Examensarbeten **2009:22**
Institutionen för skogens ekologi och skötsel

Moose distribution and browsing close to a feeding station

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Sveriges Lantbruksuniversitet Skogligt magisterprogram/Jägmästarprogrammet
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I denna rapport redovisas ett examensarbete utfört vid Institutionen för skogens ekologi och skötsel, Skogsvetenskapliga fakulteten, SLU. Arbetet har handletts och granskats av handledaren, och godkänts av examinator. För rapportens slutliga innehåll är dock författaren ensam ansvarig.

This report presents an MSc/BSc thesis at the Department of Forest Ecology and Management, Faculty of Forest Sciences, SLU. The work has been supervised and reviewed by the supervisor, and been approved by the examinator. However, the author is the sole responsible for the content.

Abstract

This thesis investigates moose distribution and browsing damages in an area where a feeding station with ensilage fodder was established. A frequently debated subject in the Scandinavian forestry sector is how to handle problems with browsing damages by large herbivores, mostly moose (*Alces alces*), in young forest stands. Today the dominant way to reduce the browsing impact is by regulating the moose population by hunting. Currently, many forest companies claim that there is too much browsing damage and want to reduce the moose population. On the contrary, voices are raised that the number of moose is too low and that they can not accept a further reduction of moose in Scandinavia. Supplemental feeding of moose has been suggested as an alternative way to satisfy the opposing views.

Four feeding stations were established the late fall of 2006 in the river valley of Susendalen in Norway. In early springtime of 2006, before these feeding stations were established, we performed baseline surveys of moose (pellet counts) and of browsing on trees (counting of browsed twigs). The four investigated areas had a square shaped formation of 2 * 2 km each. In the spring of 2007 the same plots were resurveyed. To evaluate the potential of moose management by using feeding stations we studied the difference in moose density and browsing damages the both investigated years.

Overall, the results showed that there was a threefold, significant increase in the number of pellet groups compared to 2006. This indicates an aggregation of moose around the feeding stations. Within a radius of 900 meters there was a significant increase in the number of pellet groups the year after the feeding station was established. At a further distance, up to 1300 meters from the station, there was an indication of a slight increase in pellet groups. In addition, there was a significant increase in number of browsed twigs within a radius of 200 to 300 meters. The total numbers of all counted browsed twigs was slightly, but insignificantly, lower after the establishment of the feeding stations.

More studies about the economical aspect of supplemental feeding aimed for moose are desirable, but the conclusion of this study is that supplemental feeding can reallocate moose to a wanted location and therefore can be an effective way to monitor browsing damages in the concerned area.

Keywords

Baseline survey, Browsing damages, Forest stands, Moose population, Pellet groups, Supplemental feeding.

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Introduction

Lately there have been several reports published discussing the potential for supplemental feeding of moose (*Alces alces*) (Gundersen and Andreassen 1999, Nystedt 2005, Rydholm 2006a, Bergström 2007). Among others, small private forest owners (Bildström 2006), larger forest companies and authorities have suggested that there may be for silviculture, both positive and negative effects gained by supplemental feeding (Enander 2007, Sveaskog 2008)

Forest owners in Sweden claim that their major silvicultural problem is the risk of a deterioration of timber quality when the young tree stems are browsed (Blennow and Sallnäs 2002). During the time period of 2003 to 2005 estimations showed that almost 50% of all Scots pines (*Pinus sylvestris*) were affected by moose browsing (Hildingsson 2007). During the 20th century the moose population in Scandinavia has increased drastically (Ekman et al. 1992). This expansion was most likely due to the transformation of land use with increased fodder production from commercial forestry, regulated hunting and the lack of natural predators (Lavsund 1987, Bergqvist 1998, Hyttring 2007). The transformation from natural forests to the clear cutting system of today has more than doubled the amount of preferred browse that moose have access to (Andersen and Sæther 1996).

If all tree species are available the following ranking seems to be preferred in wintertime: 1. Rowan or Mountain Ash (*Sorbus aucuparia*), 2. Willow (Salix spp.), 3. Aspen (*Populus tremula*), 4. Juniper (*Juniperus communis*), 5. Birch (*Betula spp.*), 6.Scots pine, 7. Alder (*Alnus incana*), 8.Norway spruce (Bergström and Heljord 1987). The moose population peaked around 1982-1983 (Ingemarson et al. 2007), with an estimated size of the winter population of moose in Sweden to between 300 000 to 350 000 individuals (Hyttring 2007). In 1983 the number of harvest was 180 000 moose (Swedish Association for Hunting and Wildlife Management 2005). After this peak, the winter population of moose in Sweden has decreased to a level of approximately 200 000 (Swedish Association for Hunting and Wildlife Management 2007). The reason behind the decrease is increased harvest quotas in relation to population size and population compositions, set by regional authorities (Ericsson 2008). Hunting is the cause of over 80 % of the mortality for moose (Ericsson and Wallin, 2001).

From an economic point of view there are opposing aspects on whether a reduced moose population size would contribute in a positive or a negative way. Forest owners and particularly the larger forest companies claim that the browsing damages are much too high in some areas of Sweden (Bildström 2004, Rydholm 2006 b), and the Swedish National Board of Forestry claims that there is a positive national economical effect by a major reduction of the moose population (Ingemarson et al. 2007). On the contrary there are actors claiming that the economic effects would be positive if the moose population increased (Forsström 2007), and there is a report claiming that the results from the Ingemarson et al. (2007) report are incorrect and argue that the result is the opposite; there can be positive effects on the Swedish national economy if the moose population size increased even more (Wibe 2006).

In the year 2000 there was a policy set in Swedish forestry. Recent browsing damage in young pine forest stands should not exceed two percent per year on average (Anon 2000, Granqvist 2008). To monitor moose damage, the "ÄBIN-method" was introduced. This method measures the damages on Scots pine and can therefore provide an estimate if the moose population is too big for the present food supply (Kjellander 2007). According to this two percentage goal, the Swedish forests can hold a moose population of 3.2 individuals per 10 km^2 (Bergqvist and Bergström 2006). A common level of moose population in northern Sweden today is 3 to 7 moose per 10 km^2 (Andersson 2008).

Browsing damages made by moose on young Scots pine stands in a particular area are a result of: 1) Moose population size 2) Population composition 3) Number of winter days 4) Forage concentration (Bergqvist and Bergström 2006). Managing of the moose population size is a common way of attempt to reduce browsing damages today, mostly by hunting (Essén 1999, Ericsson and Wallin 2001). It is stated in the Swedish law that the landowner and the owner of hunting rights are responsible for controlling the population development of the animal concerned (Svensk Författningssamling 1987). A complicating factor for hunting as a method of reducing damages in young plantations of pine is that the most severe browsing damages are made predominantly in the winter (Lavsund 1987).

