Department of Physics, Chemistry and Biology

Master Thesis

Activity patterns of musk ox (*Ovibos moschatus*) housed in different conditions.

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Contents

1. Abstract

The wild musk ox (Ovibos moschatus) in Scandinavian has a high level of inbreeding and by using metapopulation management, the genetic variation could increase. A direct reintroduction of captive musk ox to the wild population can cause problems. By improve the body condition; the animals' possibility to survive in a wild habitat can increase. The aim of the study was to investigate the musk ox activity in relation to the size and shape of the enclosure, as well as if changing of feeding and watering places can increase the activity of the musk ox, and thereby improve their hoof status. These measures could lead to a better reintroduction of musk ox into the wild established population in the future. This study was performed at Musk ox centrum in Tännäs and at Kolmårdens Wildlife Park. The musk ox activities were registrated through a Tellus GPS-collar, and the hoof status were estimated by trimming before and after the study period. The study shows the musk ox in Tännäs was more active compared to the one in Kolmården. The activity rate was 4.7 km/day in Tännäs and in Kolmården it was 1.9 - 2.2 km/day. The hoof growth of musk ox in captivity was 1.6 cm/month for Tännäs and for Kolmården it was 1.8 cm/month. The activity of the musk ox is affected both by the size of the enclosure, and temperature. The hoof status can be improved in an environment with adapted substrate, as well as improving the condition of the animal. All this could prepare a captive musk ox for a reintroduction into an established wild population in the future.

Keywords: Musk ox (*Ovibos moschatus*), activity, hoof status, metapopulation management, reintroduce

2. Introduction

The wild musk ox (*Ovibos moschatus*) in Scandinavian has a high level of inbreeding, because they are descends from only 10 individuals, transported from Greenland to Norway in 1953. In 1971, five musk oxen were established in Sweden, these five animals were related to today's living animals. There are seven musk ox individuals in the wild today (Alendal, 1973; Alendal and Heller, 1983; Bretten, 1990; Groves, 1992; Klein, 1988; Laikre, et al., 1997; Lent, 1999; Lundh, N.G., 1992; Lønø, 1960). Genetic variation can in the future be provided by metapopulation managements for the Swedish wild musk ox population. The metapopulation consist isolated and small populations with genetically viable. Exchange between animals in captivity and wild population can increase the genetic variation (Groom, et al., 2006; Wikramanayake, et al., 2004; Yuttham, et al., 2003). A direct replace of the animals can be used from wild-to-wild (an animal from one wild population move to another wild population). Replacing can cause problems in form of transmission and contamination of diseases between populations. The transport from captivity to wild respectively wild to captivity is safer because every animal is investigated in order to discover different disease before transporting to new populations. The metapopulation management is a program, which is dynamic, in form of genetic information of all musk ox both in captivity and in wild are registered in a breeding program. This program prevents inbreeding for example by genetic information and location about every musk ox, is used by different facilities when planning breeding (McCullogh, et al., 1996). The metapopulation management program was running in Sweden between 2003 and 2006, and was both positive and negative for the wild population. The first musk ox in the program was "Ingemar" which was transported from wild to captivity in 2003. At that moment he was the father to most of wild musk ox. In 2004, "Willy" from Kolmården Wildlife Park was transported to the wild population. He become father to a calf, but the calf did not stay alive for a long time, without any foundlings behind its early death.

Unfortunately both “Ingemar” and Willy died shortly after they came to the new habitats. In 2004, “Sofie” was transported from the wild to Järvzoo. The Zoo had recently imported “Pitorak” from Greenland, which she should mate with. After one year “Sofie” got pregnant and was transported back to wild. She gave birth to a male calf, “Pitorak Jr”, in May 2006. The DNA tests of the wild musk ox showed that the calf had two alleles which distinguished from other musk ox in the Scandinavian populations (1). “Pitorak Jr” became father of a calf in July 2010 (2). This was the first wild-born in 11 years. Although all this efforts have been done for the Swedish musk ox population, are still near to get extirpated. The main reason for this is inbreeding, but also that the females are too old for reproduction (Groves, 1992; Lundh, N.G., 1992).

One possibility to become a higher success of reintroduction of musk ox in captivity to wild is to increase their body condition before transportation. It was shown that “Willy” was not prepared enough for wildlife. He had lived in captivity too long and the season for the reintroduction was not optimal (Bengt Ole Röken and Torsten Möller). One way to increase the body condition of captive animals is to increase their activity, which can be an area problem. The average size core areas in wild musk ox are changed under the season, in summer the animal can move in an area of 223 km^2, compared to during calving or winter season the area is only 27-70 km^2. The average movement is also changing under the seasons, in the summer it is 10 km/day and during the calving or winter period it is 0.66 km/day (Jingfors, 1982; Lent, 1988; Reynolds, et al. 1998).

The musk oxen activity is also dependent on the weather and the temperature. In the summer the animals are more active than during winter season. In the summer they construct fat reserves before the winter period. During this period the animals are inactive because of their problems with finding food under the snow; their hoofs are not formed to dig in deep snow (Jingfors, 1982; Reynolds, et al. 1998). Musk ox are normally well adapted to digesting low quality food and maintaining mass at low rate of intake under the long arctic winter period (Adamczewski, et al., 1994; Jingfors, 1982; Staaland and Thing, 1991). In order to survive the long arctic winters, the musk ox has thick under wool that protects them against temperatures below -40 C°. In the summer the wool becomes a problem, especially for the captive animals which can get difficulties to find any area to cool down in (Crater and Barboza, 2007; Munn and Barboza, 2007; Ytrehus et al, 2008).

The increasing of the activity of the musk ox improves their hoof status, if the substrate is right. A hoof is growing normally about 0.6-0.9 cm/month (Hahn, et al., 1986; Lewis, 1995), sometime faster because of high quality of food, decreasing activity or absence of abrasive surface, which can occur in captivity (Clauss and Kiefer, 2003; Groves, 1992; Liesegang, et al., 2001; Marma, 1972). The Zoo animals can develop serious hoof problem, which can affect the way the animals walk. This requires regularly veterinarian examination, avoiding the hoof to break off which is very painful and can make the animal lame (Blowey, 2005; Clauss and Kiefer, 2003; Groves, 1992; Manson and Leaver, 1989). There have been observations that the musk ox in the wild has better hoof status, compared to captive ones. This can be proved by “Willy” which lived in the wild for a short period, where an autopsy of him showed that the hoofs status had get improved compared to when he lived in captivity. The main reasons were the chancing of substrate and the increasing of activity (Bengt Röken).

The aim of the study was to investigate the musk ox activity in relation to the size and shape of the enclosure, as well as if changing of feeding and watering places can increase the activity of the musk ox, and thereby improve their hoof status. These measures could lead to a better reintroduction of musk ox into an established wild population in the future.

