Effects on Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) in the sapling stage from ungulate browsing

Author: Markus Velin

Email: ma7705ve-s@student.lu.se

Course: BIOK01 Spring 2019

Supervisor: Fredrik Widemo

Co-supervisor: Bengt Hansson

Abstract

Ecosystem services from forestry are highly valuable and may be limited by ungulate browsing. Thus, I investigated the impact and seasonality of browsing on Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) using seasonal exclosures. Slightly more than 10 % of the pine trees were browsed at the top shoot, compared to spruce where top shoot browsing was almost non-existent. Pines that had a browsed top shoot had a significantly lower height to width ratio. Further, for pine there was a significant difference between the seasonal browsing in height to width ratio, where the exclosure that prevented ungulate browsing all year around had the highest ratio while the exclosure that was open for browsing all year around had the lowest ratio. Results also showed, for both pine and spruce, that height, width, and number of shoots seemed to be more affected by different sites than from ungulate browsing. For a tree individual, both species also showed that there were strong correlations between both height and diameter and number of shoots. To sum up, this study showed that top shoot browsing limits height to width ratio in pine and might also limit growth. It also showed that the browsing distribution between species can be very uneven, since spruce was hardly not browsed at all. Furthermore, the study also showed that different sites can have a strong impact on growth.

Introduction

About 70 % of Sweden's land surface consists of woodland, whereof 80 % of this area is actively used for forestry (SkogsIndustrierna, 2019). Today, Norway spruce (*Picea abies*) is the most abundant tree species in Sweden, followed by Scots pine (*Pinus sylvestris*) (Skogsstyrelsen, 2019). Sweden is the world's second largest exporter of paper, wood pulp and sawed timber (SkogsIndustrierna, 2019). This makes forest products economically important, not only for the country, but also for the non-industrial forest owners, since 50 % of the forest is privately owned (Lämås and Fries, 1995).

For private forest owners damage from ungulates, in terms of browsing, bark stripping, and fraying by antlers (Gill, 1992), causes economic losses (Ingemarson et al., 2007). For example, it has been observed previously that coniferous trees, that have been browsed at the top shoot, decreased in growth and changed their morphology to a more shrub-like appearance (Bergqvist et al., 2013), which will later on have a negative effect on timber quality and forest products (Ingemarson et al., 2007). Earlier research has shown that game related production loss on pine widely exceeds the production loss on spruce (Kalén and Bergquist, 2004).

Due to the economic value of forests, conflicts are often created between the forestry and other interest groups. One example is the necessity of finding trade-offs between ecosystem services from game and disservices in the form of damage on production trees, for example from browsing (Boman, 2014 and Ezebilo et al., 2012). The monetary value of hunting has an estimated value of 4.5 billion SEK and ungulates make up most of this value (Fredrik Widemo, verbally). In addition to values from hunting, ungulates also provide cultural ecosystem services and provide important structuring effects in the ecosystems (Mattson et al., 2014 and Widemo et al., in press)

The competitive interest among hunters to have large populations of ungulates for hunting, as well as the interest from forest owners to keep their forest undamaged, are strong (Ezebilo, 2012 and Ezebilo et al., 2012). Over 50 % of the hunting land-owners takes account of the game in their forestry and can allow a decrease in timber production (Widemo et al., 2013). At the same time, forest owners that not hunt themselves, often want to minimize damage from ungulates (Ezebilo et al., 2012) and maximize timber growth, while hunters in general want larger ungulate populations (Ezebilo, 2012). This difference in interest between forest-owners and hunters, often leads to conflict (Ezebilo, 2012).

The condition of a forest stand, for example soil type, topography, microclimate etc. generates a special site productivity, which is a measurement of how much stem volume the site can produce per hectare and year (Skogsstyrelsen, 2012). Site productivity, together with factors as for example height of the ground vegetation, can have a large impact on both mortality and growth for all plants, and therefore a different growth pattern can be observed in different sites (Palmer and Truscott, 2002). Some sites are more suited for pine, while others are better for spruce (Skogsstyrelsen, 2012). Earlier research has shown that competition from vegetation or neighboring trees affects an individual's height to width ratio, with higher ratio with relatively high competition and a lower ratio with low competition (Opio et al., 2000).

