Regeneration establishment after conversion to multi-layered stands in Jämtland, central Sweden

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Abstract

In 2010, different thinning treatments were applied in two Norway spruce (Picea abies) stands of 45 and 46 years in Jämtland, central Sweden. The goal of the main treatment was to achieve a high diameter variation with the long- term goal to develop a multi-layered stand. In some study plots, soil scarification and fertilization measures were carried out to promote early natural regeneration. The purpose of this master thesis was to quantify the very early establishment and development of forest regeneration in both study stands.

Five years later, the regeneration was measured again. Data from 2010 and 2015 were used to investigate if there was any difference between the two stands, if sufficient regeneration had occurred and if the different thinning-, fertilization-, and scarification treatments or the forest floor cover had an influence on recruitment, height increment and mortality of naturally regenerated Norway spruce and birch seedlings.

The differences in species of seedlings between the two stands were rather large. While more Norway spruces ha^{-1} regenerated in one stand, the regeneration of birch ha^{-1} was a lot bigger in the other stand.

Regeneration was rather poor, especially the regeneration of Norway spruce in a Norway spruce- dominated forest. In average, there were only about 1600 Norway spruce seedlings ha^{-1} on the plots which was very little compared to other regeneration studies and taking into account that every Norway spruce on a subplot was counted as a seedling, which included seedling sizes between 2.5 and 99 cm. However, calculating with a general ingrowth ratio, the current regeneration might still provide sufficient ingrowth in the future.

The influence of treatments was small five years after the initiation of the experiment. The only significant result was that seedlings had smaller height increment on control plots, while no clear conclusions could be drawn on the mortality or recruitment. If the forest floor was dominated by mosses, the regeneration of both Norway spruce and birch were smaller than expected. Other important factors for the regeneration were probably wet soil and good light conditions for birch and coarse woody debris to germinate on for Norway spruce.

In addition to the results presented, the value of this study is the documentation of the initiation and very early regeneration development of this experiment.

Keywords: Norway spruce, recruitment, mortality, height increment, conversion thinning, multi-layered forest

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1. Introduction

1.1 General introduction

In Sweden, about 42% of the forest area is covered by Norway spruce (*Picea abies Karst.*) (Skogsstyrelsen, 2016), which is often managed in a system of planting, thinning from above and below to maintain trees with good quality and a homogenous stand structure and a final clearcut (Wallentin, 2007). There are good reasons for this, as this type of management is generally considered to have low costs, quick return of the invested money, the possibility to choose tree species and to utilise genetic improvement when replanting the stand (Miller and Spoolman, 2011; Nilsson et al., 2010).

At the same time, even-aged stands often have a very low biodiversity and it is a common claim that even-aged stands of Norway spruce are sensitive to wind damages, especially after thinnings late in the rotation (Miller and Spoolman 2011; M. Hanewinkel 2013).

Beside the fact that the main tree species in northern Sweden is Scots pine, a pioneer species, another issue has to be taken especially into account in this part of the country. As all trees are removed during a clear cut, lichen cover is reduced, which strongly decreases the amount of available fodder for reindeer (*Rangifer tarandus*), especially during winter times (Berg, 2010; Wibe and Jones, 2013). This has since the large-scale introduction of clearcuts to northern Sweden in the 1950s led to conflicts with the Sami people (Berg, 2010; Sandström et al., 2006; Widmark, 2006). The Sami people are exclusive owners of reindeers and have a special interest that the forests provide enough lichens, while forest owner (in northern Sweden often larger companies) are interested in efficient forest management and good economy which often includes clearcuts (Berg, 2010).

As it is claimed that selective cuttings did not severely influence the availability of lichens in the time before clear cuts (Berg, 2010; Esseen et al., 1996), this type of forestry might become interesting again for the big forest owners in northern Sweden to avoid further conflicts with the Sami people. Because of that, an economically good method to converse even-aged stands to multi-layered stands might be very interesting to have.

1.2 Study and hypotheses

In early 2010, two experiments were established in Jämtland, Sweden, with the goal to test different thinning methods which had the goal to "promote diameter differentiation, single-tree stability and initiate natural regeneration" by heavy removals, soil scarification and fertilisation and to develop a multi-layered forest within the next 50 years (Drössler et al., 2014). The long-term goal of this intervention was to convert even-aged stands into multi-layered stands.

In all thinning treatments, 60% of the basal area was removed by a first commercial thinning. On some plots, fertilisation and/or soil scarification were performed as well (Drössler et al., 2014). In addition, all other tree species than Norway spruce higher than 1.3 m were removed from the experimental plots. After that, the regeneration and forest floor cover types on the plots were recorded.

In 2015, new regeneration and the development of the regeneration which already was present in 2010 were re-measured. Three hypotheses were tested using the combined data from 2010 and 2015:

- H1: There was no difference concerning Norway spruce regeneration in height classes of Norway spruce seedlings and forest floor cover types between the two stands.
- H2: There has been sufficient regeneration of Norway spruce.
- H3: Different silvicultural treatments and forest floor cover types had a positive influence on the establishment and height increment and a negative influence on mortality of Norway spruce and birch.

2. Material and method

2.1 Forest stands and experimental plots

This chapter will give an overview over the most important facts concerning the stands and plots of the experiment. A more detailed description of the design and other facts about the larger trees can be found in Drössler et al. (2014).

2.1.1 Halåsen

The stand Halåsen is located close to Östersund in Jämtland, central Sweden with latitude N 63° 17′ 58′′ and longitude E 14° 42′ 52′′ (Drössler et al., 2014). At the beginning of the experiment in 2010, the stand age was 46 years old. A detailed description of the stand can be found in Drössler et al. (2014).

2.1.2 Mordviksboderna

The stand Mordviksboderna is located close Bräcke in Jämtland, central Sweden with latitude N 62° 47′ 24′′ and longitude E 15° 30′ 3′′ (Drössler et al., 2014). At the beginning of the experiment in 2010, the stand age was 45 years old. A detailed description of the stand can be found in Drössler et al. (2014).

2.1.3 Experimental plots of the forest stands

On different forest experimental plots, different types of thinnings were applied. In total, 24 different plots were part of the research, of which 3 were control plots without any kind of treatment, 10 plots were only thinned, 6 plots were thinned and soil scarified, 3 plots were thinned and fertilised and 2 plots where thinned and both soil scarified and fertilised. 7 plots are located at site Halåsen (one experimental block) and 17 at site Mordviksboderna (two experimental blocks in one stand). Each experimental plot has a size of 2500 m^2 (squares of 50 x 50 m).

2.1.4 Subplots for sampling regeneration

In each experimental plot 20 small subplots were established to sample and re-measure regeneration. Every subplot had the size of 1 m^2 (squares of 1 x 1 m). The distribution of the subplots in the experimental plots can be seen in Figure 1.

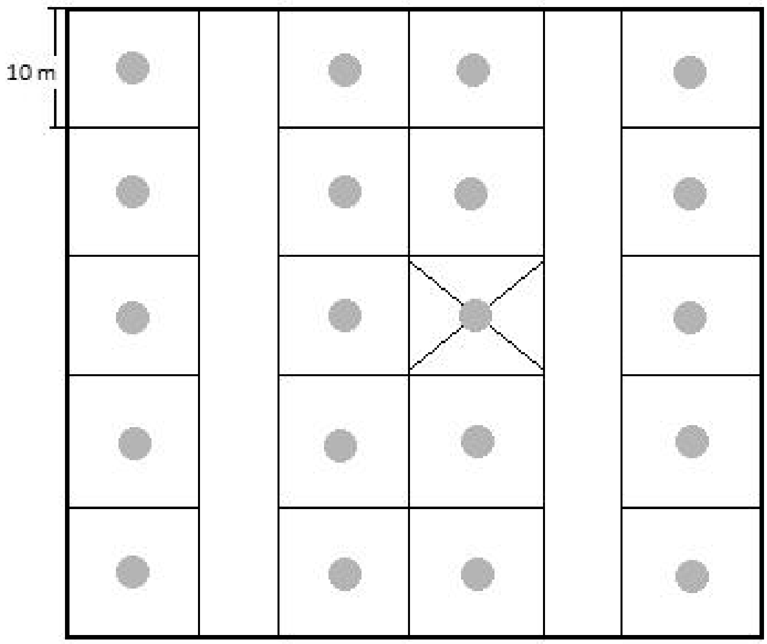

Figure 1. Distribution of subplots in experimental plots (every grey dot is a subplot)

2.1.5 Ground squares

Each subplot was divided into 16 equal squares of 0.125 m^2 (25 x 25 cm). In this thesis, these squares are referred to as "ground squares", as for each single one of them, the forest floor cover type was determined. As there were 24 plots with 20 subplots, there were 7680 ground squares in total.

2.2 Silvicultural treatments

On the 24 different plots, 11 different combinations of treatments were done (Table 1). The used abbreviations are explained in 2.2.1-2.2.6. All thinnings were done in autumn 2010.

Table 1. Combination of treatments and their quantity

Treatment combination	Quantity	Plots
thin	4	H4, H5, M1, M16
thin fert	1	M12
thin scar	3	H3, M9, M15
thin scar fert	1	M7
spat thin	3	H1, M3, M10
spat thin fert	1	M13
spat thin scar	3	H6, M8, M17
spat thin scar fert	1	M4
limit thin	3	H2, M6, M14
limit thin fert	1	M5
control	3	H7, M2, M11

2.2.1 Thinning

The thinning aimed to keep the complete diameter range on the plot while removing 60% of the basal area (Drössler et al., 2014). This kind of thinning will be referred to as "thinning" or "thin" during this thesis.

2.2.2 Spatial thinning

The spatial thinning had like the thinning the goal to remove 60% of the basal area while maintaining the diameter range on the plot. In contrast to the thinning, removals were not evenly distributed over the plot. Actually removals on plots with spatial thinnings were concentrated on small areas with only light removals in the remaining areas (Drössler et al., 2014). The abbreviation used for the spatial thinning is "spat thin".

2.2.3 Limited diameter thinning

The limited diameter thinning had the goal to homogenise the stand by removing the smallest and biggest diameter classes. The removal was 60% of the basal area (Drössler et al., 2014). The abbreviation used in the thesis is "limit thin".

2.2.4 Control

On the control plots, neither any kind of thinning, soil scarification nor fertilisation was done (Drössler et al., 2014). These plots are called "control" in the thesis.

2.2.5 Scarification

On scarified experimental plots, the top layer of the forest floor was removed by an excavator in the autumn after the thinning. An extensive scarification was carried out, where one third of the plot area was scarified excluding the area within a 1 m distance to trees. All soil scarifications were done in autumn 2011.

2.2.6 Fertilisation

On fertilized plots, 150 kg nitrogen per ha were applied manually one time in spring 2012. The fertilizer was named SkogCan (with a 25% N proportion).

2.3 Data acquisition

2.3.1 Forest floor cover type

In 2010, the forest floor cover type for every ground square of the experiment was determined. This determination consisted of evaluating the types of forest floor on the ground square (see Table 2) and the percentage of cover the types have on each ground square. For the percentage, cover classes were formed from 1 to 4 (1: 0%-25% cover; 2: 25%-50% cover; 3: 50%-75% cover; 4: 75%-100% cover).

Table 2. Meanings of used abbreviations

Abbreviation	Meaning
B	Bracken
D	Dwarf shrubs
G	Grasses
M	Mosses
R	Woody debris from harvest
V	Coarse dead wood
MB	Scarified

2.3.2 Vegetation

In 2010, the heights of all seedlings which were found on the subplots were measured and tree species was determined. Additionally for Norway spruce, the yearly increment of the leading shoot was measured as far back as possible. Both seedling heights and lengths of leading shoots were measured with a folding rule.

In 2015, it was determined which seedlings survived or died from 2010 to 2015. For all surviving seedlings, the new height was measured and for surviving Norway spruce seedlings also the yearly increment of the last five years. Like in 2010, the height and species of new seedlings was determined. In addition, the yearly increment of the top shoots of the new Norway spruce seedlings was measured.

In this thesis, seedlings which had already been measured in 2010 and again in 2015 were called “survivors”, seedlings which had been measured in 2010 but died until 2015 “dead” and seedlings which had not been measured in 2010 but in 2015 for the first time “new”. If not explained differently, the expression “seedling” refers to individuals of all sizes which include heights sizes between 2.5 cm and 99 cm.

