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Boreal vegetation responses to forestry as reflected in field trial and survey data and the quality of cover estimates and presence/absence in vegetation inventory

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Front cover: ‘*Vaccinium myrtillus*’ by Frida Wall.

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Abstract

This thesis has two main focuses; first, the response of forest ground layer flora on forestry, mainly harvesting and secondly, the quality of the vegetation assessment methods, cover estimates by eye and presence/absence data.

The effect of harvesting intensity was evaluated with survey data from permanent plots as well as vegetation data from a field trial fourteen years after harvesting. Both data sets confirmed that response of ground layer flora increased with increasing logging intensity. Thereby, indicating that survey data is possible to use in research. From the survey data set, existence of a time lag was evident for several species and also a threshold level was evident in cutting intensity needed to affect a number of species. Logging had a modest, but significant positive effect on the change in species number per plot. Species turnover increased (i) with increasing dominance of *Picea abies* in the tree canopy; (ii) with increasing site productivity; and (iii) with increasing logging intensity. In the field trial scarification had a strong effect that was different from the one created by cutting.

In plant ecology cover estimate by eye and presence/absence recording are the two most frequent methods used. The methods were evaluated with survey data and a field trial.

In the first data set vegetation was recorded independently by two observers in 342 permanent 100-m^2 plots. Overall, one third of each occurrence was missed by one of the two observers, but with large differences among species. Species occurring at low abundance tended to be frequently overlooked. Variance component analyses indicated that cover data on 5 of 17 species had a significant observer bias. Observer-explained variance was <10% in 15 of 17 species.

In the second data set, 10 observers independently estimated cover in sixteen 100-m^2 plots in two different vegetation types. The bias connected to observer varied substantially between species. The estimates of missing field and bottom layer had the highest bias, indicating that missing layers are problematic to use in analysis of change. Experience had a surprisingly small impact on the bias connected to observer. Analyses revealed that for the statistical power, cover estimates by eye carries a higher information value than do presence/absence data when distinguishing between vegetation types, differences between observers is negligible, and using more than one observer had little effect.

Populärvetenskaplig sammanfattning

Den här avhandlingen belyser hur avverkning och markberedning påverkar markfloran i den svenska barrskogen. Dessutom utvärderas två inventeringsmetoder som används inom växtekologin. Vid arbetet har både rikstäckande inventeringsdata och fältförsök använts och de likartade resultaten tyder på att rikstäckande inventeringar är en underutnyttjad resurs i forskningen.

Ju större andel av träden som avverkas desto större blir förändringen av markflorans sammansättning. Vissa arter, som lingon, ljung, etc., verkar dock inte påverkas i nämnvärd omfattning, medan andra, som blåbär, minskar i relation till hur mycket som avverkats. Gräs och mjölkört ökar efter avverkning, dock visar sig vissa gräs och mjölkört inte reagera om inte avverkningen överskrider ett tröskelvärde på ca 80 %. Avverkning har en liten, men signifikant, effekt på antalet arter, medan artomsättning, d.v.s. arters etablering på och/eller försvinnande från provytorna, framförallt påverkas av andel gran innan avverkning, markens produktionsförmåga och först därefter av hur stor andel av träden som avverkas. Det var också uppenbart att markberedning har en stark effekt som skiljer sig från avverkning. Framförallt gynnas björnmossor av markberedning men även vårfryle, kruståtel och mjölkört. Arter som missgynnas av markberedning var bl.a., en levermossa, lingon, väggmossa och kråkbär.

I växtekologi är visuell täckningsbedömning, d.v.s. hur stor del av en provyta som täcks av en växtart, och registrering av förekomst/icke förekomst, d.v.s. finns en växtart på en provyta eller inte, de två vanligaste metoderna vid vegetationsinventering.

Vid registrering av förekomst/icke förekomst missas upp till en tredjedel av förekomsterna, vanligaste orsaken till missade registreringar verkar vara att man inte upptäcker arten snarare än att den inte kan identifieras. Det var stora variationer mellan arter, där arter med få exemplar på provytan missas oftare.

Både den visuella täckningsbedömningen och förekomst/icke förekomst visar sig ha personberoende fel, d.v.s. att olika personer genomgående ger högre eller lägre värden än andra. Trots det personberoende felet visar sig täckningsbedömningar ha ett större informationsvärde än registrering av förekomst/icke förekomst när det gäller att särskilja olika typer av vegetation. Erfarenhet har en förvånansvärt liten effekt på kvaliteten av täckningsbedömningar.

List of papers

The following papers are included in the thesis. In the text, they are referred to by their Roman numerals.

Paper I Bergstedt J. & Milberg P. 2001. The impact of logging intensity on field-layer vegetation in Swedish boreal forests. *Forest Ecology and Management* 154, 105-115.

Paper II Bergstedt J., Hagner M. & Milberg P. 2008. Composition of vegetation after a modified harvesting and propagation method compared with conventional clear-cutting, scarification and planting: evaluation 14 years after logging *Applied Vegetation Science* 11, 159-168.

Paper III Bergstedt, J. & Milberg, P. Turnover of ground layer species in Swedish boreal forests and its response to logging. *Manuscript.*

Paper IV Milberg, P., Westerberg, L., Bergstedt, J & Fridman, J. Systematic and random variation in vegetation monitoring data. *Journal of Vegetation Science*, in press.