3. Material and Methods

3.1 Animals and management

This study was performed at Musk ox centrum in Tännäs and at Kolmårdens Wildlife Park, from May 2010 to May 2011. Those where selected to get the different housing conditions, Tännäs because the musk oxen were living in a habitat close to the wild ones and a large enclosure. Kolmården Wildlife Park was selected because of the long experience of musk ox reintroduction and they have smaller enclosures. The purpose of the Musk ox centrum in Tännäs is breeding and research. Collaboration between the wild population, the captive musk ox from Musk ox centrum, and animals from Animals Parks will be developed to extend the genetic range and increase the chances of survival in the wild musk ox population, in the future.

Musk ox centrum in Tännäs had two musk ox male youngsters (1 year old) and one of the male got a GPS-collar. These animals come from Ryøya outside Tromsø in north Norway, and the enclosure size is about 1-2 ha (Figure 1a, enclosure 3). The youngsters got 3.4 kg pellets (product name Renfor) ones a day. In the summer the animals were fed only with pellets, but they could also eat from the vegetation in the enclosure. During winter period they also got hay, and the musk ox got more food during summer comparing to winter. This feeding regime was an attempt to imitate the wild musk ox feeding regime.

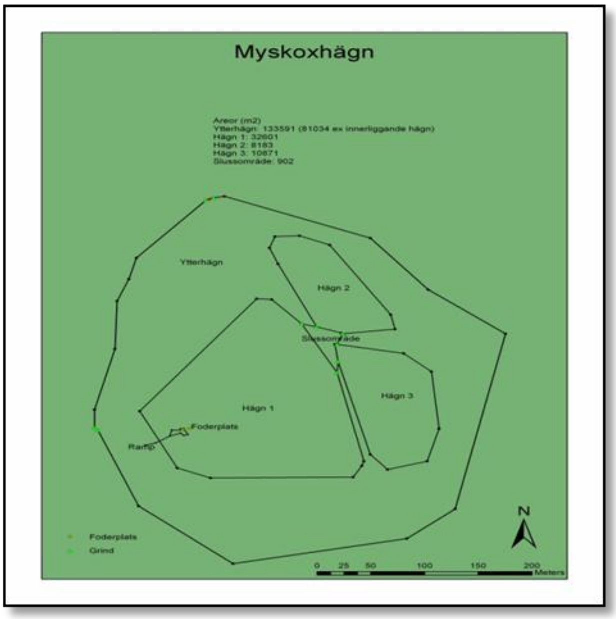

Figure 1a: The musk ox enclosure in Tännäs. The study animals were kept in the right-hand side enclosure. Figure 1b: The musk ox enclosure at Kolmården Wildlife Park.

The musk oxen in Kolmården Wildlife Park are four (one female and three males). The animal which has the GPS-collar was Sam (male) and he was born in Lycksele Animal Park and he was sex years old at the beginning of the examination. They were housed in two different enclosures, the first enclosure contained of knob of rock and some grass, which looked like tundra habitat (x ha). The second enclosure contained mostly mud (x ha) (Figure 1b, coming soon). Both of the enclosures were almost flat. The animals were fed twice a day, and got a total of 2 kg of pellets and 1.4 kg of chopped straw per animal, all year around. The feeding was connected to the musk ox passage through a gate between the enclosures. During the winter period the gates was frozen to the ground and the animals were kept in the first enclosure with the knob of rock.

3.2 Experimental set up

The animals activity were registrated through a Tellus GPS-collar with UHF (Ultra High Frequency) (Figure 2a), sited around the neck behind the ears of the animal. In the beginning of the study one of the females gave birth to a calf and the veterinarian did not want to anesthetize her, this lead to the selection to have the necklace only on males. The veterinarian could not predict how the calf would react to the situation or how the female would react to the calf when she woke up again. The collar had a downloaded function where every position would be stored. The information from the position could vary, but the important information for this project was date, time, latitude, longitude and ambient temperature. The temperature was chosen to investigate if there were any correlation between the temperature and activity of the animals. This information was directly downloaded to a laptop, via the RCD-04 receiver (Figure 2b). With the assistance of Tellus Project Manager (TPM) software, the GPS-collar was programed in order to show how often the positions should be registered. In Kolmården the positions should be registered every five minutes every day. In Tännäs the positions should be registered every five minutes every second day and the other days the positions was registered every hour. In Kolmården the collar was on the animal for totally 86 days and in Tännäs for totally 73 days.

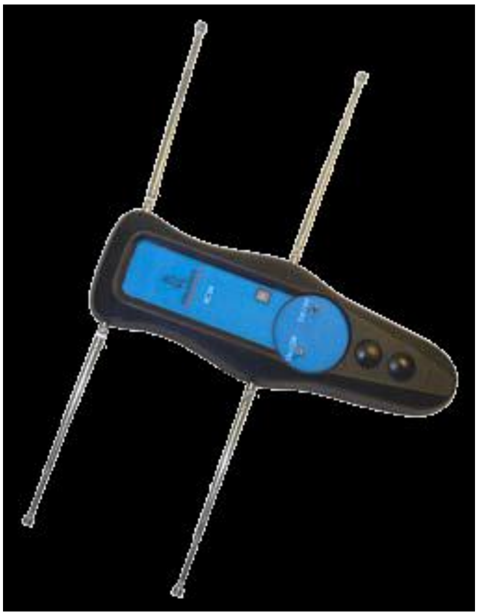

Figure 2a: The Tellus GPS-collar with UHF (Ultra High Frequency) data transfer. Figure 2b: The RCD-04 receiver used to upload data from the collar.

The enclosures were divided in four equally sized virtual boxes, in order to investigate how the animal used the area. In Tännäs the boxes represented different vegetation; box 1 was forest, box 2 was feeding trough and forest, box 3 was bog and forest and box 4 was bog and some trees (Figure 3a). The forest in Tännäs consisted pine, spruce and young birch trees and the under vegetation consisted blueberry rice, moss and grass, and the terrain was rugged. In enclosure 1 at Kolmården the boxes represented different ground substrates, box 1 was a part of the knob of rock, box 2 was new feeding place and a part of the knob of rock, box 3 was a part of the knob of rock and grass and box 4 was original feeding place, windbreaker and some grass (Figure 3b). The second enclosure (2) was not used under this period of the study, because of the problems with the frozen gates, mentioned before.