According to previous research, spruce and pine are most prone to browsing, and therefore most exposed to damage, from the sapling stage up to a height of about five meters, which corresponds to an age of 10-15 years (Kalén and Bergquist, 2004). However, damage through browsing is unusual on trees above four meters (Bergqvist et al., 2013). At heights above four meters only larger ungulates, such as moose (*Alces alces*) and red deer (*Cervus elaphus*), will browse on lateral shoots (Bergqvist et al., 2013). An adult moose could browse on top shoots up to a height of 2.8 m, while other ungulate species only can reach the top on lower trees (Bergqvist et al., 2013). This top shoot browsing will lower a trees height, but not width (Palmer and Truscott, 2002). Further, there has been shown that there is a negative correlation between top shoot browsing and sapling height (Bergqvist et al., 2001 and Palmer and Truscott, 2002). According to Kalén and Bergquist (2004), pine has the highest amount of edible biomass (approximately 0.6 kg per tree), for moose, at a height of 3.5 m. If comparing the palatability between pine and spruce, pine must be considered as most sought after and therefore most exposed to browsing (Kalén and Bergquist, 2004).

It is well-known that moose often damage pine through browsing during the winter months. Thus, until a couple of years back, most of the research has been focused on the effects of winter browsing, on pine. Today, studies show that summer browsing equals winter browsing when it comes to damage and reduced wood quality in production trees, especially in pine (Bergqvist et al., 2013). Few studies have included the summer browsing and different sites when it comes to the response in growth for production trees, such as pine and spruce. Additional studies are needed to understand the effects on growth in height, width and number of shoots in a tree species for different sites and browsing by ungulates in different times of the year.

I investigated the spatial and temporal variation of height, width, number of shoots and top shoot browsing in pine and spruce. I hypothesize that:

Height, width and number of shoots will differ between sites (H1)

Browsing will affect height and number of shoots, but not width (H2)

Browsing will be more common on pine than on spruce (H3)

Browsing will be more common during winter than during summer (H4)

The aim of this study is to see how ungulate browsing during different seasons affect production trees, which is important knowledge to be able to create a sustainable co-management of game and forestry.

Method

Data were collected between 2/4 and 11/4 – 2019, on ten different sites located north of Nyköping in the province Södermanland. The sites were clear cut in 2013-2014 and after that planted or naturally regenerated with either spruce or pine in 2014-2015.

Each site consists of four different experimental treatments, so called exclosures. One permanent exclosure (fenced all year around) (Figure 1), one control exclosure (open all year around), one summer exclosure (fenced only during the vegetation period; early April-late September) and one winter exclosure (fenced only during the non-vegetation period; late September-early April).

Figure 1. This picture is showing one of the permanent exclosures. This 14 x 14-meter square is closed with fence all year around, for the purpose to see the effects on growth for both pine and spruce without any ungulate browsing.

Each exclosure is 14 x 14 m with a buffer zone of 2 m from the fence. The purpose of the buffer zones is to eliminate factors as shading from the fence and the effects on the ground from the heavy machines that was used to put up the poles for the fence.

Each exclosure was divided into four quadrants (Figure 2). Within each quadrant (except from the buffer zone) individuals have been marked since the start of the experiment in 2015. If a site has been planted or naturally generated with pine, ideally four pines and only one spruce has been marked within each quadrant of an exclosure. If spruce has been planted, the number of marked individuals per species have been reversed. Of in total ten sites, seven were planted with spruce and three were planted/naturally regenerated with pine.

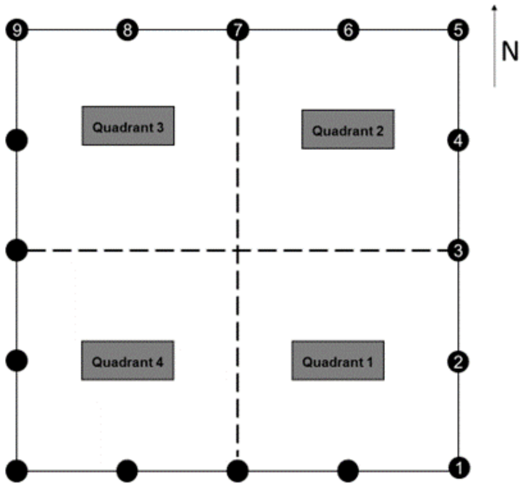

Figure 2. A sketch illustrating how an exclosure was divided into four quadrants. ©Sabine Pfeffer

For all marked individuals we measured height (cm) using a steel ruler and, width (mm) 5 cm above the ground using digital calipers. Furthermore, we counted the total number of shoots (>1 cm long; sensu. Ånöstam, 2017) and the number of branches. Also, we noted if the top shoot had been browsed since the vegetation period of 2018 (yes or no). We only counted total number of shoots from one randomly chosen spruce per quadrant, when there was more than one marked individual (using a random number generator). However, we counted the total number of shoots on all marked pine trees. We were two persons that alternated between counting the number of shoots to avoid a decreasing quality during long working days due to a lack of energy and concentration.

