 8 positions and home ranges of the different individuals are mapped. All individuals would move freely through their home ranges, sometimes travelling over 40 km a day (in 24 hours), meaning that for example individual M269 could be in the northern part of its home range one day only to be in the southern part of its home range two days later.

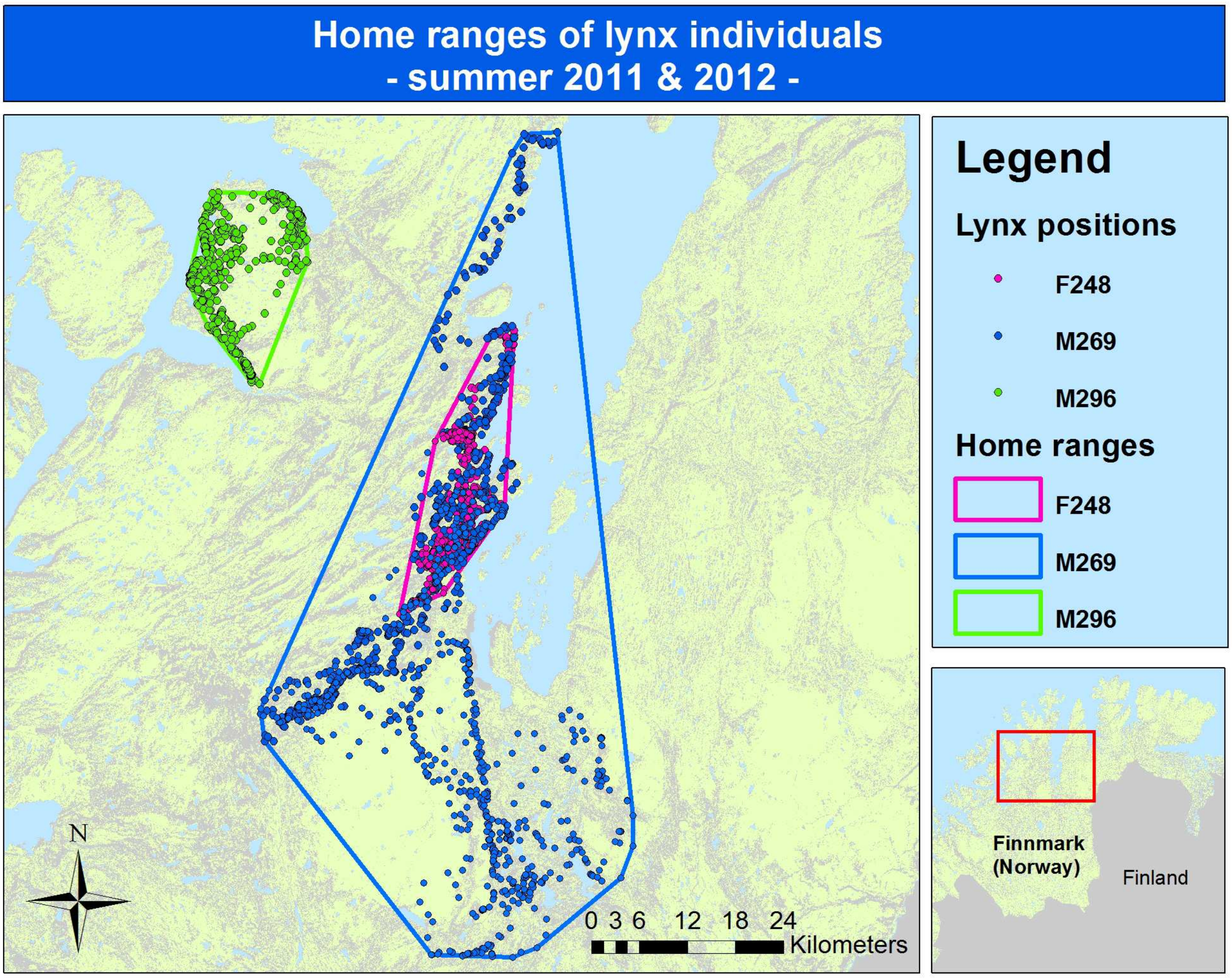

Figure 8: Home ranges (MCP100) and positions of lynx individuals in the year 2011 and 2012. Data from F248 and M269 are from June and July 2011 and from July and August 2012. Data from M296 are from June and July 2011 only. In these periods positions were transmitted 24 hours a day.

With help of the received position points, kill and rest sites were visited (Fig. 9).

