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Do moose *Alces alces* spend more time and change their behaviour in areas of increased food availability created as a result of changed logging practices?

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Abstract

The Norwegian population of moose *Alces alces* causes huge a financial loss to the logging industry every year by browsing on young pine *Pinus sylvestris*. There is currently a conflict between the logging and hunting industries concerning which number of moose for which the population should be managed. One solution which may benefit all stakeholders is to provide an alternative food resource, which will allow for a large population of moose without increasing the browsing damage.

This study investigates if moose will spend more time in an area of eastern Norway where logging residues have been left in large piles to ensure that they remain above snow level, thereby providing a source of food in the winter. This method is known as slash treatment. Trail cameras were used in control and experimental areas to collect data on i) total frequency of moose visits, ii) the duration of each visit, and iii) changes to behaviour concerning browsing, resting, and walking between experimental and control sites. In addition data on snow level, stand age and time of year was compared with the results to identify additional factors which may determine the frequency of moose visits. Results show that the sites with increased food availability have a significantly higher frequency of moose visits, that the visits last longer, and that moose visiting the sites are more likely to browse and rest instead of just passing through. Snow level, the age of the stand and date all had significant impacts on the frequency of moose visits.

The result from this study will inform management decision, and provide evidence that availability as a result of changes in logging practices can sustain a large moose population without increasing the damage to young pines.

Acknowledgements

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1.0 Introduction

1.1 Historical population growth ï the *Alces alces* population in Fennoscandia

The Fennoscandian population of moose *Alces alces* has experienced an unprecedented growth since the 1960s, after the near extermination of the wolf *Canis lupus* population in the 19th and 20th centuries (Hörnberg 2001). Reliable information concerning the population size of Fennoscandian moose is historically derived from analysis of density indices, harvest density, seen individuals per unit effort, seen individuals density, and density of moose-vehicle collisions (Ueno et al. 2014). However, the most commonly accepted indicator of the population size remains the number of annually harvested individuals, which increased by over 2000% between the years 1900 and 2000 (Lavsund et al. 2003).

Moose is a migratory species and can travel great distances between their summer and winter foraging areas (Singh et al. 2012). It is also, however, also a very mobile species which introduces difficulties in understanding when migration starts and ends, and how migration strategies differ from normal foraging movement (Singh et al. 2012, Lindberg 2013, Moorter et al. 2013). Choice of migration strategy is heavily influenced by climate, predation risk, and human presence (Singh et al. 2012). Timing, duration, and distance vary between sexes and ages (Singh et al. 2012). Power lines have also been shown to have an effect on moose movement, both regarding migration and edge effect in foraging (Bartzke 2014). Resource availability has been found to be the most important driver for large-scale movement, though short-scale movement is mainly dictated by rapid local changes (Moorter et al. 2013).

Moose is a solitary species, the only exception being calves which will stay with their mother for up to two years (Jensen et al. 2013). This is reflected in their foraging behaviour: though forage availability and quality are still the determining factors, individuals show a preference for smaller patches where they can avoid conspecific interactions (Smeets 2014). They also appear to avoid red deer *Cervus Elaphus*, with which they partially share their winter food preference (Mysterud 2000, Johnsen 2012).

A popular management tool on the Fennoscandian moose population is selective culling; where the size of the population can be maintained by issuing hunting licences for old males only (Solberg et al. 1997, Solberg et al. 1999, Sæther et al. 2003). This method has had unexpected outcomes regarding a decline in male body mass (Solberg and Sæther 1994), antler size (Solberg and Sæther 1994), and a delay in parturition and associated calf body mass decreased (Sæther et al. 2003). Despite these unforeseen consequences, it remains the main management tool used to control the population.

One of the consequences of the large population of moose in Fennoscandia is an increase in animal-vehicle collisions. Police records report an average of 4500 collisions per year in Sweden alone, including 10-15 human fatalities (Seiler 2005). A common management tool to prevent this is to erect fences along roads, along with designated crossing sites. This seriously impedes movement for the moose population and causes an uneven distribution (Olsson et al. 2008). Moose biogeographical behaviour show avoidance of roads, but it is weakened in the late winter when the population faces depletion of food sources (Eldegard et al. 2012). A possible solution to this which is currently being investigated is to establish overpasses or to establish artificial feeding sites during winter to keep the population away from heavily trafficked roads (Olsson et al. 2008).

1.2 The hunting industry

Moose hunting is a deep-seeded cultural phenomenon in Fennoscandia, with meat being sold on the free market and land owners retaining the right to hunt on their own land (Storaas et al. 2001). The number of moose harvested annually reached 200 000 in the year 2000 (Lavsund et al. 2003). The annual hunt generates a large economic profit for many landowners (Storaas et al. 2001). The revenue from the hunting industry is large enough to cause animosity between landowners and recolonising predators, which are necessitating a change in harvesting strategy (Jonzén et al. 2013).

There is evidence to suggest that the high harvesting pressure on the Fennoscandian moose population has had impacts on the behavioural characteristics of the population (Sand et al. 2006, Chen and Skonhoft 2013, Ofstad 2013, Ericsson et al. 2015). Sand et al. (2006) found that re-colonising wolves *Canis lupus* had a higher predation success in Fennoscandia than comparable populations in North America, and hypothesised that the results were due to the defence strategy of Fennoscandian moose having been adapted to the hunting techniques used during culling. Their results were supported by Ericsson et al.

(2015) who measured behavioural response to dogs used during hunting, and found that individuals were more likely to flee than to front when exposed to a threat. It, therefore, supports that the behaviour of the Fennoscandian moose population is more adapted to predation by humans and brown bears *Ursus arctos* (Ericsson et al. 2015). Chen and Skonhoft (2013) suggested that the opportunistic nature of the harvesting behaviour is also affecting migration patterns. Landowners issue hunting licences to maximise the economic outcome, and a model was developed to show how moose will respond to the geographically varying hunting pressure (Chen and Skonkoft 2013). Also, it has been shown that site fidelity among the moose population is lower during the hunting season, which poses a management issue as policymakers are reliant on being able to predict the location of the population (Ofstad 2013).

There is selectivity among hunters on the individuals harvested; the selective culling management strategy has resulted in a strongly female-biased population, which has lowered the selection pressure on old and big males (Nilsen and Solberg 2001). Hunters appear to avoid females with calves, both to maintain the population by preserving fecund females and also because of the emotional stress associated with leaving a calf without a mother (Nilsen and Solberg 2001). This has created a selection pressure on pre-prime females (1-3 years old), which are more likely to be found without a calf (Nilsen and Solberg 2001). However, the selection pressure is lowered later in the season as calves leave their mother and prime females are again considered acceptable (Nilsen and Solberg 2001).

1.3 The logging industry ï damage to trees caused by the increased moose population

Fennoscandia is an area dominated by boreal conifer forest, which has been utilised by humans for millennia (Esseen et al. 1997). Within the last 100 years, however, logging in Fennoscandia has become highly mechanical, and is now one of the most efficient in the world (Esseen et al. 1997). The intensive and unvaried method of harvesting has been suspected of being a threat to biodiversity (Siitonen 2001, Kuuluvainen 2002), with some varied evidence of deterioration of lichen (Hämäläinen et al. 2015) and dense forest habitats (Imbeau et al. 2015). Intense browsing by moose can have a severe detrimental impact on the biodiversity, structure and regeneration of coniferous forest (Franklin and Harper 2016); an extensive study investigating 25 years of browsing damage found that the selection pressure created less diverse communities, as well as denser stands of lowered quality (Metslaid et al. 2013). These impacts are exacerbated by the intensity of the harvesting activity, and could be lowered with a decreased rate of extraction (Santaniello et al. 2016). Harvesting is, however, a cost-consuming activity and lower extraction rates come with a high economic cost (Santaniello et al. 2016).