We entered the collected data into Excel and then exported it into SPSS version 25 in which all statistical analysis was performed. Because of not normally distributed data for height, width, and number of shoots, I log-transformed the data to come closer to a normal distribution before testing my hypotheses. After the log-transformation, the data were close enough to normally distributed given the relatively large sample size. To test the hypothesis that there will be a correlation between height, width and number of shoots, I used a linear regression. To test for the difference in the amount of top shoot browsing between the four treatments I used the non-parametric Kruskal-Wallis (K-W) test. For all the remaining hypotheses I used a General Linear Model (GLM) with the post-hoc Tukey test.

Results

With an increasing height, the number of shoots in pine increased significantly (n= 406, R^2 = 0.734, $p < 0.001$) (Figure 3). A similar significant relationship was found between pine width and the number of shoots (n= 406, $R^2 = 0.844$, $p < 0.001$) (Figure 4).

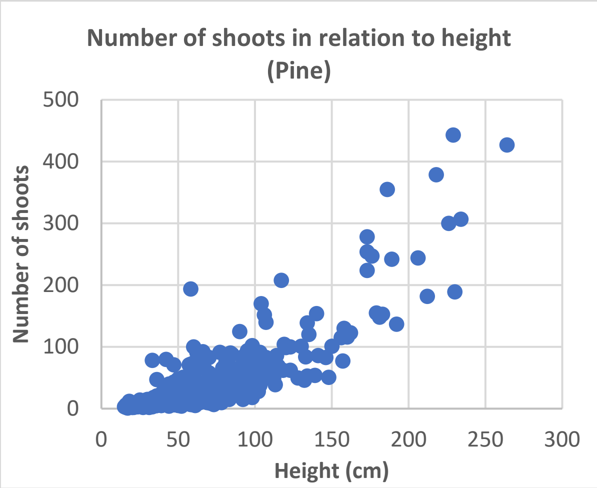

Figure 3. The relation between non-transformed values for height, measured in centimeter, and number of shoots for pine.

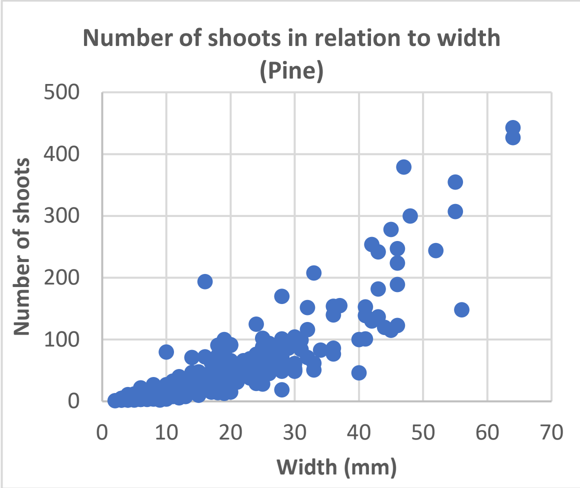

Figure 4. The relation between non-transformed values for width, measured in millimeter, and the number of shoots for pine.

Spruce showed a similar strong correlation as for pine. With an increasing height, the number of shoots in spruce increased significantly (n= 142, $R^2 = 0.806$, $p < 0.001$) (Figure 5). A similar significant relationship was found between spruce width and the number of shoots (n= 142, R^2 = 0.927, $p < 0.001$) (Figure 6).