Paper V Bergstedt, J., Milberg, P. & Westerberg, L. In the eye of the beholder: bias and stochastic variation in cover estimates. *Manuscript*

Papers I, II and IV are reproduced with permission from the publishers.

1 Introduction

The notion that forestry affects boreal forests in an adverse manner has been acknowledged for a long time in Sweden. In 1904 Gunnar Andersson, lecturer at Skogsförsökanstalten and later professor in economic geography (Handelshögskolan) gave a speech at Föreningen för skogsvård:

”Så har våra dagars mångenstädes ohejdade afverkning och förödande av skogen, dess växter och djur, framkallat fordran på skydd för och omsorgsfull vård av skogen.”

(“In many places today the unrestrained cutting and devastation of the forest, its plants and animals, calls for protection and careful maintenance of the forest”)

In the last decades of the 20th century, the ultimate aim of old for forest management, to produce as much timber of the right qualities as possible, got competition from the aim to preserve the biodiversity of the forests (Skogstyrelsen 1994, Erlich 1996, Larsson & Danell 2001, Simberloff 2001, Raivio *et al.* 2001, Spence 2001). And lately, forests’ capability of sequestering carbon dioxide and provide biofuels has received a lot of interest in light of the discussion on global warming. All this has started a discussion on, and implementation of, new or modified forest management methods. Many of these new and modified forestry methods are the results of intelligent guessing and the need for research has been emphasized, both by the forest industry (Raivio *et al*. 2001), as well as the scientific community (Ehrlich 1996, Simberloff 2001).

When biodiversity and nature conservation became an issue for forest management, rare and endangered species received much attention, especially species mainly occurring in forests of long continuity. Clear-cutting has, naturally, an adverse effect for these species but the presence or absence of a rare species probably has very little importance for other species in the forest eco system. Abundant species have, probably, far greater impact. Many herbivores, like insects, grazers, *etc*., are dependent on common species and changes in their abundance could therefore have major effects on other organisms. For an old, new or modified forest management method, one of the long term objectives should be to maintain the abundances and spatial distribution of common species. To evaluate the effects of forest management methods, experiments and monitoring with appropriate methods is needed.

1.2 Aims

This thesis has two main objectives. The first objective is to evaluate the response of forest ground vegetation on selected forestry operations. Does harvesting intensity affect the composition of ground layer species in the boreal forest? If so, how does the response vary in relation to species and time since cutting? What effect does scarification have on the ground layer vegetation?

The second objective is to evaluate the common methods of estimating vegetation, cover estimates by eye and presence/absence recording. Among questions addressed are:

How large is the bias component in cover estimates and how does it relate to experience and/or species?

In distinguishing different vegetation types, how does the statistical power vary in relation to observers, number of observers, species and cover estimates and presence/absence?

In presence/absence recording, how large is the extent of missed occurrences and, are missed occurrences connected to attributes in the taxa and/or their abundance?

As a bonus, two of the papers in the thesis allowed a comparison of survey data in forestry research with more traditional research on field trials. That is, can survey data be used and produce results that complies with those emerging from more traditional research in field trials?

2 Vegetation responses to forestry

Many aspects of the effects of conventional forestry practices have been investigated, not least the response of the ground layer vegetation. Advantages with studies of the flora are that the species assembly and abundance reflects the environment at the scene and its history. Furthermore, plants are mostly relatively easy to identify. Animals do move around and especially among the insects, there are many species requiring special knowledge to identify. Due to their mobility, the causative relationship between the presence, absence or abundance of an animal species as a result of a forestry operation is difficult to distinguish.

Vegetation can respond to forestry by changes in mortality, growth and recruitment (Kimmins 2004). In the boreal forests of Sweden, the resulting changes are mainly changes of abundance and not in species richness (Esseen *et al*. 1997). Forestry can affect a multitude of variables important for the vegetation, *i.e.* light availability, competition for nutrients, microclimate, leaking of nutrients, *etc.* (Kimmins 2004). Forestry machinery can disturb the humus layer, compact the soil, alter the temperature of the soil, *etc.* (Kimmins 2004). Scarification conducted to facilitate tree seedling establishment, does, among other things, produce bare mineral soil, disrupts the continuity of the ground layer vegetation and change the temperature of the soil (Wetzel & Burgess 2001, Karlsson *et al*. 2002, Béland *et al*. 2003).

New and modified forest management methods might change or abandon old procedures and/or they might invent new ones, but whatever new forest management methods will prescribe, they will have one thing in common with the old ones, they will harvest and the diminishing, or complete removal, of the forest canopy will affect the forbs, graminoids, bryophytes and lichens on the forest floor as well as other forest-dwelling species.