Unlike the American north-western moose *Alces alces andersoni*, the Scandinavian moose eat primarily Scots pine *Pinus sylvestris* in the winter, the shoots of which constitute the main part of their winter forage (Rea et al. 2014). The consequent browsing damage on pine has for some time been a source of financial loss for the logging industry in Scandinavia. Browsing of the apical leader is a common browse damage by moose, which makes trees less suitable for economic harvesting (Bergquist et al. 2001). This is also the case with bark stripping, which makes the tree unsuitable for timber within three years due to decay (Randveer and Heikkilä 1996). The damage is aggravated by the expanding road network, which interferes with migration patterns. Moose are hesitant to cross roads, leading to a build-up of browsing damage in areas close to roads (Ball and Dahlgren 2002, Bartzke et al. 2015). Fences alongside roads are a common management tool to prevent moose-vehicle collisions, but limits movement further (Olsson et al. 2008). Moose are typically opportunistic foragers (Milligan and Koricheva 2013), but there is evidence to suggest that the monocultures of pine which have been created by the modern logging industry are causing intense browsing in certain areas (Edenius et al. 2002).

Moose can also cause a large impact in their summer foraging areas, however their summer food source is primarily deciduous trees, in particularly silver birch *Betula pendula,* downy birch *Betula pubescent,* rowan *Sorbus aucuparia* and aspen *Populus tremula,* few of which are harvested for economic gain (Sæther and Andersen 1990, Bergström and Danell 1995). It is therefore not relevant to this conflict. The browsing level is influenced by many variables, such as site productivity (Månsson et al. 2007), forage availability (Månsson et al. 2007), moose density (Andrén and Angelstam 1993, Månsson et al. 2007) and stem density (Andrén and Angelstam 1993, Cassing et al. 2006). Rebrowsing is common, which decreases the number of potentially damaged trees (Bergquist et al. 2003).

Being a migratory species, moose will travel between high altitude browsing areas in the summer, and more low-lying habitats in the winter (Andersen 1991). Hunting season in eastern Norway is in the early autumn, and so it is at the summer browsing areas that the landowners profit the most from issuing hunting licences. Those who own land in the low altitude winter habitats are more likely to profit from forestry, and it is these landowners who are experiencing the economic loss from browsing damage. It is difficult to calculate the exact economic gain and loss of browsing damage; total annual revenue for the land owners is calculated to be between US $ 70 million and $90 million, and costs to the logging industry from US $23 million to $80 million (Storaas et al. 2001). It is difficult to predict future costs as it takes several years for the browsing damage to affect the trees harvested (Nilsson et al. 2016).

1.4 Previously investigated solutions to the economic conflict

Many methods have been investigated in an attempt to solve the conflict of for how many individuals the Fennoscandian population of moose should be managed. One such method is to establish supplementary feeding stations, which is a commonly used management tool for large herbivores to mitigate conflicts with humans (Andreassen et al. 2005), increase wildlife productivity or increase the carrying capacity of the ecosystem (Putman and Staines 2004, Brown and Cooper 2006). It can also be implemented to increase the total food availability, thereby reducing the browsing on sensitive flora (Putman and Staines 2004, Brown and Cooper 2006). This is the case in the management of moose, where supplementary feeding stations are used with the aim of reducing the browsing impact on nearby stands of young pine (Gundersen et al. 2004, van Beest et al. 2010a), as a result of increased artificial food availability.

A recent study by Mathisen et al. (2014) however found that browsing damage by moose in eastern Norway on the landscape scale was not influenced by proximity to the feeding stations, and browsing of the leader stem was high both at a local and landscape scale. Also, browsing on the economically harvested Norway spruce *Picea abies*, which is typically avoided by moose, increased locally. It was therefore concluded that establishing artificial feeding stations is an unsatisfactory method of preventing browsing damage on pine (Mathisen et al. 2014). Milner et al. (2014) supported this view and investigated the many unintended consequences of supplementary feeding stations, including changes to demography, behaviour, vegetation, and the expected effect on other trophic levels, as well as the increased risk of disease transmission.

A more recent method to reduce reducing browsing damage is increasing the natural food availability within the ecosystem, whilst keeping the moose population at a stable level through culling regimes. One method used in Fennoscandia to improve yield and food availability is soil scarification. During this treatment, methods like ploughing, disc trenching, and inverting the humus layer are employed, aiming to facilitate a faster nutrient release from decomposing pine needles and improve seedling establishment and growth (Johansson 1994, Örlander et al. 1998, Hille and Ouden 2004, Johansson et al. 2006). However, soil scarification can also attract large herbivores, causing high levels of trampling, and is ,therefore, now also considered an unsatisfactory method of increasing yield (Ring 1996, Bergsten et al. 2001, Hille and Ouden 2004, Roturier and Bergsten 2006, Nikula et al. 2008, Nevalainen et al. 2016).

Another much more promising method of improving the food availability in the ecosystem is to increase the amount of logging residues, such as tops and branches, which are left onsite after final harvesting (Edenius et al. 2014). This is called slash treatment. The tops and branches contain a large amount of potential forage for moose (Månsson et al. 2010). Current harvesting operations leave only 5%-15% of shoots on logging residues available for browsing (Månsson et al. 2010). It has been shown that increasing residue availability can increase browsing (Heikkilä and Hårkönen 2000). Promoting the use of harvested areas for ungulate use can ideally relax the browsing pressure on fragile young pine stands where the most detrimental damage occurs (Bergquist et al. 2001). Edenius et al. (2014) investigated the importance of timing in harvesting and advised logging to take place in the early winter to maximise forage increase.

There is currently a large research project in eastern Norway organised by Hedmark University College, investigating the effect of the aforementioned methods of solving the economic conflict between the hunting and logging industries. This project is called the Forest and Moose Research Programme. It is currently focused on slash treatment and research is being carried out in cooperation with local landowners, logging personnel, and Statskog, the state-owned company responsible for the management of forest real estate.

Browsing has been measured in a variety of ways when investigating the utilisation of the harvested areas. Methods include pellet counts to determine the number of visiting individuals and species identification (Heikkilä and Hårkönen 2000, Edenius et al. 2014, Edenius et al. 2015), bitten shoot counts (Edenius et al. 2014), and a few attempts to quantify visits by track counts by the Forest and Moose Research Programme. However, research has yet to be carried out with the aim of investigate the behaviour of moose in areas of slash treatment, however.

1.5 Aims and objectives

This study aims to identify if moose prefer areas where changed logging practices, slash treatment, have created higher food availability over areas where logging has continued as before (control), to investigate if there are any changes in the behaviour between areas and which factors might influence that behaviour. This study will investigate preference by determining if the moose population spend more time in the treated areas throughout the winter season. This study will also determine if the behaviour of moose change between treated and untreated areas by investigating time spent in a stand by each moose and the number of individuals found to be browsing, walking, or resting. Variation in activity pattern will be compared to the snow level, time of year and the amount of time since treatment, to investigate if these factors influence the frequency of moose visits.

2.0 Method

2.1 Experimental design

This study functions as a part of Hedmark University Collegeœs Forest and Moose Research Programme and was carried out in southern Norway between January 1^{st} and April 30^{th}, 2015. The area and site selection, as well as site treatment, were decided on in cooperation with this project. Though the project has already included studies which look at browsing in the sites, these studies were primarily focused on counting bites and did not investigate other behaviours. This study is the first in the project to use trail cameras, allowing for data collection on the amount of time individuals will spend on the site and changes in behaviour.