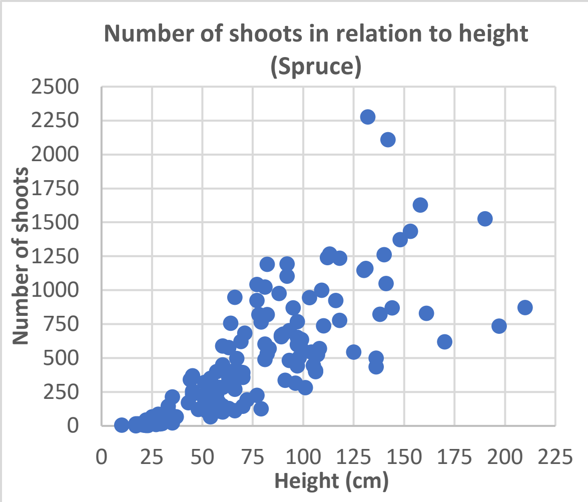

Figure 5. The relation between non-transformed values for height, measured in centimeter, and the number of shoots for spruce.

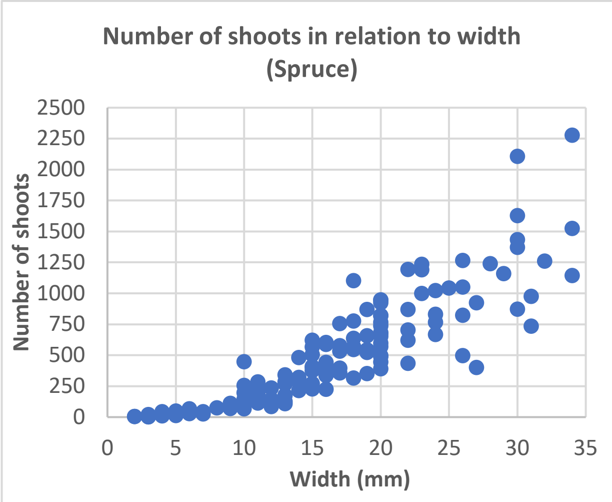

Figure 6. The relation between non-transformed values for height, measured in centimeter, and the number of shoots for pine.

Height of both, pine (GLM, n= 406, F= 3.71, p = 0.004) and spruce (GLM, n= 142, F=14.0, p < 0.001), differed significantly among sites. However, neither pine (GLM, n= 406, F= 0.344, p = 0.793) nor spruce (GLM, n= 142, F= 1.53, p = 0.230) showed any significant difference among treatments.

A similar pattern was observed for width. Width of both, pine (GLM, n=406, F= 6.11, p < 0.001) and spruce (GLM, n= 142, F= 12.8, p < 0.001), differed significantly among sites. However, between treatments neither pine (GLM, n= 406, F= 0.635, p = 0.597) nor spruce (GLM, n= 142, F= 1.15, p = 0.347) showed any significant difference.

Total number of shoots of both, pine (GLM, n= 406, F= 5.63, p < 0.001) and spruce (GLM, n= 142, F= 13.9 p < 0.001), differed significantly among sites. But as well as for height and width, the number of shoots did not differ significantly for neither pine (GLM, n= 406, F= 0.480, p = 0.699) or spruce (GLM, n= 142, F= 1.51, p = 0.233) among treatments.

Height to width ratio for pine, differed significantly among treatments (GLM, n= 406, F= 5.44, p = 0.004) (Figure 7) but not between sites (GLM, n= 406, F= 0.938, p = 0.510). For the difference in treatment the post-hoc Tukey test showed that there was a significant difference between “permanent” and all three other treatments, and a significant difference between “summer” and “control” (Figure 7).

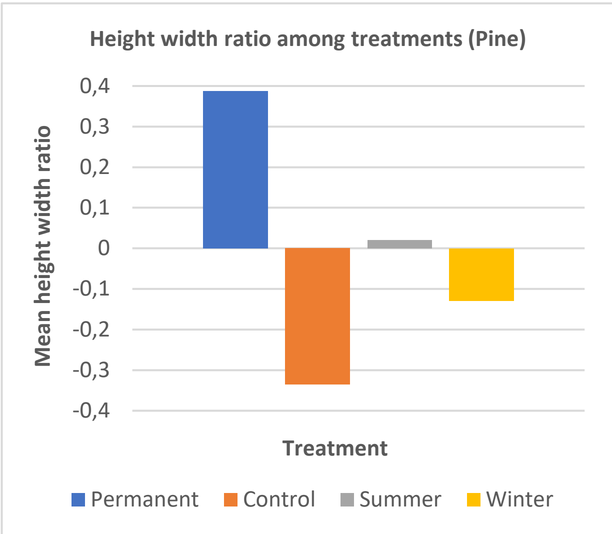

Figure 7. Bar graph illustrating the mean height to width ratio for the different treatments with transformed values. Positive values indicate a higher height to width ratio and vice-versa for negative values.