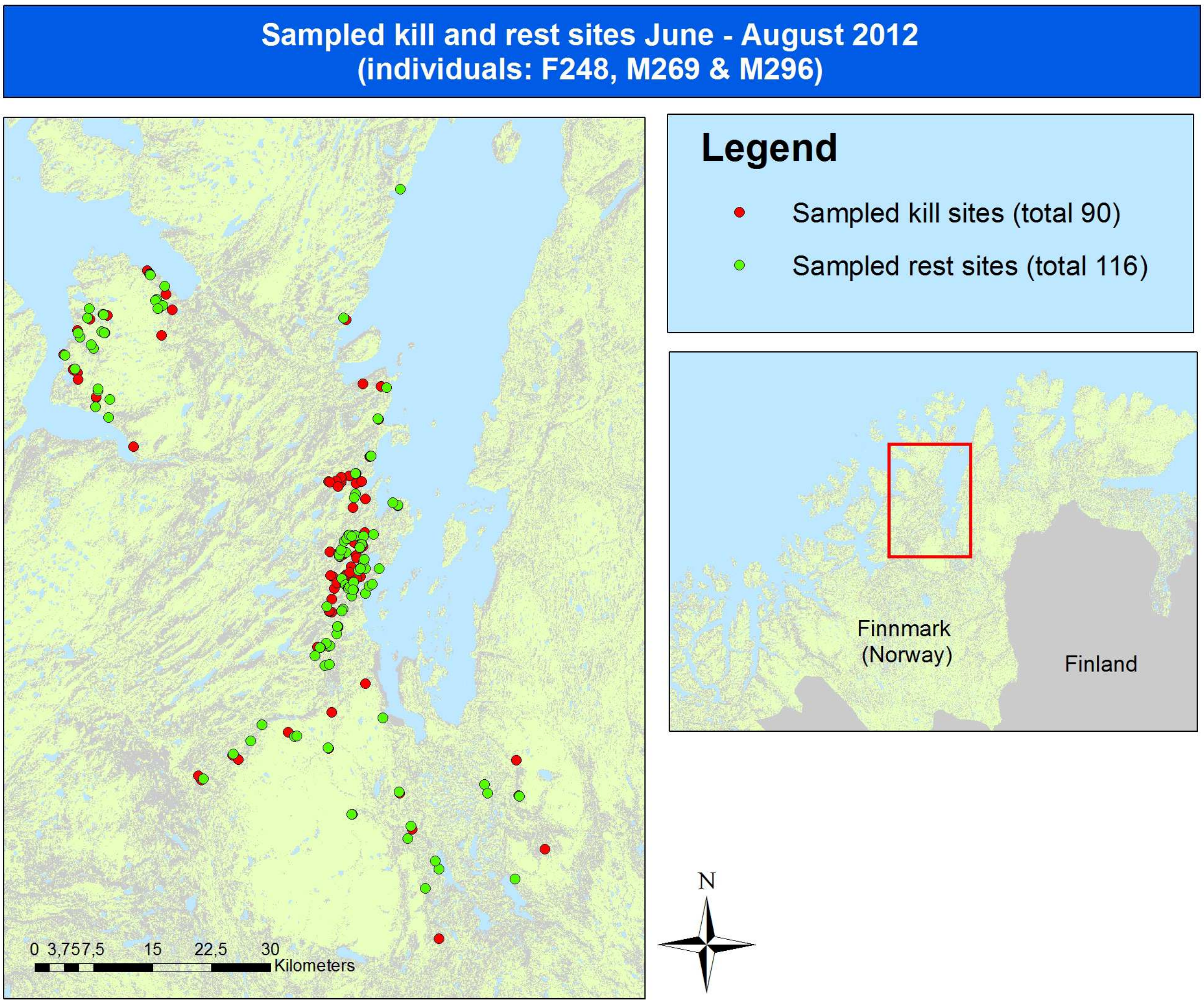

Figure 9: Sampled kill and rest sites from June until August 2011 & 2012 from all three individuals

A visit to the site was conducted, if at least two non-continuous GPS-positions (accuracy ± 5m) (J. Odden, pers. comm. 24th March 2012) within a radius of 100m were recorded from one of the individuals.

Kill sites (shown in Fig. 10) were determined as follows: The rumen of the kill indicated the actual kill point. It was presumed that the consumption site was equivalent to the kill site, because larger prey is hardly dragged away by lynx (Breitenmoser & Breitenmoser-Würsten, 2008).

When smaller prey such as hares or birds were found, they were not taken into the analysis.

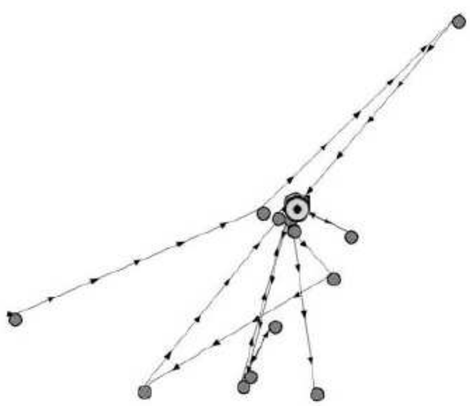

Figure 10: Movement pattern around a reindeer carcass for lynx (8 positions/ day) (Mattisson, 2011)
Filled circles are animal positions and the large circle with dot indicates the location of the carcass.

Rest sites were determined when lynx hair was found and/or if the ground surface showed indications of a bed of lynx lying (e.g. flattened vegetation).

All sites of 2012 were visited, except for a few because of hazardous terrain, e.g. too steep and/or danger of loose rocks. Sites of 2011 were selected on date to avoid differences in habitat characteristics, so when a site was sampled on the 22nd of June 2011, it was sampled within a week of that exact date a year later. This was especially done because of differences in vegetation height, during the summer season the height of most of the plant species increased and a site that is suitable in June might be unsuitable in August because vegetation can be 20cm higher. Furthermore only sites where fieldworkers from last year had saved exact location points (accuracy of ± 5m) of rest or kill sites were visited.

To be able to compare the sampled sites and come to representative results, control sites within the study area were generated (Kolowski & Woolf, 2002; Podgorski et al., 2008; Nellemann & Fry, 1995). A random number between 0 and 360 was generated in an Excel file before going into the field, indicating a given bearing. In the field this number was set on a compass. The distance between lynx site and control site was 100m (Anderson, 1990). Every kill and every rest site was paired with a control site, so that the total number of control sites was the same as the total amount of sampled rest and kill sites. In total, 90 kill sites (plus 90 control sites) and 116 rest sites (plus 116 control sites) were sampled during the 3-month data collection. In Appendix I show the number of sampled kill and rest sites per lynx individual.

5. Data Collection

Microhabitat variables that were measured were related to habitat type, relief (such as elevation, terrain ruggedness, slope, aspect, elevation and rock wall), and vegetation (like substrate structure, visibility and vegetation height) of lynx kill and rest sites. To ensure that all potentially important characteristics for lynx kill and rest sites were measured, the variables were recorded on a 10m-radius around the plot (Gorini, 2006; May et al., 2012). Below is described how and why they were measured and in Appendix I the field dataform can be found.

1) Habitat type:
It is reported that lynx are more often recorded in forest habitats in mid-Europe (Breitenmoser & Breitenmoser-Würsten, 2008). The possible habitat types recorded in the field were Mountain Birch Forest (MBF), Boulder fields (BF), Bog (B) and Alpine habitats including Low Alpine (LA), Mid Alpine (MA) and High Alpine (HA) (Johansen et al., 2009) (Fig. 11).

Figure 11: The six different habitat types recorded in the field during summer 2012 (Eva Schevers & Magali Frauendorf, 2012).

2) Elevation:
Some studies recorded that elevation influenced site selection of lynx (Rolstad & Wegge, 1987; Beauvais et al., 2001). Also McKelvey et al., (1999) concluded in a study that there is a preference for terrain between 250 - 750 m in elevation, with Canadian lynx (*Lynx canadensis)* making limited use of terrain below 250 m in the northeast of the United States.
The elevation was obtained from the hand-held GPS during data collection in the field.