A brief pilot study was carried out at Hedmark University College Campus Evenstad, where there is a pen with three adult moose. Cameras were places in different locations and heights around the pen and left overnight to test the motion trigger, range, and flash. Motion sensors were found to require approximately three metres distance or less to the individual and were, therefore, inadequate for the study. Range during the day was excellent but became very limited during the night. Flash only improved visibility to approximately five metres during the night. Data collection was therefore limited to daylight hours, though possible for most of the dawn and dusk period.

2.2 Stand selection

The areas selected were chosen to fit certain criteria; they must be dominated by forest, contain a large proportion of pine in pure or mixed stands, contain a mix of stands of different ages, be large enough to establish approximately 10 stands in each area (approximately 30-50 km^2), and contain wintering areas for moose without having extremely high moose densities.

Two logging areas were selected in accordance with the aforementioned criteria: Gravberget in the Våler Municipality and Plassen in the Trysil Municipality, both in the Hedmark district. The stands were selected due to the desired composition of tree species, their location in the winter range of the Hedmark moose population, their large size and the sporadic human settlements which made them deemed representative of many areas of Norway. The areas were managed by landowners cooperating with the Forest and Moose

Research Programme. All stands in the relevant area were visited as they became available after logging from December 2014 to March 2015, with six experimental stands and three control stands in Gravberget and four experimental stands in Plassen.

2.3 Site treatment

The slash treatment was the independent variable of this study. In treated areas pine residues were left in piles after harvesting, which were large enough to stay partially above snow level (Figure 1). This was done so the branches and tops would freeze together, thereby providing the resistance moose needs to eat the shoots. The creation of the piles was done by the logging machine operators at the same time as the site was logged. Piles were 1-3m tall and remained above snow level at all times; if this was not the case, the stand would not be counted as treated. No changes were made to regular logging practices in control stands, where logging residues were left on the ground and typically covered by snow at the next snowfall (Figure 2). Data on stand type (final or thinning), age, size, dominant tree species, snow level, and pile height, width and quality was collected to ensure comparable results.

Figure 1: A pile of logging residue which will remain above snow level and be available as a food source throughout the winter. The creation of these piles was the key element of the experimental treatment (Sletten 2015).

Figure 2: A thinning control stand after snowfall. The logging residues have been covered by snow and are no longer available for browsing (Sletten 2015).

2.4 Cameras

Two trail cameras, both of the model Wingcam II TL were placed on trees in each stand, angled to cover as much of the stand as possible without overlapping with one another. The cameras were placed more than 5m from the edge of the stand to avoid edge effect and were put in place as soon as possible after logging ceased. The cameras took 1 picture every 5 minutes from 5 am to 8 pm, based on daylight hours in March. Camera GPS position was recorded, and memory cards were collected every two weeks.

There were initially some problems with snow and frost on the lens which resulted in fully or partially obscured pictures. Plastic roofs were created from oil canisters to avoid this (Figure 3, Figure 4).

Figure 3: Camera without plastic roof after snowfall. The lack of protective roofs caused pictures to be fully or partially obscured by snow, resulting in many pictures being discarded (Sletten 2015).

Figure 4: cameras with protective plastic roofs to avoid the lens being obscured by snow (Sletten 2015).

Seven cameras disappeared from their locations during three weeks in February and were considered stolen. Hedmark University College, whose well-marked car was used during the study, carries out a lot of research on wolves which is a matter of contention in rural areas. It was therefore suspected that the camera theft was sabotage. To circumvent this, cameras were locked to the tree with a coded bicycle lock and moved as high up the tree as possible using a ladder. The plastic roofs were also painted brown to make them harder to detect from a distance. In addition the researchers started to go out of their way to stop and talk to the local people they encountered in the field about this study in order to make it clear that they were not investigating wolves. Camera disappearance desisted soon after.

In very cold conditions (<-30^{o}c) some of the cameras began taking pictures erratically, resetting the time and date or ceased to function completely. It was assumed this was due to a technical error or moisture within the camera, as others functioned well regardless of temperature. Where the camera had reset its time and date correct data could be recovered by calculating memory card start date and time of sunrise or sunset. Pictures taken irregularly were still accepted, providing there were less than 10 minutes between each picture.

Researchers were moving within the stand using skis or snowshoes when data was collected on the size and quality of the piles. It was observed that moose tracks tended to follow the researcherôs tracks. This is a potential source of bias.

2.5 Data collection

Pictures were marked as ófailedô if enough of the picture was obscured to allow an individual moose to go undetected, usually as a result of snow on the lens (Figure 5). Pictures were also marked as ófailedô if humans, typically the researchers, could be seen in the stand as this was assumed to deter moose from visiting (Figure 6). Failed pictures were not included in the analysis. There were 62 095 clear pictures in treated stands and 30 414 clear pictures in control stands, which represent 215 and 105 days of monitoring respectively.

Figure 5: A picture taken by one of the cameras when the lens was partially obscured by snow. These pictures were marked as ófailedô and omitted from the analysis as there may have been undetected moose in the picture (Sletten 2015).

Figure 6: Researchers in a control stand. Pictures showing humans in the stand were marked as ófailedô and omitted from analysis (Sletten 2015).

Data was collected on the number of pictures with or without *Alces alces*, in relation to the time of day, time of year, and type of stand. Once an individual had appeared in the stand, usually alone, it was possible to follow its movements despite the 5-minute gap between pictures. Data was collected on the amount of time spent on the stand by the individual, the number of other individuals in the stand, and age and sex when discernible (Figure 7). Data was also collected in Boolean categories on if the individual was observed walking, browsing, resting, or multiple of those three while it was within the stand (Figure 8).

Figure 7: A female moose with a calf in a control stand before snowfall. The sex of visiting individuals was indiscernible except when females could be seen with offspring (Sletten 2015).

Figure 8: a picture taken by the trail camera in a treated area, with three adult moose. Two of the moose are browsing. The piles of logging residue seen here remained available as a food source throughout the winter (Sletten 2015).

Occasionally an individual would lie down in the stand until nightfall, and seemingly still be lying there in the morning. Due to the 9 hour gap between 8 pm and 5 am without pictures, it was impossible to know if it was the same individual and it was therefore counted as two separate moose observations. Data was collected on snow level every 14 days. The dates of harvesting were supplied by the landowners.

2.6 Statistical analysis

The total number of pictures taken by one camera between the hours of 5 am and 8pm in a single day was used as the unit of observation effort. The unit of effort was then combined with the number of pictures per day in which one or more moose could be observed to generate the dependent variable; Moose Observations per Unit Effort (MOPUE). The Mann-Whitney U test was used to test the null hypothesis of no significant change in the MOPUE between experimental or control stands throughout the study. The Mann-Whitney U test was also used to test for change in the other dependent variables; the amount of time an individual will spend in the site, and the number of individuals observed to be browsing, resting or walking in control or experimental areas. T-tests were used to test for correlations between the MOPUE in treated and untreated areas in relation to changes in snow depth, time since logging, and time of year.

3.0 Results

In total, 216 individual moose were observed in the stands; 187 in treated stands and 29 in control stands. The quality of the pictures taken did not allow for sex identification, except in the cases where females and calves could be seen together. This was observed 16 times, 12 in treated stands and 4 in control stands.