Clear-cutting has, occasionally, been compared with forest fires but there are important differences between forest management and a natural disturbance such as forest fire (McCrae *et al.* 2001). The scale is different, forest fires may cover large areas compared to the patchy occurrence of clear cuts. Frequency, location in the landscape, shape of affected area, *etc.*, may also differ between clear-cuts and fires (McCrae *et al.* 2001). Trees over large areas die in a forest fire as well as in a clear-cut but, after a forest fire, the trees are still there, even if they are dead, providing shade and substrate for other organisms (McCrae *et al.* 2001). The effect of forest fires can be attributed to two variables, frontal fire intensity and soil heating, which can vary independently. While frontal fire kills all above-ground parts of grasses, forbs and dwarf shrubs, soil heating has a selective impact (Schimmel & Granström 1996). After severe disturbances seed-bank species have an advantage, since the fire will kill off some of the competitors and expose the seed bank, while mild disturbances will be an advantage for species with rhizomes in the upper mor layer (Schimmel & Granström 1996). Hart & Chen (2008) found distinctive differences in species composition between logged and burnt sites in boreal forests in Ontario, Canada. Even if the cover and species richness were similar in post-logged and post-fire stands, there were differences. The cover of vascular plants was higher in post-logged, 25-31 year old stands, compared to post-fire stands of the same age, while non-vascular plants had a much higher cover in post-fire stands (Hart & Chen 2008). Rees & Juday (2002), however, found that burned plots supported more species at all developmental stages than did logged plots. The difference could be due to the choice of study area (Hart & Chen 2008). Rees & Juday (2002) also found a higher species turnover in post-fire stands, attributed to a succession with more distinctive and specialized plant species. While post-logged areas usually had some of the common ground-layer species, dominant in mature forest, in the newly logged sites, and these species increased in dominance during the maturing of the stand (Rees & Juday 2002).

When it comes to cutting regimes and their effect on the flora and with different time perspectives, the question has been addressed in a number of studies (Hannerz & Hånell 1993, Atlegrim & Sjöberg 1996, Hannerz & Hånell 1997, Bråkenhielm & Liu 1998, Jalonen & Vanha-Majamaa 2001, Pykälä 2004). The studies focused on cutting intensities common in conventional forestry and in particular on clear-cuts, but with new and modified forest management methods a variety of cutting intensities may be realized and the vegetation response on a gradient of cutting intensities needs to be evaluated.

The effect of scarification has mostly been investigated with respect to tree seedling establishment (Wetzel & Burgess 2001, Karlsson *et al.* 2002, Béland *et al.* 2003), but the magnitude and temporal persistence of its effect on ground layer vegetation is little known.

Most studies, so far, have compared cutting with an undisturbed control (Elliott & Knoepp 2005, Zenner *et al.* 2006, Moora *et al.* 2007) but for the forest owner the alternative is rarely to leave the forest at peace, so when new management methods are evaluated the comparison with conventional forestry is of high interest. In Paper II the comparison is done between conventional harvesting and a modified forest management method, "Naturkultur" (Hagner 2004).

2.1 Vegetation responses to cutting intensity

2.1.1. Community responses to cutting intensity

In Papers I and III vegetation response on a gradient of cutting intensities was evaluated. Data were obtained from permanent 100 m^2-plots in coniferous forest (n=789 in Paper I, n=650 in Paper III), visited twice with an interval of 10-11 years. The National Survey of Forest Soils and Vegetation (NFSV) and the National Forest Inventory (NFI) executed the inventory. Analyses showed that logging intensity explained more of the changes in vegetation cover than did age and volume of the stand prior to cutting, site productivity, temperature sum and percentage *Pinus sylvestris* prior to cutting (Paper I). While for species turnover, percentage *Pinus sylvestris* and site productivity were more influential than cutting intensity (Paper III). The results also suggested that increasing cutting intensity produced greater changes in abundance, as did the results from a field trial in central Sweden (Paper II) and a study in the Missouri Ozarks (Zenner *et al.* 2006). This could possibly be explained by the sample plot size. In a plot of 100 m^2, small-scale heterogeneity can offer habitats for many species (Esseen *et al.* 1997) even if they diminish in abundance due to the removal or diminishing of the canopy.

In Paper II, a complete block design with four treatments and four replicates was set up 14 years prior to the vegetation inventory. The treatments were three different selective cuttings and a control with conventional harvesting, *i.e.* clear-cutting and scarification.

There seems to be a group of species little affected by cutting (Papers I and II, Figure 1). Among species increasing after cutting, some exhibit a threshold effect (Paper I), *i.e.* that cutting has to exceed certain limits to initiate a response. Paper I also revealed a pattern of change exhibited by some species, *i.e.* a time-lag between cutting and response.

2.1.2 Species-wise responses to cutting intensity

The effect that some species, *i.e.* narrow-leaved grasses and *Epilobium angustifolium*, respond to diminishing of the canopy by increasing abundance (Papers I and II) is in accordance with current autoecological data. The opportunistic character of narrow-leaved grasses (a group dominated by *Deschampsia flexuosa* in the boreal forests of Sweden), and *Epilobium angustifolium* have been acknowledged in a number of studies (Dyrness 1973, Kellner 1993, Schimmel & Granström 1996), as is their response to clear-cuts (Sjörs 1971, Ingelög 1974, Corns & La Roi 1976, Kielland – Lund 1981, Zobel 1989, Nieppola 1992, Hannerz & Hånell 1997). The threshold effect found in paper I (Figure 1), however, has not been shown previously. The reason for the non-linear response to cutting is unclear.

Epilobium angustifolium is an early successional species, common the first years after forest fires and clearcuts (Broderick 1990, Engelmark & Hytteborn 1999). The presence of *E. angustifolium* as a dominant species has been attributed to increased nutrient levels (Olsson & Staaf 1995, Bråkenhielm & Liu 1998), but the period of dominance can be rather short as tree layer become denser (Engelmark & Hytteborn 1999) and the competition for nutrients increases. The long period between cutting and vegetation inventory, could possibly explain the low ordination score for *E. angustifolium* in Paper II (Figure 2). The low abundance of *E. angustifolium* in the field trial of Paper II, possibly as a result of overall low nutrient levels (productivity between 2 and 3 m^3 ha^{-1} $year^{-1}$ (Hagner 1992)), gives also some uncertainty to conclusions on the ordination score.

Deschampsia flexuosa, the dominant narrow-leaved grass in Swedish boreal forests, is also an early successional species (Bråkenhielm & Liu 1998). In the analyses (Papers I and II), its abundance correlates to increasing cutting intensity (Figure 1 and 2). The occurrence of *D. flexuosa* on clear cuts is mainly due to increased light (Strengbom *et al*. 2004). This could explain why it maintains a high degree of presence even after 14 years (Paper II), since, although the tree seedlings had grown since planting, the canopy had not yet closed.

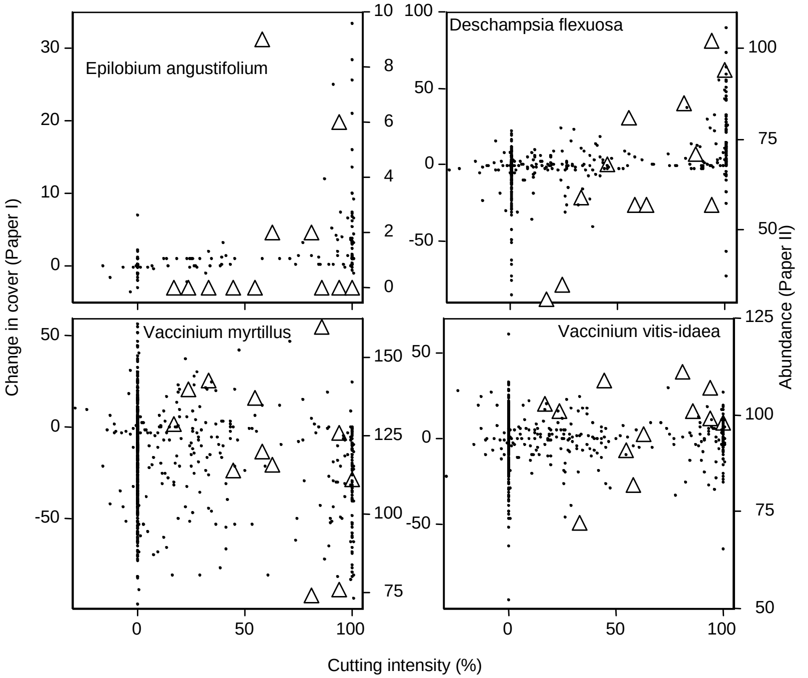

Figure 1. Change in cover (Paper I) and abundance in a few cover classes (Paper II) for four species. The group “narrow-leaved grasses”, from Paper I, is here treated as *Deschampsia flexuosa*. Change in cover (Paper I) is calculated as cover at the second minus cover at the first visit. Paper II indicated by triangles and Paper I by black dots.

Vaccinium myrtillus, an ecologically important species in the boreal forest of Sweden, declines in abundance as cutting intensity is increasing as shown in Papers I and II (Figure 1 and 2), as well as numerous other studies (Atlegrim & Sjöberg 1996, Hannerz & Hånell 1997, Bråkenhielm & Liu

1998) but Nielsen *et al*. (2007), found that performance (and cover) of *V. myrtillus* peaked in the most recently disturbed forest stands (i.e. no trees of diameter >5 cm at breast height), in south-eastern Norway. This difference could be explained by small clear-cuts in the study (Nielsen *et al*. 2007) or the choice of study area.

The central group in Figure 2 seems to represent a group of species indifferent to cutting (Papers I and II), i.e. *Vaccinium vitis-idaea* (Figure 1), *Trientalis europaea*. Since the boreal forest in Sweden is a dynamic system (Esseen *et al*. 1997), one could expect that many species are adapted to a habitat with irregular disturbances of varying magnitudes, and thus are resilient to cutting and other disturbances.

The species *Vaccinium myrtillus*, *Epilobium angustifolium* and the group narrow-leaved grasses displayed a time lag in their response to cutting (Paper I). The response remained unclear during the first couple of years and only became profound as the time since cutting increased (a maximum of 10 years). For the species increasing after cutting, this could possibly be attributed to the pattern of growth, *i.e*. that when encountering favorable conditions growth can be exponential. It is more difficult to explain for species diminishing in response to cutting, but it is possible that this could be a result of the method of assessing the abundance of a species. In the field instruction for the NFSV (Karltun *et al*. 1996), the cover of a species is supposed to be assessed as the cover at the peak of the growing season. The observers could have the same cover standard for individuals on clear-cut areas as in the forest, which probably would result in a higher cover estimate for declining species. Another explanation is competition, when the above mentioned increasing species start to increase, the competition for light and nutrients could diminish the abundance for species less suited for open areas without or with little canopy.

2.2 Vegetation responses to scarification

Scarification is a common method of soil preparation before planting or an expected seed fall from seed trees, in Sweden, 150 000 ha are scarified annually (Anonymous 1999). Scarification does not affect the whole of these 150 000 ha, depending on the method/machinery used, 25-50 % of the area is directly altered. But forestry adds this area to the area affected by uprooted wind-thrown trees, and this is probably a major increase of the area of bare mineral soil in the boreal forest. Considering the effect on ground layer vegetation suggested by Paper II, and the magnitude of the area affected, it is surprising that scarification has received so little attention (but see Haeussler *et al.* 2002, Yoshida *et al.* 2005).

2.2.1 Community responses to scarification

In Paper II the difference in response by the vegetation between High and Conventional is proposed to be a result of scarification. The difference in cutting intensity between the two treatments, does not explain the substantial multivariate distance between them. In the treatment High (cutting intensity from 81-100%), the plant community will respond to diminishing canopy. The resulting plant community will be dependent on species present at the time of the harvesting. Species that suffer from the new environmental regime will diminish or disappear, while others will increase. Some species will establish, from seed fall or seed bank, in response to the new environment. In Conventional (cutting intensity 100%) the removal of the canopy together with a thorough scarification created a different environment. A substantial part of the area was affected by the scarification, in some blocks close to 50% (personal observation). Species with good propagation abilities or presence in the soil seed bank, high demands on light and absence of competition for nutrients will take advantage of the possibilities in the scarified areas. At the same time the removal of the vegetation layer and humus will diminish many species. Hautala *et al.* (2008) found that, when producing small areas with bare mineral soil in a otherwise undisturbed 130 year old forest in northern Finland, dwarf-shrubs, forbs, graminoids, bryophytes and lichens exhibited a different response, only bryophytes and lichens substantially increased their cover during the 5-year period of monitoring. Palviainen *et al.* (2007) found, that establishment of mosses and field layer species exhibited differences in their response to scarification. Mosses tended to establish in the furrows while field layer species established most rapidly on the ridges of the scarification (Palviainen *et al.* 2007).

It seems to take a long time for the vegetation to recover after scarification. For example, there were still clear differences in vegetation composition between scarified and non-scarified areas 14 years after cutting (Paper II). In a study in eastern Finland there were differences in biomass and nutrient contents between ridges, furrows and undisturbed surfaces five years after clear-cutting and site preparation (Palviainen *et al.* 2007). While, in Finnish Lapland, 19 years after scarification, there was no significant difference in soil water content compared to untreated areas, except directly under the furrows (Mäkitalo & Hyvönen 2004).

2.2.2 Species-wise responses to scarification

In Paper II, a liverwort, *Barbilophozia lycopodioides, Vaccinum vitis-idaea* and *Pleurozium schreberi* seems to be negatively affected by scarification while the genus *Polytrichum* increased in abundance. The high abundance in *Polytrichum* spp. is probably a result of some species in the genus increasing in scarified treatments. Mäkipää & Heikkinen (2003) found an increase of *Polytrichum juniperum* in the period 1951 to 1985 in young stands in Finland which, they attributed to an increase of young and scarified stands. In a study of different disturbances of the vegetation community under the canopy (i.e. no cutting) in northern Finland, *Polytrichum commune* increased in areas where the bare mineral soil was created (Hautala *et al.* 2008). *Luzula pilosa* seems favoured by bare mineral soil, as well as *Picea abies* and *Pinus sylvestris* (Hautala *et al.* 2008, Paper II).

3 Cover estimates by eye and presence/absence

When monitoring plants an important decision is which method to use. There are a number of methods in use, point frequency, biomass harvesting, cover estimate by eye, presence/absence recording, *etc.* They all have different strengths and drawbacks. Point frequency, put forward by proponents as an unbiased method, is laborious (Leps & Hadincova 1992), weather dependent (Vittoz & Giusan 2007), misses many of the less frequent species (Leps & Hadincova 1992, Bråkenhielm & Qinghong 1994) and requires special equipment. Biomass harvesting is the most complete method, producing objective abundance and presence information, but if change over time is the focus or permanent plots are used, a destructive method is not appropriate. Cover estimates by eye is inexpensive, requires little or no equipment, but it is a subjective method and the extent of bias and stochastic variation is seldom known. Presence/absence recording is as inexpensive as cover estimates by eye but lacks the abundance information. The two last methods also share the drawback that the proportion of missed occurrences and misidentifications is rarely known, or even acknowledged in analyses.

Cover estimate by eye has been the method of choice for many researchers in plant ecology, due to its production of data on presence and abundance at a low cost. While others have preferred presence/absence (*i.e.* the frequency) in many plots to get both a species list and abundance information (Økland 1988). There have been several studies made in order to compare different methods and/or to assess the variation in the collected data (Smith 1944, Sykes *et al.* 1983, Jukola-Sulonen & Salemaa 1985, Nilsson & Nilsson 1985, Økland 1988, Leps & Hadincova 1992, Bråkenhielm & Qinghong 1995, Kercher *et al.* 2003, Ringvall *et al*. 2005, Vittoz & Giusan 2007). But the relative contribution of bias and random error have rarely been reported, nor have the statistical power of the methods been investigated.

3.1 Cover estimates and presence/absence

Many researchers have used cover estimates by eye with little or no explanation why the method was chosen and, mostly there is no discussion about the impact of the subjective character of the estimates when conclusions have been drawn (*e.g.* Paper I, Paper II, Nielsen *et al.* 2007, Hart & Chen 2008).

Among plant ecologists, there are many views of the advantages and disadvantages with cover estimates by eye and presence/absence. In the following, I reflect on a selection of questions related to this.

3.1.1 How does data, obtained by cover estimates by eye, vary, and how large is the relative contribution of bias?

Variation reported, typically, range between 10 and 30 % (Nilsson & Nilsson 1985, Leps & Handicova 1992, Archaux *et al.* 2006, Paper V), with some exceptions. In Paper V, ten observers from the NFSV independently assessed the same 16 100 m^2 plots, placed in two, easily distinguished vegetation types, 8 in each type. The time allowed was 8 hours and only cover estimates were done. The bias component in variation was substantial, varying between 8.2 and 47.8 % for species. For groups of species and estimates of areas without field or bottom layer the bias was even higher.

In Paper IV, the observer-explained variance was <10%. In the study, data from the NFSV was used. In the years 1983-87 a selection of the sample plots were visited by a quality assessment team, who independently screened the vegetation, thus, there were two independently estimated data sets (n=342). There, the estimates were made as a part of an ongoing survey of Swedish boreal forests, and the cover estimates were interspersed with a number of other tasks. Thus, increasing the time spent on each plot. With increased time on the plot it is possible, that observers get a better overview of the plot and may, when performing other tasks, constantly evaluate and reevaluate estimates made, or, to be made.

The variation in cover estimates is correlated with abundance, with largest relative error when cover is low (Paper IV, Paper V, Vittoz and Guisan 2007). There seems also to be a variation in estimates connected to species (Paper IV, Paper V, Sykes *et al.* 1983).

The bias in cover estimate by eye is not negligible and varies with species, observer and observer in relation to species

3.1.2 Could cover estimates by eye be more reliable, if using more than one observer?

Some have used teams of observers in order to lessen variation in cover estimates (Nilsson 1992, Jalonen *et al.* 1998). But, using the mean of several observers estimate did not increase statistical power (Paper V) and, Vittoz & Guisan (2007) showed that, in alpine meadows, working in pairs did not improve the cover estimates.

3.1.3 Is the use of one percent-classes better than using wider classes, geometric or otherwise constructed?

This is a choice with different strength and weaknesses. Peet *et al.* (1998) argue that the human mind perceives cover on a geometric scale rather than a linear one, and that geometric classes results in more rapid data collection and greater satisfaction among observers. On the other hand, geometric classes contain less information than one percent classes and constrains the possibility for statistical analyses (Mitchell *et al.* 1988). Depending on purpose with the inventory it might be sufficient with wider classes. Jukola-Salonen & Salemaa (1985) showed that information content, in one percent classes, 9 and 12-class scale, gave about the same resolution when distinguishing sample plots in 4 different forest site types by means of Detrended Correspondence Analysis (DCA). In Paper V, one percent classes were used, while a 15-point scale was used in Paper IV. The difference in observer bias in cover estimates could possibly partly be attributed to the use of wider classes in the latter paper.

Vittoz and Guisan (2007) found, when considering the limits of detectable change between two successive surveys that cover estimate as a percentage was clearly superior, as these are narrower in classes and one percent classes could later be made into any classes, if considered relevant during analysis.

3.1.5 Which effect does experience/training have on cover estimates?

The use of experienced observers has been a common practice to diminish variation of cover estimates but, experience/training, has been found to explain a surprisingly small part of the variation in cover estimates (Paper V). Smith (1944) showed that training did diminish the error in density estimates, but, there still remained significant differences. Why training and experience seems to play such a small role in cover estimates could in part depend on the training. In cover estimates the "true" value is usually unknown, so acceptance of the average value as the "right" value can be questioned. It is also doubtful if it has been acknowledged that troublesome species can be different for individual observers (Paper V), when training has been planned. Another important question that needs evaluation is, whether, training in one or a selection of vegetation types improves performance when encountering vegetation not covered in training. To improve training, Gallegos (2005) used created images, with known cover, shown on a computer screen. By getting rapid feed back with the correct cover values observers became more consistent in their estimates. This implies that a "correct" value in training plots could increase precision substantially. The problem is a correct value, but if precision is of greater value than accuracy, as when trying to detect temporal change, a correct value presented by a group of skilled observers and accepted by the observers could increase precision and thus make it possible to detect lesser changes in cover. Still the question would be how persistent such an improvement would be and if it could be extended to vegetation not covered in the training.

Experience, seems not to be an assurance for quality estimates of cover.

3.1.6 Which method, presence/absence or cover estimate by eye, produces the most useful data?

The answer to this question is probably dependent on the research question. Presence/absence recording has been proposed as an objective method, without the subjective character of cover estimate by eye but the frequency of differences between species lists produced by different observers is relatively high (Papers IV and V). The range of missed occurrences varied substantially depending on species, but as an average, ranged from 10 to 30 % as in most studies (Nilsson & Nilsson 1985, Leps & Hadincova 1992, Gray & Azuma 2005, Archaux *et al*. 2006). The missed occurrences were more common among less frequent species but with some exceptions (Paper IV and V), implying that the relationship between species and detection is more complex than just a matter of abundance. Misidentification was probably a minor contributor since the species were common and, in Paper IV, chosen for the ease of identification. Ringvall *et al.* (2005) reported a low frequency of missed occurrences when using a limited list of eight, in the area common taxa, which also indicates that many discrepancies between species lists are misses in detection of rare species. Thereby, confirming the findings in other studies that missed occurrences seem mostly to be due to overlooking rather than misidentification (Scott & Hallam 2002, Archaux *et al*. 2006).

The proportion of missed taxa was not dependent on life form or height (paper IV). In a study by Vittoz & Guisan (2007), density of vegetation influenced the frequency of missed occurrences. The high values of missed occurrences in many studies (Archaux *et al.* 2006, Paper IV, Paper V) could possibly be attributed to the greater size of the sample plots in these three studies. But, Klimes *et al.* (2001) had five experienced observers recording species in seven plots of different sizes. They found that in very small plots (9.8 cm^2) the frequency of missed occurrences was 33 % while in larger plots (4 m^2) the frequency was 10-20 %. Ringvall *et al.* (2005) could not detect any major difference connected to plot size, when having two sample plot sizes of 0.33 m^2 and 0.01 m^2. With a small plot it is possible to have a good overview of the whole plot and the area to search is small, on the other hand the proportion of the area with delimitation problems, *i.e.* to determine if a species is inside or outside of the study area, is relatively large. While in a larger plot the area subjected to search is larger, thereby, increasing the risk to miss a species but the proportion of areas with delimitation problems is smaller.

Økland (1988) proposed that the frequency in many small plots would be a less biased mean to assess abundance. Bråkenhielm & Qinhong (1995) concluded that visual estimates of cover gave a more accurate estimate (as measured for visible species in photographs) than did sub-plot frequency. When using data to distinguish vegetation types, cover data performed better than did the same data transformed to presence/absence (Paper V). Thus, implying that, in boreal forest, the abundance information in cover estimates is vital for identifying vegetation types.

4 Survey data and field trial

How then, can vegetation change in response to forestry be studied?

Field trials have been the traditional avenue of research and mostly with undisturbed forest as control. Problems with field trials are the limited transferability of the results to other areas, the cost of implementation and management of the areas. In forest research management of experimental areas can be needed for decades. An alternative to field trials could be studies based on survey data.

Survey data has been used for a long time to estimate forest resources (in Sweden the National Forest Inventory (NFI) started in 1923; Anon. 1932), since it is an efficient method for estimating current values, net change, and components of change (Scott 1998). Many variables collected for estimating forest resources could also be used when questions concerning nature conservation need to be addressed, *i.e.* age of forest, amount of debris and dead wood, abundance of common vascular plants, soil types, *etc.*

That only a few studies have been made based on survey data (Tonteri 1994, Vilà *et al.* 2003, Mäkipää & Heikkinen 2003) could probably be attributed to tradition in forest research. Other explanations could be that the large size of many survey datasets has been difficult to handle in the past. With the advanced computer capacity and the progress of software, that is no longer a problem.

One problem with survey data is the high amount of unexplained variation, resulting from all the variation present in the surveyed area and caused by irrelevant confounding factors. So, is it possible to use survey data without finding that the answers are overwhelmed by unexplained variation? That is, the variation in factors not included in the survey data.

There is always a trade-off between detail and precision versus transferability in the designing of a study. Forest-related trials are especially difficult due to their spatial and temporal distribution. In forest research unreplicated trials distributed over vast areas has often been the solution (e.g. Hagner 1992).

Since the change in abundance of each species was evaluated by ordination, where axis 1 represented cutting intensity in both Papers I and II, it is possible to compare the ordination for some species. In Paper I, the abundance was calculated as percentage cover at second visit, minus percentage cover at first visit, while in Paper II, abundance was estimated as cover in a crude scale. The ordination scores from Papers I and II correspond well (Figure 2).

In planning vegetation research there is a number of factors to consider. First you want to be able to generalize your results. In that respect, survey data have an advantage over field studies. While results from survey data are possible to generalize over the whole surveyed area, results emerging from field trials are confined to the field area and, possibly areas close by with similar environmental factors. The results presented in paper I are applicable to large areas of northern and central Sweden, while paper II is confined to the study area in central Sweden.

Survey data are, mostly, inexpensive and often kept in large accessible data bases. In paper I and paper III, data from the National Forest Inventory (NFI) of Sweden and the National Survey of Forest Soils and Vegetation (NSFV) are used. Both surveys are executed by the Swedish University of Agricultural Sciences, and the data are accessible for research. In forest field trials the study area has to be large to reduce the edge effect. To address the research question of paper I and III in a field trial, an area of 50-100 ha, depending on the number of cutting intensities chosen, would have been needed. The cost would have been enormous, first to acquire the area needed and then to finance the field work for a task of that size, especially since the trial must be maintained over several years.