2.3.3 Seeds

24 seed traps (12 in each stand) were installed in 2010 to measure the amount of Norway spruce seeds per m^2 in both stands. The seeds were counted in 2011 for spring 2011. The details can be seen in Table 21 (Appendix).

In addition to that, data about the count of cones of Norway spruces in Jämtland which was measured by Riksskogstaxeringen was provided by Skogforsk.

2.4 Data use

2.4.1 Forest floor cover type

Only the dominant forest floor cover type was registered. The dominant forest floor cover type of a certain ground square was that type which had the highest cover class on this specific ground square. If two or more forest floor cover types had the highest cover class on a ground square, they were called co-dominated ground squares and built an own forest floor cover type, this means that they were combined. The used abbreviation can be found in Table 2.

The forest floor cover types were used for a first description of the stands. As there were too many different forest floor cover types for a proper analysis, it was decided to assort the forest floor cover types into functional groups for further analysis to have sufficient numbers of seedlings in each group. Two sets of functional groups were set, one for the analysis of establishment and one for the analysis of height increment and mortality.

Establishment

Because of the influence of mosses on the regeneration, it was decided to form five groups of forest floor cover types when analysing the seedling establishment. The groups depended sole on the cover class of mosses (“M”). The groups were M0 (no mosses at all), M1, M2, M3 and M4.

Height increment and mortality

It was tried to form groups taking into account the influence that a certain forest floor cover type might have on height increment and mortality of seedlings. The forest floor cover types were group by the following scheme:

- B- group if bracken was dominant or co-dominant
- D- group if dwarf shrubs were dominant or co-dominant and the forest floor cover type was not already part of the B- group
- RV- group if woody debris form harvest or coarse dead wood were dominant or co-dominant and floor cover type was not already part of the B- group or the D-group
- M-group formed by all remaining forest floor cover types (which all were dominated by “M”)

2.4.2 Vegetation

For a first comparison of the stands, the Norway spruce seedlings where divided into 9 different height classes of 5 cm each. Later, the influence of treatments and forest floor cover types on establishment, height increment and mortality of Norway spruce seedlings was investigated.

In addition to that, influences of treatments and forest floor cover types on establishment and mortality of birch seedlings were analysed.

The establishment was evaluated by the amount of seedlings on the subplots. This number was used to calculate the number of seedlings ha^{-1}. The height increment was estimated by measuring the gained length of the top shoot of each measured Norway spruce. The mortality was calculated from the ratio of seedlings which died and which survived from 2010 to 2015.

When calculating how many seedlings that were recruited on a certain forest floor cover type, it had to be taken into account that some vegetation types were more frequent than others, and so the absolute number of seedlings on these vegetation types would be bigger. To quantify this, the ratio between the number of new seedlings and frequency of the forest floor cover types was calculated.

2.4.3 Seeds

The data of the seed traps in the stands is displayed in the individual descriptions of both stands, but as there was not data for any other time than spring 2011, no data to compare to was available. Because of that, no further analysis was done with this data.

The data provided by Skogforsk was used to evaluated the quality of the seed fall of Norway spruce seeds in the years 2010-2015

2.4.4 Statistical tests

2.4.4.1 Kolmogorov-Smirnov Test

The Kolmogorov-Smirnov Test can be used to qualify if one or two sample have a normal distribution (Feldman and Valdez-Flores, 2009). This test was used to determine whether the values of the following samples were distributed normally or not:

- Number of Norway spruce individuals on subplots in control plots, all plots but control plots, scarified plots and fertilised plots
- Height increment of Norway spruce individuals on subplots in control plots, all plots but control plots, scarified plots and fertilised plots

The used p-value was 0.05 at all times.

2.4.4.2 Mann-Whitney-U Test

As most samples were not normally distributed, it was not possible to use the Student T-Test (Feldman and Valdez-Flores, 2009; Tokarski, 2009). Instead, the Mann-Whitney-U-Test was used to check for possible significant differences between the values mentioned in the bullet points above (see 2.4.3.1).

In an effort to avoid yearly fluctuations as much as possible, the height increment of one certain seedling was calculated as the average height increment of the last three years if possible. If the height increment could only be measured for the two latest years or the latest year, the increment value used for the statistical analysis was the average of the two latest years or the increment of the latest year, respectively. The used p-value was 0.05 at all times.

2.4.4.3 Chi-Square Test

The Chi-Square Test can be used to qualify if expected and observed distributions differ significantly from each other or not (Rumsey, 2007). This test was used in the thesis to determine if the stronger presence of mosses (forest floor cover type “M”) had an influence on the recruitment of Norway spruces and birches. As the hypothesis was that there was no influence, the expected values were the respective percentages of the amount of ground squares with a certain cover class of “M”. The observed values were the percentages of the actual distribution that was observed in 2015. For both, Norway spruces and birches, there were five cover classes (M0 (no M at all), M1, M2, M3 and M4). The used p-value was 0.05 at all times.

3. Results

3.1 Single Stands

In the beginning, the results from the two stands Halåsen and Mordviksboderna will be presented individually. For both stands, the distribution of tree species, the height distribution of the Norway spruces and the distribution of forest floor cover types are shown.

3.1.1 Halåsen

3.1.1.1 Seeds

The average seed density in Halåsen in spring 2011 was calculated at 10.6 seeds m^{-2}.

3.1.1.2 Seedlings

In 2015, 77 seedlings were measured on the 7 plots of the stand Halåsen; the tree species included Norway spruce (*Picea abies Karst.*), birch (*Betula pendula Roth.*), rowan (*Sorbus aucuparia L.*) and willow (*Salix caprea L.*). Most seedlings were birches and Norway spruces.

Table 3. ***Overview over all seedlings measured on the subplots of Halåsen in 2015***

	Seedlings on subplots	Seedlings (ha^{-1})
Norway spruce	26	1857
Birch	32	2286
Rowan	15	1071
Willow	4	286

3.1.1.3 Height classes of Norway spruces

Most Norway spruces in Halåsen were rather small, 15 of the 26 are not bigger than 5 cm, and another 8 were between 5 and 10 cm.

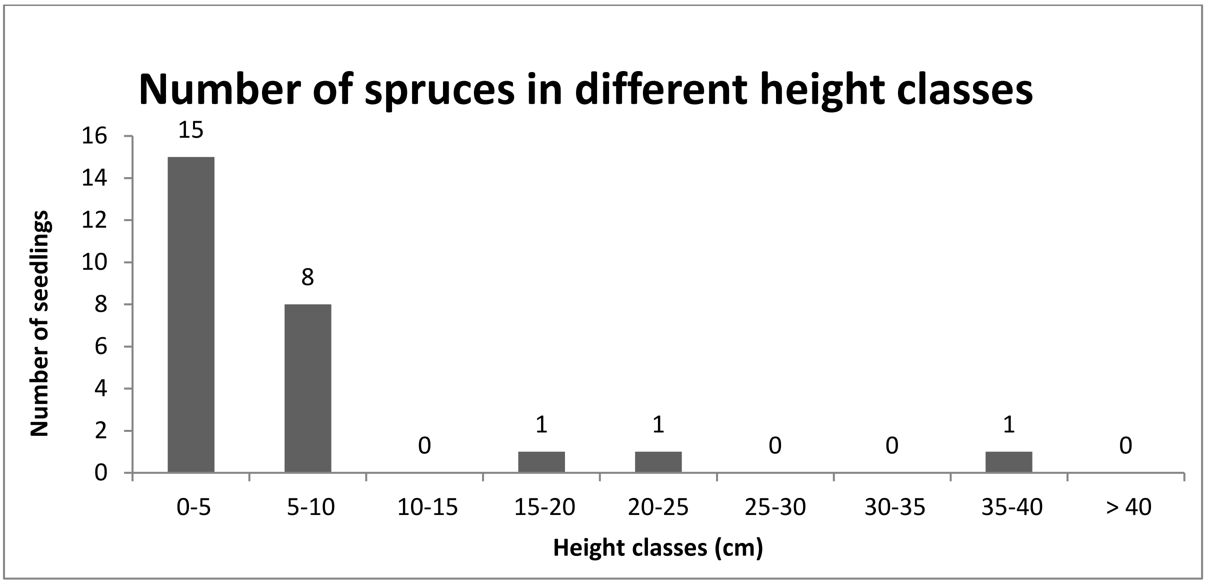

Figure 2. Height class distribution of Norway spruce seedlings on subplots in Halåsen

3.1.1.4 Forest floor cover types

In Halåsen, most forest floors were dominated by mosses. By far, the most frequent forest floor cover type was M4 as it was present on more than half of all ground squares. M3 and M2 were the second and third most frequent forest floor cover type

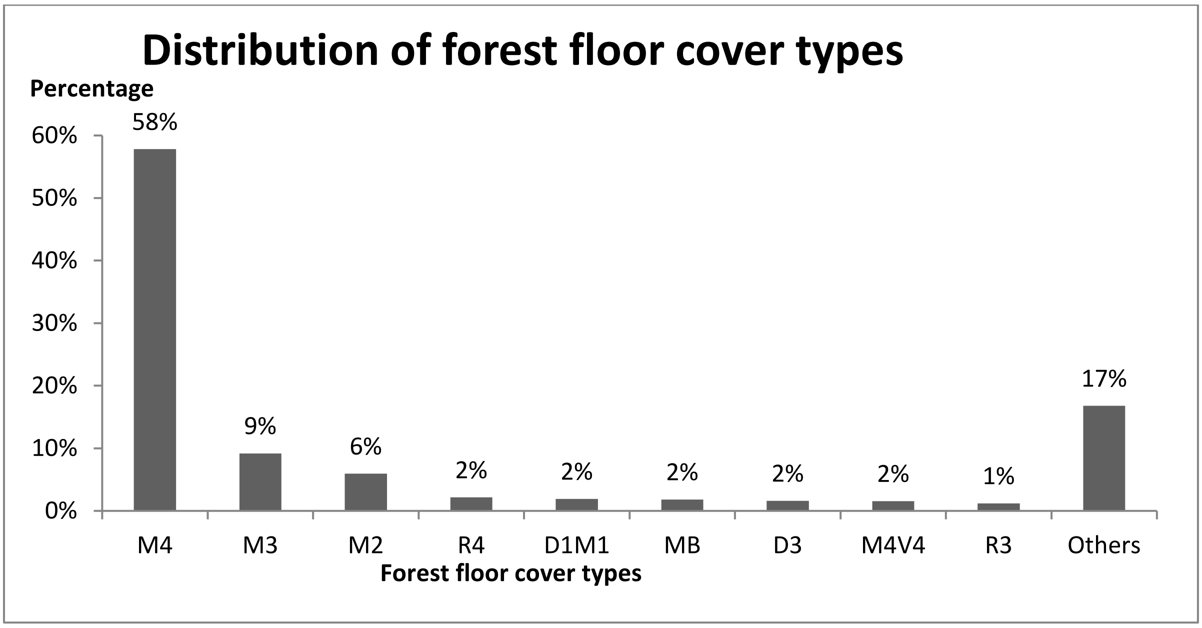

Figure 3. Frequency of forest floor cover types in Halåsen, abbreviations see Table 2.

3.1.2 Mordviksboderna

3.1.2.1 Seeds

The average seed density in Mordviksboderna in spring 2011 was calculated at 12.8 seeds m^2

3.1.2.2 Seedlings

In addition to Norway spruce, birch, rowan and willow, alder (*Alnus glutinosa Gaertn.*) and pine (*Pinus sylvestris L.*) were measured on Mordviksboderna as well. 251 seedlings were found on the different plots of Mordviksboderna in 2015. Once again, birch was the most frequent species, ahead of rowan and Norway spruce.

Table 4. Overview over all seedlings measured on the subplots plots of Mordviksboderna in 2015

	Seedlings on subplots	Seedlings (ha^{-1})
Norway spruce	52	1529
Birch	99	2912
Rowan	81	2382
Willow	1	29
Alder	17	500
Pine	1	29

3.1.2.3 Height classes of Norway spruces

The majority of the Norway spruces in Mordviksboderna were bigger than 10 cm. Most Norway spruces were between 10 and 15 cm, and only one was 5 cm or smaller.

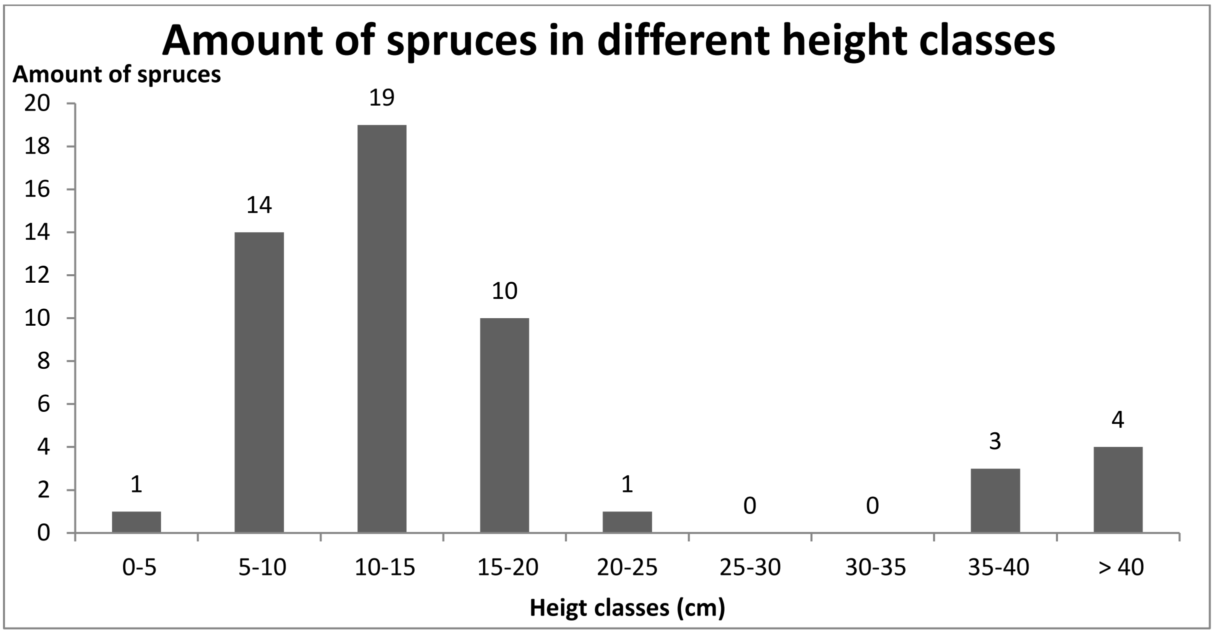

Figure 3. Height class distribution of Norway spruce seedlings on subplots in Mordviksboderna

3.1.2.4 Forest floor cover types

Mosses dominated the majority of ground squares in Mordviksboderna. In addition to the mosses, woody debris and dwarf shrubs were (co-) dominant on a mentionable amount of ground squares.

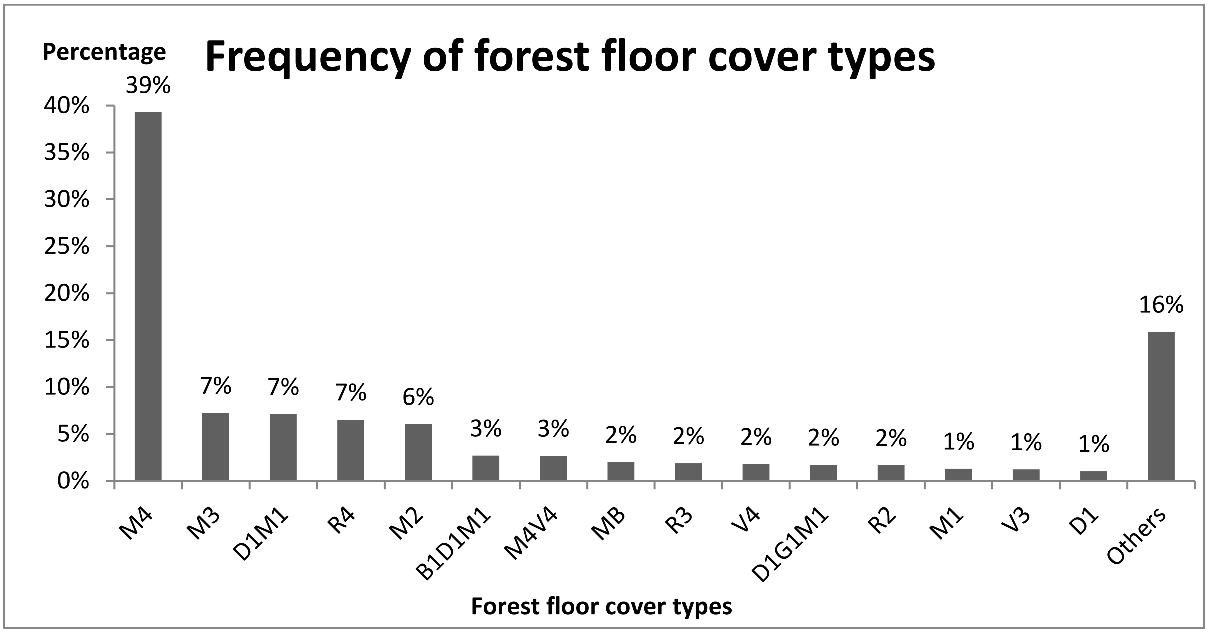

Figure 4. Frequency of forest floor cover types in Mordviksboderna

3.2 Joint analyses of both stands

As it can be seen in 3.1, the amount of seedlings (especially Norway spruce) was rather small and definitely smaller than expected. Because of this, it was decided to make a joint analysis where the different combinations of treatments of both stands will be investigated, but no differences between the two stands. At the same time, all seedlings which were found on subplots were used for calculations without any gradation of height classes.

3.2.1 General overview

3.2.1.1 Seedlings

In total, 410 different seedlings were observed during the two data collections in 2010 and 2015. These seedlings comprised of the six different species mentioned earlier: alder, birch, pine, rowan, Norway spruce and willow. An overview of the frequency of the different species can be seen in the following table.

Table 5. Summary of all measured seedling, separated by species and status

	Dead	Survivors	New	Total
Alder	0	16	1	17
Birch	51	41	90	182
Pine	0	0	1	1
Rowan	24	72	24	120
Norway spruce	5	16	62	83
Willow	2	2	3	7
Total	82	147	181	410

The most abundant tree species of the experiment were birch, rowan and Norway spruce (Table 5). Alder, pine and willow amounted only to 6% of the observed seedlings.

Out of all species, Norway spruce had the biggest increase in numbers from 2010 to 2015, while Birch increased as well, but in smaller amounts. Out of the three most abundant tree species, Birch and Rowan had the highest mortality rates which were double or more than the mortality of Norway spruce

Table 6. Overview over the change so species composition and mortality from 2010 to 2015

Tree species	2010	2015	Increase 2010-2015	Mortality 2010-2015
Alder	16	17	6%	0%
Birch	92	131	42%	55%
Pine	0	1	-	-
Rowan	96	96	0%	25%
Norway spruce	21	78	271%	24%
Willow	4	5	25%	50%
Total	229	328	43%	36%

As there were in total 480 subplots with 1 m^2 area each, the numbers of the seedlings could easily be extrapolated to seedlings per ha. The state of regeneration in the year 2015, not taking into account any differences between sites or treatments is shown in table 7.

Table 7. Number of seedlings in total and per ha in 2015 divided by species

	Alder	Birch	Pine	Rowan	Norway spruce	Willow	Total
Seedlings Total	17	131	1	96	78	5	328
Seedlings per ha	354	2729	20	2000	1625	104	6833
Percentage	5%	40%	0%	29%	24%	2%	100%

3.2.1.2 Forest floor cover types

By far, the forest floor cover type M4 was the most frequent. Figure 6 shows the distribution of the different forest floor cover types.

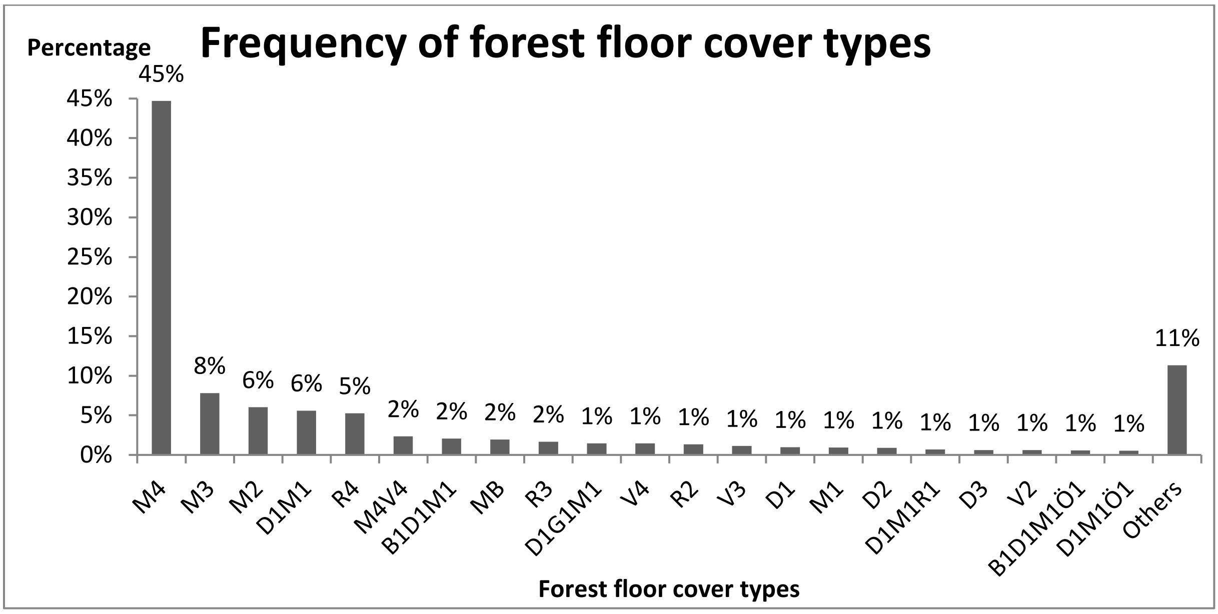

Figure 6. Display of the frequency of the different forest floor cover types over all ground squares

All in all, mosses were (co-) dominating on the majority of ground squares. With M4 and M3 being the two most frequent forest floor cover types and mosses being present on a lot of forest floor cover types , ”M” was (co-) dominating on 6106 of the 7680 ground squares (= 79.5 %). The most important forest floor cover type without M dominating or co-dominating was R4 (woody debris from thinning).

3.2.1.3 Scarification

About 10 % of the area of scarified subplots was completely uncovered from the humus layer, an average from all subplots with scarification treatment plots.

3.2.2 Norway spruce

3.1.1.1 Influence of treatments on establishment, height increment and mortality of Norway spruce seedlings

Establishment

With a density of more than 5000 seedlings ha^{-1}, the control plots had by far the biggest establishment. None of the actual treatments had a seedling density close to 5000 seedlings ha^{-1}.

Table 8. Display of the new Norway spruce seedlings

	Amount of plots	Seedlings	Seedlings (ha^{-1})
fert	5	12	1200
not fert	16	19	594
scar	8	7	438
not scar	13	24	923
thin	9	12	667
spat thin	8	16	1000
control	3	31	5167

U-tests were applied to quantify the differences in seedling density between the control plots and all other plots, between fertilised and not fertilised plots, between scarified and not scarified plots and between plots with normal thinning and special thinning. All these U-tests showed that the differences were not significant.

At this early stage of regeneration, it should also be mentioned that the number of individuals in these two treatments was not evenly distributed. In terms of the control plots, 22 of the 31 individuals are clustered at one single subplot (subplot 7 of plot H7), just like 8 of the remaining 9 individuals (subplot 18 of plot M11). A similar situation was found at the spatial thinning with scarification, where 7 of the 8 individuals were clustered at one subplot (subplot 7 of plot M13).

In addition to the forest floor cover types, it was marked during the data acquisition in 2015 that all Norway spruce seedlings on these three mentioned subplots (7 of H7, 18 of M11 and 7 of M13) germinated on dead stumps.

Height increment

Looking at Table 9, it can be seen that the average height increment of the Norway spruce seedlings was smallest in the control plots every year, while the biggest average height increment was measured in the scarified plots every year as well.

Table 9. Average increment and number of all surviving and new Norway spruces for the different years depending on treatment of the plot (full Table as Table 20 in appendix)

	Annual shoot lengths (cm)					Number of individuals	
Treatments	2011	2012	2013	2014	2015	Survivors	New
fert	2.1	1.9	1.8	2.0	2.4	4	12
not fert	1.8	1.7	1.9	2.0	2.4	11	19
scar	2.3	2.4	2.2	2.7	3.1	0	7
not scar	1.8	1.7	1.8	1.9	2.3	15	24
thin	1.6	1.6	2.0	2.0	2.4	8	12
spat thin	2.2	1.9	1.7	2.0	2.5	5	16
control	1.3	1.3	1.5	1.5	1.6	1	31

U-tests were applied to quantify the differences height increment between the control plots and all other plots, between fertilised and not fertilised plots, between scarified and not scarified plots and between plots with normal thinning and special thinning. All these U-tests showed that the differences were not significant.

The height increment of single individuals ranged from 0.5 cm to 6 cm per year. No top shoot damages were seen on these seedlings, but 14 out of 16 survivors (87.5%) gained less height (distance between the ground and the top shoot) than the sum of the yearly increment of the top shoot. This phenomenon is discussed in 4.3.2.

Mortality

As it can be seen in Table 5, 5 out of 21 Norway spruce seedlings which were found on subplots died until 2015, which results in a mortality rate of 24%. Because of this low number, a proper analysis seemed hardly possible

3.1.1.2 Influence of forest floor cover types on establishment, height increment and mortality of Norway spruce seedlings

Establishment, height increment and mortality were analysed in respective to the forest floor cover.

Establishment

Looking at the distribution of the 62 new Norway spruce seedlings over the different forest floor cover type groups described in 2.4.1, the new seedlings were not evenly distributed (Table 10).

Table 10. Overview over amount of seedlings per forest floor cover type group, percentage of forest floor cover type groups compared to new seedlings and overall and the ratio of these two values

Forest floor cover group	Number of seedlings	Percentage of total seedlings in group	Percentage of ground squares in groups	Ratio of both percentages
M0	23	37%	20%	1.85
M1	9	15%	17%	0.88
M2	10	16%	7%	2.20
M3	5	8%	9%	0.94
M4	15	24%	47%	0.51

Most Norway spruce seedlings (37% of them) were found on forest floor cover types without any mosses present, even though only 20% of all forest floor cover types did not contain any mosses. Because of that, the ratio in the fourth column is bigger than 1.

24% of all spruce seedlings were found on forest floor cover types with mosses having a cover between 75% and 100%, even though these forest floor cover types made up 47% of all forest floor cover types.

The Chi- Square Test comparing the expected and observed distribution of Norway spruce seedlings depending on the cover class of mosses showed significant differences with Norway spruce being more likely to regenerate on ground squares without mosses dominating.

Height increment

The annual top shoot length during the different years can be seen in Table 11.

Table 11. Average increment and number of all surviving and new Norway spruces for the different years depending on the forest floor cover types

	Annual shoot lengths (cm)					Number of seedlings	
Forest floor cover groups	2011	2012	2013	2014	2015	Survivors	New
B-Group	2.1	1.5	1.8	1.9	1.9	1	3
D-Group	1.3	1.2	1.1	1.2	1.3	1	8
RV- Group	2.1	1.7	1.8	1.8	2.1	5	30
M-Group	1.7	1.7	1.8	2	2.3	9	21

The smallest average increment was recorded every year on forest floor cover types with dwarf shrubs being present (D- Group; for exact definition of group see 2.4.1). The largest average increment could not be assigned for on specific forest floor cover group over all 5 years. All three other groups (B, RV and M) had the largest average increment (joint) in at least one year.

Mortality

As mentioned earlier, the five Norway spruce seedlings which died on subplots between 2010 and 2015 were too few to analyse the mortality further.

3.2.3 Birch

3.2.3.1 Influence of treatments on establishment and mortality of birch seedlings

Establishment

In total, there were 90 new established birch seedlings which occurred on the experiment between 2010 and 2015. Table 12 shows that plots with spatial thinning and scarified plots had by far the highest density of new birch seedlings, being more than double as big as the as the density of new birch seedlings on plots with normal thinning and plots without any scarification. No birch seedlings established on control plots.

Table 12. Overview over distribution of new birches over different treatments

Treatments	Amount of plots	Seedlings	Seedlings (ha^{-1})
fert	5	12	1200
not fert	16	78	2438
scar	8	50	3125
not scar	13	40	1538
thin	9	26	1444
spat thin	8	60	3750
control	3	0	0

Mortality

51 Birch individuals died during the time from 2010 to 2015. The mortality rate for birch seedlings was highest on fertilised plots being 80%. On all other treatments, mortality rates did not differ strongly from each other.

Table 13. Overview over the distribution of the dead birch seedlings and the mortality rate over different treatments

Treatments	Birches in 2010	Birches which died between 2010-2015	Mortality rate
fert	20	16	80%
not fert	72	35	49%
scar	34	19	56%
not scar	58	32	55%
thin	30	17	57%
spat thin	50	31	62%

3.2.3.2 Influence of forest floor cover types on establishment and mortality of birch seedlings

Establishment

Table 14 shows the distribution of the 90 freshly regenerated birch seedlings over the five forest floor cover groups described in 2.4.1. The biggest percentage of birch seedlings regenerated on forest floors with light cover of mosses (group M1). This group had the highest ratio as well. The lowest ratio was calculated for forest floors with very strong cover of mosses (M4) at 0.28.

The Chi- Square Test comparing the expected and observed distribution of birch seedlings depending on the cover class of mosses showed significant differences with birches being significantly less probable to regenerate on forest floors with a lot of mosses.

Table 14. Overview over distribution of new birches over different forest floor cover groups

Forest floor cover group	Number of seedlings	Percentage of total seedlings in group	Percentage of ground squares in group	Ratio of both percentages
M0	27	30%	20%	1.49
M1	38	42%	17%	2.55
M2	3	3%	7%	0.45
M3	10	11%	9%	1.30
M4	12	13%	47%	0.28

Mortality

In 2010, 92 birch seedlings were growing on the subplots of the experiment, of which 51 died. The mortality rates for the D-group and the M-group were nearly identical, while it was nearly

50% smaller in the RV-group. The one birch which grew on forest floors being part of the B-group died, which resulted in a mortality rate of 100%.

Table 15. Overview over amount of new birches per forest floor cover group and resulting mortality rates

Forest floor cover group	Birches in 2010	Birches which died between 2010-2015	Mortality rate
B-group	1	1	100%
D-group	20	12	60%
RV-group	15	5	33%
M-group	56	33	59%

4. Discussion

When comparing the results of this thesis to the results of other empiric studies, it was problematic that not differentiation of height classes of seedlings growing on subplots was done in this study. In most other studies, this was done and made seedling numbers or mortality rates hard to compare. To be able to compare the results of this thesis to others, a differentiation in height classes was done in the discussion to be able to compare different results in a useful way. In addition, regeneration in uneven-aged Swedish forests is normally measured by ingrowth (trees reaching a certain dbh) and not an amount of seedlings (Lundqvist et al., 2011). Because of that, an ingrowth model was used to evaluate the sufficiency of the regeneration.

4.1 Differences between the two stands

4.1.1 Different recruitments of Norway spruce and birch

Comparing the results of the two stands separately, Norway spruces were slightly more frequent in Halåsen while birch was more frequent in Mordviksboderna.

An explanation for the higher recruitment of birch might the location of the stand in Mordviksboderna close to a mire (for detailed description see 4.4.1) which probably favoured the regeneration of birch (Holmström et al., 2016; Wikberg, 2004). In addition, Mordviksboderna was also affected by a wind throw. In other case studies in the mountains in Central Europe (Fischer et al., 1990; Jonášová et al., 2010; Keidel et al., 2008) it could be seen that birch and rowan often play an important role in regeneration after a wind throw.

In contrast to Mordviksboderna, the stand in Halåsen did not have the same conditions. This can be seen by the fact that out of 90 birches which freshly regenerated between 2010 and 2015, 86 were growing in Mordviksboderna. The site in Mordviksboderna was wetter than Halåsen and had a bog with mature birches close by. All these factors probably favoured the regeneration of birch in Mordviksboderna.

The question why the recruitment of Norway spruce was bigger in Halåsen than in Mordviksboderna seems difficult to answer. A possible answer is the fact that 22 out of the 26 new Norway spruces in Halåsen recruited on a decaying trunk, a substrate which has been proven to be important in the regeneration of Norway spruce (Hofgaard, 1993; Hörnberg et al., 1995; Zielonka, 2006). Taking this into account, the higher recruitment of Norway spruces in Halåsen might just be a coincidence due to very good conditions in one specific subplot.

4.1.2 Different frequencies of height classes

In Halåsen, most Norway spruces where between 0 cm and 5 cm high when measured in 2015 while most Norway spruces in Mordviksboderna where between 10 cm and 15 cm high.

This situation had probably two main reasons: On the one hand, there were 16 Norway spruces surviving in Mordviksboderna from 2010 to 2015, but none in Halåsen. This means that there were 16 seedlings in Mordviksboderna which had more years to grow compared to all Norway spruces in Halåsen.

On the other hand, 22 of the 26 Norway spruces in Halåsen were growing on a control plot, but only 9 out of 52 Norway spruces in Mordviksboderna. As mentioned, all stands in Mordviksboderna were damaged by wind throw as well. This means that the light conditions to grow were in general better in Mordviksboderna than in Halåsen. Having the smallest increments on control plots is a common result which has been seen in other studies as well (Drössler et al., 2015). The latter study also showed that soil scarification can have a negative effect on Norway spruce regeneration and a positive effect on birch – in such short-term observations.

4.1.3 Different frequencies of mosses as the dominant forest floor cover type

When looking at the forest floor cover types in Halåsen and Mordviksboderna it was shown that mosses were more often dominating in Halåsen than in Mordviksboderna. Nevertheless, the trend of mosses being very dominant was the same in both stands.

4.2 Sufficient amount of regeneration

It could be seen that the design of the subplots has not been ideal. Even though a subplot size of 1 m^2 is not exactly unusual, many studies which had a plot sizes of 2500 m^2 and bigger used either more subplots or bigger subplot sizes for better accuracy and to avoid overestimations (Ammer et al., 2004). The results of the amount of seedlings ha^{-1} have to be seen with a certain doubt as the number of seedlings is so small. In fact, the empirical data base does not allow further conclusions from a plot wise analysis. However, the following considerations were made on more general level for the first five years of seedling establishment after conversion thinning in northern Sweden described in Drössler et al. (2014).

Of the 78 Norway spruce seedlings growing on the subplots in 2015, 10 individuals were smaller than 5 cm (208 seedlings ha^{-1}), 65 individuals were between 5 cm and 50 cm (1354 seedlings ha^{-1}) and 3 individuals were between 50 cm and 130 cm (the biggest individual had a height of 99 cm) (63 seedlings ha^{-1}).

In a study from Finland, natural regeneration after thinnings in stands with comparable standing volume recorded a mean regeneration of Norway spruce seedlings between 5 cm and 50 cm height of 4200 seedlings ha^{-1} and 5300 seedlings ha^{-1} respectively in two different substands (Lin et al., 2011). For seedlings between 50 cm and 130 cm, Lin et al. (2011) found in average 200 seedlings ha^{-1} and 467 seedlings ha^{-1}. The differences between the results of this thesis and the ones of Lin et al. (2011) are rather big, as the seedling numbers are 3-4 times higher for both height classes in Lin et al. (2011).

Laiho et al. (2011) showed an overview of Norway spruce regeneration in uneven-aged stands dominated by Norway spruce. The numbers of so-called “stabilized seedlings” (height between 0.1 m-1.3 m) in stands with comparable standing volume ranged in most studies between about 2700 seedlings ha^{-1} and 4000 seedlings ha^{-1} (Laiho et al., 2011). The number of stabilized seedlings in this thesis was calculated to 1417 seedlings ha^{-1}.

Holgén and Hånell (2000) and Nilsson et al. (2002) measured regeneration of Norway spruce in shelterwoods. For seedlings heights between 10 cm and 100 cm, Holgén and Hånell (2000) measured an average between 1330 seedlings ha^{-1} and 11000 seedlings ha^{-1} 10 years after interventions for stands with comparable location in Sweden. While the lower border was even lower than the respective amount of seedlings in this study (1417 seedlings ha^{-1}), the higher range was over than 7 times more than 1417 seedlings ha^{-1}. Nilsson et al. (2002) measured amongst others regeneration of Norway spruce under different shelterwood densities. Five years after the intervention, regeneration of Norway spruce seedlings in undisturbed soil ranged between 0 seedlings ha^{-1} and ca. 18000 seedlings ha^{-1}.

All mentioned studies (Holgén and Hånell, 2000; Laiho et al., 2011; Lin et al., 2011; Nilsson et al., 2002) seem to show that regeneration in this study was inside a possible range, but rather poor. Nevertheless, the big question is whether it is sufficient or not. Drössler et al. (2014) were simulating that a transformation of the stands to multi-layered forests within 50 years might be possible assuming an annual ingrowth (dbh of 5 cm) of 10 trees ha^{-1}).

Wikberg (2004) suggested in a general growth model for Swedish forests a ratio of saplings reaching a dbh of 4.5 cm ranging between 1% and 6%. Calculating with these values, annual ingrowth in this study might range between 3.3 trees ha^{-1} and 19.5 trees ha^{-1}. This ingrowth would be below the one which was measured by Eerikäinen et al. (2014), but might under good circumstances be able to provide sufficient regeneration, but it would be very unsure.

What makes the results even more doubtful is that the seedling density is by far highest in the control plots, as the following table shows.

Table 16. ***Overview over seedling density in 2015 and calculated ingrowth from Wikberg (2004)***

Treatments	Amount of plots	Seedlings	Seedlings (ha^{-1})	Range of ingrowth (Wikberg (2004); Trees ha^{-1})
fert	5	16	1600	3.2-19.2
not fert	16	30	938	1.9-11.3
scar	8	7	438	0.9-5.3
not scar	13	39	1500	3.0-18.0
thin	9	20	1111	2.2-13.3
spat thin	8	21	1313	2.6-15.8
control	3	32	5333	10.7-64.0
Total	24	78	1625	3.3-19.5

The seedling density of all treatments is below the overall average, and only fertilized and not-scarified plots are close to the average. Using the general growth model by Wikberg (2004), scarified plots will not be able to provide sufficient ingrowth even under best conditions. Most other treatments might be able to provide sufficient ingrowth if the ingrowth is on the top range of the growth model. Only the ingrowth rates calculated from the seedling density in the control plots would be sufficient in case of an ingrowth on the lower end of the spectrum according to the model by Wikberg (2004).

When looking at the ingrowth rate in the control plots, a couple of things have to be taken into account. First, 22 of the 32 spruces were found in one subplot. Compared to all other subplots, this seems very random and is likely to cause an overestimation of the actual regeneration. Second, even if this was the standard, only one tree within a square meter would be able to reach a dimension which made it interesting from an economical point of view. Last, different publicatios (Hagner, 2012; Schmidt-Vogt, 1991; Tjoelker et al., 2007) suggest that the Norway spruce seedlings hardly every reach bigger dimensions in unthinned plots. This means that the mortality rate in the control plots is probably a lot higher than the ones which were used in the model by Wikberg (2004). The numbers of Table 16 have to be seen from this perspective as well.

4.3 Norway spruce

4.3.1 Establishment of Norway spruce seedlings

The establishment rate of Norway spruce was highest on the control plots, but the U-test was insignificant comparing the control plots to all other plots. This insignificance is most likely due to the big amount of empty subplots without any regeneration on all plots.

The actual treatments seemed to have no significant influence on establishment according to the applied U-tests. This seemed very remarkable, as soil scarification is known to reduce the competition of the seedlings with other vegetation (Nilsson and Örlander, 1999). A possible explanation is the availability of seeds. On the one hand, scarified soil will not be open longer than a few years (Nilsson et al., 2002), so the scarification needs to be timed well with a seed years. The cone presence in Jämtland in the years 2011-2014 has been well below the 30-year average for this region (Wennström, 2016). This means that a scarification could just have been useless as there were too few seeds available to establish on the area. It seems very important to coordinate soil scarification better with seed availability in the future to profit from it.

On the other hand, the Norway spruce trees in the stands are younger than seed trees normally are. This might have decreased the availability of seeds as well.

As mentioned, 37 of the 62 Norway spruce seedlings regenerated clustered on only three subplots growing on decaying stumps. In other studies is has been shown that this is a substrate favouring Norway spruce regeneration (Hofgaard, 1993; Hörnberg et al., 1995; Zielonka, 2006). It seems likely that such good conditions in single subplots played a much bigger role for the Norway spruce regeneration than the different treatments, as the control plot would be expected to be the treatment with the lowest number of regenerating seedlings like it has been in other studies of older forest (Drössler et al., 2015).

The Chi-Square Test showed that significantly less Norway spruce seedlings occurred on spots where mosses were more present. In another study from northern Sweden, smothering of seedlings was seen as the main reason for the mortality of Norway spruce seedlings (Hörnberg et al., 1997). It is possible that this happened to Norway spruce seedlings in this study as well, as it might explain the low regeneration on mosses.

Nevertheless, one has to be careful not to make a logical fallacy here. Even though significantly less Norway spruces established on plots with a strong moss cover, this might not necessarily mean that that mosses have a negative influence on the establishment of Norway spruce seedlings, but simply that mosses rather are growing in areas with a microclimate that is not in favour of Norway spruce establishment and vice versa. This means that the moss cover itself might just be an indicator of what is and what is not a good spot for Norway spruces to regenerate, but a strong cover of mosses might actually not impede the establishment of Norway spruces at all.

4.3.2 Height increment of Norway spruce seedlings

Looking at height increment of Norway spruces, it can be seen that increment was in average smallest on the control plots (but insignificant according to the U-Test). This does not seem to be surprising, as light conditions are worst on the control plots, for instance. This result was observed in other studies of mature forest as well (Drössler et al., 2015; Lin et al., 2011). Comparing all other treatments to each other, very little differences could be detected due to the small number of observations.

The forest floor cover type seemed to have a very small impact on the height increment of Norway spruces. The low increment of seedlings in the D-group was most likely due to the fact that all these Norway spruces were growing on a control plot and not because of the forest floor cover type. The differences between the other forest floor cover groups were very small.

In addition to treatments and forest floor cover type, it has to be mentioned that snow probably plays an important role in the height increment as well. When comparing the actual heights of the Norway spruce regeneration in 2010 and 2015, it was seen that 14 out of 16 individuals did not grow as much in height as their top shoots grew in length during the same period. For 8 out of 16 Norway spruces, the difference between accumulated top shoot growth and actual height gain was more than 5 cm with a maximum of 15.5 cm, for instance. This phenomenon of snow pressing down young vegetation and bending it back has been recognized but barely described or reliably documented in northern Sweden or Finland (oral communication with Lars Lundqvist and Sauli Valkonen).

The average height increment of Norway spruce over five years calculating it from the height difference between 2010 and 2015 resulted in 2.6 cm (this value was calculated form the 11 surviving seedlings which had a height between 10 cm and 40 cm in 2015). This seems extremely small compared to other studies, where average 5-year increments for comparable height classes including negative values have been calculated to ca. 13 cm and ca. 9 cm in norther Sweden and Finland respectively (Chrimes, 2004; Eerikäinen et al., 2014). If height increment of the same seedlings is calculated by summing up the yearly length gain of the top shoots it results in ca. 9.3 cm, which is very close to the corresponding studies. It seemed that snow pressing down seedlings was a prevailing problem in the study stands.

4.3.3 Mortality of Norway spruce seedlings

As there are only 21 Norway spruce seedlings from which the mortality rate was calculated, a deeper analysis seemed to be very speculative. For most treatments and forest floor cover types, no mortality rate could have been calculated (as there was no seedling growing) or it had resulted at 0%.

Disregarding treatments and forest floor cover types, 15 out of 21 seedlings had a height between 10 cm and 40 cm in 2010. For this height class, Eerikäinen et al. (2014) measured mortality rates for Norway spruce seedlings during 5-year periods between ca. 18% and 22%. These measurements took place in uneven-aged Norway spruce dominated stands in Finland (Eerikäinen et al., 2014). These results are rather close and in line with the findings of this thesis.

4.4 Birch

4.4.1 Establishment of birch seedlings

When estimating the influence of treatments on birch regeneration, it had to be taken into account that 86 out of 90 birch seedlings regenerated on plots in Mordviksboderna. As mentioned earlier, the most important for this fact was probably the location of the stand, as there is a bog with plenty of mature birches nearby. Comparing both stands, it needs to be considered that the stand Mordviksboderna was much larger in size (20 ha) with two experimental blocks and more variable site conditions. The eastern part was adjacent to a mire and a small creek could occur in springtime between the two most western experimental plots. Hence, these more diverse and often wetter conditions in Mordviksboderna have most likely resulted in good conditions for birch regeneration (Holmström et al., 2016; Wikberg, 2004)

In addition to that, the stand in Mordviksboderna had been affected by wind throws. As a pioneer species which demands light, birch has shown its ability to regenerated well after wind throws in other studies (Jonášová et al., 2010; Roloff, 2012), it seems much more likely that these combined conditions had a much bigger impact on the birch regeneration than the different treatments.

Nevertheless, it could be seen that the density of freshly established seedlings was more than double the amount on scarified and spatial thinned plots than on not-scarified and normally thinned plots. This might show that the scarification can be an advantage for establishment if enough seeds are present. At the same time, freshly establishing seedlings might profit from the bigger supply of light on spatially thinned plots in contrast to normal thinnings.

In terms of the forest floor cover type, the Chi-Square Test showed that significant less birches regenerated on areas with a strong cover of mosses. This result is in line with other studies, where regeneration of birch was worst on mosses as well (Kinnaird, 1974). At the same time, the remarks which were made in 4.3.1 about the logical fallacy which can be made in this analysis are also valid regarding the regeneration of birch.

4.4.2 Mortality of birch seedlings

The mortality rate of birch seedlings was biggest on fertilised plots, while the mortality rates on other treatments did not differ strongly from each other. In terms of forest floor cover types, the seedlings in the RV-group had a lower mortality rate than seedlings growing on other forest floor cover types.

Disregarding treatments and forest floor cover types, the overall mortality rate of the 92 seedlings was 55%. Of these 92 seedlings, 34 were between 10 cm and 40 cm in height in 2010. Among these seedlings, the mortality rate was 50%. This is very close to the findings of Eerikäinen et al. (2014) for the same height class. 23 seedlings had a height between 40 cm and 70 cm in 2010. Their mortality rate was about 48%. This mortality rate is between the mortality rates which Eerikäinen et al. (2014) calculated for the same height class.

While it is hard to tell what caused the differences of mortality rates between the different treatments and forest floor cover groups, the most important factor for seedling mortality seemed to be browsing from moose, as 11 out of the 41 birches which survived form 2010 to 2015 actually lost height, and 6 grew less than 10 cm in that period. Browsing on birch in Sweden has been described as a common problem in other studies before (Danell et al., 1985; Drössler et al., 2012).

4.5 Conclusions

There were certain differences between the stands Halåsen and Mordviksboderna. Most of them were caused by more diverse site conditions and the wind throw Mordviksboderna was affected by.

In conclusion, it can be said that the regeneration of Norway spruce was rather poor compared to other studies. Nevertheless, the current regeneration of Norway spruce still might be sufficient when calculating the ingrowth from it, even though this is very unsafe and would require an ingrowth on the top range of the applied growth model.

It was unlikely that the treatments had a large positive effect on regeneration. Regeneration seemed to be caused a lot more by decaying wood to grow on (Norway spruce), wetter ground, close by seed trees and sufficient light presence (birch). At the same time, a strong cover of mosses on the forest floor seemed to impede the regeneration of both Norway spruce and birch.

While the forest floor did not seem to have any kind of impact on the height increment, it could be seen that there was a slight, but not significant difference of the height increment between the control plots and the other plots.

From a silvicultural perspective, the most important lesson learned from this study might be that treatments have to be coordinated better with seed years, as the lack of seeds seems to be the main reason for the poor regeneration of Norway spruce at this point of time. As an example, soil scarification is known to improve the establishment of seedlings, but seeds need to be present before the scarified soil closes again, otherwise the treatment has been useless.

A possible solution could be that a time period of 10-15 years is set for each stand which is ready to thin. As soon as a good seed year is predicted, all treatments are done. At the same time, it might be wise to choose containing older trees with a bigger seed production. Like that, chances are bigger that the following establishment is more successful than the establishment in this study.

The main value of this master thesis can be seen in the documentation and description of a case study, a rare conversion regime of even-aged Norway spruce forest to multi-layered forest. If there the initiation of natural Norway spruce regeneration continues with the rate of the first five years, there may be a lack of smaller trees in 50 years to continuously harvest trees by single tree selection cuttings. In that case, longer conversion periods with delayed harvest interventions to assure sufficient regeneration need to be considered. However, there are still 20 years of time to observe if the establishment of larger seedlings may increase.

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Appendix

Table 17. ***Summary of all trees which were part of the thesis***

Abbreviations:

St: Stand
Pl: Plot
SPl: Subplot
Sp: Species
FFVT: Forest floor cover type
H: height in cm
I: increment in cm
H: Halåsen
M: Mordviksboderna

A: Alder
B: Birch
P: Pine
R: Rowan
S: Norway spruce
W: Willow
N: New
D: Dead

St	Pl	SPl	Sp	FFCT	H10	I11	I12	I13	I14	I15	H15	N	D
H	1	1	B	D1M1V1	45							No	Yes
H	1	2	W	D1G1S1	84							No	Yes
H	1	2	B	M4	41						75	No	No
H	1	2	B	M4	23							No	Yes
H	1	3	B	M4	6							No	Yes
H	1	4	B	R3	10							No	Yes
H	1	4	B	R4	7						82	No	No
H	1	5	B	D1G1M1	23						43	No	No
H	1	9	B	B1D1M1V1	48							No	Yes
H	1	11	B	M4	32						55	No	No
H	1	11	B	M2	79						87	No	No
H	1	11	B	M4	33							No	Yes
H	1	11	R	M4	22						13	No	No
H	1	11	R	M3	66						64	No	No
H	1	12	B	M1V1	76						70	No	No
H	1	13	B	V3	52						39	No	No
H	1	14	B	D2	12							No	Yes
H	1	14	B	D1M1S1	26							No	Yes
H	2	5	B	M4	42						66	No	No
H	2	8	R	M4	89						99	No	No
H	2	8	R	M4	10							No	Yes
H	2	11	B	M4	40						44	No	No
H	2	11	B	M4	40						37	No	No
H	2	11	B	M4	50						62	No	No
H	2	12	B	M4	60							No	Yes
H	2	12	B	V3	40						43	No	No
H	2	14	B	M4	25						62	No	No
H	2	14	B	M4	10						28	No	No
H	2	19	R	M4V4	80						51	No	No

Appendix, Table 17 continued													
St	Pl	SPl	Sp	FFCT	H10	I11	I12	I13	I14	I15	H15	N	D
H	2	19	B	M4	35							No	Yes
H	3	2	B	M4	70							No	Yes
H	3	3	B	V3	70							No	Yes
H	3	5	R	V4	22						49	No	No
H	3	5	R	V4	21							No	Yes
H	3	5	B	V4	27							No	Yes
H	3	5	R	V4	25							No	Yes
H	3	5	B	V4	30							No	Yes
H	3	5	R	M1	55						21	No	No
H	3	5	R	B1M1	75						68	No	No
H	3	5	B	M2							43	Yes	No
H	3	6	B	M1	26							No	Yes
H	3	7	B	M3	57							No	Yes
H	3	7	B	M3	40							No	Yes
H	3	7	B	M3	28							No	Yes
H	3	7	B	M2	39							No	Yes
H	3	7	B	M3							38	Yes	No
H	3	7	B	M4							48	Yes	No
H	3	8	B	D1G1M1V1	50							No	Yes
H	3	9	B	M4	40						38	No	No
H	3	11	B	D1M1	21						70	No	No
H	3	12	B	V1	32						42	No	No
H	3	12	B	M3	30						32	No	No
H	3	12	R	M3	30							No	Yes
H	3	14	B	D1M1	62						53	No	No
H	3	14	W	M4	17						19	No	No
H	3	14	B	D1M1							32	Yes	No
H	3	15	B	M3V3	62							No	Yes
H	3	15	B	M3V3	38						21	No	No
H	3	15	B	D2M2	40							No	Yes
H	3	19	R	D1G1	19						32	No	No
H	3	19	R	M4	11						15	No	No
H	3	19	R	D1G1							12	Yes	No
H	3	20	B	M2	35						22	No	No
H	3	20	B	M2	37						43	No	No
H	4	3	B	D3	42							No	Yes
H	4	4	B	V3	50						42	No	No
H	4	4	B	D1M1S1V1	51							No	Yes
H	4	8	B	M4	50							No	Yes
H	4	8	B	M4	27							No	Yes

Appendix, Table 17 continued

St	Pl	SPl	Sp	FFCT	H10	I11	I12	I13	I14	I15	H15	N	D
H	4	9	B	M4	68						82	No	No
H	4	11	S	M4		2	2	4	3	6	19	Yes	No
H	4	12	W	I3	62						53	No	No
H	4	15	W	M3							30	Yes	No
H	4	15	W	M3							28	Yes	No
H	4	15	S	M3		1.5	1	2	3	2	22	Yes	No
H	4	17	S	M3				3	2.5	3.5	9	Yes	No
H	4	19	B	V3	41						36	No	No
H	5	2	B	V2	44						42	No	No
H	5	3	R	M4	73						51	No	No
H	5	11	B	M4	30						52	No	No
H	5	11	B	M4	26							No	Yes
H	5	17	R	M4	79						58	No	No
H	5	17	R	M4	48						34	No	No
H	5	17	R	M3	20						41	No	No
H	6	3	B	M4	40							No	Yes
H	6	3	B	M4	33							No	Yes
H	6	13	R	M4	61							No	Yes
H	6	14	R	M4	44							No	Yes
H	6	14	R	M4							35	Yes	No
H	6	20	B	M3	42						67	No	No
H	7	7	S	V3				2	1.4	2.1	5.5	Yes	No
H	7	7	S	V3				2	2	2.2	6.2	Yes	No
H	7	7	S	V3				2	1	2	5	Yes	No
H	7	7	S	V3					1.5	2.2	3.7	Yes	No
H	7	7	S	M4					3	2	5	Yes	No
H	7	7	S	V4				2	2.5	2	6.5	Yes	No
H	7	7	S	V4				2	3	2	7	Yes	No
H	7	7	S	V4			2	3	1.8	1.5	8.3	Yes	No
H	7	7	S	V4					2	2	4	Yes	No
H	7	7	S	V4				1.8	2	2.1	5.9	Yes	No
H	7	7	S	V4				2	2.2	2.4	6.6	Yes	No
H	7	7	S	V4				1.5	1	2	4.5	Yes	No
H	7	7	S	V4				1	1	1.5	3.5	Yes	No
H	7	7	S	V4				2	2	1	5	Yes	No
H	7	7	S	V4				1.5	1	1	3.5	Yes	No
H	7	7	S	M3				1	1	1	3	Yes	No
H	7	7	S	V4			1	1	1	1.5	4.5	Yes	No
H	7	7	S	V4			1	1	1	1.5	4.5	Yes	No
H	7	7	S	V4						2.5	2.5	Yes	No

Appendix, Table 17 continued													
St	Pl	SPl	Sp	FFCT	H10	I11	I12	I13	I14	I15	H15	N	D
H	7	7	S	V3					2.3	2.2	4.5	Yes	No
H	7	7	S	M4					2.5	2.5	5	Yes	No
H	7	7	S	V4			1.5	1.5	1	1	5	Yes	No
H	7	14	S	B2M2		3	2	2.5	2.5	1.5	40	Yes	No
M	1	1	R	M4	27						26	No	No
M	1	3	S	M3	13	1.5	2.5	2	2	2.5	14	No	No
M	1	3	S	M2	12	1.5	2	2.5	2	2	12	No	No
M	1	3	S	M4	9	1.5	1.5	1	1.5	1.5	12	No	No
M	1	3	S	M3	7	1.5	1	2	2	1.5	13	No	No
M	1	3	S	M3	7	1	1	1.5	1	1.5	12	No	No
M	1	3	S	M4	10	1.5	1	1	2	1.5	12	No	No
M	1	4	B	M4							31	Yes	No
M	1	17	S	R4		2	2.5	2	2.5	2.5	12	Yes	No
M	1	19	R	M3	43							No	Yes
M	2	1	R	M4	5							No	Yes
M	2	4	R	D1M1Ö1	3							No	Yes
M	2	4	R	D2	3							No	Yes
M	2	4	R	D2	3							No	Yes
M	2	6	R	M3	52							No	Yes
M	2	6	R	M4V4	10							No	Yes
M	2	7	R	M2	4							No	Yes
M	2	8	R	M4	5							No	Yes
M	2	8	R	M4	6							No	Yes
M	2	10	R	M4	6							No	Yes
M	3	5	B	R4	44						45	No	No
M	3	5	B	R4							22	Yes	No
M	3	5	B	D1M1V1							17	Yes	No
M	3	5	B	D1M1V1							21	Yes	No
M	3	5	B	V4							12	Yes	No
M	3	5	B	R4							14	Yes	No
M	3	5	B	V4							9	Yes	No
M	3	8	R	D1G1M1R1	38						47	No	No
M	3	11	S	M4	42	2.5	2.5	1.5	1.5	2	41	No	No
M	3	12	R	M3	158						140	No	No
M	3	16	B	R3							19	Yes	No
M	3	16	B	M1							21	Yes	No
M	3	16	B	D1M1							11	Yes	No
M	3	16	B	M1							19	Yes	No
M	3	16	B	D1M1							25	Yes	No
M	3	18	R	M4	21						20	No	No

Appendix, Table 17 continued

St	Pl	SPl	Sp	FFCT	H10	I11	I12	I13	I14	I15	H15	N	D
M	3	18	R	V2	27						26	No	No
M	3	19	S	M4		2	2	2	2.5	3	18	Yes	No
M	3	19	S	M4			1.5	1.5	2	2	10	Yes	No
M	3	19	S	M4		1.5	2	2	2	2	11	Yes	No
M	3	19	S	M4			1	0.5	1	2	7	Yes	No
M	3	19	S	M4				0.5	1	2	6	Yes	No
M	4	2	R	D1M1							19	Yes	No
M	4	2	R	D1M1							23	Yes	No
M	4	2	R	M2							26	Yes	No
M	4	2	S	M2		3	3	1.5	3	3.5	22	Yes	No
M	4	2	R	M2							28	Yes	No
M	4	3	B	B1D1M1R1							53	Yes	No
M	4	4	R	M4	29						23	No	No
M	4	10	R	M4							17	Yes	No
M	4	12	R	D1M1V1	21						42	No	No
M	4	17	R	M1R1	30						24	No	No
M	4	18	B	D1M1							22	Yes	No
M	4	19	R	M2	3							No	Yes
M	4	19	R	M2	3						6	No	No
M	4	19	B	M2							19	Yes	No
M	4	19	B	M3							18	Yes	No
M	5	1	R	M4	71						25	No	No
M	5	3	R	R3							20	Yes	No
M	5	5	W	M2	102							No	Yes
M	5	13	R	R4							30	Yes	No
M	5	13	R	R3							27	Yes	No
M	5	13	R	R4							10	Yes	No
M	6	1	R	M3	32						14	No	No
M	6	1	R	M4	7						8	No	No
M	6	3	S	R2	30	3	2	3	3	4	63	No	No
M	6	5	R	M4	58						43	No	No
M	6	5	R	M4	25						22	No	No
M	6	5	S	M4		1.5	1.5	2	1.5	0.5	40	Yes	No
M	6	6	R	M4	12						18	No	No
M	6	6	R	M4	30						66	No	No
M	6	6	R	M4	10						13	No	No
M	6	6	B	M4	10						21	No	No
M	6	7	R	M4	50						45	No	No
M	6	10	A	R3							125	Yes	No
M	6	10	R	R3							31	Yes	No

Appendix, Table 17 continued													
St	Pl	SPl	Sp	FFCT	H10	I11	I12	I13	I14	I15	H15	N	D
M	6	11	A	M4	11						22	No	No
M	6	11	A	M2	45						97	No	No
M	6	11	A	M3	15						67	No	No
M	6	11	A	M3	11						90	No	No
M	6	11	A	M3	17						77	No	No
M	6	11	A	M2	28						80	No	No
M	6	12	S	M3		2	2	1.5	1.5	2	16	Yes	No
M	6	14	R	M2	27						43	No	No
M	6	14	R	M3	58						59	No	No
M	6	14	R	M2	37						40	No	No
M	6	17	R	M4	10						17	No	No
M	6	19	S	R4					1.5	1.5	5	Yes	No
M	7	1	A	B1D1M1R1V1	105						125	No	No
M	7	2	A	V3	41						42	No	No
M	7	2	A	D1M1V1	30						69	No	No
M	7	2	A	D1M1	17						43	No	No
M	7	2	A	B1D1M1V1	52						37	No	No
M	7	2	A	B1D1M1	13						33	No	No
M	7	2	A	B1D1M1	15						73	No	No
M	7	2	A	D1M1	18						32	No	No
M	7	7	R	M4							16	Yes	No
M	7	7	R	M4							31	Yes	No
M	7	9	R	M4V4	52						48	No	No
M	7	9	R	M4V4	35						38	No	No
M	7	9	R	M4V4	52						40	No	No
M	8	2	B	M4	27						39	No	No
M	8	9	R	B1D1M1	60						32	No	No
M	8	9	R	M4	29						28	No	No
M	8	11	R	M4							11	Yes	No
M	9	5	R	V3	70						11	No	No
M	9	5	R	V3							8	Yes	No
M	9	5	B	V3							12	Yes	No
M	9	10	A	M3	25						71	No	No
M	9	10	A	M1	16						45	No	No
M	9	11	R	M4	50						43	No	No
M	9	11	R	V3	35						38	No	No
M	9	11	R	M1V1Ö1	53						46	No	No
M	9	12	R	M4	20						14	No	No
M	9	15	S	M4		2	3	4	3	2	38	Yes	No
M	9	20	B	V4							9	Yes	No

Appendix, Table 17 continued													
St	Pl	SPl	Sp	FFCT	H10	I11	I12	I13	I14	I15	H15	N	D
M	10	3	R	M4	71						31	No	No
M	10	3	R	M4	36						36	No	No
M	10	5	B	V4							45	Yes	No
M	10	5	B	D1M1V1							38	Yes	No
M	10	5	W	D1M1							45	Yes	No
M	10	5	B	V3							15	Yes	No
M	10	8	B	B1M1							23	Yes	No
M	10	8	B	B1M1							19	Yes	No
M	10	11	R	M4							6	Yes	No
M	10	13	R	M4V4	49						34	No	No
M	10	14	R	D1M1	20							No	Yes
M	10	16	B	M1							11	Yes	No
M	10	16	B	D1M1							32	Yes	No
M	10	17	R	B1D1M1	60						55	No	No
M	10	17	R	B1D1M1R1Ö	15						32	No	No
M	10	19	R	R4	27							No	Yes
M	10	19	B	R4							6	Yes	No
M	10	19	B	R4							12	Yes	No
M	11	2	R	M4	63						16	No	No
M	11	10	R	B1D1M1	33						24	No	No
M	11	10	R	D1M1	40						33	No	No
M	11	16	R	M4	6						10	No	No
M	11	17	R	M4	30						33	No	No
M	11	18	R	B2	32						14	No	No
M	11	18	S	D1M1Ö1		1	1	1	1	1	14	Yes	No
M	11	18	S	D1M1		1	1	1	1	1.5	16	Yes	No
M	11	18	S	D1M1		1	1	1	1	1	9	Yes	No
M	11	18	S	D1M1		1	1	1	1	1	11	Yes	No
M	11	18	S	D1M1		1.5	1.5	1	1	1.5	17	Yes	No
M	11	18	S	D1M1		1.5	1	1	1.5	1	16	Yes	No
M	11	18	S	D1M1		1.5	1.5	1.5	1	2	15	Yes	No
M	11	18	S	D2		1	1	0.5	0.5	0.5	10.5	Yes	No
M	11	19	S	M3	98	0.5	1	0.5	1	0.5	99	No	No
M	11	19	R	M3	70						67	No	No
M	11	19	R	M3	28						33	No	No
M	12	5	B	R4V4							20	Yes	No
M	12	13	S	M4		1	1	2	1	2.5	9	Yes	No
M	12	13	S	M4V4				1.5	2	2	6	Yes	No
M	12	13	S	M4V4		2	2	2	2	3.5	15	Yes	No
M	13	1	R	D1M1R1	50						48	No	No

Appendix, Table 17 continued

St	Pl	SPl	Sp	FFCT	H10	I11	I12	I13	I14	I15	H15	N	D
M	13	1	R	D1M1R1	32						31	No	No
M	13	2	B	M4	3							No	Yes
M	13	2	B	M4							25	Yes	No
M	13	2	B	M4							26	Yes	No
M	13	2	B	M4							31	Yes	No
M	13	2	B	M4							30	Yes	No
M	13	2	B	M4							37	Yes	No
M	13	3	S	M4	15							No	Yes
M	13	5	B	M4	2							No	Yes
M	13	5	B	M4	2							No	Yes
M	13	5	B	M4	1							No	Yes
M	13	5	B	M4	1						24	No	No
M	13	5	B	M4	1						24	No	No
M	13	5	B	M4	1							No	Yes
M	13	5	B	M4	1							No	Yes
M	13	5	B	M4	1							No	Yes
M	13	5	B	M4	1							No	Yes
M	13	5	B	M4	1						31	No	No
M	13	5	B	M4	1						31	No	No
M	13	5	B	M4	1							No	Yes
M	13	5	B	M4	1							No	Yes
M	13	5	B	M4	1							No	Yes
M	13	5	B	M4	1							No	Yes
M	13	5	B	M4	1							No	Yes
M	13	5	B	M4	2							No	Yes
M	13	5	B	M4	1							No	Yes
M	13	5	B	M4	1							No	Yes
M	13	5	B	M1							25	Yes	No
M	13	5	B	M2							29	Yes	No
M	13	6	S	B1D1M1		2	1.5	1.5	2	2.5	16	Yes	No
M	13	7	S	M2V2		2	2	2	2	2	15	Yes	No
M	13	7	S	M2V2		2	2	2	1.5	2	13	Yes	No
M	13	7	S	M2V2				1	1.5	1.5	6	Yes	No
M	13	7	S	M2V2		1	1	1.5	1.5	2	9	Yes	No
M	13	7	S	M2V2		2	2	2	1.5	2	13	Yes	No
M	13	7	S	M2V2		2	2	2.5	1	2.5	11	Yes	No
M	13	7	S	M2V2		2	2	1.5	2	2	10	Yes	No
M	13	12	R	M4	5							No	Yes
M	13	12	S	M4	25							No	Yes
M	13	13	P	M3		1.5	1.5	1	0.5	0.5	9	Yes	No

Appendix, Table 17 continued

St	Pl	SPl	Sp	FFCT	H10	I11	I12	I13	I14	I15	H15	N	D
M	13	16	S	D1M1V1	22	2	2	2	3	2.5	18	No	No
M	13	16	S	V4	12	2.5	1.5	2	3	3	16	No	No
M	13	16	S	V3	20	3	2	1.5	3	2	16	No	No
M	13	16	S	V3	10							No	Yes
M	13	16	S	V3	12	3	2	2	2	3.5	16	No	No
M	13	20	R	V4	37						33	No	No
M	13	20	R	V4	35						31	No	No
M	14	6	B	M3	3							No	Yes
M	14	6	B	M3							37	Yes	No
M	14	6	B	M3							32	Yes	No
M	14	6	B	M3							31	Yes	No
M	14	6	B	M4							14	Yes	No
M	14	12	R	D1M1	54						24	No	No
M	14	15	R	M4	29							No	Yes
M	14	15	R	M4	12							No	Yes
M	14	15	R	M4	10						12	No	No
M	14	15	R	M4	15						15	No	No
M	14	15	R	M4	5							No	Yes
M	14	15	R	M4	13						14	No	No
M	14	16	S	M4	93	2	1.5	2	3	2.5	89	No	No
M	14	16	R	M4V4	73						48	No	No
M	14	16	R	D1M1R1							39	Yes	No
M	14	18	B	M4	58						38	No	No
M	15	1	S	M2	12							No	Yes
M	15	1	S	M2	14							No	Yes
M	15	1	S	M2		2	2	2	3	3	14	Yes	No
M	15	1	S	M4				2	3	3.5	9	Yes	No
M	15	8	S	B1D1		2	1.5	1.5	2	2	9	Yes	No
M	15	10	B	R4							35	Yes	No
M	15	11	B	M1							15	Yes	No
M	15	11	B	M1R1							10	Yes	No
M	15	11	B	M1							34	Yes	No
M	15	12	B	D1G1M1							6	Yes	No
M	15	13	B	M1							32	Yes	No
M	15	13	B	M1							42	Yes	No
M	15	13	B	B1D1M1Ö1							29	Yes	No
M	15	14	B	B1D1M1							36	Yes	No
M	15	15	B	M4							11	Yes	No
M	15	16	R	M2	23						25	No	No
M	15	16	R	M4	11						16	No	No

Appendix, Table 17 continued													
St	Pl	SPl	Sp	FFCT	H10	I11	I12	I13	I14	I15	H15	N	D
M	15	18	R	R4	22						17	No	No
M	15	18	R	R1							15	Yes	No
M	15	18	B	M3							26	Yes	No
M	15	19	R	D1G1M1R1							8	Yes	No
M	15	19	R	D1G1M1R1							6	Yes	No
M	16	2	S	B1D1	27	1.5	1	1.5	1	1.5	39	No	No
M	16	2	S	V3	13	1	1	1.5	1	1.5	8	No	No
M	16	6	S	M4		1.5	1	0.5	1	1.5	14	Yes	No
M	16	7	R	D1M1							6	Yes	No
M	16	7	B	D1M1							9	Yes	No
M	16	7	B	D1M1							7	Yes	No
M	16	7	B	D1M1R1							10	Yes	No
M	16	9	B	B1D1M1							10	Yes	No
M	16	9	B	R3							4	Yes	No
M	16	10	R	M2							6	Yes	No
M	16	11	R	M4	17						36	No	No
M	16	11	R	M3							12	Yes	No
M	16	15	B	M4							17	Yes	No
M	16	15	B	M4							6	Yes	No
M	16	16	R	M4R4	35						20	No	No
M	17	2	B	M1							13	Yes	No
M	17	2	S	M1				2	2	2	6	Yes	No
M	17	2	B	M3							6	Yes	No
M	17	2	S	M3						6	9	Yes	No
M	17	13	B	M3							12	Yes	No
M	17	13	B	M3							6	Yes	No
M	17	13	B	M3							11	Yes	No
M	17	14	B	M4							17	Yes	No
M	17	16	B	V3							7	Yes	No
M	17	16	B	V3							10	Yes	No
M	17	16	B	V3							3	Yes	No
M	17	20	B	D1G1M1Ö1	2						26	No	No
M	17	20	B	D1M1Ö1	3						49	No	No
M	17	20	B	D1G1M1Ö1	1						30	No	No
M	17	20	B	D1G1M1Ö1	1						28	No	No
M	17	20	B	D1G1M1Ö1	1						37	No	No
M	17	20	B	D1G1M1Ö1	1							No	Yes
M	17	20	B	D1G1M1Ö1	1							No	Yes
M	17	20	B	D1	1							No	Yes
M	17	20	B	D1	1							No	Yes

Appendix, Table 17 continued													
St	Pl	SPl	Sp	FFCT	H10	I11	I12	I13	I14	I15	H15	N	D
M	17	20	B	D1	1							No	Yes
M	17	20	B	D1M1							17	Yes	No
M	17	20	B	D1							15	Yes	No
M	17	20	B	D1							25	Yes	No
M	17	20	B	D1							21	Yes	No
M	17	20	B	D1							8	Yes	No
M	17	20	B	D1							30	Yes	No
M	17	20	B	D1M1							26	Yes	No
M	17	20	B	D1M1							29	Yes	No
M	17	20	B	D1M1							8	Yes	No
M	17	20	B	D1M1							18	Yes	No
M	17	20	B	D1M1							31	Yes	No
M	17	20	B	D1M1							34	Yes	No
M	17	20	B	D1M1Ö1							28	Yes	No
M	17	20	B	D1M1							22	Yes	No
M	17	20	B	D1							22	Yes	No
M	17	20	B	D1							12	Yes	No
M	17	20	B	D1G1M1Ö1							10	Yes	No
M	17	20	B	D1							49	Yes	No
M	17	20	B	D1							11	Yes	No
M	17	20	B	D1							31	Yes	No

Table 18. Forest floor cover types in Halåsen

Forest floor cover type	Amount of ground squares	Percentage
M4	1295	57.81%
M3	206	9.20%
M2	133	5.94%
R4	48	2.14%
D1M1	43	1.92%
MB	41	1.83%
D3	36	1.61%
M4V4	35	1.56%
R3	27	1.21%
D2	21	0.94%
V3	20	0.89%
D1	20	0.89%

Appendix, Table 18 continued

Forest floor cover type	Amount of ground squares	Percentage
D1G1M1	18	0.80%
D2M2	18	0.80%
D4	15	0.67%
V4	15	0.67%
D1G1M1S1Ö1	14	0.63%
B1D1M1	13	0.58%
R2	13	0.58%
D3M3	12	0.54%
V2	11	0.49%
D1G1	9	0.40%
D1M1S1	8	0.36%
B1D1G1M1Ö1	7	0.31%
D4M4	7	0.31%
M2V2	6	0.27%
M3R3	5	0.22%
D1M1Ö1	5	0.22%
B1D1G1Ö1	5	0.22%
D1M1V1	4	0.18%
B1D1G1M1	4	0.18%
M3V3	4	0.18%
D1M1S1Ö1	4	0.18%
D1M1S1V1	4	0.18%
D1G1M1R1	4	0.18%
B1D1G1S1Ö1	4	0.18%
D1G1M1S1	4	0.18%
G2	3	0.13%
D1G1M1Ö1	3	0.13%
B2	3	0.13%
D1G1M1R1S1	3	0.13%
D1G1Ö1	3	0.13%
D1R1	3	0.13%
B1D1G1M1S1Ö1	3	0.13%

Appendix, Table 18 continued

Forest floor cover type	Amount of ground squares	Percentage
G3	3	0.13%
M1	3	0.13%
B1M1	3	0.13%
G1	2	0.09%
B1G1M1	2	0.09%
B1D1M1S1	2	0.09%
D1M1R1	2	0.09%
D1G1M1V1	2	0.09%
D1Ö1	2	0.09%
D1G1S1Ö1	2	0.09%
M2R2	2	0.09%
B1D1M1V1	2	0.09%
M2S2	2	0.09%
D3R3	2	0.09%
D1M1R1Ö1	2	0.09%
B1D1M1Ö1	2	0.09%
B2M2	2	0.09%
D1G1M1V1Ö1	2	0.09%
D1R1M1S1	2	0.09%
B1D1M1R1Ö1	2	0.09%
D1M1R1S1	2	0.09%
D1V1	1	0.04%
B1D1Ö1	1	0.04%
B1	1	0.04%
D2S2	1	0.04%
B1D1V1	1	0.04%
D1G1M1S1V1	1	0.04%
B1G1M1R1	1	0.04%
D1G1M1S1V1Ö1	1	0.04%
B1D1M1S1V1	1	0.04%
B1G1Ö1	1	0.04%
B1D1S1Ö1	1	0.04%

Appendix, Table 18 continued

Forest floor cover type	Amount of ground squares	Percentage
D3V3	1	0.04%
D1S1	1	0.04%
B1G1S1Ö1	1	0.04%
B1D1G1M1R1Ö1	1	0.04%
B1D1G1M1S1	1	0.04%
D2R2	1	0.04%
B1M1Ö1	1	0.04%
D1M1R1S1Ö1	1	0.04%
G1M1	1	0.04%
B1D1	1	0.04%
B1M1R1	1	0.04%
B1D1R1	1	0.04%
B1D1M1R1S1Ö1	1	0.04%
D1G1M1R1Ö1	1	0.04%
G4M4	1	0.04%
R1	1	0.04%
B2D2M2	1	0.04%
D1S1V1	1	0.04%
M1G1	1	0.04%
S2	1	0.04%
M1Ö1	1	0.04%
D2G2	1	0.04%
M1S1	1	0.04%
B1D1G1V1	1	0.04%
M2Ö2	1	0.04%

Appendix Table 19. Forest floor cover types in Mordviksboderna

Forest floor cover type	Amount of ground squares	Percentage
M4	2137	39.28%
M3	394	7.24%
D1M1	387	7.11%

Appendix, Table 19 continued		
Forest floor cover type	Amount of ground squares	Percentage
R4	355	6.53%
M2	329	6.05%
B1D1M1	146	2.68%
M4V4	145	2.67%
MB	109	2.00%
R3	102	1.88%
V4	97	1.78%
D1G1M1	93	1.71%
R2	90	1.65%
M1	70	1.29%
V3	66	1.21%
D1	56	1.03%
D1M1R1	51	0.94%
D2	48	0.88%
B1D1M1Ö1	43	0.79%
V2	37	0.68%
D1M1Ö1	35	0.64%
B1D1G1M1	30	0.55%
D1M1V1	29	0.53%
IJ	26	0.48%
M2V2	22	0.40%
M3V3	20	0.37%
B2	20	0.37%
D1G1M1Ö1	19	0.35%
D2M2	19	0.35%
D1G1M1R1	17	0.31%
G4	16	0.29%
B1D1M1R1	14	0.26%
B1D1	14	0.26%
M1R1	14	0.26%
B1M1Ö1	13	0.24%
B3	13	0.24%

Appendix, Table 19 continued		
Forest floor cover type	Amount of ground squares	Percentage
M1Ö1	12	0.22%
D1R1	12	0.22%
B1	12	0.22%
D1G1	12	0.22%
G2M2	12	0.22%
B1D1G1M1Ö1	12	0.22%
D3	12	0.22%
D1G1Ö1	11	0.20%
M2R2	11	0.20%
B1M1	11	0.20%
R1	10	0.18%
G1M1	8	0.15%
G3	8	0.15%
M4R4	8	0.15%
G2	7	0.13%
B1D1Ö1	7	0.13%
D1Ö1	7	0.13%
D3M3	6	0.11%
B1D1M1V1	6	0.11%
D4M4	6	0.11%
D1G1M1V1	6	0.11%
M3R3	6	0.11%
D2V2	6	0.11%
D4	6	0.11%
B1D1M1S1	5	0.09%
D1M1R1Ö1	5	0.09%
M4W4	4	0.07%
B1G1M1	4	0.07%
D1M1V1Ö1	4	0.07%
B1D1M1V1Ö1	4	0.07%
B2M2	4	0.07%
B3M3	4	0.07%

Appendix, Table 19 continued		
Forest floor cover type	Amount of ground squares	Percentage
B1D1R1	4	0.07%
B1G1M1Ö1	4	0.07%
G1M1Ö1	4	0.07%
B4	3	0.06%
B1D1M1R1Ö1	3	0.06%
B1G1Ö1	3	0.06%
M1V1	3	0.06%
G1M1R1	3	0.06%
D4V4	3	0.06%
D1V1	3	0.06%
B1G1R1	3	0.06%
W3	3	0.06%
B1R1Ö1	2	0.04%
M1R1Ö1	2	0.04%
B1D1M1R1V1	2	0.04%
D1M1R1V1	2	0.04%
B1D1M1S1Ö1	2	0.04%
D4M4V4	2	0.04%
R2V2	2	0.04%
B1G1	2	0.04%
B1M1R1Ö1	2	0.04%
B1D1G1M1V1Ö1	2	0.04%
R4V4	2	0.04%
D1G1R1	2	0.04%
B1R1	2	0.04%
W4	2	0.04%
Ö1	2	0.04%
D1R1Ö1	2	0.04%
B1D1R1Ö1	2	0.04%
B1D1G1M1R1Ö1	2	0.04%
B1M1R1	2	0.04%
V1	2	0.04%

Appendix, Table 19 continued		
Forest floor cover type	Amount of ground squares	Percentage
M3R3W3	1	0.02%
B1G1M1R1S1Ö1	1	0.02%
B2R2	1	0.02%
B1M1V1	1	0.02%
R3V3	1	0.02%
B1Ö	1	0.02%
B1D1G1M1V1	1	0.02%
G1M1R1Ö1	1	0.02%
B2R2V2	1	0.02%
G1M1V1	1	0.02%
D4R4	1	0.02%
B1D1R1V1	1	0.02%
B1M1S1	1	0.02%
W2	1	0.02%
B1W1	1	0.02%
D1M1G1	1	0.02%
B1G1M1R1Ö1	1	0.02%
B1Ö1	1	0.02%
D2G2	1	0.02%
M2Ö2	1	0.02%
D4M4W4	1	0.02%
D1M1S1	1	0.02%
D2R2	1	0.02%
G1H1M1	1	0.02%
H1M1R1	1	0.02%
M2W2	1	0.02%
D1G1M1S1	1	0.02%
B1V1	1	0.02%
D1V1Ö1	1	0.02%
M1R1V1Ö1	1	0.02%
D1G1H1M1	1	0.02%
M1S1	1	0.02%

Appendix, Table 19 continued		
Forest floor cover type	Amount of ground squares	Percentage
D1G1M1R1V1Ö1	1	0.02%
M1S1Ö1	1	0.02%
G1Ö1	1	0.02%
B1G1R1Ö1	1	0.02%
B1D1G1M1R1	1	0.02%

Appendix Table 20. Full version of Table 9

	Annual shoot lengths (cm)					Number of individuals	
Treatments	2011	2012	2013	2014	2015	Survivors	New
Thin	1.5	1.5	1.9	1.9	2.2	8	5
thin fert	1.5	1.5	1.8	1.7	2.7	0	3
thin scar	2	2.2	2.4	2.8	2.6	0	4
limit thin	2.1	1.8	2.1	2.1	2.1	2	3
spat thin	2	1.8	1.3	1.7	2.2	1	5
spat thin scar	-	-	2	2	4	0	2
spat thin fert	2.1	1.8	1.8	2	2.3	4	8
spat thin scar fert	3	3	1.5	3	3.5	0	1
Control	1.3	1.25	1.5	1.5	1.6	1	31
Number of individuals							
Thin	12	12	13	13	13		
thin fert	2	2	3	3	3		
thin scar	3	3	4	4	4		
limit thin	4	4	4	5	5		
spat thin	3	5	6	6	6		
spat thin scar	0	0	1	1	2		
spat thin fert	11	11	12	12	12		
spat thin scar fert	1	1	1	1	1		
Control	10	14	26	31	32		

Appendix Table 21. Overview over seed trap results from spring 2011

Measurements: ***Size of seed trap in cm (not possible to show for stand totals)***

Stand	Measurements (cm)	Surface area (m^2)	Norway spruce seeds (total)	Norway spruce seeds (seeds m^{-2})
H	62x57	0,28	0	0
H	54x58	0,25	1	4,1
H	58x58	0,26	4	15,1
H	56x58	0,26	3	11,8
H	58x59	0,27	2	7,4
H	62x51	0,25	1	4,0
H	57x59	0,26	4	15,1
H	61x56	0,27	4	14,9
H	61x56	0,27	3	11,2
H	57x57	0,26	0	0
H	56x56	0,25	2	8,1
H	56x54	0,24	9	37,9
Total H	-	3,10	33	10,6
M	58x59	0,27	4	14,9
M	57x55	0,25	2	8,1
M	55x59	0,25	1	3,9
M	52x47	0,19	5	26,0
M	55x57	0,25	7	28,4
M	53x58	0,24	3	12,4
M	52x63	0,26	2	7,8
M	58x58	0,26	4	15,1
M	58x55	0,25	1	4,0
M	61x56	0,27	5	18,6
M	54x63	0,27	4	15,0
M	63x57	0,28	1	3,5
Total M	-	3,04	39	12,8

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