Height to width ratio for spruce significantly differed among sites (GLM, n= 142, F= 3.76, p = 0.005) (Figure 8) but not for treatments (GLM, n=142, F= 1.07, p = 0.380).

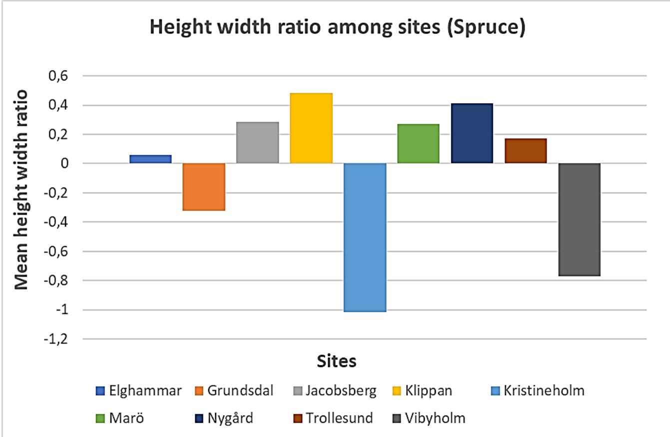

Figure 8. Bar graph illustrating, with transformed values, the mean height width ratio for the different sites. Positive values indicate a higher height to width ratio and vice-versa for negative values.

Number of shoots in relation to height and width together, did not significantly differ among sites for neither pine (GLM, n= 406, F= 0.828, p = 0.596) nor spruce (GLM, n= 142, F= 0.666, p = 0.717). Among treatments, no significant difference was found neither for pine (GLM, n= 406, F= 1.22, p = 0.313) nor spruce (GLM, n= 142, F= 0.314, p = 0.815).

Height to width ratio between individuals with a browsed top shoot and those that were not browsed, for different sites, showed for pine (GLM, n= 405, F= 5.75, p = 0.010) significantly lower height to width ratio for individuals with a browsed top shoot. Only one spruce had a browsed top shoot, making the corresponding analysis redundant for spruce.

There were a significant (K-W, n= 405, H= 21.8, p < 0.001) difference between the treatments in the amount of pines with a browsed top shoot. Significant differences were found between permanent-control (p = 0.006), permanent-summer (p = 0.003), winter-control (p = 0.010) and winter-summer (p = 0.006), where summer and control had the highest amount of pines with a browsed top shoot (Figure 9). In summer treatment, 11 out of 105 (~10.5 %) individuals had a browsed top shoot and for control 10 out of 99 (~ 10.1 %) were browsed (Figure 9). For spruce, 1 out of 142 individuals had a browsed top shoot (frequency of 0.70 %), which makes the corresponding analysis redundant for spruce.

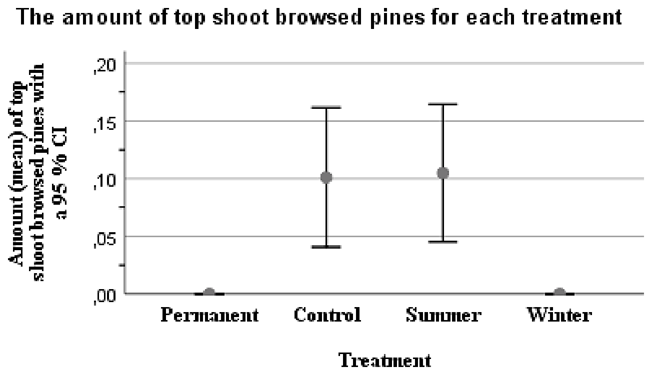

Figure 9. Graph illustrating the mean amount (%) of top shoot browsed pines with a 95 % confidence interval (CI) for each treatment. Strong significant (p<0.001) difference between the treatments, with highest amount of top shoot browsed pines in summer and control.