3) Terrain ruggedness Index:
Topography is an important ecological component affecting the distribution of wildlife and vegetation (Nellemann & Fry, 1995). The terrain ruggedness is chosen as a relevant factor, which indicates how topographically uneven, broken or rocky steep an area is (Sappington et al., 2007; May et al., 2008). According to Breitenmoser & Breitenmoser-Würsten (2008), Eurasian lynx relax during the day at positions that are more steep and rocky.
The Terrain Ruggedness Index (TRI) was given as the sum of linear distances (L) measured from the beginning to the end of a 10m rope laid down following the irregularities of the terrain in four directions (uphill and downhill perpendicular to hillside, left and right parallel to hillside) relative to the maximum possible distance of 40m. The TRI=((40 – L)/40)*100, indicating 0 for non-rugged terrain and approaching 100 with increasing ruggedness (Gorini, 2006; May et al., 2012). In case of a lack of hillside, because there was no slope, the rope was put on the ground in North-South and East-West directions.

4) Slope:
Slope seems to be an important aspect for felids, because according to Logan & Irwin (1985) and Husseman et al. (2003) Mountain lions (*Puma concolor*) selected steep terrain while hunting. They suggest that it would make it easier for them to approach prey. Also Anderson (1990) recorded bobcats in steeply sloped and rocky areas that usually provide good visibility in at least one direction.
Slope was recorded using a clinometer and was measured over 20m through the sampling site (10m above the sample point and 10m below the sample point) in the steepest slope direction. The observer stood 10m above the sample point and looked through the clinometer to a vegetation profile pole (that was also used for the variable "visibility") 10m below the sample point. The clinometer was held parallel with the slope and the pole that was looked at, was on the same height above the ground as the observer's eyes (Zobrist, 2008). The slope was recorded in degrees (°).

5) Aspect of the slope:
It can be expected that lynx use aspects in southern direction at midday as rest sites, because the direct sunlight is warm (Rolstad & Wegge, 1987).
Aspect is the direction that the slope faces and will identify the steepest valley direction. Aspect was calculated using a compass and was measured clockwise in degrees from 0 (due north) to 360 (again due north, making a full circle) (ESRI, 2012). North was recorded from 316° to 45°, east within the degrees of 46° to 135°, south from 136° to 225° and west from 226° to 315°.

6) Habitat edge:
Habitat edge is defined as an edge of two different habitats. According to Kolowski & Woolf (2002), Podgorski et al. (2008) and Laundré & Loxterman (2007), edge seems to be an important variable in habitat selection for hunting, because it can provide both sufficient cover for the predator in a forest for example as well as good visibility of the prey in an open habitat for instance.
Furthermore, Breitenmoser & Breitenmoser-Würsten (2008) found that kill sites were situated at a distance of 50-100m from the forest edge.
The distance to the nearest habitat edge in meters was measured (Klar et al., 2008). It was estimated with help of a range finder. Edge was determined as a change in habitat type, whereas the adjacent habitat type had to be larger than 1ha. Maximum distance for measuring an edge was 250m.

7) Substrate structure:
This variable defines the structure type of the substrate, because this could influence the rest site selection of lynx (Podgorski et al., 2008; Kolowski & Woolf., 2002). Kolowski & Woolf (2002) found that substrate structure such as rock cover, log-wood cover and leaf litter ground cover have influenced the selection of rest sites of bobcats. It is expected that rocky undergrowth is preferred as rest site location (chapter 3) (Breitenmoser & Breitenmoser-Würsten, 2008).
With a measuring tape a circle with a 2m-radius was set around the sampled point (Jerosch et al., 2010). Nine points, with a 1m-interval had been recorded by writing down an "A" for Absence or a "P" for Presence for different substrate types such as grass, moss, shrubs, mineral, rocks, herbs, lichens, wood, water and snow (Fig. 12). Finally, the numbers of „P" were calculated in a percentage value for the substrate structures.

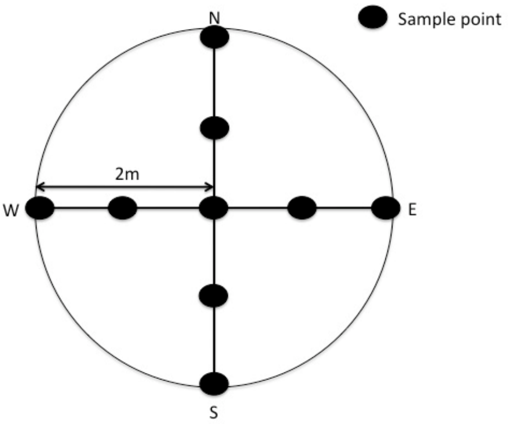

Figure 12: The four transects in all cardinal directions with 1m-intervals. In total 9 sample points were measured.

8) Visibility:
Especially for rest sites, low visibility seems to be important, which makes lynx virtually undetectable from a short distance (Podgorski et al., 2008). In addition, the same research described that kills of lynx were recorded more often in more open undergrowth. This provides a better chance to spot prey, as well as enough space for manoeuvring and safety for the predator during the attack. O´Donoghue et al. (1998) also found that Canada lynx are ineffective to hunt in dense vegetation. Also Breitenmoser & Breitenmoser (2008) showed that lynx use dense vegetation to hide before attacking their prey. At a standard distance of 10m, the vegetation profile pole of 2m was read at lynx-eye level. The pole was read in all cardinal directions, both towards the sampled site (from the outside looking in) (Nudds, 1977) (Fig. 13) and away from the sampled site (from the inside looking out). The percentage of the pole not covered by plants was recorded. The five intervals on the pole indicated each 20% and helped recording the value of sight distance.

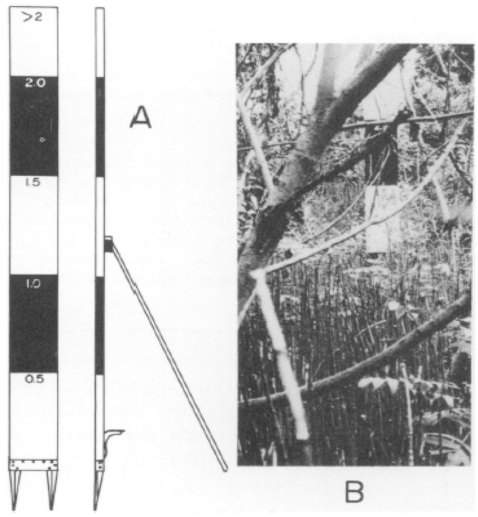

Figure 13: A. Diagram of vegetation profile board for measuring deer microhabitat structure. B. The profile board in use, August 1975. (Nudds, 1977)

9) Vegetation height:

High vegetation cover was recorded as the most important factor of summer bobcat locations (Kolowski & Woolf, 2002). Dense cover probably provides protection from extreme temperatures and wind, as well as concealment and escape cover from predators (Anderson, 1990).