The hunting season for moose in Sweden is mostly in the autumn from September to December or January depending on geographical location (Swedish Association for Hunting and Wildlife Management 2008). Some moose individuals often migrate long distances from summer to winter habitat. The reason why they migrate is mostly to better survive the winter season in an area with better climatically conditions (Ekman et al. 1992). Therefore, where the moose is hunted in the autumn is not always where the moose should have made his contingent browsing damages in the winter (Andersen and Sæther 1996, Bildström 2004). Another way to reduce damages made by moose within a certain area is to use mechanical protection, e.g. fences. This can be quite expensive, about 20 000 SEK per hectare (Palmer 2005), and has been useful only to protect especially valuable stands (Lavsund 1987). Population composition, e.g. the proportion of calves and adults, also affect browsing as the food consumption by individuals within the population differs (Bergström 2008).

The number of winter days is an important factor to consider as moose prefer browsing on twigs of coniferous and deciduous trees particularly during wintertime (Bergström and Heljord 1987). Summertime moose mostly prefers leaves and twigs from deciduous trees and different kinds of herbaceous plants (Bergström and Heljord 1987, Ekman et al. 1992).

By modifying the concentration of available forage there can be an impact on winter browsing damages by moose (Lääperi 1990, Gundersen and Andreassen 1999, Bergqvist and Bergström 2006). Some alternative ways to manage browsing damage are using feeding stations with fodder aimed for moose (Gundersen and Andreassen 1999, Nystedt 2005), to allow moose to browse on pine crowns of fallen seed trees (Anon. 2005), to leave cut trees in clear cuts and thinning areas at wintertime (Fredriksson 2008, SveaSkog 2008). Topping of young secondary stems in pre-commercial thinning, may direct moose to browse especially on the secondary stems, and reduce damage frequency on main stems of better quality (Karlsson and Albrektson 2000), is also being tested for use in managing the problem of browsing.

Supplemental feeding can according to other studies have substantially impact on important factors, for example moose-vehicle accidents (Nystedt 2005), damages in young forest plantations (Lääperi 1990) and moose activity and browsing damages around feeding stations (Gundersen and Andreassen 1999).

Actions as supplemental feeding close to roads may be taken to reduce moose-vehicle collisions (Nystedt 2005). She found that the establishment of feeding stations is not likely to reallocate moose on a regional scale. On a local scale feeding stations can have a strong impact to reallocate moose to a certain area (Nystedt 2005). Therefore, only those feeding stations which are either situated along migratory routes or in the animal’s home range have a potential to affect the pattern of migration for moose. In short, the work of Nystedt indicates that there is a potential for remedial actions to affect moose migration and therefore a possible way to reduce moose-vehicle collisions.

Lääperi (1990) studied the effect on moose damage in young forest plantations when a feeding site was established in the Ruokolahti-Imarta area in Finland. Six areas were fertilized, offered mineral licks, and the tops of aspen and fallen pine were salted and transported to the site. The feeding sites were used remarkably often. There were fewer plantations destroyed by browsing by moose the years before the establishment than during the years after. He noted severe damages on the surrounding trees when the feeding experiment ended. Therefore he highlighted the importance of feeding continuously. Lääperi suggests that winter feeding of moose can not be considered as an alternative to direct protection of plantations, rather as a complement to other remedial methods (Lääperi 1990).

The study of Strömmen (1997) is an activity study for moose using a feeding station. The result showed that there were approximately seven to eight moose using the stations. No particular time during the day or night was preferred for eating. They often stayed approximately one hour for eating and ruminating. There was an obvious hierarchy among different deer species (mostly roe deer) but also among different moose. The moose drove away the smaller deer species, and within the moose population, the largest animal was in charge. Calculations showed that the most frequent used feeding station could have supported 31 adult moose for one winter season (Strömmen 1997). Gundersen and Andreassen (1999) presented the results of moose activity and browsing damages registered around feeding stations in Stor-Elvdal, Norway. The aim with the feeding was to try find out where the station should be placed to maximize the usage. They also tried to clarify the pattern of moose movement close to the station and tried to determine if feeding stations can reduce forest devastation in nearby seedling stands. The result showed that 70% of all stations were used. Approximately 7 to 8 ensilage bales per feeding station were consumed in one winter season. With an increasing number of years in usage, the station had a positive effect on moose presence at the feeding station. The distance from the feeding station had a significant impact on moose activity, measured by number of pellet groups. In a radius of 200 meters there were significantly more pellet groups than at a further distance. According to browsing damages, there was a significant increase in damaged tree stems within a radius of up to one kilometre. Very close to the feeding station, up to 25 meters, almost all stems were browsed and at a distance of 200 – 1000 meters from the feeding stations the feeding seems to slightly induce browsing on trees compared to areas without supplemental feeding. In a radius of 1000 – 3000 meters the browsing damages were reduced to a minimum and further away, the feeding station had smaller and smaller impact on this factor (Gundersen and Andreassen 1999).

“Moose in mid Scandinavia“(Älg i Mittskandia) is a trans-border project between Västerbotten in Sweden and Helgeland in Norway that was initiated in 2004 (Schön et al. 2007). In the beginning it was started by residents in the border regions between these two countries. The main purpose of this project was to create a cooperative activity in this region based on the moose resource. The vision is for this region to have a strong and increasing moose population and a common administration. The project will suggest management strategies to strengthen the position for moose as natural recourse. One part of the project was to investigate how supplemental feeding affects migration of moose and how browsing damages changes close to feeding stations (Schön et al 2007).

Objectives
Based on the literature review above, the following questions are addressed:

- How does supplemental feeding affect the distribution of moose in an area close to a feeding station?
- How does this potential reallocation of moose affect the browsing damages in the surroundings of a feeding station?

From these questions I have developed four predictions. The predictions to be tested in this study are:

1. Moose spend more time in a surrounding area after a feeding station is established than before.
2. Establishment of a feeding station does not contribute to more browsing damages in the investigated areas, in total.
3. The area close to a feeding station should experience an increase of browsing damages compared to the same area without supplemental feeding.
4. An area at a certain distance from the feeding station gets a decrease of browsing damages, compared to the same area without supplemental feeding.