Discussion

There were significant differences in height and width between sites for pine and spruce respectively. That there is a difference between sites for height and width is rather expected. Factors like site productivity, age, and the difference between planted and naturally generated seedlings will differ between sites and will probably have a great impact on height and width. The importance of nutrients for growth have been shown before, where an increase in nutrients boosted growth (Bergh et al., 1999). There was no significant effect from treatment on neither height or width across sites for pine nor spruce. This shows that for height and width the combined effects of site seem to be more important than ungulate browsing.

Due to the strong impact on tree height and width that site has, and the strong correlation between height, width and the number of shoots for both pine and spruce, there should also be a difference in number of shoots between sites. Testing this theory confirmed that site had a strong impact on the total number of shoots while ungulate browsing did not.

When testing for differences in height to width ratio, pine showed a significant difference between treatments. The permanent treatment had the highest height to width ratio while the control had the lowest (Figure 7). An individual with a browsed top shoot will have a lower height to width ratio, because it decreases in height but not in width when it loses its top (Palmer and Truscott, 2002). Therefore, one explanation for the results for treatments could be the difference in ungulate density, and therefore browsing intensity, between sites. Within a site where the browsing intensity is high the effects from treatments will be stronger, with a lower height to width ratio in treatments like control, which is open for browsing all year around. On the other hand, in sites where the browsing pressure is low, the effects of treatments will be low because it does not matter in what time of the year the exclosure is open, there will still be a very low amount of browsing. For spruce, top shoot browsing was almost non-existent.

In contrast to my hypothesis, only spruce differed significantly in height to width ratio between sites, and for that there could be several reasons. Since high competition results in higher height to width ratio compared to sites with low competition (Opio et al., 2000), one explanation might be that competition from vegetation or other trees differed between sites. Reasons that pine did not differ in height to width ratio between sites could be many. For example, there could have been a smaller difference between the sites for pine when it comes to ground vegetation, number of neighboring trees etc. and maybe most important could be the fact that out of these ten sites only three of them had the right conditions for producing pine. Furthermore, neither pine nor spruce differed in number of shoots in relation to height and width together, in neither sites nor treatments. There could be several reasons for the absence in difference, but it seems like neither ungulate browsing nor different site properties might have any strong effect on number of shoots in relation to height and width together.

Results showed for pine that an individual with a browsed top shoot had a a lower height to width ratio. This test is very interesting and important in that way that it might indicate a negative effect from browsing on an individual's height. According to Palmer and Truscott (2002), if an individual is browsed at the top only one time it will set back the growth of about one year, with the additional effect of the top not being as long as the original would have been. Yet, with a continuous browsing on the same individual, the damage might be more severe. Based on previous research, an earlier browsed tree is more likely to be browsed again

(Bergqvist et al., 2013). For spruce, as mentioned before, we only had one single individual with a browsed top shoot which made the corresponding analysis redundant.

For pine, the highest amount of recently top shoot browsed individuals were found in the treatments; summer and control. This result was expected since they were the only treatments that had been open and available for ungulate browsing since the last vegetation period, and therefore could have had a freshly browsed top shoot. This does not show in which season the highest amount of top shoot browsing occurs, but it confirms that when the exclosures are closed they prevent ungulates from browsing. However, it showed the frequency of top shoot browsing during the winter, where roughly 10 % of the pine trees had a browsed top shoot while browsing on spruce was almost non-existent. In comparison, Bergquist et al. (2013) showed in a study a top shoot browsing frequency of 9,8 % after early summer browsing on pine.

Furthermore, there was a strong correlation between height, width and number of shoots for both pine and spruce. This relation could depend on several different factors. For example, older trees, which are often taller and have a broader width, might have had more time to grow, and therefore produced more shoots to increase its green mass for photosynthesis.

To conclude, a lot of different factors might affect the growth on both pine and spruce. To start with, site will probably have a great impact on growth. Scarification, soil properties, topography, ground vegetation, microclimate etc. will to a great extent decide the capacity for tree growth. This study showed the effect of this, with differences in both height and width between different sites. This difference in site properties together with other factors seem to affect growth more than ungulate browsing does. Despite difference in growth between sites, the study showed that there is, independent of growth rate, always a strong correlation between height, width and the number of shoots for both pine and spruce. A more detailed study on which site properties that have the highest impact could be an important and interesting angle for future research.

When it comes to damage from top shoot browsing done by ungulates there seem to be a negative effect in height to width ratio, while from this study, the damage done on spruce seems to be non-existent. We also saw that for pine, during the period from late September-early April, the frequency of top shoot browsed individuals was slightly more than 10 %.