This characteristic was measured using the step-point method, which provides a rapid, accurate and objective technique of determining the total cover of vegetation (Raymond et al., 1957; Elzinga et al., 1990). The vegetation height was recorded on four transects in all cardinal directions from the sample point with a 1m interval. In total, 25 points were recorded at each site (Fig. 14).

The vegetation profile pole also contained a ruler so that vegetation height on each sample point was measured in centimetres. Finally, the average of all sample points was calculated.

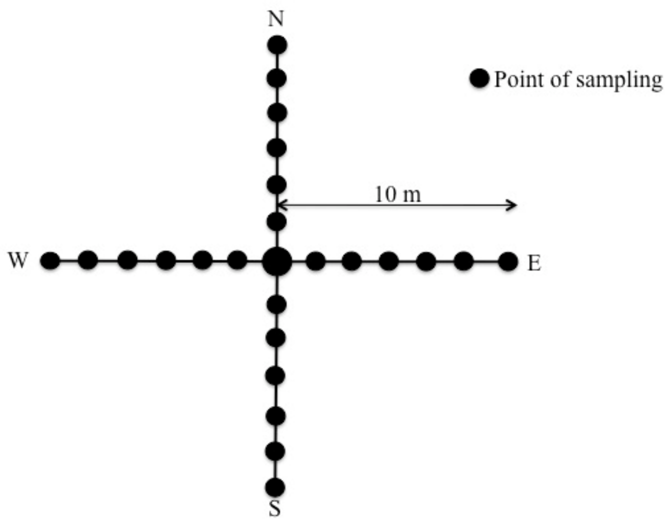

Figure 14: The four transects in all cardinal directions with 1m-intervals. In total 25 sample points were measured.

11) Presence of a rockwall

The last measurement taken was the presence or absence of a rockwall in one or more of the cardinal directions. A rockwall will obscure the view from, or to the kill or rest site and might therefore be an influential characteristic (Kolowski & Woolf, 2002).

Finally, every site had been given a unique site ID on the data form (Appendix II) including an:

- Individual number (F248, M296, M269).
- Date and time of when the lynx had killed the reindeer or had used the rest site.

6. Data Preparation

Habitat type was coded into two different classes: 1= Habitat type with trees (Mountain Birch forest) or 0= Habitat type without trees including Low Alpine, Mid Alpine, High Alpine, Bog and Boulder fields. This was done because using six classes for the variable habitat type, led to a graph that was not normally distributed. The Terrain Ruggedness Index was multiplied with a 100 to get a better impression when putting this variable into a figure. The same was done for slope but instead of multiplying it with a 100 it was multiplied with only 10.

The variable 'edge', which was recorded in meters, was transformed into a nominal scaled variable giving a 0 for sites with no edge present and a 1 for sites with an edge present, because this data was not normally distributed. Maximum distance for measuring an edge was 250m.

Not all of the measured variables were used for the analyses of both kill and rest sites. For the variable visibility, only the measurements from the outside looking in were used for kill sites, because lynx approach from the outside to catch their prey. In contrast, for rest sites, the variable visibility was measured from the rest site looking out, because lynx reside at the rest site and look to the outside (see chapter 5). Variables measured on a 2m radius (such as substrate structure and vegetation height) were left out for lynx kill sites, because a longer distance of 2m is needed for stalking and catching their prey (Podgorski et al., 2008).

7. Data Analysis

For all statistical procedures the program SPSS v. 19.0 was used. To see if lynx select certain habitat characteristics a paired t-test was conducted between the kill or rest sites and their control sites for interval scaled variables. For the nominal scaled variables the McNemar test was chosen (see Appendix III). This was followed by a paired logistic, this test is more powerful than the standard logistic regression for paired data analysis (Hoshmer & Lemeshow, 1989).

To be able to conduct a paired logistic regression, each lynx site had to be compared to one control site. The variables that had a significance value <0.25 (Bendel & Afifi, 1977) were accepted for further analysis. Next, the difference between the measured variables of the kill or rest site and their control site was calculated, this was done so it will explain what the difference is in habitat rather than the absolute measured values of habitat variables (Compton et al., 2002). This was followed by a normality test of the difference variables and an independent bivariate correlation test to see if there were strong correlations (>0.70) between the interval variables and to prevent less significant variables from "shadowing" correlated variables in the model (Compton et al., 2002). Finally, the paired multinomial logistic regression was carried out with a backward stepwise method (Gotto et al., 2000), the entry probability was set at 0.05 and the removal probability was set at 0.1, both on a likelihood ratio. The final models of the multinomial logistic regression include only variables with significance values <0.05 and include the McFadden's r^2 which is similar to the multiple correlation coefficient R^2 (McFadden, 1974), which refers to a fraction of variance and gives a value from 0 to 1, indicating how good the variables of the final model from the paired logistic regression predicts a kill or a rest site. To find out how much of the final model was correctly classified, the binary logistic regression was carried out. In addition, the discriminant analysis was conducted to visualize results with the help of a graph.

8. Results

After the 3-month data-sampling period, 90 kill sites together with 90 kill control sites and 116 rest sites together with 116 rest control sites were sampled. Lynx selected certain characteristics concerning their kill or rest sites when comparing these to the control sites situated 100m away. All measured variables (mean±SD) are shown in Table 1, bold numbers are indicating the variables found to be significant.

Table 1: Habitat characteristics (mean±SD) associated to lynx kill sites (n=90) vs. kill control sites (n=90) and rest sites (n=116) vs. rest control sites (n=116) in northern Norway in the summer of 2011 and 2012. Control sites were measured 100m away from the lynx kill or rest site. Variable descriptions are provided in chapter 5 and Appendix III. Test used are [1] paired t-test (t) and [2] McNemar /Bowker test. Bold numbers are significant (p<0.05).

