Diversity of vascular plants in Swedish forests: comparison among and within forest, partially cut down and clear cut forest communities

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Masters Project (15 ECTS)

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Summary

Swedish forests are mostly used for timber harvesting and 96% of this harvesting is made by clear cutting while only 4% is effected through other methods such as single tree harvesting. All species are not affected by forestry to same magnitude. Some specifically generalists are not affected at all. Hence, this study, had its aim to find out vascular plant species that persist, disappear or colonize other species as a result of anthropogenic disturbances in different production forests, so as to determine not only if canopy openness affects the species distribution but also the magnitude of the effects. I examined 10 different forest localities during May and June 2008. Three of these localities were made up of clear cut forest plots, 3 with partially cut down forest plots and 4 with undisturbed production forest plots. Species composition and diversity were then compared between these plots. A total of 34 different species were found. Statistical Analysis was made on how well the species in the partially cut down forest plots fitted into the undisturbed forest group as well as comparing this results with results of how counterpart species in the clear cut forest plots fitted into the undisturbed forest groups. These results showed that there was no significant difference, ANOVA values of P = 0.839, 0.602 and 0.564 respectively among the species composition between the forest, partially cut down and clear cut forest groups between the forest, partially cut down and clear cut forest plots. However, among the 54 species found in all study plots, 11 were common between the forest and partially logged sites whereas only Carex sp in the clear cut forest was common to those in the forest plots implying that canopy openness did not affect the total species number but had an effect in species composition. Clear cutting seems to kill off everything but trees and generalists. Hence, resiliency of vegetation should be increased by management practices that ensure the maintenance of prior species.

Key Words: Forest management, boreal forest, biodiversity, disturbance, clear cutting and partially cut down forest
Acknowledgement

Firstly, I would like to express my sincere gratitude to my supervisor, Göran Sahlén for his immense advice and encouragement throughout this project. I thank Filip Hedeving for giving me permission to carry out my research in Vida skog’s forestry zones. Lastly, my sincere thanks go to Henry Andersson of Vida Skog for his guidance during all the visits to the forest.
Introduction

Forestry is a big industry in Sweden. About 55% of the land area in Sweden consist of forest land and approximately 95% of all Swedish forest is used for timber harvesting (Eriksson & Hammer, 2006; Flenner and Sahlén, 2008). A forest is a plant community consisting predominantly of trees and other woody vegetation, growing closely together (Coulombe, 2008). A long history of forestry has resulted in only a small remnant of old-growth forest (Eriksson & Hammer, 2006). Forestry, including clear-felling, has been conducted in Sweden for centuries and the natural forests are very sparse today; only 0.5% of the productive forest area below the mountain zone is legally protected (Hazell & Gustafsson, 1999). Of the total annual timber harvest, 96% is made by clear-cutting while only 4% is harvested with other methods such as single-tree selection (Thuresson, 2001 in Eriksson & Hammer, 2006).

However, it is sometimes argued by the forest sector, that clear-cutting is not very unnatural because of similarities with forest fires and windthrows (Bengtsson et al., 2000). But the effects of forestry differs from natural disturbances in some fundamental ways such as shorter periodicity than that of natural disturbances, different spatial configuration with less patches partially or totally intact and the fact that a huge amount of biomass are removed from the forest during harvesting (Niemelä, 1999). The large impact of Forestry in Sweden has resulted in a depletion of habitats, flora and fauna in this region. Taking all taxa in the Swedish Red-listed species in forest land 2005, into consideration, out of the 3548 red-listed species, 1810 are forest living species (SFA, 2007). Thus, it is important to identify and preserve areas with high biodiversity values (Ericsson et al., 2005). Also, a proper classification of herb-rich forests is needed both for forests management and for conservation purposes (Hokkanen, 2006). Commercial large-scale forestry has had a considerable impact on the natural heterogeneity in Scandinavian boreal forests, leading to subdivision of natural habitats, monocultures of trees, decrease in the abundance of dead trees, fire protection, and short rotation times for forest stands (e.g. Hansson, 1992; Haila and Kouki, 1994 in Fridman, 2000). In fact many threatened forest species in Sweden have very specific substrate demands and depend largely upon the diversity of microhabitats provided by old trees, logs and snags.

There has long been a theoretical interest in ecology on how the size and spatial configuration of patches affect communities and populations. Further, in the last 20 years there has been an increasing focus on systematic conservation planning, i.e. how to select protected areas in a way that captures biodiversity as efficiently as possible. But, there is still a lack of empirical
studies in which comparisons regarding biodiversity are made between different types of set-asides or protection zones (Perhans, 2007). To date, there have been few studies addressing the possible link between forest continuity and biodiversity based on high quality forest history and species occurrence data (Ohlson et al., 1997 and Josefsson et al., 2005; in Örjan et al., 2008). The preservation of biodiversity and sustainability of a high forest yield are now legally of equal weight in the Swedish Forestry Act (SFA, 2007).

In boreal forests understorey, vegetation is more sensitive indicator of the environment than the tree layer (Cajander, 1909, 1926; Frey, 1978; Trass and Malmer, 1978; Kuusipalo, 1985 in Hokkanen, 2006). This is because, the canopy layer is often simple and poor in species, while the ground layer contains diverse vegetation (Kuuspalo, 1985 in Hokkanen, 2004). However, vascular plants and bryophytes have different relationships to environmental gradients (Ingerpuu et al., 1998, 2001, 2003; Gould and Walker, 1999 in Hokkanen, 2006). In addition, vascular plants are more indicative of other taxonomic groups (e.g. Sahlen and Ekestubbe, 2001) such as lower plants and even certain animal taxa, and in natural environments, they might be useful substitutes for predicting overall diversity (Myers et al., 2000; Anand et al., 2005 in Hokkanen, 2006).

According to Bengtsson et al. (2000), all species are not equally affected by forestry. Some species, primarily generalists, are not affected at all or even affected in a positive way: this is often species with good dispersal ability which are not that sensitive to fragmentation. They further conclude that other species often specialists, are severely affected by e.g. fragmentation and habitat loss, particularly species depending on old-growth forests or old trees.

**Purpose of Study**

When mature production forests are clear cut, most plant species die off and are replaced by a clear cut plant community. If felling is more selectively done, some forest species might survive. This would be beneficial for the recruitment of the plant community in the new forest which will be planted after some years; thus enabling species more sensitive to disturbances to survive in the long run.

Hence, the purpose of this Master’s thesis will be to find out vascular plant species that persist, disappear or colonize other species as a result of anthropogenic disturbances in
different production forests, so as to determine not only if canopy openness affects the species distribution but also the magnitude of the effects. This information will assist in conserving biodiversity and ensuring sustainable livelihoods by modifying land-use practices, business practices and consumer behaviour.

Methods

Study Area

This study took place in Sandhult, Tolljö and Hedared all located in the county of Västra Götaland, Sweden (Figure 1), during May and June 2008.

Figure 1. Map of Sweden showing sampling locations. (Compiled by Author from Lantmäteriet, August 2008).

The study was carried out in 3 different forest localities (Figure 1). These study areas were chosen based on information gotten from forest harvesters of VIDA Skog AB (Sweden’s largest privately owned sawmill group) about the age of the undisturbed forests and how long VIDA lastly harvested partially cut and clear cut forests.

The first locality found in Sandhult (Figure 1) comprised of 3 similar plots. These plots were approximately 2 hectares each and were made up of undisturbed production forest of about 65 years old with underlying vegetation (Figure 2). Quadrates of one square metre were placed into each of the 3 plots in order to count the vascular plant species. The quadrate
numbers were 20, 25 and 21 respectively for the 3 plots. No fixed number of quadrates was predetermined but a limit was reached whenever the cumulative number of new vascular plant species per plot in each plot reached a constant value.

The second set of similar plots was located in Tolljö (Figure 1). These plots were made up of partially cut down forests (Figure 3) of about 75 years old and they were 3 plots in number. Each of these plots also measured approximately 2 hectares. Quadrates of 1 square metre were aligned into each of these 3 similar plots in order to count the vascular plant species. The quadrate number was 30, 27 and 22 respectively for each plot. Here also, no fixed quadrate number was pre-determined. Rather, the maximum limit was considered whenever the cumulative number of new vascular plant species per quadrate in each plot reached a constant value.

The third set of similar plots was located in Hedared (Figure 1). These plots were made up of clear cut forests (Figure 4) of about 70 years old with cuttings of 4 years old. Each of these plots measured approximately 2 hectares. Quadrates of 1 square metre were aligned into each of these plots in order to count the vascular plant species. Again, no fixed quadrate number was preset but quadrate number was considered maximum whenever the cumulative number of new vascular plant species per quadrate in each plot reached a constant, resulting to a quadrate number of 20, 15 and 15 respectively for the 3 similar plots.

It should be noted however that in addition to the 3 study localities above, one forested plot (Figure 5) of about 75 years old made up of *Picea* spp and *Pinus sylvestris*, located in Borgstena (Figure 1), was inspected but its underlying vegetation was void of vascular plant species and comprised mostly of mosses and liverworts. Hence, data from this plot was not used in the analysis of results.

The age of undisturbed forest plots was calculated from the number of circular tree rings in the diameter of the tree stem (Niklasson, 2002) as illustrated in Figure 6, with each tree ring equivalent to one year. This age is then correlated with the age given by the land lord. The first 30 rings from the centre appear very close to one another. This indicates that the trees had unfavourable growth within the first 30 years as a result of intense competition for water, air, sunlight, space, nutrients, etc with other plants. The period thereafter followed optimal growth in the trees and this is expressed in the distance between the tree rings after the age of 30. Hence, the approximate ages were 65, 75 and 70 years old respectively for the undisturbed forest with underground vegetation, partially cut down and clear cut forests.
Figure 2: An undisturbed forest, about 65 years old, with underlying vegetation in Sandhult. (Photo taken by Author, June 2008)

Figure 3: A partially cut down forest, about 75 years old in Tolljö, with partial cuttings since 3 years ago, (Photo taken by Author, May 2008).
Figure 4: A clear cut forest (since 4 years ago) of about 70 years old in Hedared (Photo taken by Author, June 2008).

Figure 5: An undisturbed forest, about 75 years old with no underlying vegetation in Borgsten (Photo taken by author, May 2008).
Figure 6: Circular rings in the stem showing age of the tree (Photo taken by Author, May 2008)

**Climatic conditions**

Tree dominated forests can occur wherever the temperatures rise above 10 °C in the warmest months and the annual precipitation is more than 200mm (Encyclopaedia Britannica, 2008). According to Sveriges National Atlas - Västra Götaland, (2003), the mean temperatures in the hottest month (July) is 15.8°C along the coast and 15.3°C in the north western part of the county while the mean temperature in the coolest month (December) is 2.2°C along the coast while the north western part gets as cool as -2.2°C. Moreover, the annual rainfall ranges from 550 to 1000mm.

**Vegetation measurements**

The nomenclature for vascular plants was obtained from Den nya nordiska Floran (2003). Data collection was from inspection of vascular plants, by placing 1 square metre quadrates at a distance of 10 metre apart, in the different plots. This inspection was done from one plot to another. Within the individual plots, it was from one quadrate to another. For each plot, quadrates were placed starting from the left of the plot regardless of the direction I came from and movement was successively 10 metres to the right. Whenever an obstacle (such as a rock) was met on the position to place a quadrate, the position to the left of the obstacle was
chosen. The limit for the number of quadrates per plot was considered maximum whenever the cumulative number of the different species reached a constant value as illustrated in Figure 7. Quadrats in clear cut forest plots were placed 20 metres into the clear cut area in order to minimize the edge effects (Ting & Shaolin, 2008; Wuyts et al, 2009) number of forest species that might have migrated as a result of wind and insect dispersal, to nearby territories. Species that could not be determined in the field were dried flat and carried to the lab for identification and in cases where the species was difficult to be identified, the genus name was used. Plots with undisturbed forest, partially cut down and clear cut forest plots were approximately 2 hectares each. These surface areas were determined by GPS.

Figure 7. Illustration of maximum quadrate number determination

**Statistical Analysis**

Statistical analysis was performed by SPSS 17.0 for windows.

Discriminant functional analyses are used to examine how well groups differ with regards to the main of a variable and then to use the variable to predict a group membership. The three forest classes were used as groups and the vascular plant species as observation values. Thus the Discriminant analysis was made to show how well the plant composition fitted into the partially cut down forest plots, the undisturbed forest plots as well as the clear cut forest plots. The test gives an answer in percentage right classification of observations with lower percentages implying that the proposed groups do not exist. Higher percentages imply the species compositions fit well in the proposed groups. Mean characteristics for each site type were compared using Analyses of Variance (ANOVA) at 95 % confidence interval and an LSD (least significant difference) post-hoc test were used to investigate whether there was a
significant difference in species number in relation to plot types. Hence, the ANOVA was used to check for species composition.

However, it is interesting not only to see if the species compositions differ between the plots, but also diversity, so the species diversity was calculated using Simpson's Index of Diversity thus:

\[
D = 1 - \frac{\sum_{i=1}^{S} n_i(n_i - 1)}{N(N - 1)},
\]

Where;
\[D = \text{Diversity with values ranging from 0 to 1, and 0 represents infinite diversity and 1 represents no diversity;}
\]
\[S = \text{the number of species,}
\]
\[N = \text{the total number of organisms and}
\]
\[n = \text{the number of organisms of a species}
\]

Results

Species richness and diversity

A total of 34 different species were found altogether out of which 18 were found in the forest plots, 17 in the partially cut down forest plots and 19 in the completely clear cut forest plots (Figure 8). Two of these species, *Carex magellanica*, and *Phegopteris connectilis* were common to all three study types. Eleven of the species were common to both forest (See Appendix 1) and partially cut down forest (See Appendix 2) plots whereas only 2 species *Picea* sp. and *Pinus sylvestris* in addition to the above 2 common species were found in both forest and clear cut forest plots. Only five species were unique to forested plots.
Discriminant analysis

Up to 48.5 % of original grouped cases were correctly classified (Figure 9) in the discriminant analysis done to ensure that the forest species did not form groups corresponding to the partially cut down and clear cut down forests’ species. The canonical discriminant function in Figure 9 indicates that there are differences (ANOVA values of $P = 0.839$, $0.602$ and $0.564$ respectively for plots 1, 2 and 3; Appendix 1) in species composition between the forest, partially cut down and clear cut forest plots. However, the differences are not significant (ANOVA $P >0.05$, Appendix 1). The species compositions in the partially cut and clear cut forest plots seem to react in a similar way of neither colonising nor disappearing but persisting like the original species composition in the forest plots even though there is disturbance by forestry activities.
Figure 9: Canonical discriminant functions, 48.5 % of original grouped cases correctly classified, data divided in three classes. Class 1: vascular plant species in forested plots, Class 2: vascular plant species in partially cut down forest plots and Class 3: vascular plant species in clear cut forest plots.
Discussion

A total of 11 species were common between the forest and partially logged sites. This can act as a recruiting base for new vegetation. The discriminant functional analysis done with respect to samplings occasions of forest and partially cut down forests, shows only 48% separation. This implies the overall species composition in the forest is the same as in partially cut forest. Function 1 or Function 2 or both, probably stand for the disturbance level that has occurred in the various plots resulting in a different species composition.

The species unique to forested plots consisted of *Calypso bulbosa* and *Epilobium* species which grow in forests and woodlands generally in shady areas, where they grow in humus or in the decaying vegetation covering the forest floor. Hence, the presence of *Calypso bulbosa* might be a direct result of it being a circumboreal species (Boyden, 1982). *Geum urbanum* occurs widely on mildly acid to calcareous, freely draining and preferably moist soils (Vandepitte et al, 2007). Ecological settings for *Petasites* sp. include wet meadows, cedar swamps, and low woods, as well as road-side ditches, sloughs, and marshes (Plants for a Future 1997 in Shultz, 2003). Though *Petasites* can grow in full shade or semi-shade and can also be found in disturbed habitats (Shultz, 2003), it is strange enough that it was only found in forest plots. Probably due to its infrequent flowering and separate male and female plants, its sexual reproduction might have been hindered by environmental changes and disturbances, causing it to disappear in both the partially cut down and clear cut forest plots.

Only *Betula pubescens* (Birch) and *Leonurus cardiaca* (motherwort) were found exclusively in partially cut down forest plots. Motherwort naturally has its habitat on hedgerow usually on gravelly or calcareous soils (Stenberg and Mossberg, 2003). Birch is an early successional tree which is very productive, has a wind seed dispersal, a wide climatic and edaphic range and a limited tolerance to shade (Perala & Alm, 1990 in Prévostol et al., 1999). This makes it less persistent to shady conditions in the forested plots.

Most of the 11 species found exclusive to clear cut forest plots have habitats like *Knautia arvensis* which is a perennial species that grows in dry meadows, pastures, dry hills, open woods and roadsides (Lid and Lid, 1994 in Vange et al. 2004) and *Euphrasia* species which is semi-parasitic on grass and grows on moist grassland and chalky pastures. The genus *Rhinanthus* is a root hemi parasite which is outcompeted for light (Ameloot et al. 2006). Parasitic plants attach to their hosts by special roots called haustoria through which water, nutrients and carbon compounds are attracted.
However, only Carex species in the clear cut forest are common to those in the forest and partially cut forest plots. Probably, they are generalist species and hence are less sensitive to disturbances (Bengtsson et al., 2000). This makes them persistent and this explains why Carex species were found in all 3 kinds of study areas.

Seven species have totally disappeared in the clear cut forest plots while eight new have been added in these clear cut plots (Appendix 2 - 4). Clear cutting seems to kill off everything but trees and generalists as well as introducing colonising species. It is possible that the presence of new species in clear cut forest plots not inhabited by them in forest and partially cut down plots has altered the original species composition in these forests due to factors like drought, direct intense sunlight action. For instance Rhinanthus being a root hemiparasite makes it to some extent self-sustaining with respect to carbon fixation and though it has become rare in Western Europe since the 1950s, due to agricultural intensification, they are among the characteristic (re)- colonisers during restoration of semi-natural grasslands (Ameloot et al. 2006).

Gradients in latitude suggest that plant diversity in the Arctic is sensitive to climate with summer temperatures being the environmental variable that best predicts its plant diversity (Collaghan et al., 2004). Temperature and light are among the most important environmental variables that are governed by the tree layer and alterations in the tree layer are likely to cause ground vegetation changes (Bergstedt and Milberg, 2001). Hence continuous clear cutting can lead to rising atmospheric carbon dioxide concentrations which in turn has likely direct effect on tree growth, in addition to the indirect effects acting through climate change (Broadmeadow, 2000). According to Collaghan et al. (2004) species respond to changes in temperature in ways which are moderated by how its competitors, neighbours, food, herbivores parasites, pests, length of growing season, summer warmth and future immigrant species respond to the same environmental change. The relative importance of each of these factors varies from species to species, site to site and year to year and this might have had an impact on the species composition in the various study plots. Climate change can also exacerbate the disappearance of species especially those species with strict habitat and climatic requirements and limited migration capabilities. Additionally, this warming can impact the soil carbon not only directly by accelerating the carbon cycle, but also indirectly via changes in the vegetation cover (Rinnan et al., 2008). As the climate becomes warmer, the relative abundance of species are altered and areas of human disturbance become more vulnerable to invasion by exotic species (Sturm et al., 2001). These exotic species can in turn colonize existing vegetation resulting in a completely new plant community which would not
be beneficial for the recruitment of the plant community in the new forest which will be planted after some years and it will not make possible species more sensitive to disturbances to survive in the long run. Carrying out this thesis research in the high Arctic temperature months of May and June could have influenced the results of the species composition in the various plot types, for instance according to Rannie (1986), July temperatures accounts for 95% of the variance in number of vascular plant species in the Canadian Arctic.

Many of the species in the northern hemisphere have broad circumpolar distributions and large forest areas are often dominated by a single tree species such as the *Picea* species, because of human tree planting. Environmental or anthropogenic changes that radically change the abundance of these species can cause widespread changes that cascade though all components of the ecological systems (Chapin et al., 2004). According to the Annual report on Sustainable Forestry in Southern Sweden (1999), whole tree harvesting is used in 50 % of the area in southern Sweden, often without any supply of fertilizers. Few areas could take more than one or two tree generations if you don't supply with base cations and fertilizers. If you use whole tree harvesting, deficit of potassium will increase. The store of base cations will show a negative balance in 96% of the areas. Whole tree harvesting gives twice a high deficit of base cations as the outflow of trunks only. This means that the store of base cations will be emptied in 10-50 years. Some species are very sensitive to such interactions e.g. *Calypso bulbosa* which is a rare orchid that grows in mossy coniferous forests (Ekman, 1992) and as such it will be replaced by exotic and invasive species like those in the clear cut forest plots. This will not be beneficial for the recruitment of the plant community in the new forest which will be planted after some years with the consequence that the most serious invaders will threaten the conservation of native vegetation.

In recent years, forestry practices in Sweden have started to change because of the Forestry Act (Skogsstyrelsen, 1994, 2007) and because of influence from certification of Swedish forest companies by the Forest Stewardship Council. These forest practices are likely to lead to larger areas being subjected to logging that is more intense than today’s thinning but not as intense as a complete clear-cut (Bergstedt and Milberg, 2001). Resiliency of vegetation should therefore be increased by management practices that ensure the maintenance of prior species such as those in the forest plots since they will be beneficial to the recruitment of the plant community in the new forest which will be planted after some years. This should include aggressive actions to encourage return of the site to desired species post-disturbance (Millar et al., 2006). This may require significant extra and repeated efforts to supply needed nutrients and water, intensive site preparation, replanting with high-quality
stock, diligent stand improvement practices, and minimizing invasion by non-native species, remove competing understory, fertilize young plantations, develop a cover species, thin and prune.

In conclusion, canopy openness did not affect the total species number but had an effect in the species composition. All forest plots showed equity in number of species diversity with 19, 17 and 18 different species for clear cut, partial cut down and forested plots respectively. Though the effects of canopy openness was not statistically significant, the reasons could be due to the small number of plot types (n=3) or small number in the species diversity or probably because the differences in themselves are too small for instance to be shown in numbers. However, from the findings of this study, canopy openness had a noticeable effect on species composition. There was a disparity in species composition as the canopy openness increased from the dense forest canopy through the partially cut down forest less dense canopy to the clear cut forest with no canopy layer. Many of the forest species (61.1%) were found in the partially cut down forest with only 22.2 % of the forest species found in the clear cut forest plots. This shows that most forest vascular plant species are colonised by new species through clear cutting forest whereas partial cutting of forests comparatively endures the original forest species. This indicates that conservation efforts should be geared towards selective harvesting of trees than clear cutting forests in order to maintain a recruitment base for new forests. Additionally, future research should be encouraged on the extent to which regeneration of new forests is facilitated by residual/colonial species.
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## APPENDICES

### Appendix 1

**ANOVA**

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### Appendix 2

**Forest plot species**

- *Arctium* sp.
- *Calypso bulbosa*
- *Carex capillaris*
- *Carex magellanica*
- *Epilobium* sp
- *Filipendula ulmaria*
- *Geum urbanum*
- *Petasites hybridus*
- *Peucedanum ostruthium*
- *Phegopteris connectilis*
- *Picea* sp
- *Pinus sylvestris*
- *Potentilla erecta*
- *Symphytum xuplandicum*
- *Thelypteris palustris*
- *Tussilago farfara*
- *Vaccinium myrtillus*
- *Vaccinium uliginosum*
Appendix 3

Species in partially cut down forest plots
Arctium spp.
Betula pubescens
Calluna vulgaris
Carex capillaris
Carex magellanica
Carex panicea
Erica tetralix
Filipendula ulmaria
Leontodon hispidus
Leonurus cardiaca
Peucedanum ostruthium
Phegopteris connectilis
Potentilla erecta
Symphytum xuplandicum
Thelypteris palustris
Tussilago farfara
Vaccinium myrtillus

Appendix 4

Species in completely cut down forest plots
Calluna vulgaris
Carex canescens
Carex magellanica
Carex panicea
Cephalaria rapunculoides
Erica tetralix
Euphrasia nemorosa
Gentiana pneumonanthe
Hammarbya paludosa
Juncus filiformis
Knautia arvensis
Ledum palustre
Leontodon hispidus
Phegopteris connectilis
Picea sp
Pinus sylvestris
Rhinanthus serontinus
Vaccinium vitis-idaea
Valeriana sambucifolia