Because of the increasing browsing damages in the Swedish forestry, further research within this topic will be needed. In addition to this study, the effects of browsing on lateral shoots, the effects from browsing on deciduous trees etc., will be important issues that needs to be further investigated for the future, to be able to create a sustainable co-management of game and forestry.

Acknowledgement

I would like to thank my supervisor Fredrik Widemo and Sabine Pfeffer for all the help with field work, statistics and commenting on my thesis.

References

Bergh, J. Linder, S. Lundmark, T. Elfving, B. 1999. The effect of water and nutrient availability on the productivity of Norway spruce in northern and southern Sweden. Forest Ecology and Management. 119: 51-62.

Bergqvist, G. Bergström, R. and Edenius, L. 2001. Patterns of Stem Damage by Moose (*Alces alces*) in Young *Pinus sylvestris* Stands in Sweden. Scandinavian Journal of Forest Research. 16: 363-370.

Bergqvist, G. Bergström, R. and Wallgren, M. 2013. Summer browsing by moose on Scots pine. Scandinavian Journal of Forest Research. 28:2, 110-116.

Boman, M. (red.). 2014. Skogens nyttigheter. Future Forests rapportserie 2014:4. Sveriges lantbruksuniversitet, Umeå. pp. 20.

Ezebilo, E.E. 2012. Forest Stakeholder Participation in Improving Game Habitat in Sedish Forests. Sustainability. 4: 1580-1595.

Ezebilo, E.E. Sandström, C. and Ericsson, G. 2012. Browsing damage by moose in Swedish forests: assessments by hunters and foresters. Scandinavian Journal of Forest Research. 27: 659-658.

Gill, R.M.A. 1992. A Review of Damage by Mammals in North Temperate Forests: 1. Deer. An International Journal of Forest Research. 65: 145-169.

Ingemarson, F. Claesson, S. and Thuresson, T. 2007. Costs and benefits of moose and roe deer populations. Skogsstyrelsen. pp. 10-23.

Kalén, C. and Bergquist, J. 2004. ”Forage availability for moose of young silver birch and Scots pine”. Forest Ecology and Management. 187: 149-158.

Lämås, T. and Fries, C. 1995. Emergence of a biodiversity concept in Swedish forest policy. Water, Air, and Soil Pollution. 82: 57-66.

Mattson, L. Boman, M. and Ezebilo, E.E. 2014. More or less moose: how is the hunting value affected? Scandinavian Journal of Forest Research. 29: 170-173.

Opio, C. Jacob, N. Coopersmith, D. 2000. Height to diameter ratio as a competition index for young conifer plantations in northern British Columbia, Canada. Forest Ecology and Management. 137: 245-252

Palmer, S.C.F. and Truscott, A.-M. 2002. Browsing by deer on naturally regenerating Scots pine (*Pinus sylvestris* L.) and its effects on sapling growth. Forest Ecology and Management. 182: 31–47.

SkogsIndustrierna. 2019. Fakta & nyckeltal. https://www.skogsindustrierna.se/skogsindustrin/skogsindustrin-i-korthet/fakta--nyckeltal/ Retrieved: 2019-03-27

Skogsstyrelsen. 2012. Skogsskötselns Grunder och Samband. https://www.skogsstyrelsen.se/globalassets/mer-om-skog/skogsskotselserien/skogsskotsel-serien-1-skogsskotselns-grunder-och-samband.pdf Retrieved: 2019-05-03

Skogsstyrelsen. 2019. Skogsträd.
https://www.skogsstyrelsen.se/mer-om-skog/skogstrad/ Retrieved: 2019-05-03

Widemo, F. Elmhagen, G. Liljebäck, N. Viltets ekosystemtjänster - en kunskapssammanställning till stöd för värdering och förvaltning. Naturvårdsverksrapport, under tryckning.

Widemo, F. Ericsson, G. and Bergström, R. 2013. Jagande markägare tar hänsyn till viltet.
https://svenskjakt.se/uncategorized/jagande-markagare-tar-hansyn-till-viltet/
Retrieved: 2019-05-23

Ånöstam, F. 2017. Timing of ungulate browsing and its effect on sapling height and the field layer vegetation. Swedish University of Agricultural Sciences, Umeå. 2017:4. pp. 27.