Variable	Kill site	Control site	p	Rest site	Control site	P
Habitat type with trees (%)	64.4	55.6	.057[2]	78.4	62.1	**<.001[2]**
Habitat type without trees (%)	35.6	44.4		21.6	37.9	
Elevation (m)	229.7 (±93.3)	232.5 (±95.9)	.064[1]	220.2 (±102.0)	216.0 (±101.0)	.121[1]
Terrain Ruggedness Index	9.2 (±4.7)	8.6 (±5.6)	.344[1]	26.5 (±13.4)	11.7 (±6.2)	**<.001[1]**
Slope (°)	11.0 (±8.0)	12.3 (±10.1)	.225[1]	35.5 (±13.8)	19.0 (±14.1)	**<.001[1]**
Aspect (°)	176.2 (±109.8)	174.0 (±107.7)	.868[1]	161.34 (±87.138)	163.68 (±91.510)	.793[1]
Edge present (%)	50.0	43.3	.307[2]	47.4	44.0	.597[2]
Edge not present (%)	50.0	56.7		52.6	56.0	
Grass substrate (%)	20.4 (±26.0)	17.5 (±27.5)	.364[1]	4.3 (±10.3)	7.0 (±15.3)	.121[1]
Moss substrate (%)	20.3 (±21.6)	18.5 (±22.1)	.528[1]	17.0 (±19.0)	12.5 (±16.3)	**.046[1]**
Shrub substrate (%)	33.9 (±32.7)	33.5 (±33.8)	.900[1]	39.2 (±27.6)	33.8 (±32.9)	.129[1]
Mineral substrate (%)	3.6 (±11.1)	2.8 (6.1)	.570[1]	1.8 (±6.7)	3.9 (±8.9)	**.030[1]**
Rock substrate (%)	5.4 (±15.0)	9.7 (±19.4)	**.049[1]**	21.5(±24.8)	21.2 (±30.4)	.892[1]
Herb substrate (%)	13.9 (±21.6)	13.6 (±22.3)	.865[1]	13.2 (±21.4)	18.2 (±26.9)	.072[1]
Lichens substrate (%)	0.9 (±4.6)	1.9 (±7.1)	.310[1]	2.1 (±6.2)	1.1 (±3.9)	.116[1]
Visibility (inside) (%)	[a]	[a]	[a]	61.0 (±24.2)	87.1 (±16.6)	**<.001[1]**
Visibility (outside) (%)	94.8 (±8.2)	95.3 (±10.5)	.685[1]	[a]	[a]	[a]
Ave. Veg. height on 2m radius (cm)	[a]	[a]	[a]	9.3 (±7.5)	6.4 (±5.2)	**<.001[1]**
Ave. Veg. height on 10m radius (cm)	9.0 (±7.7)	7.7 (±6.0)	.193[1]	10.7 (±9.5)	7.7 (±5.6)	**<.001[1]**
Rock wall present (%)	[a]	[a]	[a]	17.2	0.9	**<.001[2]**
Rock wall absent (%)	[a]	[a]		82.8	99.1	

[a] Data not relevant for the sampled site

8.1. Kill sites

Lynx kill sites did not differ from kill control sites in microhabitat characteristics expect for the variable rock substrate. This variable was found significantly different when comparing kill sites to the kill control sites (Table 1).
Lynx kill sites were characterized by a significantly lower rock substrate structure (paired t-test: t=-1.995, df= 89, p=0.049) than for kill control sites. However, the percentage of rock substrate is still very low (Table 1).

The probability of lynx selecting their kill sites in a habitat type with trees is higher than in a habitat type without trees (OR=2.862) compared to kill control sites. The model shows that the probability of lynx selecting a kill site increases with the factor of 1, with every 1% of decrease in rock substrate compared to kill control sites.
The odds of lynx selecting a kill site increases with the factor of 1 (1/0.974) with every 1m of decrease in elevation (Table 2).

Variable	Logistic coefficient	Standard Error	Significance value	Odds ratio (OR)	95% Confidence Interval for Odds Ratio	
					Lower Bound	Upper Bound
Habitat type with trees (Reference group: Habitat type without trees)	1.051	.672	.118	2.862	.766	10.691
Rock substrate	-.024	.014	.093	.977	.950	1.004
Elevation	-.026	.016	.094	.974	.945	1.004

Table 2: Results of the final paired logistic regression model of habitat characteristics describing the Eurasian lynx kill sites (n=90) and kill control sites (n=90) in summer (June – August 2012) in northern Norway.

None of the variables of the final model are significant (Table 2), although they lean towards being significant ($p<0.05$). The predictive power of the final model, described in Table 2, is not very strong (McFadden´s r^2=0.086) and it correctly classifies 63.3% for kill sites and 47.8% for kill control sites, meaning an overall correctly classification percentage of 55.6.

8.2. Rest sites

For rest sites lynx selected a habitat type with trees (78%). For control sites 62.1% of the sites were habitat types with trees (Table 1) (McNemar test: T=14.087, n1=116, n2=116, p<0.001). Also more rugged terrain (t=10.971, df= 115, p<0.001) and a higher slope (t=10.538, df= 115, p<0.001) was selected by lynx for their rest sites. More characteristics of lynx rest sites were sites with either more moss substrate (t=2.018, df= 115, p=0.046) or less mineral substrate in comparison to the control sites (t=-2.192, df= 115, p=0.03). When looking at the visibility of lynx rest sites it seemed that a lower visibility was chosen in comparison to the control sites (t=-10.043, df= 115, p<0.001). Vegetation height at rest sites was slightly higher than at control sites (t=4.171, df= 115, p<0.001) (Table1). A rock wall was present on 17.2% of the rest sites and on 0.9% of the control sites (T=15.429, n1=116, n2=116, p<0.001) (Table 1). None of the remaining variables showed any significant difference between lynx rest sites and control sites.

At rest sites, lynx tended to select habitat types with trees (OR=18.642) in more uneven terrain (OR=1.176) with a higher slope (OR=1.008) and more moss substrate (OR=1.033) compared to rest control sites (Table 3). The odds ratio (Table 3) indicates that when slope is getting steeper with every 10 degrees, the odds results in a 1.008 increase in selection. Furthermore, this model shows a rather strong predictive power (McFadden´s r^2=0.685) and it correctly classifies 77.6% of the rest sites and 84.5% of control sites, meaning that overall 81.0% is correctly classified.

Table 3: Results of the final paired logistic regression model of habitat characteristics describing the Eurasian lynx rest sites (n=116) and control sites (n=116) in the summer of 2011 and 2012 in northern Norway.