3.1 Changes in MOPUE between treated and untreated areas

Moose Observations per Unit Effort (MOPUE) was calculated based on the number of pictures per day in which a moose could be observed. Overall MOPUE was significantly higher in areas which had received slash treatment (Figure 9) (U=36 870, $p<0.001$). This means that individual moose are much more likely to be found in the treated stands and that the treated stands are preferred at a population level. This indicates that the treatment is fulfilling its intended purpose; to create a food supply which will be utilised by the moose population.

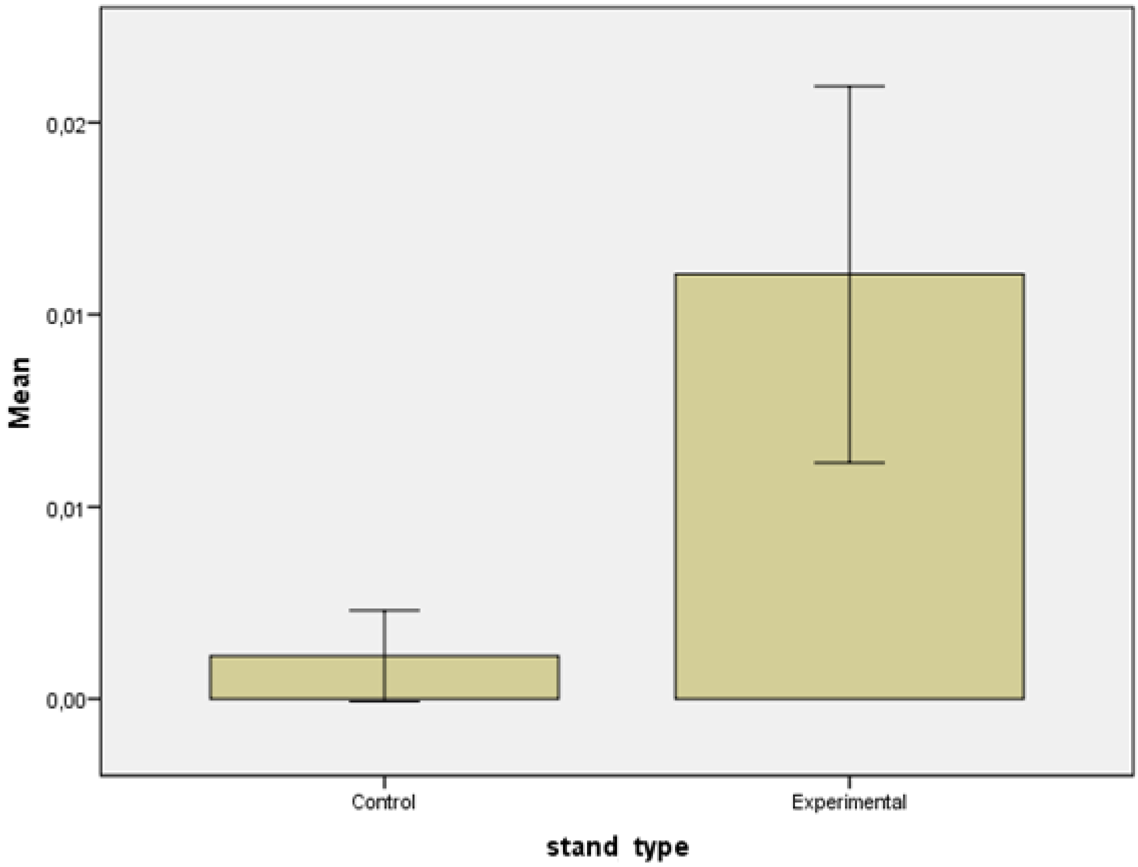

Figure 9: MOPUE (Moose observations per unit effort) in treated (experimental) and untreated (control) stands. Diagrams show mean MOPUE with error bars at +/- 2 SE.

3.2 Time spent in stand per individual moose

Mean time spent continuously in the stand per individual was 34 minutes in untreated stands, and 62 minutes in treated stands (Figure 10). The difference was significant ($U=3991$, $p<0.001$).

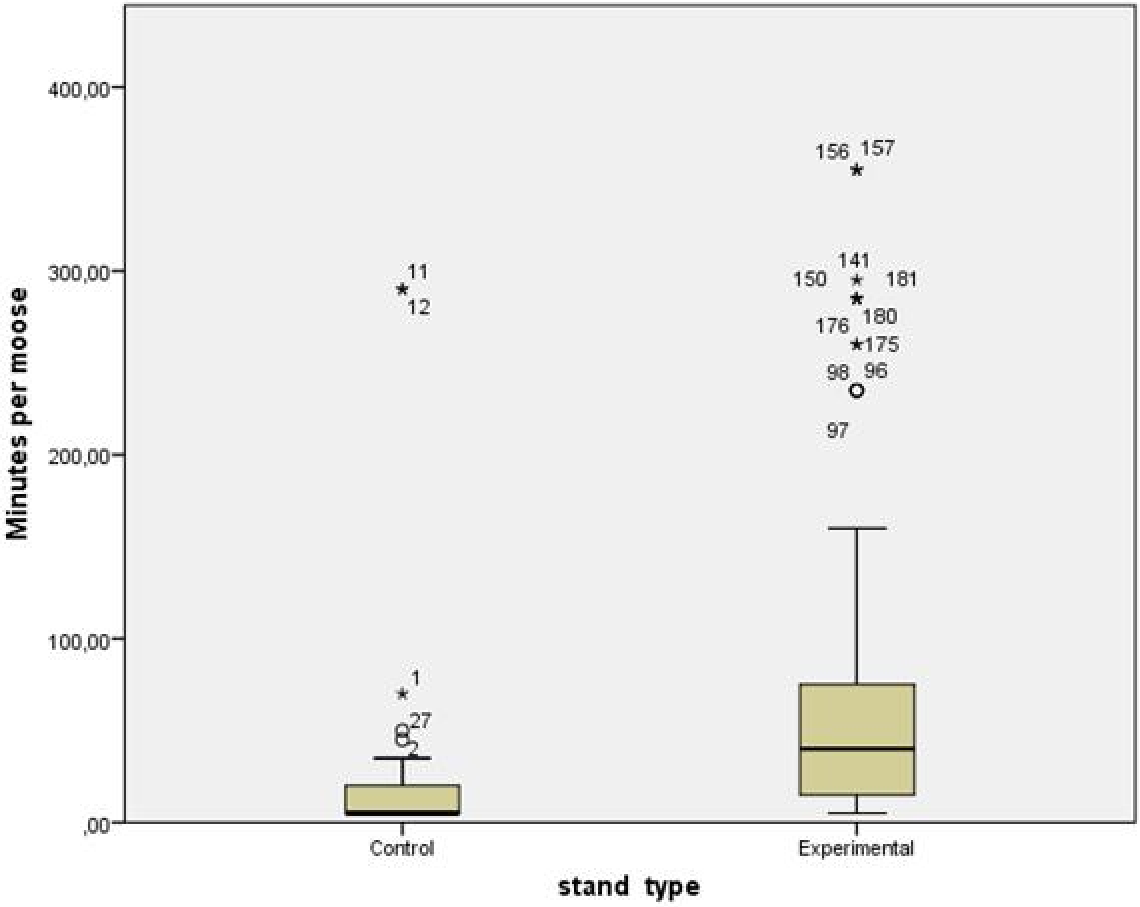

Figure 10: Minutes spent continuously in the stand by individual moose in treated (experimental) and untreated (control) stands. Box plot diagrams give the medians, 25 and 75% quartiles, interquartile range, and outliers.