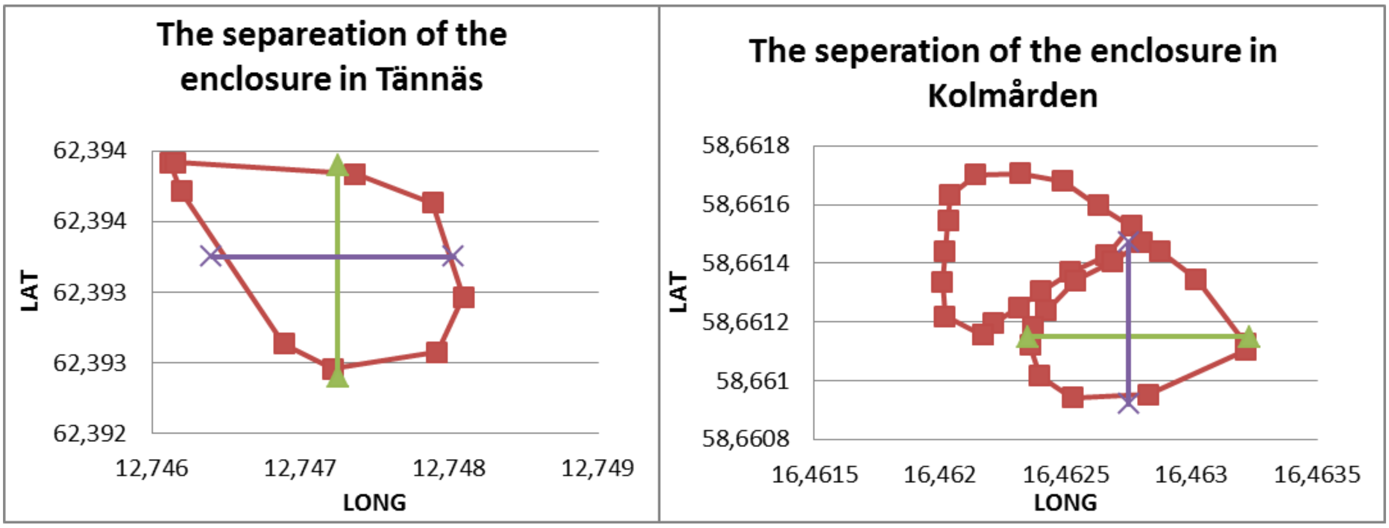

Figure 3a: The virtual box divisions of Tännäs enclosure. Figure 3b: The virtual box divisions of Kolmården Wildlife Park enclosure.

In Kolmården Wildlife Park we constructed four new feeding troughs in the enclosure to force the animals to increase their activity, and thereby increase the body condition. The new feeding troughs were placed as far as possible from the original feeding place with chopped straw and water bowl (Figure 3b). During a period of 49 days the animals got pellets every day, three times a day but at different times compared to normal feeding times. After 19 days some complications occurred in form of the snow, which covered the new feeding through, thereby we delude them to move to the new feeding place and then move back to the original feeding place for food The activities of the musk ox were measured through the distance they had moved in a 5-minutes interval during one day, and the average of the total distances.

In Kolmården Wildlife Park the musk ox got immobilized three times a year to get the hoofs trimmed, compared to Tännäs where the animals' hoofs were trimmed only twice a year. It is better for the animals if they can wear down the hoofs naturally, because the immobilizations of the musk ox are risky and stressful. The hoof status of the musk ox was difficult to estimate, but trimming the hoofs before and after each study period, lead to comparable information of their abrasion (Figure 4). When trimming the hoofs for the first time the GPS-collar was attached on the animal and they also got weighted. The second time the GPS-collar was removed from the animal.

3.3 Statistical analysis

The statistical analyses used were ANOVA and parat T-test. The calculations have been done in Minitab 15 and the kernel density analysis has been done in the program ArcGIS (Geographic Information System). The kernel density, calculates a magnitude per units area from point or polyline features using a kernel function to fit a smoothly polyline. The parameters used in this program were; output cell size 0.000002 and the search radius 1.393 E^{-05} and the area units were square kilometers.

4. Results

4.1 The activity patterns of the musk ox in Tännäs

Figure 5 shows a negative correlation between average activity and temperature, which were -0.449 and had a p-value of 0.006. The activity rate of the musk ox was 4.7 km/day.

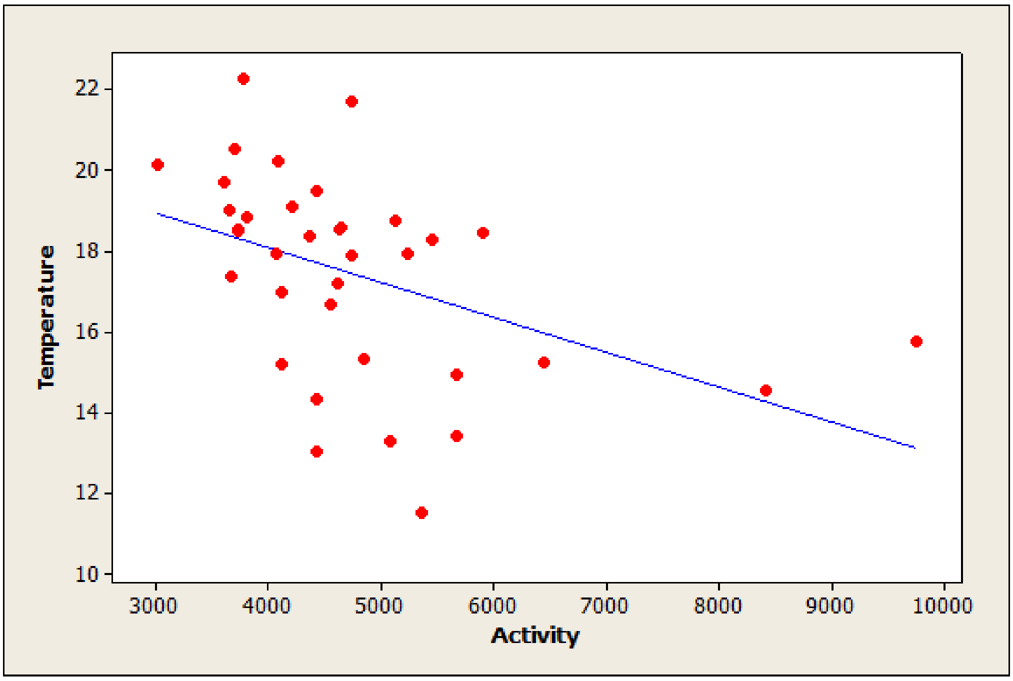

Figure 5: Tännäs. Shows the correlation between average activity and ambient temperature per day of the animal.

4.2 The kernel density analysis of musk ox in Tännäs

The enclosure was divided into four equally sized virtual boxes in order to investigate how the musk ox used the area. The differences between the boxes are shown in table 1.

Table 1: Tännäs. Mean values and standard deviation of compared boxes. This boxes represented different vegetation; box 1 was forest, box 2 was feeding trough and forest, box 3 was bog and forest and box 4 was bog and some trees (Figure 3a). (= significance differences between these boxes.*

		Box 1 v. Box 2	**Box 1 vs. Box 3**	**Box 1 vs. Box 4**	**Box 2 vs. Box 3**	**Box 2 vs. Box 4**	**Box 3 vs. Box 4**
Tännäs	Mean	* 7.39	* – 17.11	– 0.87	* – 24.50	* – 8.26	* 16.25
	StDev.	17.87	28.97	18.69	20.50	21.44	31.03

The kernel density analysis (Figure 6) shows that the musk ox had different hot spots areas under different times during one day, although the main activity was close to area where they got food ones a day (14:00-14:30). In B the musk ox movements were concentrated around the feeding area, compared to D where the musk ox did not have a special sleeping area. There were no significant differences between box 1 and 4 (p = 0.782), shown in table 1.