Variable	Logistic coefficient	Standard Error	Significance value	Odds ratio (OR)	95% Confidence Interval for Exp(B)	
					Lower Bound	Upper Bound
Habitat type with trees (Reference group: habitat type without trees)	2.925	1.417	.039	18.642	1.160	299.697
Slope (°)	.008	.002	.001	1.008	1.003	1.012
Moss substrate in percent	.033	.017	.052	1.033	1.000	1.068
Terrain Ruggedness Index (ranging from 0-100)	.162	.044	.000	1.176	1.078	1.283

Figure 15 shows that rest sites of lynx were located on a steeper slope compared to control sites. Also, rest sites were found to have a higher Terrain Ruggedness Index compared to control sites and most rest sites were found in a habitat type with trees compared to control sites.

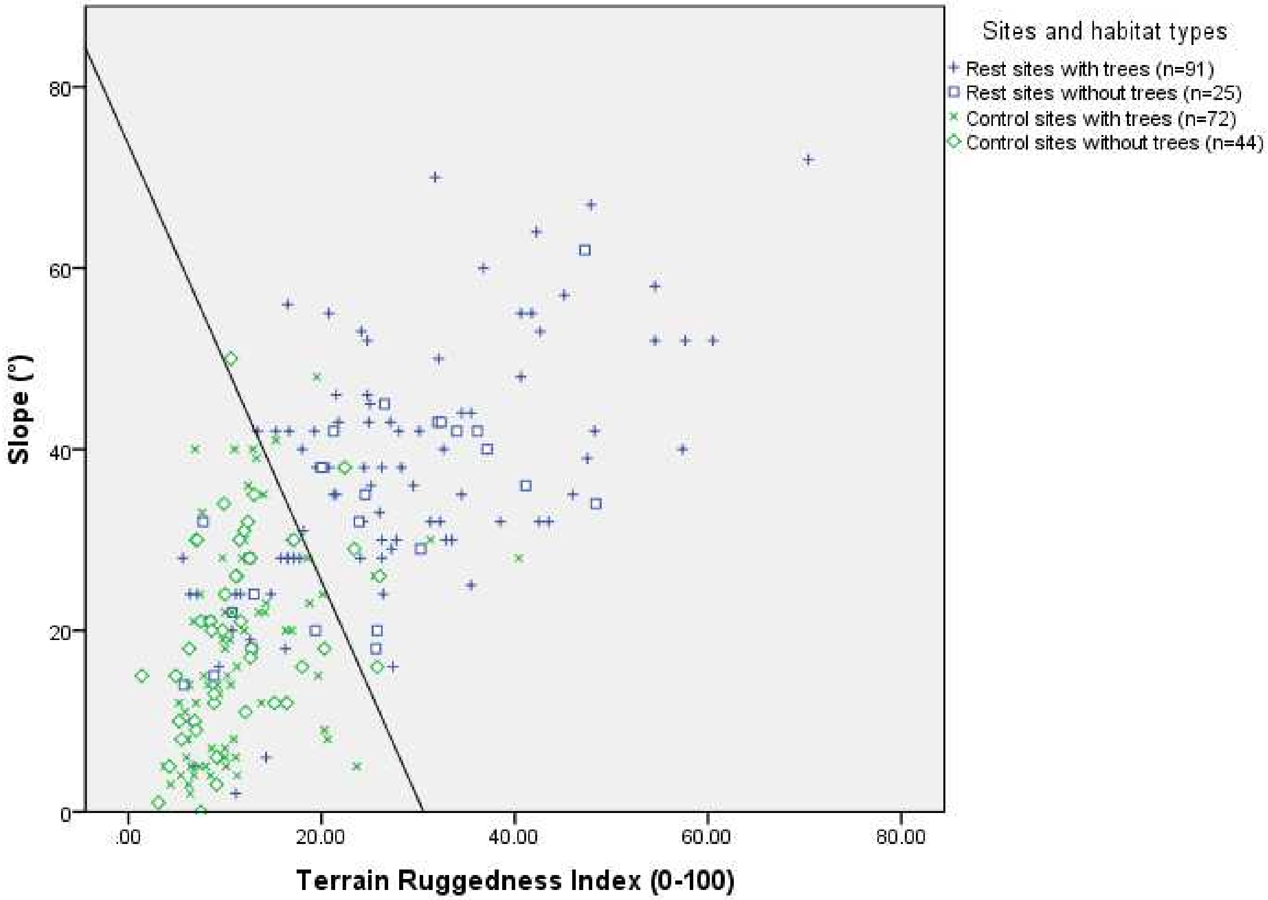

Figure 15: Terrain Ruggedness Index plotted against Slope, grouped into sites (rest: n=116, control: n=116) and Habitat types (with trees: n=163, without trees: n=69) with a discriminant line based on slope and Terrain Ruggedness Index between rest sites and control sites.

9. Discussion

Microhabitat use was analysed of only three different individuals: one adult male, a juvenile male and a female with kittens. Having only three individuals that differ in age, sex and social status can influence the ability generalizing the outcome of the research for other lynx individuals in northern Norway. The Power Analysis also indicated that a sample size of 90 for kill sites and 116 for rest sites is very low. A total sample size of 90 yields a 15% chance of detecting an effect size of 0.5 for the logistic regression. A sample size of 116 for rest sites yields a 17% chance of detecting an effect size of 0.5 for the logistic regression.

9.1. Kill sites

The first factor to keep in mind when looking at kill sites of lynx is where their prey likes to spend time (e.g. foraging, resting etc.). Because data of this kind was not available in the study area the relation between kill sites and the presence or absence of reindeer could not be taken into account. Reindeer density is a factor that could be considered when discussing the results for lynx kill sites, since it seems that reindeer are an easy accessible prey for them. Because even though the absolute number of animals is small, the density of reindeer is very high. With approximately two reindeer per km^2, the reindeer density in Finnmark is roughly four times greater than for example in Russia. (International Arctic Science Committee, 2012)

The presence or absence and the density of reindeer could thus explain some of the results found for kill sites.