3.3 Changes in number of individual moose found to be browsing, walking or resting in treated and untreated areas

The number of individuals found to be walking, browsing and resting was compared between treated and untreated areas (Figure 11). Significant differences were found in all categories. Significantly more individuals in treated areas could be observed browsing ($U=6898$, $p<0.001$), as well as resting ($U=3302$, $p<0.05$). More individuals in untreated areas could be observed walking ($U=1561$, $p<0.001$).

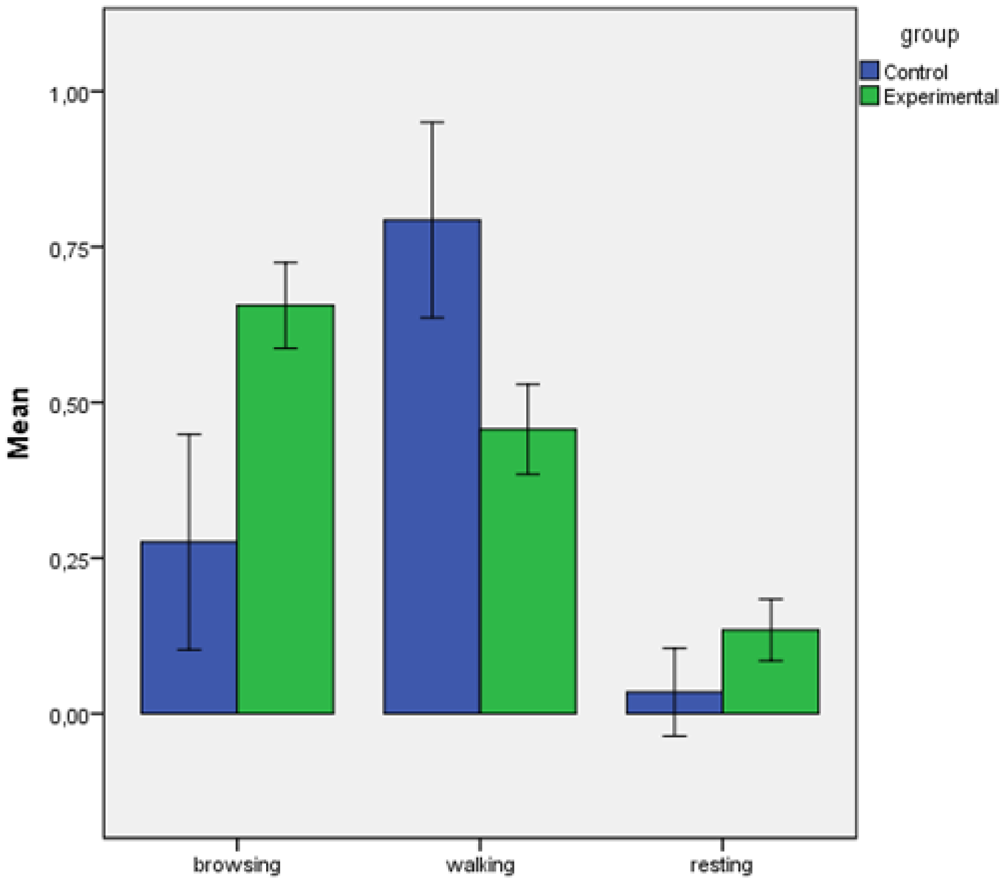

Figure 11: Differences between treated (experimental) and untreated (control) stands given by the proportion of individuals found to be displaying different behaviours. Means and 95% confidence intervals are shown.

3.4 Correlation between MOPUE and snow depth

The Spearmanȇs rho revealed a statistically significant relationship between MOPUE and snow level, showing a positive correlation ($r=.148$, $p<0.001$).

3.5 Correlation between the time since harvesting and MOPUE

The Spearmanȇs rho showed a statistically significant negative correlation between MOPUE and time passed since logging finished ($r=-.183$, $p<0.001$).

3.6 Correlation between date and MOPUE

The MOPUE was found to increase by a statistically significant amount towards the end of the season, between January 1st and April 30th, 2015 ($r=.170$, $p<0.001$).

4.0 Discussion

4.1 Overall Moose observations per unit effort

The results show that the moose population prefer areas with increased food availability as a result of changed logging practices. It indicates that individual moose are not deterred from visiting areas, despite the high levels of human activity during logging and the invasive nature of the harvesting. Human activity has previously been shown to be the main cause of disturbance to moose, but the results indicate that this is not a deterring factor in the areas of increased food availability (Stankowich 2008). It is concurrent with results from previous studies which suggest that food availability is the governing factor of moose distribution and biogeographical behaviour (Vivas and Sæther 1987, Dussault et al. 2005).

4.2 Time spent in stand continuously by individual moose

The increase in time spent by each individual once at the site makes for an important change in behaviour. Moose are typically opportunistic foragers who move great distances while eating (Vivås and Sæther 1987, Vivås et al. 1991), and this tendency increases especially in areas of high food availability, resulting in fewer shoots eaten in each location (Vivås and Sæther 1987). This behaviour can appear to be suboptimal, but arises from moose being a highly mobile species (Vivås et al. 1991). The results from this study concerning the time spent continuously in one stand by individual moose indicated that moose change their behaviour in the treated areas, and could mean that even more forage from the treatment is being utilised per individual than what was initially expected. This is an unintended outcome of the treatment, as the method was developed to sustain a larger number of individuals, not to attract the population or to make individuals spent more time in designated areas. Nevertheless, it supports the treatment in ensuring that the increase in food availability is being utilised (Edenius et al. 2014).

4.3 Changes in the number of individuals found to be browsing, walking and resting

Browsing was shown to be more common in the treated stands, which was expected as food may not be available whatsoever all in untreated stands. The result concerning resting is strengthened by the results from the time spent by each individual in the site, which indicates that individuals in treated areas stay longer. In concurrence with the results concerning resting, this is likely because they chose to rest before resuming feeding. This result is relevant because the amount of forage being utilised can be effectively doubled if individuals feel comfortable enough in stands to rest and then feed a second time before leaving the stand. Edenius et al. 2014 hypothesised this and noted that the pellet groups found in commercially harvested areas seemed to indicate that the moose population utilised the areas for other activities in addition to foraging, such as resting. The results of this study go some way to confirm this hypothesis. There is little published material to compare to the results of this study due to the novelty of slash treatment as a management tool.

When combined with the knowledge that individuals tend to stay for a shorter time in the untreated areas, the results concerning the number of individuals walking in untreated areas is unsurprising. It can seem like individuals in untreated stands do not stop to browse, but simply walk through. Individuals in untreated stands may still be foraging more than the cameras have detected as they pass through, but they will not have stopped to browse for any extended time. This contradicts previous studies, where moose have found to be more mobile in areas of high food availability (Vivås and Sæther 1987, Vivås et al. 1991). This study did, however, take place on a small spatial scale, investigating the direct mobility in small stands only. It is likely that mobility on the landscape scale was affected differently, and landscape scale mobility may have increased in accordance with previous studies (Vivås and Sæther 1987, Vivås et al. 1991). This requires further investigation.

4.4 The increase of MOPUE with increased snow levels

An increased snow level was originally expected to cause a decrease in MOPUE as forage became less available and cost of travelling increased (Lundmark and Ball 2008). The results of this study contradict this, and could be the result of moose, which is a species adapted to deep snow, not being as deterred by the snow level as what was expected (Telfer and Kelsall 1984). In addition, snow levels in the logging sites were always somewhat lower than the outside of the site, so it is possible that as higher snow level made travel elsewhere more physically demanding the preference for areas of comparatively lower snow level became stronger (Telfer 1978).