Material and Methods

Study area

This thesis paper is a result of data collected in the surroundings of four feeding stations placed in the northern part of Norway (Fig.1). These feeding stations is a part of the ”Moose in mid Scandinavia” project that has a geographical range in the counties of Helgeland in Norway and Västerbotten in Sweden.

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Fig. 1. A regional overview of northern Scandinavia. The current area of this particular study is about 25 km south of the Hattfjelldal in Helgeland county, Norway. The plots mark the sites of the supplemental feeding stations. The feeding stations are latitude 65°30´ and longitude 14°0´.

Susendalen is the name of the river valley where the field survey for this study was carried out. The four feeding stations were placed so they covered the landscape from the bottom of the valley by the river up to higher altitude above the tree limit. They all had a similar distance from each other (Fig. 2)

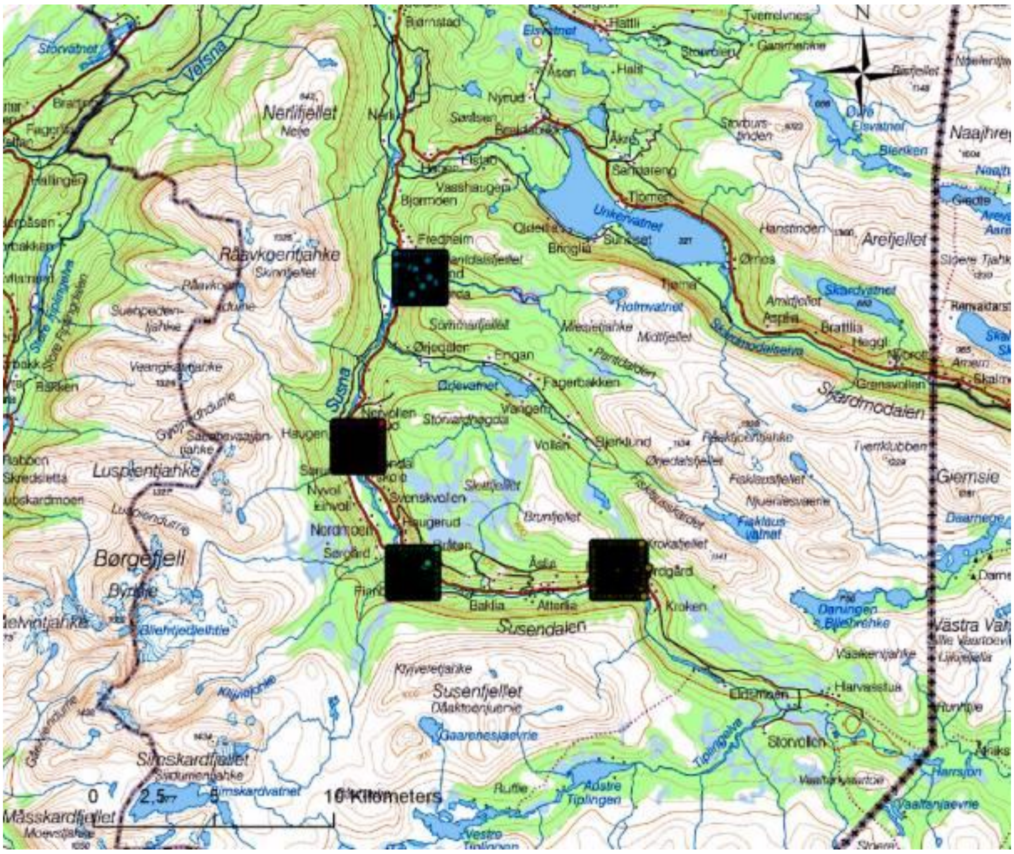

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Fig. 2. Local overview of the four inventory areas in Helgeland in Norway. The feeding stations are placed by the River valley Susendalen. The working titles for these areas were (from north to south) Pantdalen, Skolan, Finnbacken, and Kroken.

This valley is connected to the Swedish border and to the Kittelfjäll and Borgafjäll regions. The neighbourhood contains productive soils and the tree line is about 600 meters above sea level, which is unusually high for this latitude (Destination Helgeland 2007).

Field survey year 2006.

The field survey started in 2006 by search for adequate location of areas to accomplish the purpose of the study. To make these areas achieve the goals, four grid nets were constructed on locations that could meet certain conditions. Criteria to place the feeding stations in this study were:

- on Norwegian State Forest (Norske Statskog) grounds. No other land owner should be subject of any major impact of change in moose behaviour (browsing damage in particular).
- in an area with normal amount of natural fodder in young conifer forest stands and areas containing willow (*Salix sp*). The idea of this criterion is to eliminate the risk of moose having an unhealthy one sided diet, and because of the risk of getting inaccurate results if the stations were placed in an area with only one food e. g. in an old spruce forest.
- not too close to a frequently used road, because of the risk of increasing the number of vehicle collisions.
- to cover gradient of altitude from above the tree limit down to the river; all types of moose biotopes, depending on altitude should be included.
- fairly good access, so it would be easy to bring the ensilage to the feeding station (Nordström 2008).

The recorded area for every inventory area was created as a 2 * 2 km grid with an inner square formation of 100 * 100 meters (Fig 3). The locations of feeding stations were set close to the centre of the grid net. The valley by the river Susnan was chosen as study area because this valley had a documented strong moose population, with considerable moose migration between summer and winter areas. This information was mostly collected by GPS-transmitter tagged moose in order of the “Moose in mid Scandinavia” project (Schön et al. 2007). Another factor for why this area was taken in use is because 89 % of the land in this county is owned by Norwegian state forest (Hattfjelldal kommune 2007). Four areas were selected. The working titles of these four areas were set to Pantdalen, Skolan, Finnbacken and Kroken (Fig 2). Theses larger areas are in this study also mentioned as “major areas”

In May 2006, before the establishment of the feeding stations, the first year of field survey of browsing and moose distribution were initiated. Ordinary measurements were taken every hundred meters and extra measurements every 20 meters if the field surveyor landed up in a young forest stand with a stand height of 0.5 – 3 meters. Theses smaller inventory areas are in this study also mentioned as “survey plots”
GPS-receivers were used to locate the desired destinations. The formation of a specific area can be seen in Fig. 3.

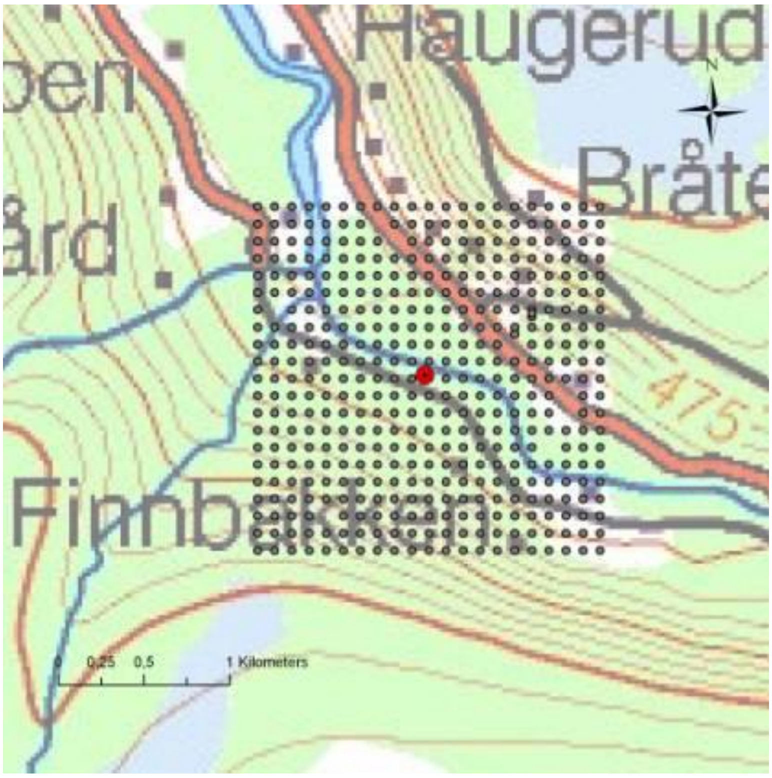

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Fig. 3. Overview of one major inventory area (Finnbacken), containing smaller survey plots as a grid of 100 meters and some extra survey plots for every 20 meters. The feeding station is marked as a larger plot in the centre of the grid.

Every survey plot got a unique coordinate number and this was the point that all other attributes were connected to in the GIS system. For every point the following data were collected:

- **Plot type**. Ordinary survey plots were documented as “0” and extra survey plots were documented as “1” in the field protocol. The extra survey plot was taken in use if the surveyor landed up in a young forest area with a stand height of 0.5 to 3 meters. This division was made to collect more data from younger stands.

- **Numbers of pellet groups.** Recordings were taken in a circular area of 100 m^2. Every pellet group containing more than 20 pellets and with group centre inside the area, was counted. Only pellets from the past winter season was included.
- **Number of bites.** To count the number of bitten twigs the closest tree, of every species, to the survey plot centre was used as a sample tree for registration. The area of the survey plots was 50 m^2. The measured stand height interval on the trees was set to 0.5 to 3 meters. The measured species were differentiated in eight groups: "Rowan"," Pine", "Salix", "Birch", "Spruce", "Alder", "Aspen" and "Other" for all other tree species, mostly juniper.

Two major areas (Kroken and Pantdalen) had complete data for "Number of bites". The other two areas (Skolan and Finnbacken) did not have complete data for this aspect and were therefore excluded.

Establishment of the feeding stations was set at the centre of the survey areas the late fall of 2006. Local farmers brought the ensilage bales to the stations. When necessary they brought new bales during the entire winter season (Nordström 2008).

Field survey year 2007

In May 2007 the recording for the second year was initiated. This year all four major areas had complete data for the number of browsed twigs and number of pellet groups. The data were collected the same way as before. However, one difference was that the area for measuring browsing damages was 100 m^2 this year.

Data analysis

Every survey plot's attributes were connected to a unique coordinate number in Excel. All the recorded factors previously described were connected to this unique coordinate number. Distance from every survey plot to the particular feeding station was calculated by using the coordinate numbers. For some factors considered in this study the distance from the feeding station was used to aggregate the results of measurements for every 100 meters. Some of the following results are mentioned are "mean value". According to browsing damages it must be considered that this "mean value" is of the sum of all counted bitten twigs, for every included tree species. Because only two major areas were fully documented for browsing damages in year 2006 (Kroken and Pantdalen), only the same two areas from 2007 were considered when the different calculations were made. To obtain results that might better show the trends and exclude local extreme values, a complementary calculation was made, "Floating average". This is the value of merging the present distance value with the value of the distances before and after.

To interpret the results there have been a number of calculations made from the data collected, mostly by using Excel to present the results by graphs and tables but also by visualizing the results with geographical information system, ARCGIS version 9.2 (Mitchell 1999).

Statistical analyses were made by using the program Minitab (Ryan and Joiner 2000). Level of significance was set to ($P<0.05$). To test if the measured values from the two both years significantly differed from each other, the Wilcoxon Signed Rank Test was used. For every survey plot that had two years of measurements, the value of the year 2006 was subtracted from the value of the year 2007 to determine the two years differed significantly from each other ($P<0.05$). This method was used for calculations for the spatial distribution of pellet groups, spatial distribution of number of browsed twigs, the number of pellet groups per hectare and the number of browsed twigs per hectare. "N" is the number of values in the sample. “N for test” is the number of remaining observations after elimination of values equal to the median. “Wilcoxon statistics” is a calculation that gives a value exceeding the hypothesized median. From this value comes the “P-value” that tells if the present calculation can reject the prediction of equality from one median value to the other. From the Minitab sub program “Fitted Line Plot” regression lines were visualized and equations were calculated, based on the mean values of the certain data for every desired distance interval.

Results

Pellet groups

Moose density during both winter seasons was estimated by counting pellet groups in all of the studied areas. The number of pellet groups per hectare year 2006 was 17.7 droppings per hectare and in the year 2007 the number of pellet groups per hectare was 50.6 droppings per hectare, 2.85 times higher (Fig 4). There was a strong significant difference between the two years (Wilcoxon Statistics P< 0.001, Appendix Table 1).

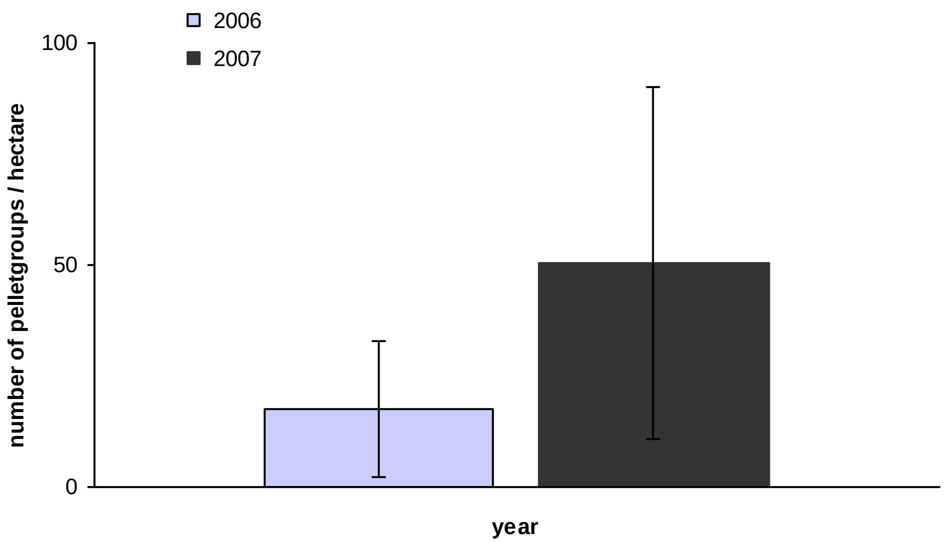

Fig. 4. The number of pellet groups per hectare in 2006 and 2007. The numbers of inventoried plots in 2006 were 1734 and the numbers of inventoried plots in 2007 were 1915. The error bars indicate the standard error of the mean: SE(2006) = 31 SE(2007) =79.

Spatial distribution of pellet groups

Spatial distribution of pellet groups from calculations of mean values for every 100 meters, from all four feeding stations, showed that the year of 2006 had a significant increase of pellet groups (Minitab Fitted Line Plot P<0.001), and the year of 2007 also had a significant increase in pellet groups (Minitab Fitted Line Plot P<0.001), the closer to the feeding station registrations were recorded (Fig. 5). Differences in median values from the both years showed a significant difference (Wilcoxon Statistics P<0.05) for the distance 0 – 900 meters from the feeding station. At a further distance there were no significant difference (Wilcoxon Statistics P>0.05, appendix table 2.) Standard errors for all distances can be found in Appendix table 3.

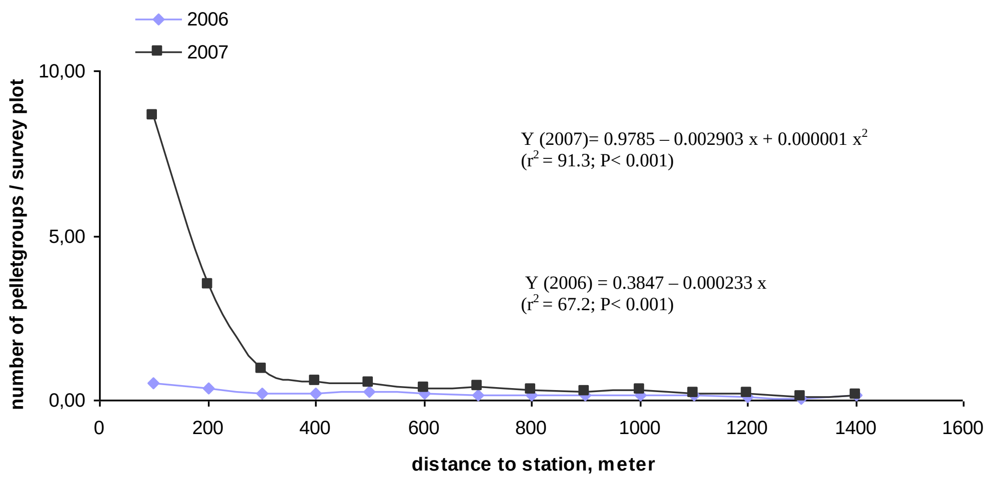

Fig. 5. Number of pellet groups per survey plot depending on distance to feeding station. Mean value of the number of pellet groups per survey plot from all feeding stations are visualized.

Browsing damages

Browsing damages during both winter seasons were estimated by counting number of all browsed twigs in two of the studied areas, Kroken and Pantdalen. The number of browsed twigs per hectare was 258 in the year 2006 and in 2007 the numbers of browsed twigs per hectare was 234, 9 % fewer browsed twigs per hectare than in 2006 (Fig. 6). There was no significant difference proved in the mean values of number of browsed twigs between the both years (Wilcoxon Statistics P> 0.05, Appendix tab. 4).

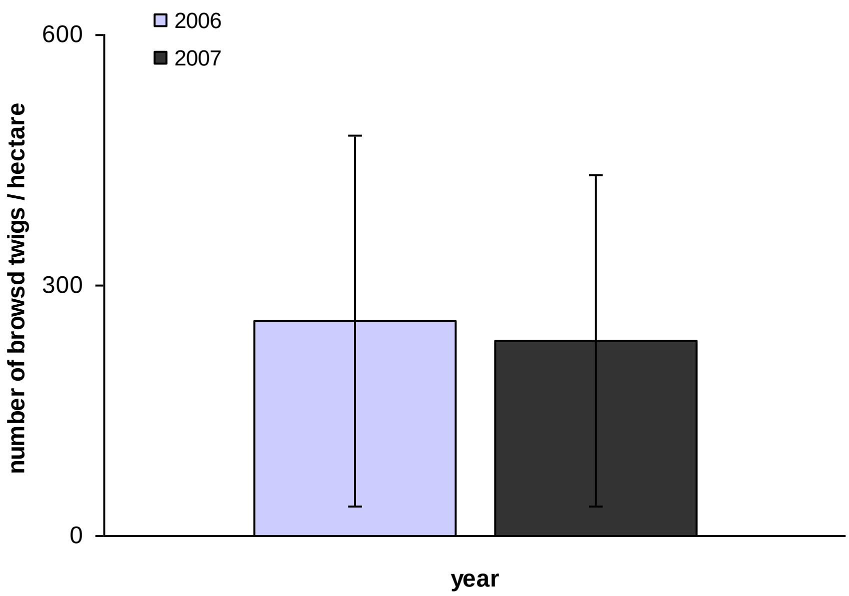

Fig. 6. The number of browsed twigs per hectare in year 2006 and year 2007. The numbers of inventoried plots in 2006 were 954 and the numbers of inventoried plots in 2007 were 1005. The staples represents the standard error: SE(2006) = 442 SE(2007) = 395

Spatial distribution of browsed twigs

Spatial distributions of browsing, estimated by aggregated mean values for every 100 meters from two feeding stations (Fig. 7), showed that year 2006 had no significant increase (Minitab Fitted Line Plot, P>0.05). The year of 2007 showed a significant increase in the number of browsed twigs the closer to the feeding station measurements were recorded (Minitab Fitted Line Plot, P<0.001). Differences in median values from both years showed one significant difference (Wilcoxon Statistics P<0.05 appendix tab. 5) for the distance of 1200 meters from the feeding station. Standard errors for all distances can be found in Appendix table 6.

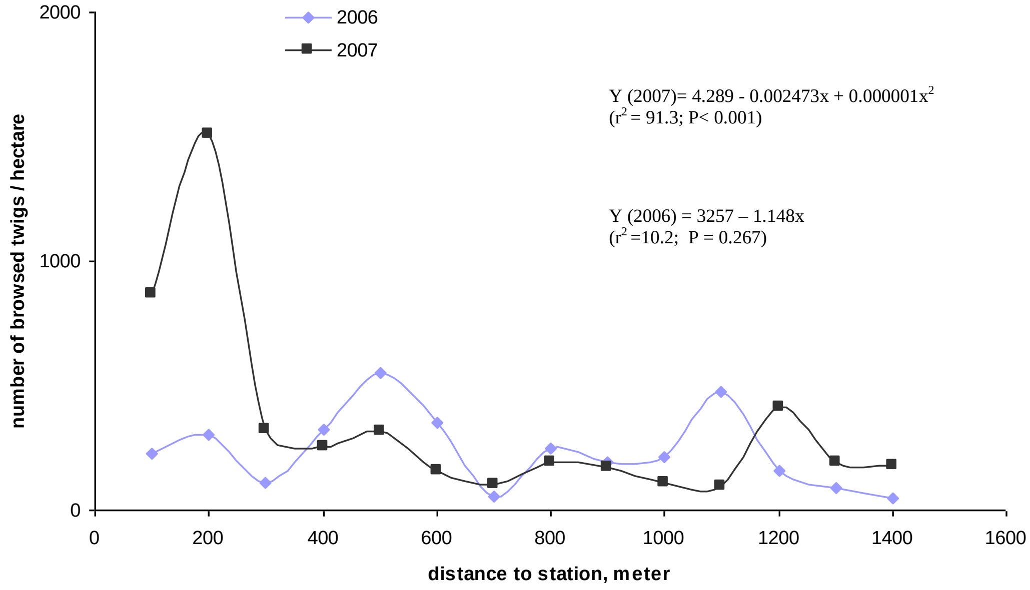

Fig. 7. Number of browsed twigs per hectare depending on distance to feeding station. To count the number of bitten twigs the closest tree, of every species, to the survey plot centre was used as a sample tree for registration. The major areas of Kroken and Pantdalen the year of 2006 and 2007 are included.

Spatial distribution of browsed twigs, using floating average

By using the method of floating average, spatial distribution of browsing from calculations of mean values for every 100 meters, from two feeding stations showed that the year 2006 had no significant increase (Minitab Fitted Line Plot, P>0.05). The year of 2007 showed a significant increase of number of browsed twigs the closer to the feeding station measurements were recorded (Minitab Fitted Line Plot P<0.001). Differences in median values from the both years showed a tendency of difference (Wilcoxon Statistics P<0.1, appendix tab. 7) for the 100 meter distance from the feeding station, and a more significant difference (Wilcoxon Statistics, P<0.05, Appendix tab. 7) for the 200 meter distance from the feeding station. At a further distance there was only the distance of 1200 meters that proved to be a significant difference (Wilcoxon Statistics P<0.05, appendix tab. 7). Standard errors for all distances can be found in appendix table 8.

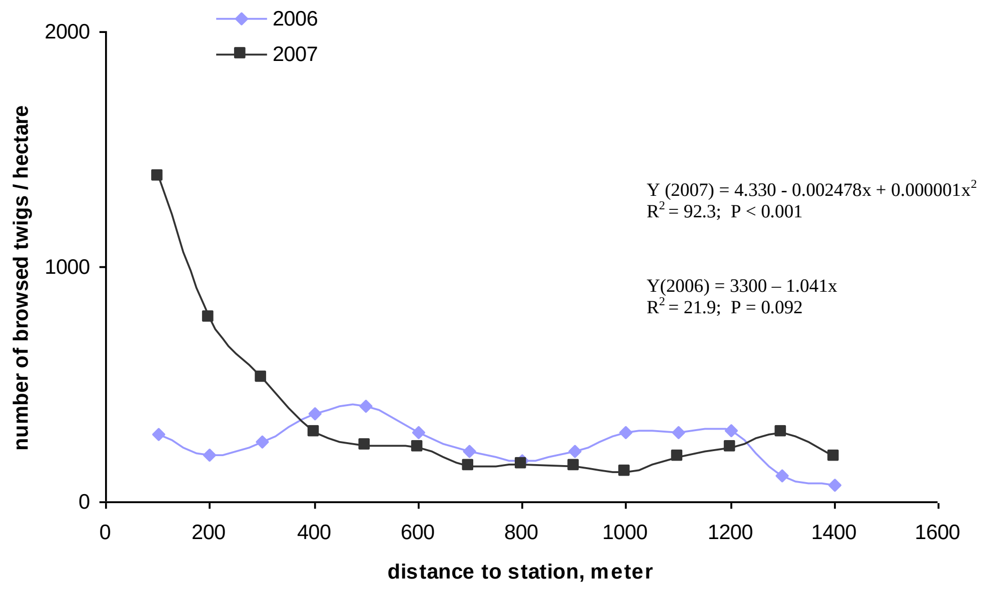

Fig. 8. Floating mean values of the number of bitten twigs per hectare, for all measured tree species, depending on distance to feeding station. To count the number of bitten twigs the closest tree, of every species, to the survey plot centre was used as a sample tree for registration. The major areas of Kroken and Pantdalen the year of 2006 and 2007 are included.

Discussion

This study investigated if there was any major impact on moose distribution and therefore a changed magnitude of moose browsing damages in an area when a feeding station is established. My results certainly suggested that there is such an effect.

Prediction 1 and 2

The most significant evidence for this statement above is that the spent time by moose in the investigated areas (number of pellet groups) increased almost three times the winter season after the feeding station was established compared to the year before (Fig 4). So there is no doubt that the first prediction, that moose spends more time close to this station compared to a similar area without a feeding station, was confirmed. According to the second prediction concerning browsing damages (counted browsed twigs) there was no significant difference proved between the investigated years, and only a slight reduction the year after the feeding station was established was indicated (Fig 6). This result contra the time spent by moose in the area must be considered as remarkable.

Prediction 3 and 4

The third and fourth prediction concerned the spatial distribution of browsing damages and pellet groups. The results showed that there was a significant increase of both of these factors within a certain distance from the feeding stations. Number of pellet groups increased significantly up to a radius of 900 to 1000 meters when the feeding station was established. Further away there was no significant difference. For the number of browsed twigs, a significant increase could be detected up to a radius between of 200 to 300 meters from the feeding station. Further away there was one distance (1200meter) that showed a significant difference. My results could confirm the third prediction, (browsing increases close to the feeding station) but could not confirm the fourth prediction (browsing decreases at a certain distance from the feeding station).To sum up prediction one to four I can say that both moose presence and moose browsing damages change when a feeding station aimed for moose was established.

Comparisons to similar studies
The most similar report to my present study is the Gundersen and Andreassen (1999) publication. Knowledge from their study has in many ways affected the goals and the manner of the way my experiment was set up. Some recordings were set to test findings from Gundersen and Andreassen (1999), but other recordings were set to fill gaps of information that I needed to achieve my goal. They aimed at studying young conifer stands and had only one year of measurements. My study has comparative measurements from one year without a feeding station and another year with a feeding station, and is not just applied to for forest industrial important species, but for all tree species in the study area. Therefore we could estimate the spatial difference of browsing damages round a feeding station and we could also estimate how moose changed its food intake from one year to another when a feeding station was established between these two years.

Gundersen and Andreassen (1999) had a different way of handling the measurements according to distance from the feeding stations. The distance from the stations in their study were placed in an objective way in the radius of 200 meters. Up to 7 kilometres from the station they had a more subject location of the survey plots in only young conifer stands. My study confirmed that if there is an establishment of a feeding station there is a difference in the moose activity according to both attendance and browsing damages between the year with and without extra fodder. Gundersen and Andreassen (1999) found a spatial pattern in that there were significantly more pellet groups in a radius of 200 meters than at further distances. For the number of browsed twigs they found a significant increase of browsing damages within a radius of 200 meter from the station and an apparent decrease when the distance to the fodder was 1000 to 3000 meters.

The results in Susendalen can partly support Gundersen and Andreassens results. There is no doubt that close to the feeding stations there were apparently a lot of browsing damages, but when the distance increased there was a decrease in both moose activity, measured by numbers of pellet groups, and browsing damages. My study supported Gundersen and Andreassens (1999) results according to spatial pattern of pellet groups in the surroundings of the feeding stations in most parts. From their results of browsing damages I could see a similar pattern in my results that told a significant increase of damages close to the station. Gundersen and Andreassen (1999) also saw a decrease in browsing damages in a distance (1000-3000 m) that I did not detect. The results in my and Gundersen and Andreassens (1999) studies, showed a significant increase of browsing damages at a close distance from the feeding station. The obvious gained concentration of moose has of course a big impact, but other factors must also be taken in consideration.

Strömmen (1997) described a strong hierarchism inside the moose population. When a smaller animal is driven away from the feeding station, other nearby fodder resources (twigs) might be consumed by this individual. The importance of diversity in the diet (Andersen and Sæther 1996) is another factor that can be mentioned as a reason why there were severe damages on trees very close to the station. Observations in captivity shows that if the moose are exposed to unlimited amounts of fodder with a great difference in quality and many types of tree species, they mostly consume the fodder with high quality but they also consume a substantially amount of twigs with low quality fodder (Andersen and Sæther 1996). In short, moose can not only consume ensilage to get a satisfying diet. Moose also eat complementary food in the neighbourhood.

Aspects on feeding station arrangements and economy

So how should a feeding station be arranged to get maximal usage? In my study only ensilage bales were used as fodder. Lääperi (1990) had another way to present remedial fodder for moose. He supplied the feeding site extra food as the area was fertilized, offered mineral licks, and offered tops of aspen and fallen pine that was salted and transported to the site. This method of gaining fodder might be better in the aspect of getting all the nutrients needed for moose satisfied. In the aspect of hours of work, this method must be demanding. Lääperi, however also points to the work of continually keeping the feeding sites with food as very important. The person responsible for the feeding must consider that an adult moose consumes approximately 6 kg (dry weight) food per day at wintertime (Strömmen 1997) and therefore must adjust the amount of fodder brought to the feeding station after the present number of moose using the station. To use ensilage bales was an easy way of getting the food to a wanted place. Perhaps could a combination of these two methods be optimal. Strömmen (1997) found a hierarchy among moose and therefore feeding sites that presents more than one place to eat can be preferred.

Can supplemental feeding be an alternative way to manage the problem of browsing damages in Scandinavian silviculture? This question must first of all be related to the economic aspects. One result of this study tells us an increase of time spent by moose in the investigated areas to almost three times more the year with feeding than the year without. Another of my results, however, shows that there was no difference in the total amount of browsing damages. According to this pattern it can be concluded that if all moose had contact with a feeding station, the moose population could grow to a level of three times more than the present and there would not be any increase in the amount of damage. A following question is if all moose had contact to a feeding station would the browsing damages decrease almost three times if the moose population were kept at the present? More studies are needed to investigate this.

However, is the subject of supplemental feeding realistic to consider from an economic point of view? I have dared to try a simple calculation to give a hint of the answer to this complex question. The total cost of browsing damages in Sweden is approximately 900 million sek / year (Ingemarsson et al. 2007). The total forest land in Sweden is 23 million hectares (Joshi 2007). This gives a cost of 40 sek / hectare and year for devastations in Swedish forests made by browsing.
The studied area of Susendalen is 1600 hectares and I guess there is 1000 hectares of forest land. Therefore does moose accomplish damages to a value of 40000 sek / year in this area. The total cost of the supplemental feeding in Susendalen landed at 50000 sek (Ericsson 2008). If the discussion above that assumes a reduction of browsing damages to a third in an area with supplemental feeding is correct, I can say that the cost of browsing damages would bee reduced by slightly over 25000 sek. Therefore, the feeding in Susendalen is not profitable as the cost of feeding is 50000sek compared to the savings from less browsing damage of 25000 sek. For the feedings to be profitable there must be smaller cost for the fodder. Again I must point out that this calculation is far from rigorous and is not the central aim for this study, but can perhaps give a hint about the economical aspects of supplemental feeding.

In Susendalen there is not much available Pine fodder for moose and in other parts of Scandinavia, pine is a highly preferred winter browse for moose (Ekman et al. 1992). Based on my results I can not say that moose acts the same way in all biotopes when they are exposed to supplemental feeding. The results could have been different if there were lot of pine in Susendalen instead.

The survey plots were laid out as a square shape grid net. This had the consequence that close distances from the feeding station contained fewer survey plots than at further distances. An improvement to an upcoming similar study should consider this fact and arrange more survey plots close to the feeding station and fewer at a further distance.

This study showed that moose activity increased close to the feeding station. Therefore the location of these stations must be careful chosen because there is a risk of severe browsing damages within a radius of 200 – 300 meter. The feeding station must not be established such that a valuable forest stand is exposed to more browsing. Furthermore the risk of increasing vehicle collisions in this area must be considered. The study could not detect any “safety area” at a certain distance away from the feeding station. According to my data, up to 900 meters from the station, moose spent significant more time. If a frequently used road is in the area of concern, the safety distance from the station to this road should be at least 900 meters

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Appendix

Table 1. The difference in the number of pellet groups per hectare, from the both years." Wilcoxon statistic – sign ranked test" tests if the median value from this difference is significantly different from zero. P-value < 0.000 proves a significant difference from zero. The value of year 2006 is not the same as the value of 2007

N	*N for Test*	*Wilcoxon statistics*	*p-values*
1653	432	69713	0.000

Table 2. Statistical test for mean values of "number of pellet groups". This estimates the median value from the difference of number of pellet groups for every survey plot that had a possibility to compare the values from both years. The method in use is "Wilcoxon Statistics - sign ranked test"

Dist.(meters) to station.	N	N for test	Wilcoxon statistic	P-value
0-100	12	10	50.0	0.025 *
100-200	42	24	275.5	0.000***
200-300	60	23	221.0	0.012 *
300-400	90	31	389.0	0.006 **
400-500	115	42	733.5	0.000***
500-600	134	38	544.5	0.012 *
600-700	145	40	627.5	0.004 **
700-800	176	44	799.0	0.000***
800-900	194	46	758.0	0.018 *
900-1000	215	46	672.5	0.151 NS
1000-1100	206	40	460.0	0.506 NS
1100-1200	131	29	308.0	0.052 NS
1200-1300	78	10	41.5	0.169 NS
1300-max dist	55	9	22.0	1.000 NS

NS=not significant. *P<0.05, **P<0.01 ***P<0.001

Table 3. Standard error of "Pellet counting containing aggregated measured values of intervals for every hundred meters", from Fig. 5

Dist. to stn. (m)	Standard error 2006	Standard error 2007
100	0,78	10,39
200	0,62	4,30
300	0,40	1,20
400	0,37	0,80
500	0,40	0,89
600	0,35	0,66
700	0,27	0,59
800	0,30	0,67
900	0,24	0,49
1000	0,30	0,48
1100	0,31	0,52
1200	0,20	0,34
1300	0,12	0,35
>1300	0,26	0,24

Table 4. The difference from the number of browsed twigs per hectare, from the both years." Wilcox statistic – sign ranked test" tests if the median value from this differences is significant differentiated from zero. P-value = 0.505 doesn't indicate a significant difference from zero. The value of year 2006 was not different from the value of 2007

N	*N for Test*	*Wilcoxon statistics*	*p-values*
895	224	13247	0.505

Table 5. Statistical test for mean values of number of browsed twigs. This estimates the median value from the difference of number of browsed twigs for every survey plot that had a possibility to compare the values from both years. The method in use is "Wilcoxon Statistics - sign ranked test"

Dist.(meters) to station.	N	N for test	Wilcoxon statistic	P-value
100	6	6	9.0	0.834 NS
200	25	12	61.0	0.092 NS
300	33	4	10.0	1.000 NS
400	49	13	41.5	0.807 NS
500	60	20	81.0	0.380 NS
600	73	16	49.0	0.339 NS
700	82	17	103.5	0.210 NS
800	100	30	186.5	0.349 NS
900	111	31	236.0	0.822 NS
1000	115	27	182.5	0.885 NS
1100	105	17	58.0	0.394 NS
1200	71	18	137.0	0.026 *
1300	36	9	30.0	0.407 NS
>1400	29	4	66.5	0.361 NS

NS=not significant. *P<0.05, **P<0.001 ***P<0.001

Table 6. Standard error of mean values of the number of bitten twigs per hectare, for every measured tree species, from Fig. 7

Dist. to stn. (m)	Standard error 2006	Standard error 2007
100	195.9	1344.4
200	517.4	2180.2
300	191.7	494.9
400	563.0	418.2
500	899.8	507.0
600	572.8	276.1
700	104.4	182.9
800	404.6	313.3
900	323.9	293.4
1000	377.1	189.2
1100	838.2	172.7
1200	279.6	697.0
1300	170.4	327.9
>1300	84.5	315.9

Table 7. Statistical test for floating mean values of "number of browsed twigs". This estimates the median value from the difference of number of browsed twigs for every survey plot that had a possibility to compare the values from both years. The method in use is "Wilcoxon Statistics - sign ranked test

Dist.(meters) to station.	N	N for test	Wilcoxon statistic	P-value
0-200	31	18	124.0	0.098 NS
0-300	64	22	195.5	0.026 *
100-400	107	34	368.0	0.231 NS
200-500	142	42	418.5	0.684 NS
300-600	182	49	500.0	0.265 NS
400-700	215	53	658.0	0.614 NS
500-800	255	63	920.0	0.549 NS
600-900	293	78	1486.5	0.790 NS
700-1000	326	88	1756.5	0.403 NS
800-1100	331	75	1286.0	0.465 NS
900-1200	291	62	1075.5	0.490 NS
1000-1300	212	44	611.5	0.176 NS
1100-1400	130	30	356.0	0.011 *
1200-max dist	65	13	66.5	0.152 NS

NS=not significant. *P<0.05, **P<0.001 ***P<0.001

Table 8. Standard error of values from Fig. 8. "Floating mean values of the number of bitten twigs per hectare, for every measured tree species"

Dist. to stn. (m)	Standard error 2006	Standard error 2007
100	440.8	2033.1
200	328.4	1199.1
300	442.9	833.2
400	630.7	473.6
500	677.3	397.4
600	503.3	314.0
700	368.9	262.3
800	297.5	270.5
900	369.4	263.4
1000	511.8	219.1
1100	527.6	336.0
1200	546.4	403.9
1300	209.7	501.9
>1300	132.7	321.8

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