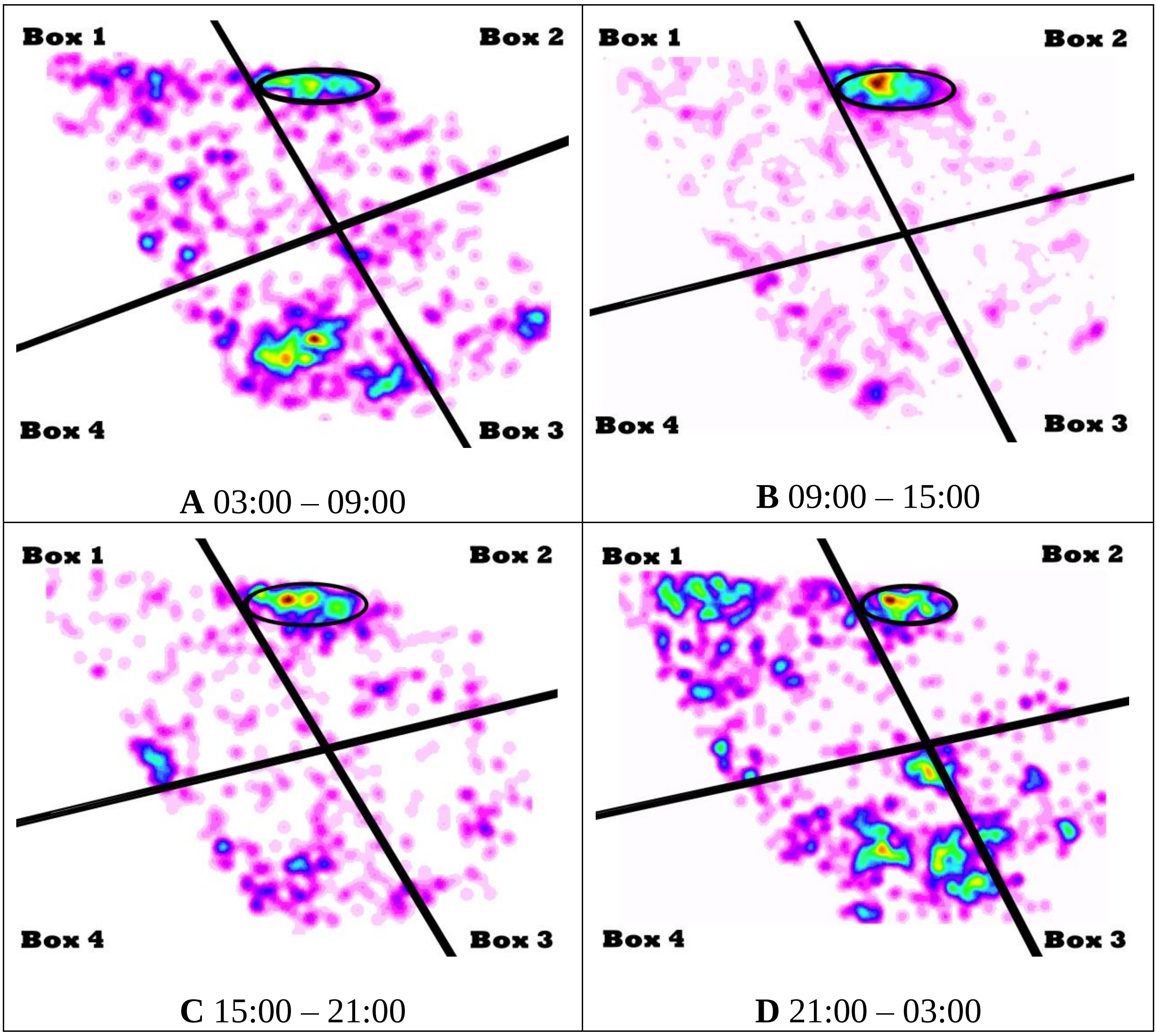

Figure 6: Tännäs. The elongated circle was the feeding place. Every hot spot time square was divided in four boxes and these boxes represented different vegetation; box 1 was forest, box 2 was feeding trough and forest, box 3 was bog and forest and box 4 was bog and some trees (Figure 3a).

4.3 The activity patterns of the musk ox in Kolmården

Figure 7, shows a weak negative correlation between average activity and ambient temperature, which were -0.020 and had a p-value of 0.920. The activity rate of the musk ox was 2.1 km/day.

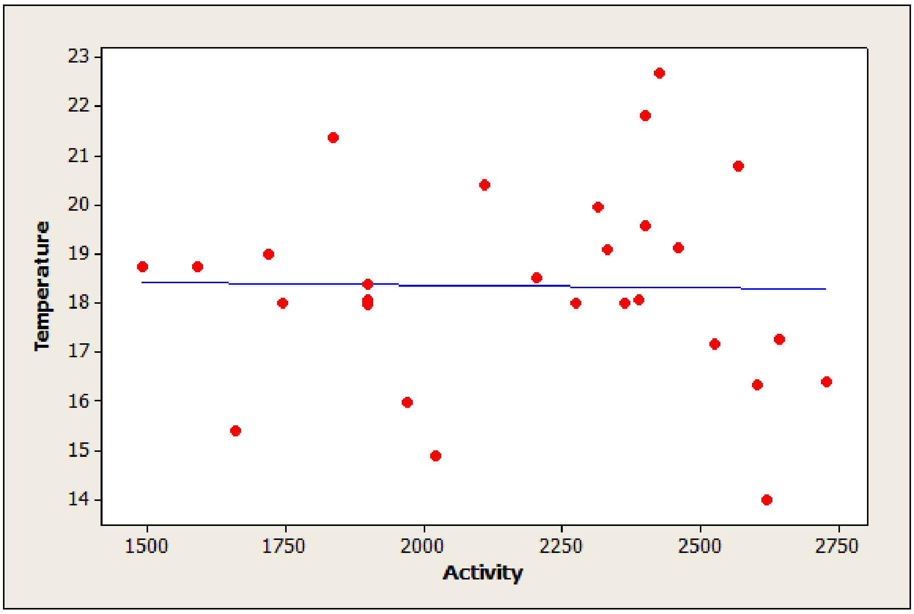

Figure 7: Kolmården. Baseline. Shows the correlation between average activity and ambient temperature per day of the animal.

Figure 8 shows a positive correlation between average activity and temperature, which were 0.102 and had a p-value of 0.728. The activity rate of the musk ox was 2.3 km/day.