Irrespective of the mechanism responsible, the result indicates that increased snow levels will not result in less use of the sites. This can make the timing of the logging less crucial, and potentially lessen the need for new logging sites throughout the winter to sustain forage availability, as Edenius et al. 2014 suggested being a necessity. The results from this study cannot however guarantee that browsing remains high after snowfall, only that individuals visit the area with a higher frequency; it is possible that individuals return to areas where snow is lower and there has been food available in the past, to find that the forage has become unavailable since then. This site fidelity has been observed in many cervids and similar animals though less so in moose (Linell and Andersen 1995, Igota et al. 2004, Wittmer et al. 2006, Crampe et al. 2007, Webb et al. 2010) and has in the past been shown to be less in winter. It may have increased as a result of the increased food availability (Beest et al. 2010b). It has been observed in red deer *Cervus elaphus* in similar conditions, and may be occurring at a larger degree in moose in this study as food availability has increased (Beest et al. 2013). This can be investigated by counting bites, and must be studied before these conclusions can be considered final.

4.5 Decrease in MOPUE with time since logging

The hypothesis that moose will cease visiting logging sites as the shoots dry and become less attractive can be supported by the negative correlation between the age of the stand and the MOPUE. Although it could also be due to the food resource being depleted rather than degrading in quality, it contradicts the result Edenius et al. 2014 presents which indicate that forage consumption increased with the age of the stand. The results of this study may also be because the stand is easier to find initially, as the harvesting is a loud and intrusive process; some of the logging staff reported that they would frequently see individuals at the edge of the stand, waiting for logging to finish. This is supported by studies concerning moose behaviour in relation to road overpasses, which suggests that moose as a species is less disturbed by prolonged loud noises (Laurian et al. 2012, Grilo et al. 2015).

The decrease in MOPUE as the stand ages can, depending on the cause, have implications for management which may use slash treatment as a tool in the future. If the food source is depleted as a result of changes in the browsing behaviour of moose it will indicate that the maximum amount of forage in the stand is being utilised. This can be expected to lead to reduced damage to young pine trees (Edenius et al. 2014). If however the forage is drying and becoming less attractive, individuals are likely to return to browsing on young pine trees as studies show they do around supplementary feeding stations (Beest et al. 2010c). In this scenario management will be relying on a steady supply of recently logged stands throughout the winter, as suggested by Edenius et al. 2014, though not for the same reasons.

4.6 The increase in MOPUE later in the winter season

The increase in MOPUE towards the end of the study period (April) is likely to have coincided with the onset of spring migration. It may be that our study site was partially located on a migration route, which could be the sole cause of this trend. Some studies, however, suggest that moose are particularly selective of their habitat choice during migration when energy demands are higher (Ball et al. 2001). It is possible that the increase in MOPUE towards the end of the study period is the result of this increase in selectivity. More research is required to conclude this, but if found to be true it could create a useful tool in manipulating moose distribution during migration. Moose have been found to show a preference for pine over that of other tree species which makes the approach even more promising regarding preventing damage to young stands of pine not only during winter but also during spring migration (Histøl and Hjeljord 1993). Previous studies on the slash treatment have concluded that harvesting should occur in the late autumn or early winter to increase the amount of forage being utilised (Edenius et al. 2014). The results of this study indicate that this conclusion may need revisiting, as the frequency of individuals visiting the site increases towards the spring migration season. The location of the treated stands on a home range scale can, consequently, be considered another factor which may have had a large impact on the amount of forage being utilised towards the end of the season (Mathisen et al. 2014).

4.7 The impact of the results of this study on the economic conflict

The results from this study constitute the basis of a strong argument for using slash treatment to establish more areas of increased food availability. This increase in food availability will initially only create a population response, where more individuals are expected to survive the winter when food availability and therefore survival becomes less dependent on snow level (Mech et al. 1987). This will aid the long-term purpose of the treatment, reducing browsing damage, unless the number of moose harvested in the relevant areas is adjusted accordingly. If the number of individuals harvested annually is increased while treatment continues, browsing damage can be expected to decrease, as suggested by Mathisen et al. 2014. This treatment, therefore, can have a positive impact both on the logging industry and the hunting industry. The results of this study indicate that simple adjustments to current logging practices can create food resource which will be utilised by the moose population, and when combined with careful population estimates and culling to prevent population increase this can be expected to mitigate the negative economic impact on the logging industry (Mathisen et al. 2014). The results from this study indicate that slash treatment may succeed in achieving supplying the moose population with an alternative food resource, unlike previously failed methods like supplementary feeding stations (Mathisen et al. 2014) and soil scarification (Ring 1996, Bergsten et al. 2001, Hille and Ouden 2004, Roturier and Bergsten 2006, Nikula et al. 2008, Nevalainen et al. 2016). At the same time, landowners will have a greater opportunity to issue hunting licenses within management aims, as this strategy is depending on the population size staying relatively constant. The results of this study indicate that slash treatment is a management tool which can benefit all stakeholders.

4.8 Possible negative aspects of treatment

Though the slash treatment appears to be effective in its purpose, to generate forage which the moose population will utilise, there could be unexpected negative aspects of the treatment. Some of the logging staff at the time of logging voiced concerns that the branches and top which were now left available usually would be used to create a steadier surface on which the harvesting machines could operate. Instead, the machines now stood on bare snow and soil, and as they have a considerable weight it is possible that this can lead to soil damage and affect wood and undergrowth regeneration. This view is supported by a detailed study which documented the increase in dead wood destruction and diversity loss associated with a higher harvesting intensity (Santaniello et al. 2016). This detrimental impact on the forest environment could have long-term negative effects on the logging industry, which may go unnoticed for several years. A species of special concern is bilberry *Vaccinium myrtillus* which is an important foraging plant and can be adversely affected by high-intensity harvesting (Wam et al. 2010). Other common impacts of logging which may be aggravated by slash treatment are changes in ground vegetation, with several years lag in response by some species (Bergstedt and Milberg 2001). It is recommended that research is done on the soil quality for an extended period after treatment to ensure that there is no drastic decline. Logging staff also voiced concerns that the action of leaving branches and tops available will take up enough time to constitute an important economic cost to the logging industry due to the cost of keeping machinery. The economic loss to the logging industry has previously prevented management techniques from being implemented (Putz et al. 2008). Calculations will be required to ensure that landowners are not losing more money than they expect to gain by limiting browsing damage, though initial calculations by the Forest and Moose Research Programme indicates that the loss will be minimal.

4.9 Manipulating behaviour

Though primarily focused on creating an alternative food resource which will be utilised by the moose population, the results from this study indicate that the experimental treatment seems to have resulted in several behavioural changes. Primarily concerning resting time and lowered mobility, these changes could make it possible to use this treatment as a management tool to directly manipulate behaviour. This is relevant because there are more factors influencing the browsing damage than simply foraging availability: distribution and spatial behaviour is also important (Gundersen et al. 2004, Mathisen et al. 2014). In addition animal-vehicle collisions are an important problem, especially during winter (Neumann et al. 2012). More research is needed, but it is hopeful that slash treatment can be used to go some way to influence these factors. By making the population apparently less mobile and less prone to ranging, it may be possible to manipulate the biogeographical distribution of the population and centralise the population in desired areas such as areas far from young pine stands (Mathisen et al. 2014). Depending on the spatial use it may be more productive to locate the treated stands closer to vulnerable forests, to provide an alternative site-specific food source. Similarly, the forest in close proximity to roads often have high levels of browsing damage (Ball and Dahlgreen 2002), and designating treated stands in these areas may decrease the pressure on sensitive areas. However, depending on the response in spatial use by the population, treated areas could also act as a tool to attract individual moose away from busy roads to avoid collisions (Dussault et al. 2005).