Why elevation is an almost significant characteristic could be because reindeer tend to spend their time during spring and summer on grazing grounds which are areas where snow melts early and where there is good access to fertile grazing (Norsk Villreinsenter, 2012). In this study area such grazing grounds were mainly at low elevation. Sunde et al. (2000) described in a study conducted in central Norway, that lynx select lowlands as foraging habitats. On the other hand, a research in Sarek National Park (northern Sweden), carried out by Danell (2006), suggest that reindeer during the height of the summer, are usually found in alpine areas above the tree line or in de adjacent subalpine birch forests. Which in this study area would mean that reindeer were on higher elevation. Reindeer grazing at higher elevation can also be supported by a study from Skarin et al. (2004) that concludes that reindeer use higher elevation in summer to avoid insects.

Lynx selected habitat types with trees. This fact can be supported by a study on lynx foraging in central Norway (Sunde et al., 2000) where forest habitats were the most favourable foraging habitats. Trees can provide a better chance of approaching prey undetected and launching an attack from as close as possible (Podgorski et al., 2008).

Forested habitat covers 37% of the total land area in Norway (Selvik, 2012). The main forested areas are located in southeast Norway (Figure 16). In northern Norway, where this research took place, forest cover is relatively low. This indicates that even habitats with a low coverage of forest still seem to be advantageous when lynx are hunting.

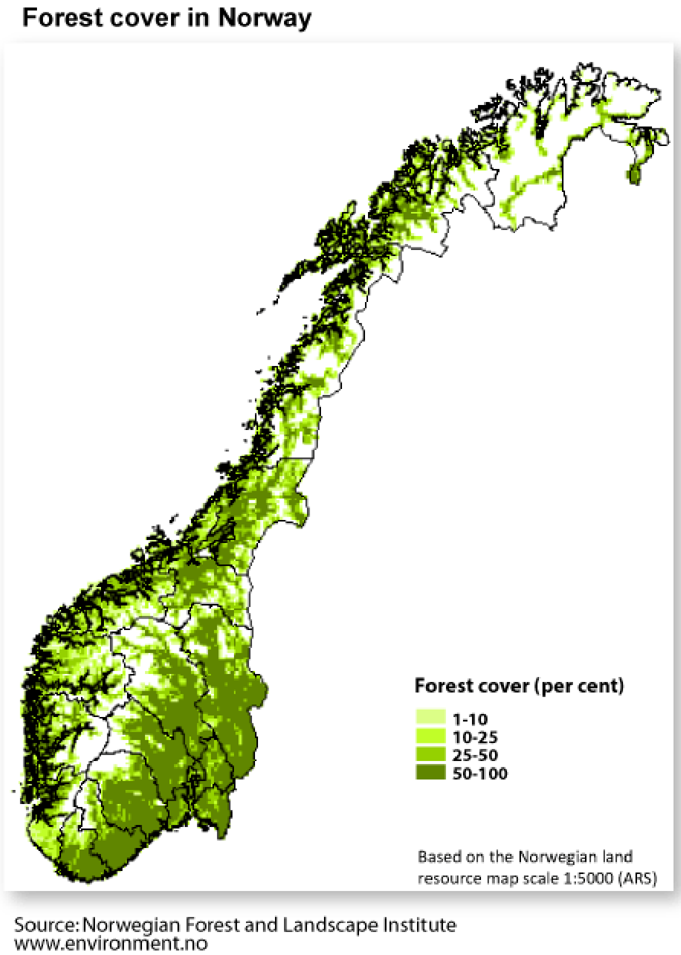

Figure 16: Forest cover in Norway in percent (Selvik, 2012).

In addition, the results show a higher percentage of rock substrate at control sites compared to lynx kill sites. This can also be explained by the fact that lynx kill sites depend on the habitat use by their prey. Reindeer do not graze on rocks, so there would probably be fewer opportunities for lynx to kill a reindeer on a spot where the substrate consist out of rocks.

None of the other variables seem to be important for the Eurasian lynx in northern Norway to select their kill sites. This is in contrast to some other studies done on habitat selection of felids. For example, Mountain lions selected more often steep and rugged terrain (Logan & Irwin, 1985) to approach prey and Podgorski et al. (2008) found that lynx selected sites in the vicinity of forest edges for hunting. Since reindeer in northern Norway are semi-domesticated and have a relatively poor anti-predator behaviour (Moa et al., 2006) it can be assumed that it is a relatively easy prey for lynx. In addition, reindeer occur more clumped than roe deer and their presence is less predictable and can vary from none to extremely high densities in a short period of time (Mattisson et al., 2011), which provides an easy accessible prey for the lynx. Another reason is that there are no alternative ungulate prey species of the same size available in northern Norway. Only Mountain hare (*Lepus timidus*), tetranoids (*Lagopus lagopus, Lagopus muta, Tetrao urogallus, Tetrao tetrix*), red fox (*Vulpes vulpes*), and small rodents (*Clethrionomys spp., Microtus spp. and Lemmus lemmus*) are potential alternative prey species for lynx (Mattisson et al., 2011).

9.2. Rest sites

Lynx selected a habitat type with trees as their rest sites. This corresponds with the study on microhabitat selection of lynx in Poland that showed that lynx selected more dense vegetation as their rest sites (Podgorski et al., 2008). Furthermore, lynx selected rest sites with a more rugged terrain and a steeper slope similar to what have been found in northern Sweden (Mattisson, 2011). This could be explained by the fact that on a steeper slope, lynx have a better view over the area surrounding them, but also their prey can use the advantage of not being easily seen in uneven terrain. Poor visibility can provide a kind of shelter and security, which is also described by Podgorski et al. (2008). Higher vegetation height could also contribute to low visibility and lynx do select for this as well. The study of Kolowski & Woolf (2002) about microhabitat use showed that bobcats in Southern Illinois also select more often areas with a high vegetative cover.
Furthermore lynx select their rest sites close to a rock wall. An explanation for this could be because of the fact that this characteristic also reduces the visibility from one side (often in uphill direction). This, in combination with a high slope, leads to a good view over the area in downhill direction. On the contrary, a study on microhabitat selection of bobcats showed that they avoided rock walls for resting (Kolowski & Woolf, 2002).
Because the female in this research had kittens during the time of sampling, fewer daybeds were sampled of her because she spent more time at the den or at the same place. This is in contrast with the adult male, more rest sites were sampled of him and therefore it could be that the adult male lynx is overrepresented in relation to the rest sites.

Habitat characteristics can differ a lot among seasons. This study was conducted in a 3-month period (June – August) of the year and can therefore not be generalised over a whole year.
In addition, it is arguably if these results, based on microhabitat scale are suitable for creating a reindeer predation risk map that is most likely created on macro scale.

10. Conclusion

The probability of lynx selecting their kill sites in a habitat type with trees is higher than in a habitat type without trees compared to kill control sites. In addition, the probability of lynx selecting a kill site increases with decreasing rock substrate and decreasing elevation compared to kill control sites.

Also for rest sites it is found that the probability of lynx selecting a habitat type with trees is higher than in a habitat type without trees compared to rest control sites. Furthermore, the results show that when steepness of the slope goes up and the terrain is more uneven, there is an increasing probability of lynx selecting this site as their rest site compared to rest control sites. In addition, the probablility of lynx selecting a rest site increases with a higher percentage of moss substrate.

10.1. Recommendations

To see if there were any differences between the tracked individuals and between the two years an analysis was done. However, due to the fact that there were not enough sites recorded for an anylsis like this (sample size was too small), no significant differences were found. Further research should be carried out to collect more data on the same individuals.
Also there were rest sites found correlated to a kill site. By correlated is meant that the rest sites were used just before the lynx killed a reindeer or between the consumption of the same reindeer. It would be interesting to see if these correlated sites have different habitat characteristics than sites that are not correlated to each other.
As mentioned before in this report, the knowledge gained about microhabitat use of lynx should contribute to the creation of a reindeer predation risk map. Since the landscape in this sudy area, and thus the habitat characteristics, must be very different during wintertime due to snowfall, these results cannot be generalized over the whole year. Gaining knowledge about habitat use of lynx during winter is essential when creating a risk map for the whole year.

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Pictures:

Cover picture: Åhlander, J. (2009). j_olanderr@gmail.com

Figure 1: Breitenmoser, U., Breitenmoser-Würsten, C. (2008). Der Luchs – Ein Grossraubtier in der Kulturlandschaft. Salm Verlag. Wohlen/Bern.

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Figure 11: Frauendorf, M. & Schevers, E. (2012).

Figure 13: Nudds, T. D., 1977. Quantifying the Vegetative Structure of Wildlife Cover. *Wildlife Society Bulletin*, 5, (3). 113-117.

Appendix I: Sampled kill and rest sites per individuals

Table 1: Number of sampled kill and rest sites per lynx individuals from both years (2011&2012)

	Mattis (M269)	Ella (F248)	Joe (M296)
Kill			
K 2012	23	21	0
K 2011	11	16	19
Total	**34**	**37**	**19**
Rest			
R2012	30	26	0
R2011	24	14	22
Total	**54**	**40**	**22**

Appendix II: Field data form

Field data-form of Microhabitat analysis of Lynx

	Date:		**UTM's area:**	**Site ID:** x:	**Data form Nr.** y:
1. Site visited	kill	rest	control	**2a. Animal type killed at kill site:** **Reindeer Fox Bird Hare Others** **2b. Age/Sex of dead animal:** **2c. Signs of rest site:** **Hairs Substrate Nothing**	
3. Habitat type	CF DF B Other:	MF MBF	LA MA HA	**4. Elevation:**	_________m
5. Slope	_________ °	**6. Aspect**	_________°	**6.TRI:**	P1: _________ m P2: _________ m S1: _________ m S2: _________ m
7. Edge	_________ m	**8. Hillside**	H M L		
9. Substrate structure (2m radius)	N2_________ N1_________	E2_________ E1_________	S2_________ S1_________	W2_________ W1_________	M_________
10. Visibility in % (10m radius) → pole outside → pole middle	N ________ N ________	E ________ E ________	S _________ S _________	W ________ W ________	Average _________ Average _________
11. Vegetation height in cm (2m radius)	N2_________ N1_________	E2_________ E1_________	S2_________ S1_________	W2_________ W1_________	M_________ Average_________
12. Vegetation height in cm (10m radius)	N10_________ N8_________ N6_________ N4_________ N2_________	E10_________ E8_________ E6_________ E4_________ E2_________	S10_________ S8_________ S6_________ S4_________ S2_________	W10_________ W8_________ W6_________ W4_________ W2_________	M_________ Average_________

Appendix III: Dependent variables with used test

Table 2: Dependent variables with used test

Nr.	Variables	Types	Definition	Used test
1	Habitat type	Nominal	0= Habitat type without trees 1= Habitat type with trees	McNemar test
2	Elevation	Interval	Increasing values expressing increasing elevation	Paired t-test
3	Terrain ruggedness index (0-100)	Interval	Increasing values expressing increasing steepness and ruggedness	Paired t-test
4	Slope in °	Interval	Increasing values expressing increasing elevation	Paired t-test
5	Aspect of the slope	Interval	With values from 0° to 360°	Paired t-test
6	Edge presence (distance<250m)	Nominal	1= edge present (within 250m) 0= no edge present (within 250m)	McNemar test
7a	Grass substrate cover in %	Interval	0-100 with increasing values expressing an increasing substrate cover	Paired t-test
7b	Moss substrate cover in %	Interval	0-100 with increasing values expressing an increasing substrate cover	Paired t-test
7c	Shrub substrate cover in %	Interval	0-100 with increasing values expressing an increasing substrate cover	Paired t-test
7d	Mineral substrate cover in %	Interval	0-100 with increasing values expressing an increasing substrate cover	Paired t-test
7e	Rock substrate cover in %	Interval	0-100 with increasing values expressing an increasing substrate cover	Paired t-test
7f	Herb substrate cover in %	Interval	0-100 with increasing values expressing an increasing substrate cover	Paired t-test
7g	Lichens substrate cover in %	Interval	0-100 with increasing values expressing an increasing substrate cover	Paired t-test
8a	Averaged vegetation height on a 2m radius (concerning rest sites)	Interval	Increasing values expressing an increasing vegetation height in cm	Paired t-test
8b	Averaged vegetation height on a 10m radius (concerning kill sites)	Interval	Increasing values expressing an increasing vegetation height in cm	Paired t-test
9a	Visibility in % (from outside of the circle to the lynx site)	Interval	0-100 with increasing values expressing an increasing visibility	Paired t-test
9b	Visibility in % (from the lynx site to the outside of the circle)	Interval	0-100 with increasing values expressing an increasing visibility	Paired t-test
10	Hillside	Ordinal	0= low, 0,5= mid, 1=High	McNemar test
11	Rockwall	Nominal	Presence of rockwall=1, Absence of rockwall=0	McNemar test