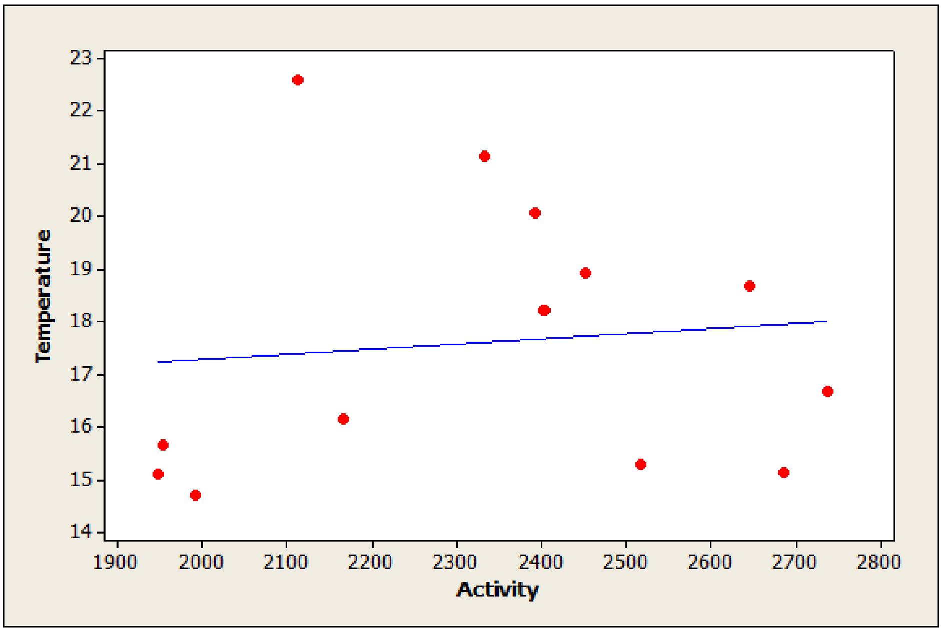

Figure 8: Kolmården. Changed feeding place. Shows the correlation between average activity and ambient temperature per day of the animal.

Figure 9 shows a weak negative correlation between average activity and ambient temperature, which were -0.022 and had a p-value of 0.898. The activity rate of the musk ox was 1.9 km/day.

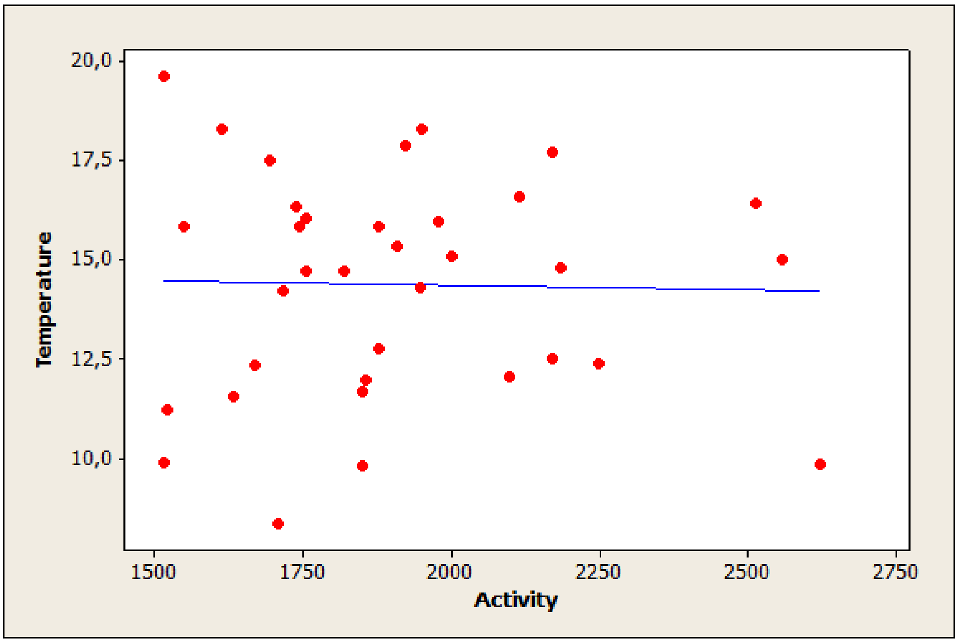

Figure 9: Kolmården. Deluded feeding in snow. Shows the correlation between average ambient temperature and average activity per day of the animal.

The investigations have shown that the activity patterns of the musk ox was significant higher between baseline and delude feeding in snow and between changed feeding place and delude feeding in snow ($p > 0.05$).

4.4 The kernel density analysis of the musk ox in Kolmården Wildlife Park

The enclosure was divided into four equally sized virtual boxes in order to investigate how the musk ox used the area. The different treatments had an effect on how the animal was using the area in the enclosure; this is shown in table 2. The comparison between the different treatment boxes (1, 2, 3 and 4) by One-Way ANOVA has shown that there were significant differences between the treatment boxes in 2, 3 and 4 ($p < 0.05$).

Table 2: Kolmården. Mean values and standard deviation of compared boxes between different treatments. These boxes represented different ground substrates; box 1 was a part of the knob of rock, box 2 was new feeding place and a part of the knob of rock, box 3 was a part of the knob of rock and grass and box 4 was original feeding place, windbreaker and some grass (Figure 3b). (= significant differences between that boxes and treatment.*

Treatments		**Box 1 vs. Box 2**	**Box 1 vs. Box 3**	**Box 1 vs. Box 4**	**Box 2 vs. Box 3**	**Box 2 vs. Box 4**	**Box 3 vs. Box 4**
Baseline	Mean	1.07	* -33.37	* -31.75	* -34.43	* -34.82	1.62
	StDev.	11.43	26.03	24.75	24.62	24.14	40.24
Chanced feeding	Mean	2.38	* -17.33	* -33.45	* -19.70	* -35.82	-16.12
	StDev.	13.42	21.29	25.46	20.02	22,58	30.88
Deluded feeding in snow	Mean	* -10.51	* 9.01	* -45.30	* 19.52	* 34.79	* 54.31
	StDev.	26.82	12.02	26.68	27.34	50.72	27.16

The kernel density analysis (Figure 10) shows that the musk ox had different hot spots areas under different times during one day. Although the main activity was close to area where they got food (in boxes 3 and 4) in all hot spot times (A,B,C and D). There is no significance between box 1 and 2 (p = 0.63) and between box 3 and 4 (p = 0.83), shown in table 2.

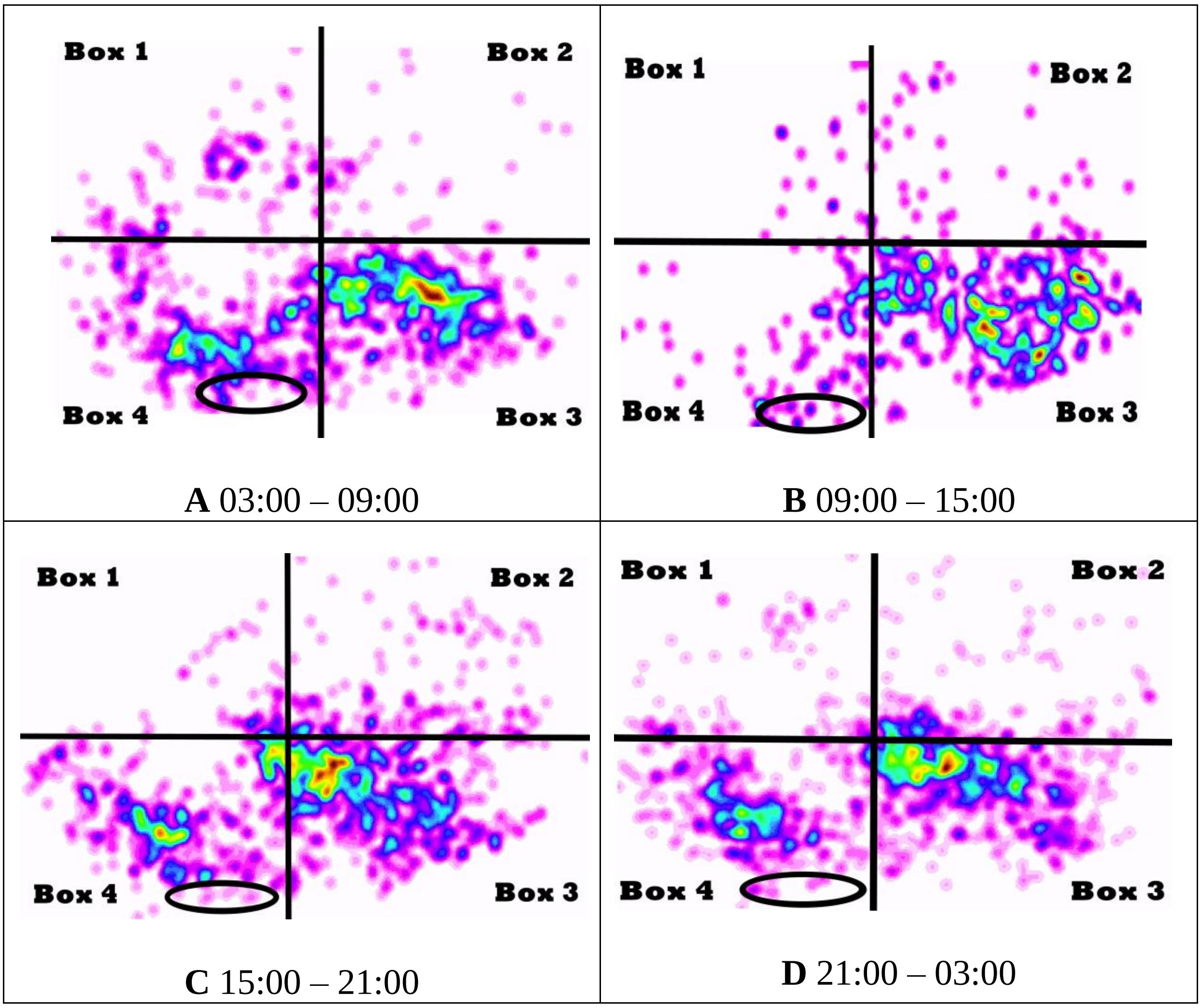

Figure 10: Kolmården. Baseline. The elongated circle was the original feeding place. Every hot spot time square was divided into four boxes and these boxes represented different ground substrates; box 1 was a part of the knob of rock, box 2 was new feeding place and a part of the knob of rock, box 3 was a part of the knob of rock and grass and box 4 was original feeding place, windbreaker and some grass (Figure 3b).

The kernel density analysis (Figure 11) shows that the musk ox had different hot spots areas under different times during one day. The activity in B was more spread in the whole enclosure compared to the other time squares (A, C and D). There were no significant differences between box 1 and 2 (p = 0.26) or between box 3 and 4 (p = 0.07), shown in table 2.

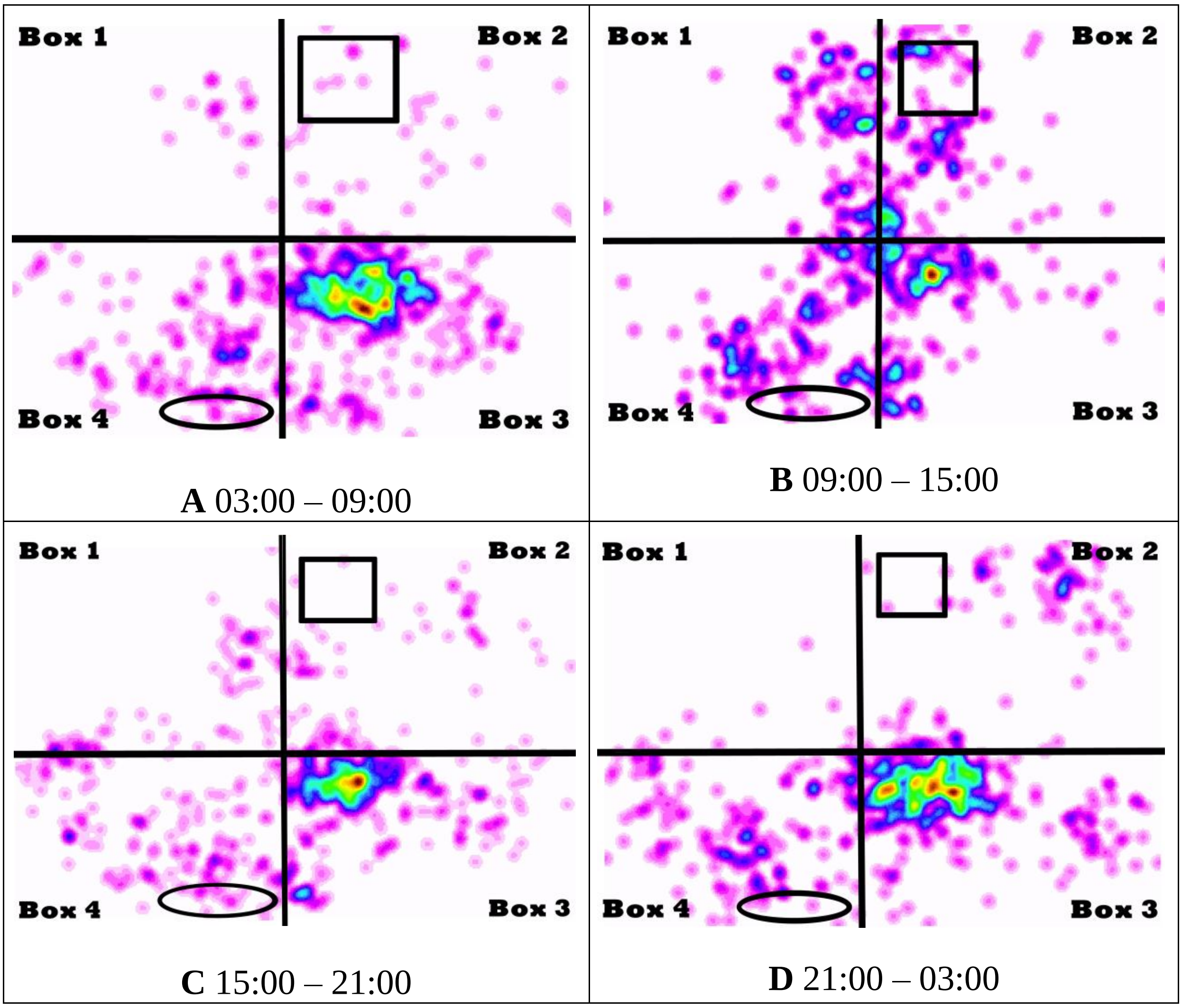

Figure 11: Kolmården. Changed feeding place. The square was the new feeding paces and the elongated circle was the original feeding place. Every hot spot time square was divided in four boxes and these boxes represented different ground substrates; box 1 was a part of the knob of rock, box 2 was new feeding place and a part of the knob of rock, box 3 was a part of the knob of rock and grass and box 4 was original feeding place, windbreaker and some grass (Figure 3b).

The kernel density analysis (Figure 11) shows that the musk ox had different hot spots areas under different times during one day. The activity in all time squares were concentrated in box 2 and 4. There were significant differences between all the boxes (p > 0.05), shown in table 2.

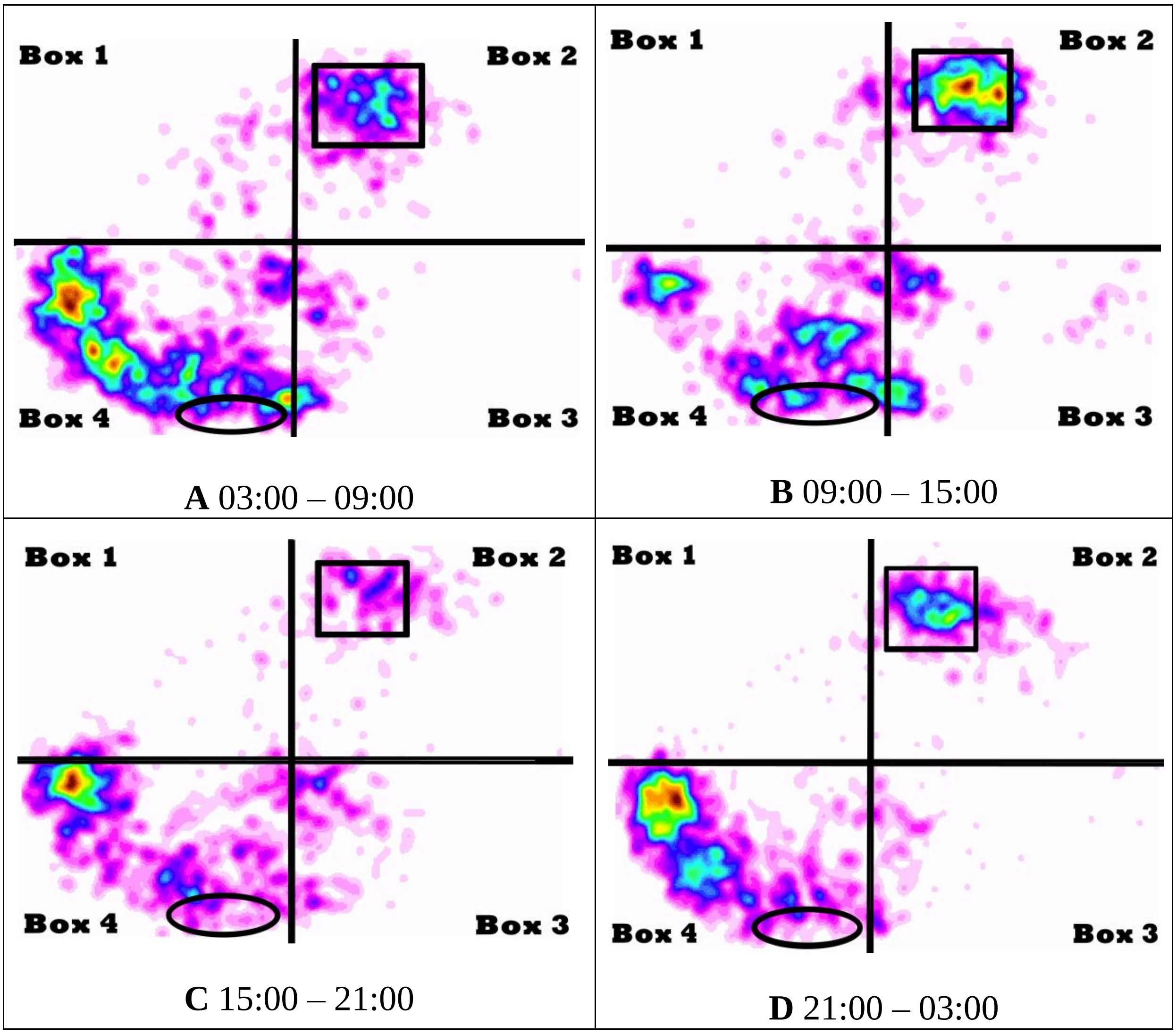

Figure 12: Kolmården. Delude feeding in snow. The square was the new feeding paces and the elongated circle was the original feeding place. Every hot spot time square was divided in four boxes and these boxes represented different ground substrates; box 1 was mountain, box 2 was new feeding place and mountain, box 3 was mountain and grass and box 4 was original feeding place, windbreaker and some grass (Figure 3b).

4.5 Hoof status in the different housing conditions

The hoofs of the musk ox in Tännäs were growing about 4 cm under 73 days; growth rate of hoofs was 1.6 cm/month. The hoofs of the musk ox in Kolmården were growing about 5 cm under 86 days; growth rate of the hoof was 1.8 cm/month.

4.6 Comparing between Tännäs and Kolmården

The comparing of musk ox activity between the Tännäs musk ox and Kolmården animal, shows that the animal in Tännäs was more active ($p < 0.05$) (Figure 13).

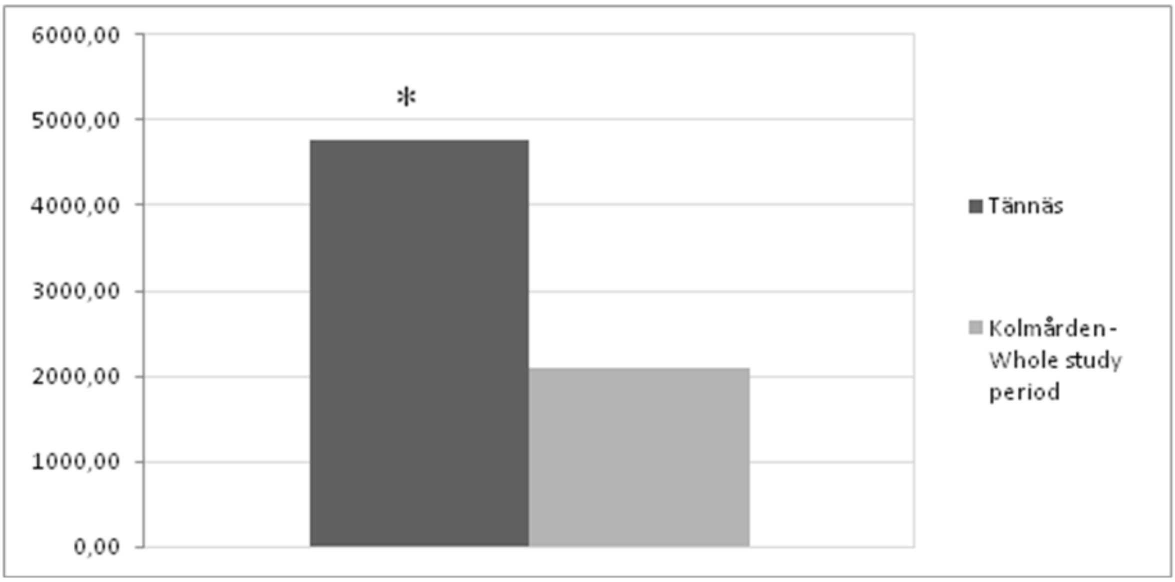

Figure 13: Show the averages activity in the different housing condition (Tännäs, large enclosure and Kolmården, smaller enclosure).

5. Discussion

The reason for this study was to investigate if we can prepare captive musk ox for a reintroduction into an established wild population in the future. The animals need to go through special preparations in form of higher activity to increase the body condition and improve the hoof status. In captivity it is hard to create naturally environment for the musk ox because of the limitations of enclosure size, and the animals habits of spending a lot of time lying on the ground, ruminating (Schaefer and Messier, 1996).

The increasing of the body condition of captive musk ox before a reintroduction can improve the animals' possibility to survive in a wild habitat. "Willy" was not prepared adequately for wildlife, because he had lived in captivity too long (Bengt Ole Röken and Torsten Möller).

In this study we have demonstrated that the musk ox in Tännäs was more active compared to the one at Kolmården. One reason for this could be that the animals in Tännäs have a larger enclosure and the habitat was closer to the wilds ones habitat. Although a study by Kreeger et al. (1996), of grey wolfs activity patterns, which were housed in small vs. large enclosure, showed that the enclosure size did not have any effect on wolfs activity. One reason for their results could be that the sample was too small, both in numbers of animals and in equipment's (GPS-collars). The kernel density analysis shows that the animals in Tännäs as well as in Kolmården was moving close to the feeding area, but after changing feeding place the movement was higher in the whole enclosure in Kolmården. Activity of the animal in Kolmården was different between the different treatments. It was significant higher between baseline and delude feeding in snow and between changed feeding place and delude feeding in snow ($p > 0.05$). Another explanation to different activity of animals could be the temperature; we did a correlation between the average activity and the ambient temperature. It shows a negative correlation in Tännäs (-0.449) and in Kolmården it was different between the different treatments. A negative correlation for the baseline (-0.020) and deluded feeding in snow (-0.022), and a positive correlation for the changed feeding place treatment (0.102). A negative correlation means that, when the temperature was high the activity was low. One explanation could be the animals thick under wool which protect the animal against temperatures below -40 ºC, becomes a problem in the summer (Ytrehus et al, 2008; Munn and Barboza, 2007; Crater and Barboza, 2007). When an animal in captivity got warm it decreases its activity, because of problems to found any area to cool down in, and not getting over heated. One system that could help the musk ox to decrease the body temperature is the nasal mucosa. The temporal exchanger in musk ox is instrumental in the conservation of heat and water. Exchanger efficiency is temperature depending reaching up to 75% of heat recovery and 80% of water recovery. This system also helps to decrease the brain temperature by the circle of Willis-sinus cavernosus. The musk ox have this system like other animals, but it needs more studies to investigate if the musk ox has the same effectively system like the caribou (Blix, 2005).

During the immobilization of the animal the GPS-collar was attached and the musk ox was weighted. The examination showed that the animal in Tännäs weighted more and had better body condition in overall, compared to them in Kolmården. One explanation for that could be that the activity rate was higher in Tännäs (4.7 km/day respectively 1.9-2.2 km/day) and that the terrain was more rugged compared to Kolmården. A part of our study in Kolmården took place during the winter. It has been shown in earlier studies that the musk ox moves in a higher degree during the summer period compared to calving and winter period (Jingfors, 1982; Reynolds, et al. 1998; Lent, 1988). Another explanation for the different activity rate could be the different age on the animals. In a study by Sarrazin and Legendre (2000), it was shown that it was better to reintroduce captive younger animals to a wild population, because of their higher surviving rate and better adaption to the new habitat and herb, than the older ones.

By improving the body condition of the animal during more activity, the hoof status is getting better, if the substrate is right. An improved hoof status before the reintroduction could prevent problems in the beginning of the release to the wild, by facilitating the animal to keep up with the herb pace etc. Studies by Lewis (1995) and Hahn et al (1986) showed that a hoof is growing normally about 0.6-0.9 cm/month, compared to our study where the hoof growth was higher than normal. In Tännäs the hoof growth was about 1.6 cm/month and in Kolmårdens it was about 1.8 cm/month. The main reason for that could be the ground was too soft, that the hoof did not wear naturally and the food quality was too high for a musk ox. It has been shown that high nutrition levels in the food affect the animals hoof growth rate negatively, by overgrowth (Marma, 1972; Wallach and Boever, 1983; Liesegang et al., 2001). Changing of the ground substrata could help to wear the hoofs naturally, for example the musk ox "Willy" hoofs was in better conditions after the time in the wild because of the rocky substrata (Begnt Röken and Torsten Möller). Even if the Tännäs musk ox has larger area to move on compared to Kolmården, the musk ox in both places needed help to trim the hoofs, unfortunately is this a common problem for animals in captivity (Groves, 1992, Masui, et al., 1975).

The temperatures in the collar was not the same as the air temperature because the collar thermometer was in contact with the animal's body surface, which made the ambient temperature to a mix between air temperature and animal's body temperature (Kitchens Maier, 1996). In future studies we recommend to have a local weather station which can give information of the air temperature.

Another recommendation would be to make registries every 5 minutes, in order to not losing too much information about the animal movement patterns. In our study in Tännäs we registered positions every five minutes every second day and every hour other days. A consequence of having every hour every second day is that we lost important information about the musk ox movement patterns. We selected to use only the positions which were registered every five minutes.

In conclusion our study shows that the activity of the musk ox is affected both by the size of the enclosure, and the temperature. The hoof status can be improved in an environment with adapted substrate, as well as improving the condition of the animal. All this could prepare a captive musk ox for a reintroduction into an established wild population in the future.

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