4.10 Advantages of using trail cameras

Using trail cameras has had many advantages over previously employed methods of measuring browsing for the particular aims of this study. Theoretically, the use of trail cameras avoids the necessity for researchers to spend a lot of time in each stand, which will make the samples more representative of non-monitored situations and avoiding scaring large and medium-sized mammals away from the study site (Lyra-Jorge et al. 2008). This occurred to a less degree in this study, as data on bites were being collected simultaneously. The presence of humans will impact the behaviour of the moose, so it is vital to keep it to a minimum when trying to investigate behaviour (Andersen et al. 1996, Stankowish 2008). This is a theoretical advantage of using trail cameras but was somewhat less in this particular study.

The use of cameras in behavioural studies provides invaluable data when studying large and shy ungulates, because cameras allow for collecting data on many behavioural variables which other methods do not allow for (Lyra-Jorge et al. 2008). For this reason, many studies on ungulate behaviour use cameras (Altendorf et al. 2001, Kuijper et al. 2009, Tobler et al. 2009, Kuijper et al. 2014). These variables include how long each individual would stay in the stand, how many individuals were there at the same time, differences in age and sex, the presence of calves and yearlings, and which time of year the studied species show the highest degree of activity. In this study it allowed for a total count of the moose visiting the stand, and revealed changes in behaviour which no other method of data collection, aside from direct observation could have investigated. Such changes include the number of individuals found to be browsing and the time spent continuously in the stand. Collecting data from the pictures taken did, however, take a large amount of time compared to simply counting bites; after collecting memory cards it took 2 researchers 2 ï 3 days to look at the pictures and write down all results. In this capacity it can be very resource-draining, though previous comparisons has concluded that camera monitoring is more cost-effective and precise than other methods (Lyra-Jorge et al. 2008).

4.11 Shortcomings of this method

Trail cameras, while allowing for data collection on a great number of behavioural variables and activity, cannot measure browsing in terms of weight and energy output. The amount of forage going out of the stand, and therefore the exact amount of browsing damage which can be prevented, must be measured by other methods such as those used by Edenius et al. 2014. Trail cameras can only measure the amount of time individuals spend in stands, and behaviour must be judged to the best of the ability of the researcher which will always remain somewhat biassed. Also, the cameras could only take pictures of a satisfactory quality during daylight hours, and since moose is primarily a crepuscular species some data might have been lost (Lowe et al. 2010).

This study has only investigated moose preference of treated logging sites over that of untreated ones. To have a real impact on the ongoing economic conflict it is crucial to also investigate the damage to young pine stands in relation to distance from the logging site, throughout the winter range of the moose population. Only in this way can it be investigated if this method of treatment is in fact causing a decrease in browsing damage (Hörnberg 2001, Bergquist et al. 2001, Ball and Dahlgren 2002, Bergquist et al. 2014). Such a study has yet to be carried out, but could also provide valuable context on the changes in behaviour detected in this study and would be necessary to make informed management decisions.

4.12 The potential for future research

The possible preference of females with calves for treated areas

The number of females with calves observed in this study was not great enough to derive any statistically significant results (n=16). Nevertheless, 75% of all females with calves observed were found in the areas of increased food availability. In the absence of any predator population worth mentioning food availability becomes a key factor in calf survival and thus it is likely that females with young will seek out these areas (Cedersund et al. 1991, Boutin 1992). If this can be empirically proved that females with calves show a preference for treated areas it would provide a stronger argument for the establishment of these areas of increased food availability, as a female with calves typically brings with her several mouths which would otherwise have been causing damage to living pine trees. This is also important in the light of the increasingly female-biased moose population, which is a result of selectivity among hunters (Nilsen and Solberg 2001).

The influence of areas of increased food availability on the spatial use of the moose population

Areas of increased food availability such as those used in this study can be seen as key resources within an animalŝ home range, not unlike waterholes or supplementary feeding stations (Bailey et al. 1996, Mathisen et al. 2014). It is therefore not unlikely that the creation of these areas will lead to changes in the spatial use of the population on a landscape scale, as has been observed around supplementary feeding stations (Mathisen et al. 2014). This potential effect will be an unintended consequence of increasing natural food availability through slash treatment, and may have consequences for the geographical location of browsing damage. It may have a similar affect to that of artificial feeding stations, such as changes in demography, vegetation, other tropic levels, and an increased risk of disease transmission (Milner et al. 2014). Similarly, it may have some effect on the migration routes chosen by the population, though change in migration patterns in moose can take several generations (Andersen 1991). If it is found to have an effect on migration pattern, it may be relevant for animal-vehicle collisions. It is recommended to investigate this potential effect on the biogeographical behaviour of the population before increasing food availability on a large scale by using slash treatment.

The increased likelihood of individual moose resting overnight in stands of increased food availability

A shortcoming of this study was the inability to collect data during the night. On several occasions an individual would arrive in the stand near dusk, and browse and rest until nightfall. The next morning an individual could be seen in the same part of the stand, where it would continue feeding. These were counted as separate observations, as it could not be proved to be the same individual. If a study could be designed to monitor the site during night time in order to quantify the exact behaviour of each visiting individual, a more precise result of the behavioural characteristics could be obtained (Houston et al. 2013, Lauper et al. 2013). In this case, it could show that several visiting individuals felt comfortable enough to rest overnight in the stand, and feed twice. This would effectively double the amount of forage utilised by each individual, and such a study could give a stronger argument for the establishment of such areas.

The potential of treated stands of supporting several individual moose simultaneously

Though not statistically significant due to a low sample size, it appears that the treated areas more frequently had several individuals visiting at the same time. Moose is a solitary species and usually does not associate with other individuals except during mating season and when rearing young (Jensen et al. 2013). It is possible that the increased food availability made individuals less focused on avoiding conspecifics. This which would allow for a larger rate of forage consumption, as more individuals visited the stand simultaneously instead of avoiding it (Mysterud 2000, Johnsen 2012, Smeets 2014). A statistically significant result could create a better argument for the establishment of treated stands.

Additional research needed to maximise the positive impact of the treatment

As this and similar studies have shown the positive effect of slash treatment on the food availability after logging (Edenius et al. 2014), it is perhaps time to investigate the specifics of the site treatment to optimise results. This study used a variety of stand types, such as stands of a mixed tree species composition of pine and Norway spruce as well as pure pine stands, and both final logging and thinning. It did not however have a large enough sample size to investigate the differences between them. Future research should investigate the differences in effect associated with logging types, location, and species composition, so that the positive outcome of increasing food availability by changed logging practices can be maximised.

4.13 Conclusion

This study has identified that moose prefer areas of increased food availability created by slash treatment over those created by current logging practices. It has also found that moose will spend more time continuously in these areas and that moose are more likely to browse and rest when in these areas. Results show that the activity of moose in the treated areas is positively influenced by the snow level and negatively influenced by the age of the treated area. They will also show increased activity towards the onset of the spring migration. The possible impact of the results of this study on the ongoing economic conflict has been discussed, as well as the potential negative or unforeseen impacts and the advantage of using cameras when investigating the behaviour of large herbivores. Further research has been suggested.