In field trials, the study area defines the research while in survey data, the platform is created by applying inclusion criteria. This is an advantage for the field study since all relevant information about the study area can be evaluated. In survey data, the impact of the criteria for including plots can be difficult to assess. The use of inclusion criteria is a crude way of defining the limitations, and thereby transferability, of a study. The exact nature of the plots included in the final dataset is not known in all aspects, except the ones defined in the inclusion criteria. The choice of inclusion criteria is limited by the variables present in the data set. In paper I and III, many criteria were used and plots could have been included in spite of an environmental condition that not would have been accepted in a field trial.

The control of the field work is much better in field trials. In most cases, the researcher performs the work personally or hires personnel with known skills. In survey data, especially in surveys running over several years, a lot of different personnel of varying skill will have been collecting the data. Even if training is provided, the control of accuracy and precision is often lacking. Wulff (2002) found that, in a survey of forest damage assessments, accuracy was reasonable while precision was not reliable. In paper I numerous persons have been involved in the field work while, for paper II, the field work was conducted by a single person. Still, the results that are comparable from Papers I and II suggest that survey data is reliable enough for research (Figure 1 and 2)

Survey data could be used in search of interpretable patterns (exploratory analysis) and also for hypothesis-driven analyses (Hallgren *et al.* 1999). Since the part of the dataset in which the exploratory analyses are conducted cannot be used for hypothesis testing (Hallgren *et al.* 1999), survey data have an advantage. Most survey data sets are big and when part of one has been used for the exploratory phase, there is still a substantial part left for testing hypothesis. In many survey datasets there is a huge amount of variables, which makes them appropriate for search of interpretable patterns.

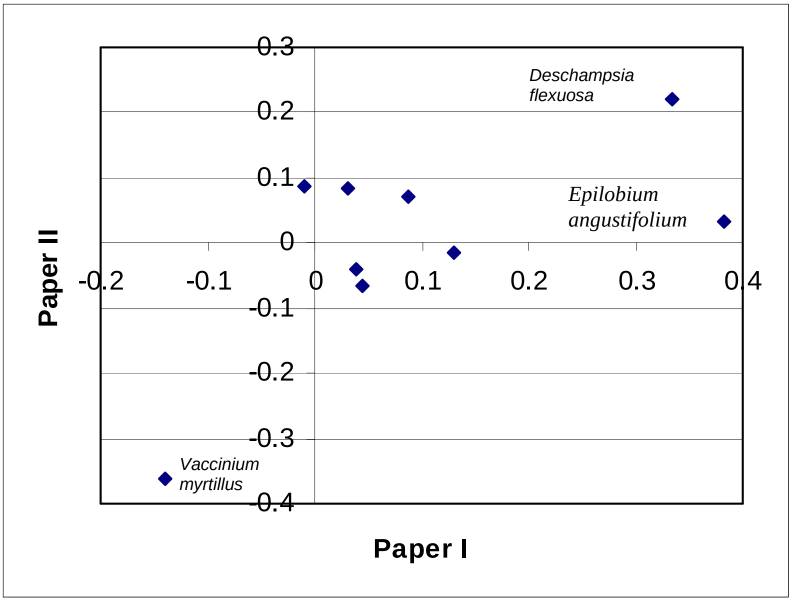

Figure 2. Plotted ordination scores for selected species from paper I and paper II. In paper I, scores from an RDA on change in cover between two visits with 10-11 years interval and axis 1 representing cutting intensity. In paper II, scores from an RDA on cover, 14 years after cutting, and axis 1 representing cutting intensity The group "narrow-leaved grasses", from paper I, is here treated as *Deschampsia flexuosa*. The group consisting of *Eriophorum sylvaticum*, *Carex globularis* and *Menyanthes trifoliata* from paper I, is plotted against *Carex globularis* from paper II.

There are several ways of categorizing ecological experiments, they can either be mensurative or manipulative (Gibson 2002), or, they can be laboratory, field, natural trajectory or natural snapshot experiments (Gibson 2002). With this terminology, Papers I, III and IV are natural trajectory experiments, since the investigator had no control over the independent variables, while Papers II and V are field experiments. The choice of research mode depends on the question addressed. When investigating a new research question, the extent is of high priority, and then natural experiments are most appropriate as they are a sample of reality. But later in the research process, when causative relationships are the target, field or lab experiments are preferred. In them, the investigator can manipulate the experiment to make it more appropriate for the specific task at hand.

4. Conclusions

The plant community change in response to cutting and the response increases with the proportion of canopy removed. Individual species exhibit a variety of responses to cutting, increasing, decreasing or being indifferent. The response can be dependent on time since disturbance, *i.e.* a time lag or intensity, *i.e.* a threshold level.

Scarification has a major impact on the ground layer flora and it seems to have a long-lasting effect.

Considering the substantial bias in cover estimates by eye and the magnitude of missed occurrences in presence/absence recording, they are still useful methods in plant ecology. When distinguishing vegetation types in boreal forest the abundance information in cover estimates is vital.

Survey data is a resource not used to its potential in vegetation research.

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