5.0 Summary

There is an economic conflict in Fennoscandia between the logging and hunting industries. The hunting industry wishes to manage for a large number of moose so as to maximise the economic profit from issuing hunting licences. The logging industry finds that large numbers of moose create extensive damage on economically important young pine trees, which makes the trees unsuitable for harvesting. Moose is a migratory species, and the conflict is between the landowners whose land is in the summer range of the moose population when the annual hunting occurs and the land owners whose land is in the winter range when moose prefer to browse on pine. Management is now concerned with finding a solution which allows for a greater number of individuals of the Fennoscandian moose population while not causing further damage to young pine trees.

The main proposed solution to the conflict is to increase the food availability and by extension the carrying capacity of the ecosystem, but there are several ways of doing this. Supplementary feeding stations with hay have been used in eastern Norway for an extensive period, but this method has not been found to influence browsing patterns on the landscape scale. It only affected browsing patterns in the immediate vicinity of the feeding station from pine to spruce, which is also harvested economically. Soil scarification has been attempted to manipulate the growth rates of young pine stands but has been found not to be the most effective method as well as simultaneously creating other management problems.

This study instead investigates the practice of leaving residues available for browsing after harvesting, known as slash treatment. This has been shown to increase the availability of browse, and several projects are currently investigating whether the moose population utilises the new food resource. This study is the first to use trail cameras to investigate moose behaviour in the slash treatment areas.

The moose population showed a statistically significant preference for the treated areas, and could be found there much more often. The results of this study indicate that the areas of increased food availability as a result of changed logging practices will be utilised by the moose population.

In addition to quantifying the preference of the moose population for treated areas, this study found certain changes in behaviour from treated to untreated sites. Moose in treated areas stayed twice as long in the stand as moose in untreated areas and were much more likely to stop and browse as well as to lie down and rest. Moose in control areas were more likely to be found walking.

This postulates that the slash treatment is a useful management tool. The increase in food availability as a result of slash treatment will be utilised by the moose population, as this study shows, but the treatment can also result in behavioural changes. The increase in time spent in treated areas, as well as the increased likelihood of moose resting in treated areas, can potentially be used as a tool to manage the location and time budget of the moose population.

Though potentially important for solving the economic conflict this study relies on further investigations before slash treatment can be implemented as a management tool on a large scale. It is important to investigate if the spatial distribution of the moose population is affected by the location of the treated sites. It is also vital to investigate how much browse is going out of the site, to calculate the approximate increase in carrying capacity and the potential for a population increase.

This study will make an important contribution to the ongoing economic conflict between the hunting and logging industries. The results can contribute to making slash treatment a powerful management tool.

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7.0 Appendices

APPENDIX A

Evaluative supplement

The main strengths of this project have been its novelty in investigating behaviour in a setting where behaviour has never directly been measured before, and its implications for an economically important and very real problem.

Another strength of this study was that it was greatly aided by the support, expertise and equipment from Hedmark University College. This made it possible to carry out the study on a much larger scale than what would otherwise have been possible within the time and capacity constraints. The study would otherwise have been carried out using much fewer cameras and in a much smaller area, and less time could have been devoted to data entry. Fewer questions concerning behaviour could, therefore, have been answered.

Behaviour of wild populations is complicated to investigate, but this study managed to use the available field cameras and technical expertise as well as the resource of placement students to collect a great deal of data. The combination of available placement students and available resources such as the cameras and the car supplied by Hedmark University College was very fortunate and allowed for the detailed data collection necessary to discuss behavioural questions of the wild moose population. The combined effect made this study a much larger investigation than could otherwise have been made within the scope of an undergraduate dissertation.

The ongoing economic conflict is important to solve to find the best possible management of the Fennoscandian forests. This study directly ties into this conflict, and the results will give real-world impacts. It will also open up for a more extensive investigation into how moose behaviour changes with management aiming to improve food availability, and how behavioural changes can be utilised to maximise the profit gained from those changes. The study has identified areas which are important to investigate further to reach a satisfactory conclusion to the success of slash treatment as a management tool, primarily the impact on the biogeographical distribution of the moose population.

The main limitation of this study was a lack of a solid method of data collection from the pictures taken from the start. On several occasions, the researchers had to go back and start over as the method developed and new categories were added to the data sheets. Though making the data collection time consuming and occasionally frustrating, the process led to a lot of reflection on the investigation process. This was highly educational, and towards the end of the study the researcherôs ability to create a well-planned and thought out study had greatly improved.

Another constraint on the study was that the skill of the researchers improved over time. As the study progressed camera placement became better and better, and the development of the plastic roofs meant that more and more cameras delivered clear pictures. Initial results were low quality as the skill of the researchers needed time to develop, however by the end of the study very high-quality data could be obtained.

Considering the time it took to develop these skills, it would have been ideal if the study period was longer than three months, or, due to seasonality constraints, could be repeated the following winter. The amount of time to develop the necessary skills and prepare the study sites would ideally deserve a much longer study period devoted to it.

One of the unforeseen problems of the study was the disdain that met with the researchers from the local people encountered in the field. Hedmark University College is famous for the research done on the wolf population, which is a hugely controversial subject in rural Norway. A colleague doing research in the same area at the same time reported having all four tyres of his car slit with a knife when doing fieldwork. However, after the theft of 7 of the cameras used the researchers began actively engaging with the local community by always stopping to talk to people encountered in the field and also to seek out the logging staff who were preparing the logging sites, to make sure that everyone knew that the aim of this study was to aid the logging and hunting industries and not to weigh in on the wolf debate. At the same time, the researchers were forced to get creative in developing methods to protect the cameras, such as camouflage paint and bicycle chains with locks. Either by education or increased protection, the theft soon stopped. Witnessing first-hand the impact of openness and misinterpretation with local people was a hugely educational experience for the researchers.

While undertaking the fieldwork, the researchers were very independent. Having been equipped with all necessary equipment including a car and unlimited petrol they were working with a high level of autonomy, only checking in with the supervisor at Hedmark University College every two weeks. Having such a large amount of independence required high levels of maturity on the researchersô part, which developed rapidly at the beginning of the project.

Since data collection for other projects run by the Hedmark University College was taking place at the same time, there were two researchers who did their fieldwork simultaneously and in the same area, with a high degree of cooperation. The two researchers involved in data collection lived in close quarters during the 3-month span of the study. This required both of them to develop excellent interpersonal skills, the ability to cooperate effectively, and a solid partnership. The environment in which the study took place could occasionally be very demanding, and both researchers learnt the importance of being a reliable partner. The researchers also came from different countries, which created an understanding about international differences and the ability to cooperate with people with a different cultural background.

Though the study underwent several changes from the original design, the outcome is a valuable and insightful piece of research. It will benefit an ongoing real-world conflict, giving a scientific background for managers to evaluate available management tools. It has also been a very rewarding experience for the researcher, who has developed many important skills along the way.

APPENDIX B

Interim interview comments

Independent Research Project Interim Interview : Agreed Comments Form

Student Name: Magnhild Sletten	Programme: Ecology and Wildlife Conservation
Date: 06.10.2015	IRP Title: An alternative method of monitoring alces alces browsing damage in an experimental treatment area
Supervisor Name: Anita Diaz	

During the meeting the student presented her originals aims and proof of data collection. The quality of the data was verified and the method was confirmed to be sound. The student and the supervisor further broke down the aims into managable objectives and discussed different alternatives for presenting the data.

Two copies of this form are needed – student to retain one copy the other is to be handed in to the student admin office C237.

Student Signature:	Supervisor Signature: