Evaluation of the forest composition in browsed Scots pine plantations

Utvärdering av skogens sammansättning efter betesskador i unga tallbestånd

Carl Stefan Noyce

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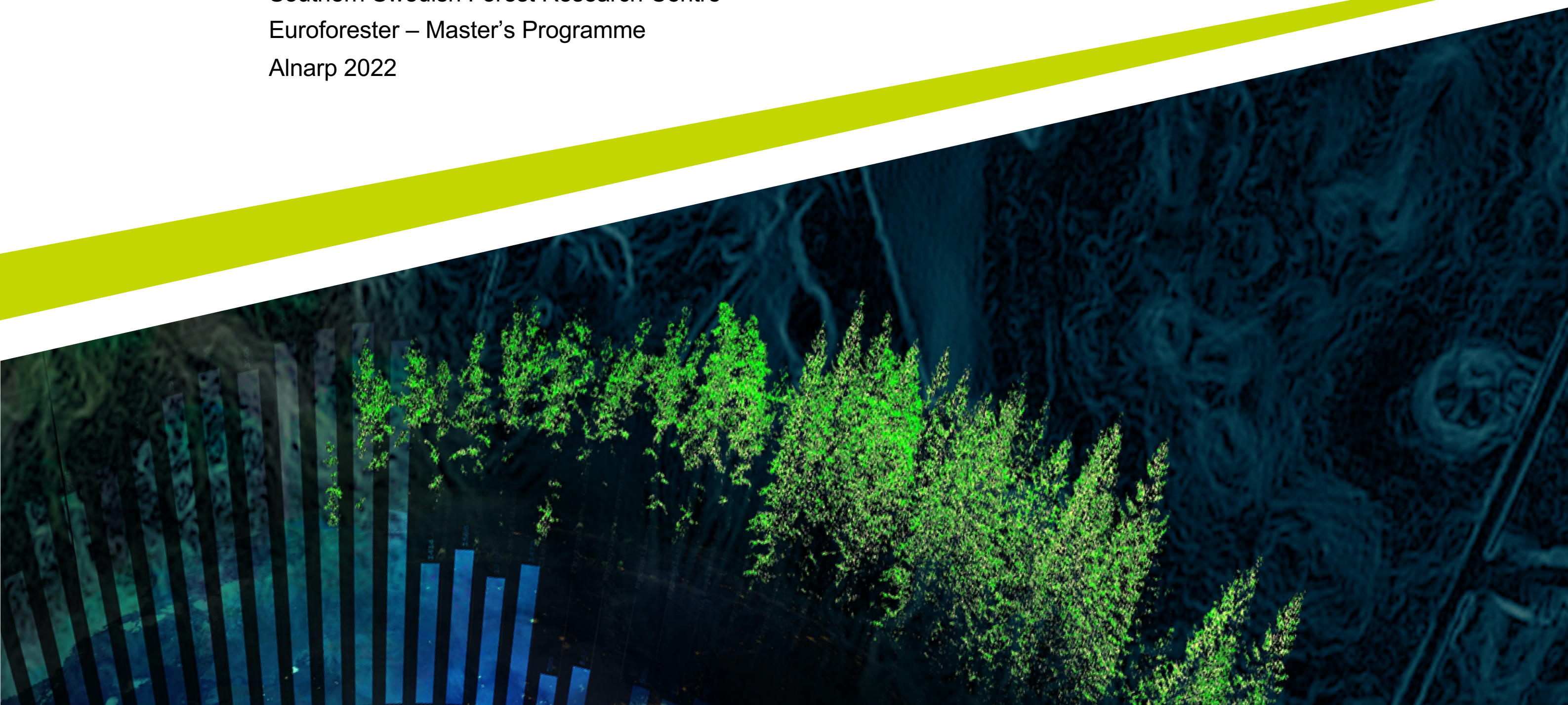

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Carl Stefan Noyce

Supervisor:	**Emma Holmström, Swedish University of Agricultural Sciences, Southern Swedish Forest Research Centre**
Assistant supervisor:	Therése Strömvall Nyberg, Swedish University of Agricultural Sciences, Swedish Forest Research Centre
Examiner:	Annika Felton, Swedish University of Agricultural Sciences, Swedish Forest Research Centre

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Swedish University of Agricultural Sciences
Faculty of Forest Sciences
Southern Swedish Forest Research Centre

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Abstract

Since the early 2000s browsing damage to Scots pine (*Pinus Sylvestris*) in the Götaland region of Sweden has been consistently estimated to be 15% per year, peaking at around 25% between 2009-2016, the highest of any region in the country.

The Swedish Forest Agency has set a goal of achieving pine damage levels below 5% on average in the long-term, even if higher levels can be accepted in an individual year. Damage levels are influenced by a range of factors e.g., Scots pine density, moose density, tree species composition and forest stand management decisions. Scots pine monocultures planted for production forestry purposes are at risk of being replaced by competing species when browsing damage from moose (*Alces alces*) occurs.

The aim of this study was to evaluate if intentional Scots pine plantations can be a future pine forest, or if browsing damage may be too severe to reach the goals of the investment. Fieldwork was carried out in 22 young stands located in Götaland which were regenerated with the planting of Scots pine between 2016-2018, on sites managed by forest owner association Södra Skogsägarna – who have raised the issue of what will become of Scots pine plantations. In addition, forest owners were interviewed regarding their aim with the regenerations and what they think about the possibility to combine Scots pine plantations with the population of moose.

Results from the fieldwork indicated that the average damage level of Scots pine across all 22 stands was 25% and that Scots pine faces strong competition from regenerating Norway spruce (*Picea abies*), birch (*Betula spp*.) and other broadleaved species. Scenario analyses employed to determine the future dominant tree in stands revealed that targeted thinning may be necessary of competing trees to ensure Scots pine plantations are realised in the future. Results from the forest owner questionnaire indicated that forest owners' management decisions are affected by browsing damage to Scots pine and that additional guidance from forest owner associations and financial support from relevant authorities to implement additional browsing deterrents is welcomed.

Keywords: Browsing damage, forest owners, mera tall, moose, pine regeneration, Södra

Sammanfattning

Sedan början av 2000-talet bedöms betesskador på tall (*Pinus Sylvestris*) i Götaland (Sverige) ligga på 15 % per men ännu högre, runt 25 % mellan 2008–2016, högst av alla regioner i landet.

Skogsstyrelsen har satt upp ett mål att betesskadorna på tall ska ligga under 5 % i genomsnitt på lång sikt, även om högre betesskador nivåer kan accepteras under ett enskilt år. Betesskador påverkas av ett flertal faktorer till exempel, förekomst av tallskog, älgtäthet, trädslag i bestånden och skogsskötsel. Planterade tallföryngringar riskerar att utvecklas till skogar med andra trädslag på grund av betesskador från älg (*Alces alces*).

Målet med den här uppsatsen var att utvärdera om tallmonokulturer kan utvecklas till de bestånd som var det tänkta, eller om betesskador gör att markägaren inte kan nå målet. Inventering gjordes i 22 föryngringar i Götaland med planterad tall mellan 2016–2018. Möjliga utfall efter röjning utvärderades i scenarier med och utan hänsyn till betesskadorna. Vidare, skogsägarna intervjuades gällande deras mål med föryngringen och vad de tror om möjligheterna att kombinera tallföryngringar med närvaron av höga älgstammar.

Resultaten från inventeringen visade att medelvärdet av betesskador för de 22 bestånden var 25 % och att tall möter stark konkurrens från gran (*Picea abies*), björk (*Betula spp.*) och andra lövträd. Röjningsscenarierna visade att riktad röjning krävs för att försäkra att de framtida bestånden blir talldominerade i framtiden. Resultaten från skogägarenkäten visade att deras skogsskötsel-beslut påverkas av betesskador på tall samt att ytterligare vägledning från skogliga rådgivare och riktade stöd för skydd mot betesskador välkomnas.

Nyckelord: Betesskador, mera tall, tallföryngringar, skogsägaren, Södra, unga tallbestånd, älg

Preface

This master thesis project is part of a larger research project in regeneration of Scots pine, Norway spruce and conifer mixtures, funded by SLU and Södra Skogsägarnas forskningsstiftelse. The research and the data related to this project will be used and led by Dr Emma Holmström, alongside PhD student Therése Strömvall Nyberg, both of whom work for SLU in the Southern Swedish Forest Research Centre.

Additional thanks for the thesis funding which came from Partnerskap Alnarp and their collaboration with Södra skogsägarna, without their support it would not have been possible to fund the fieldwork surveys and travel involved.

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Secondly, I would like to extend my gratitude to the research group for their input and feedback. Furthermore, I would like to express my appreciation to all the forest owners who allowed me to survey their stands, participate in the in the questionnaire process and to Henrik Holmberg from Södra for all his support.

Finally, I would like to say thank you to my family, friends and my partner for their past and ongoing support, and additionally my late grandfather who was a keen nature enthusiast.

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Abbreviations

	English	Swedish
EAF	Even-aged forestry	Kalhyggesbruk
LRF	The Federation of Swedish Farmers	Lantbrukarnas Riksförbund
PCT	Pre-commercial thinning	Röjning
RASE SPECIES	Rowan (*Sorbus aucuparia*), Aspen (*Populus tremula*), Salix (*Salix spp*) and Oak (*Quercus spp*)	Rönn (*Sorbus aucuparia*), Aspen (*Populus tremula*), Salix (*Salix spp*), Ek (*Quercus spp*)
SCB	Statistics Sweden	Statistikmyndigheten
SEPA	Swedish Environmental Protection Agency	Naturvårdsverket
SFA	Swedish Forest Agency	Skogsstyrelsen
SHA	Swedish Hunters Association	Svenska Jägareförbundet
SLU	Swedish University of Agricultural Sciences	Sveriges Lantbruksuniversitet
SSNC	The Swedish Society for Nature Conservation	Naturskyddsföreningen
ÄBIN	Annual Moose Damage Inventory	Älgbetesinventering

1. Introduction

1.1. Forestry in Sweden

Forests monopolise the landscape in Sweden. Consequently, forestry has become a critical element of the national economy (Gicquel et al. 2020, Vysinova 2010), in addition to the high cultural value forests hold in Swedish society (SFA 2015).

Sweden has 28 million hectares of forest land, of which around two million hectares are set-aside for conservation purposes, primarily in the form of national parks and nature reserves (SFA 2015). According to Forest Statistics 2021, 69% of Sweden's total land area is forest land, 13% is bare unproductive land, 13% is classed as other land and 6% as other wooded land. Apart from Finland, this means Sweden has the highest proportion of forest land in relation to total land area within Europe (SCB 2020). In terms of forest land there is around 5.5 million hectares (ha^{-1}) in Götaland, the study area for this thesis (Forest Statistics 2021).

In terms of standing volume composition nationally - 40% is Norway spruce (*Picea abies*), 38% is Scots pine (*Pinus sylvestris*), 12% is birch (*Betula spp*.), 6% is other deciduous species, 3% is dead trees and only 1% is Lodgepole pine (*Pinus contorta*) (SFA 2015).

In a global context Sweden may seem small as it contributes around 1% to the world's commercial forest area, however, it makes up around 10% of sawn timber, paper and pulp globally (SFA 2015).

In 2021 the Swedish Forest Agency (SFA) reported that timber stocks amounted to 8.8 million cubic meters (m^3), with 5.1 million being pulpwood, 2.7 million for softwood saw logs and a further 1.1 million in pulp chips (SFA 2021a).

Given that Sweden is dominated by forests managed for forestry purposes, it is logical that the forest habitats and biodiversity values have been largely influenced by decisions and methods chosen by forest managers and owners. Observed changes to forests have helped to inform revised versions of the Forestry Act (SFA 2020), first passed in 1903, to reflect today's challenges, identified as finding a suitable balance between the needs of forestry (production goals) and observed biodiversity concerns (environmental goals) (Bush 2010, Simonsson et al. 2015).

Perhaps the most critical change to forest governance came in 1993 which introduced the deregulated forest management system of "freedom with responsibility", placing the emphasis on private forest owners to balance production goals and environmental goals (Bush 2010, Löfmarck et al. 2017).

However, despite this deregulation, Swedish forest owners must still adhere to national environmental regulations and European Union (EU) protection regulations e.g., EU Habitats and Birds directives, (Angelstam et al. 2011, Uggla et al. 2016), which contributes to the ongoing confusion and conflict around how best to manage Swedish forests (Löfmarck et al. 2017, Sandström et al. 2013).

1.1.1. Forest ownership and structure

The largest proportion of forest ownership in Sweden is 'private owners' who make up around 47% of forest owners, followed by 'other owners' (30%) and 'companies' (23%), according to data collected by the Swedish National Forest Inventory (Forest Statistics 2021). Many forest owners join associations to obtain guidance, advice and representation regarding forest management issues. One such example is Södra, an economic association, made up of approximately 53,000 forest owners in southern Sweden (Södra 2021a).

1.1.2. Tree species selection for silviculture in Sweden

The dominant silvicultural system since the 1950s in Sweden has been even-aged forestry (EAF), (SFA 2015) – which aims to sustain a long-term flow of timber, managing to maximise production values. This silvicultural system has received much criticism for the role it has played in the decreasing biodiversity values associated with forests across Sweden (Cherubini et al. 2018, Felton et al. 2020a, Kuuluvainen 2009, SSNC 2021).

Scots pine is one of the most common trees selected for production in Sweden alongside Norway Spruce, and one of the most common species forming remnant trees in natural forests of northern Europe (Elfving and Jakobsson, 2006), making it (Scots pine) both economically and culturally valuable (Vysinova 2010). A fact that is reflected in the recent debate concerning pine forest's conservation values and future management (Djupström and Weslien 2019).

There has been a general preference for Norway Spruce in the south of Sweden and Scots pine in the north. In the 2000s it is estimated that more than 70% of the forest land in Sweden has been regenerated with Scots pine and Norway spruce at the end of rotation periods (Ara et al. 2021).

One trend that has been associated with forestry in Sweden and has attracted much attention in recent decades, has been the replacement of Scots pine by Norway spruce and the biodiversity and ecosystem service implications of this (Felton et al. 2020b). Coupled with this concern; is the lack of forest dedicated to retaining biodiversity values in Sweden, indeed, formally protected areas make up only 9 % of Sweden's total forest land (SCB 2020). The need to improve Sweden's management of forests for biodiversity and protecting ecosystem services is not only recognised at national level (the Swedish Forestry Act – amended 1994) (SFA, 2020, SHA 2016) but also recognised as a problem globally (Brockerhoff et al. 2017, Cernansky 2018, SSNC 2021, Stanturf et al. 2014).

1.1.3. Scots pine

Scots pine is a coniferous tree that is commonly distributed across Sweden and considered of 'Least Concern' in Sweden's Redlisted species list (Artfakta 2020). However, the species is subjected to damaging agents such as browsing and pine weevil, which influences both economic and environmental goals associated with forests (Cederlund et al. 1980, Gicquel et al. 2020, Härkönen 1998, Månsson 2009, Saursaunet et al. 2018, SFA 2021c, Vuorinen et al. 2020, Vysinova, 2010). Browsing is defined as eating woody and non-woody dicotyledonous plants, which is different to grazing (eating grass), and are two distinctively different types of feeding behaviour among ungulates (Janis 2008).

As browsing pressure intensifies in Scots pine plantations, the risk of failure (e.g., to produce valuable timber) increases (Felton et al. 2020b). Browsing by ungulates such as red deer (*Cervus elaphus*), fallow deer (*Dama dama*), roe deer (*Capreolus capreolus*) and of course moose (*Alces alces*) on Scots pine is a major concern and may result in mortality in up to 30-35% of seedlings (Ara et al. 2021), which can be of concern from both a forestry and conservation perspective (Drössler et al. 2019, Felton et al. 2020, Holmström et al. 2018, Lindbladh et al. 2019, Petersson et al. 2021).

Scots pine regeneration

Scots pine is a pioneer species that regenerates easily after major disturbances, when competition from field vegetation is low, with rapid initial growth. The species grows in a wide fertility range, also on poorer, sandy soils, rocky outcrops, peat bogs or close to the forest limit, (Nilsson 2020). Its moderate site demands make Scots pine a suitable species for artificial regeneration. However, in most cases Scots pine requires human intervention (such as prescribed burning) to prevent ecological succession, e.g., being outcompeted by other species such as birch or Norway spruce, (Mátyás et al. 2004).

Nevertheless, Scots pine can form pure stands at nutrient poor sites where few other tree species can compete in addition to having a deep root system, making it more resistant to wind than Norway spruce (Nilsson 2020).

Natural regeneration is the ideal method of establishment but given the light demands of pine, stand structure and species composition should be simplified, and consequently regeneration felling should be carried out in a methodical process (Mátyás et al. 2004).

When intervention is required, direct sowing is preferred to planting. But if possible, planting should be carried out with higher density, allowing for more natural selection and to reduce the proportion of pine browsed (Heikkilä and Härkönen 1996, Mátyás et al. 2004).

Soil scarification and shelterwood

Soil scarification is commonly used in Scandinavia to produce successful regenerations of Scots pine, as it helps to reduce pine weevil damage with a patch of bare soil around seedlings. In addition, scarification can result in easier germination and greater seedling survival as there is a reduction from natural regeneration and resource competition e.g., for water, (Nilsson et al. 2010, Saursaunet et al. 2018, Wallertz et al. 2018). It is a way of stimulating dense seedling establishments of pine and birch, either by planting, sowing, or by natural regeneration (Saursaunet et al. 2018).

1.2. Scots pine in Götaland

In terms of productive forest area, Forest Statistics 2021 estimates that there are 5,046,000 ha in Götaland of which 23.8% is pine. Growing stock of pine is estimated at 39.3% in Sweden and 29.6% in Götaland (Forest Statistics 2021).

Figure 1 marks the region of Götaland and different counties within Sweden.

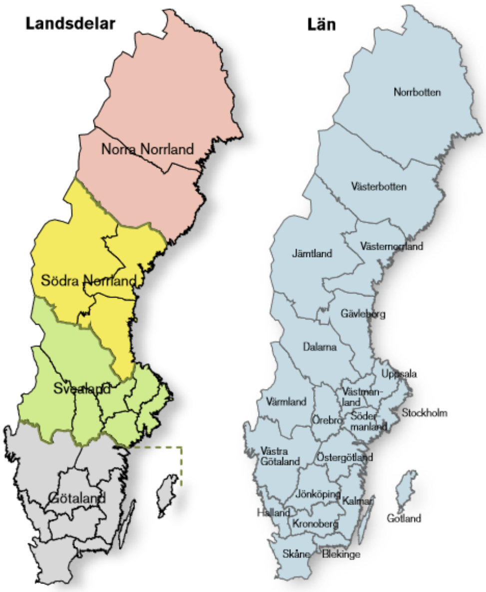

Figure 1 - Map of Sweden divided into regions (left) and counties (right), study area of is Götaland marked in the south of the map on the left side (Forest Statistics 2021)

Forest Statistics 2021 reveals the extent of damage from moose browsing in productive forest land outside formally protected areas between 2018-2020 in Götaland. Most notably 'only recent moose damage' (damage that is not older than three years) to pine is recorded at 5%, 'recent and older moose damage' at 6%, 'only older moose damage' at 25% and 'other damage' at 23% (Forest Statistics 2021).

Götaland records the highest proportion of damage from moose browsing out of all regions in Sweden (Figure 2).

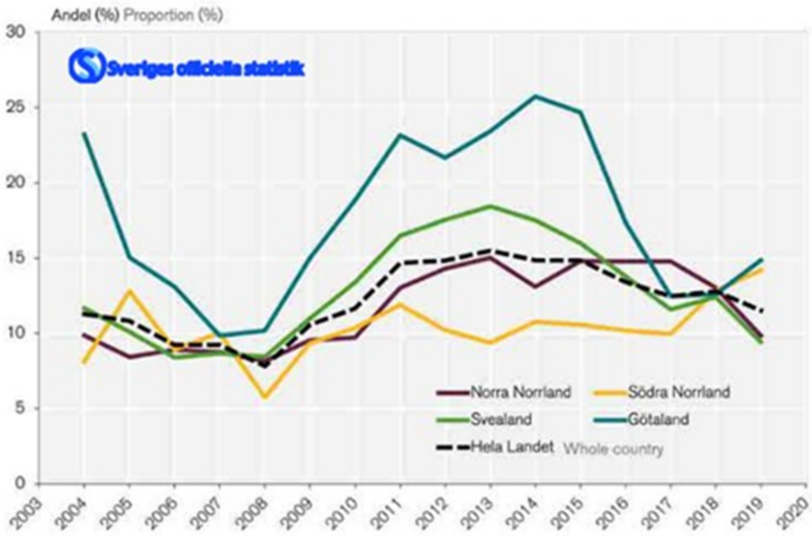

Figure 2 - Swedish Official statistics of proportion of pine stems with recent damage from moose browsing between 2004–2019. Götaland is represented by the blue lime in the graph, (Forest Statistics 2021)

Within the Götaland region of Sweden are ten counties (or provinces). These include Jönköping, Halland and Blekinge, where the moose population appears to be increasing after reduced hunting levels in recent years. Nevertheless, in Blekinge and Kalmar (another country within Götaland – Figure 1), damage levels are decreasing for the third year in succession (SFA 2021g). Furthermore, it has been calculated that browsing damage each year corresponds to a social cost of SEK 4.5 billion in Götaland, around 440€ million (Södra 2021c).

Data from the Annual Moose Browsing Damage Inventory (ÄBIN) shows that browsing damage to pine in Götaland is consistently estimated to be 15% per year (SFA 2021g), which is consistent with the data shown in Figure 2.

The main purpose of the National Forest Assessment is to produce statistics that describe conditions and changes in Sweden's forests and to inform relevant statistics (Forest Statistics 2021). While ÄBIN is an inventory method developed by the SFA (Swedish Forest Agency) and the Swedish University of Agricultural Sciences (SLU) to estimate levels of browsing damage on young trees in Sweden. The surveys are performed in young forests with mean stand heights between 1m - 4m (Ara et al. 2021).

'Mera tall'

'Mera Tall' ('More Pine') is a scheme introduced by the SFA with the purpose to engage and inspire more hunters and forest owners to collaborate to achieve a good balance between forest and game and was established in 2010 (SFA 2021e).

Why has Scots pine become a focus point for the SFA?

> "Pine has for a long time been outcompeted by spruce in large parts of central and southern Sweden. In other parts of the country, pine forests have been severely damaged by game browsing. The pure pine forests are declining and in the large areas of mixed forests there is a clear tendency for the spruce to take over" (SFA 2021e).

Three key aims of 'Mera Tall' is to diversify the young forest plantations by:

- Reduce browsing damage to the agreed level (as outlined in Section 1.3.1.).
- Retaining the RASE species in the regenerations. RASE stands for Rowan (*Sorbus aucuparia*), Aspen (*Populus tremula*), Salix (*Salix spp.*) and Oak (*Quercus spp.*), which is naturally regenerated within the conifer plantations.
- Selecting tree species for regeneration by adapting to site properties, e.g., soil moisture and fertility.

To achieve a good balance between forest and game, hunters and forest owners need to reach a better consensus on how to achieve the goals listed above (SFA 2021e). However, the SFA warns that merely hunting moose (*Alces alces*) is not just the answer and that an equilibrium should be maintained between feed supply and game stocks (SFA 2021e).

1.3. Ungulates in southern Sweden

Ungulates have a considerable and long-term impact on forest habitats, and to a large extent determine tree species diversity in boreal forests (Olsson 2008, Persson et al. 2005, Rautiainen et al. 2021, Spitzer et al. 2021). A keystone species is defined as having disproportionate importance within their community (Mouquet et al. 2013). In Sweden moose is regarded as a keystone species because of the significant impact it has on plant species diversity and the long-term development of young trees (Angelstam et al. 2000, Månsson 2007).

However, the concern around the presence of moose is primarily focussed on how browsing pressure will negatively affect trees of economic importance to the forest industry, such as Scots pine (Månsson 2007, Wallgren et al. 2013), especially when moose are present in high densities near young forests (Andrén and Angelstam 1993).

In Northern-Central Europe, non-native species of deer (especially the fallow deer) are expected to have a wide resource overlap with native cervid species (Rautiainen et al. 2021). In addition, research also shows that with increasing deer density results in moose diets than contain greater consumption of pine and less *Vaccinium*, (Spitzer et al. 2021).

A SFA report released in October 2021 stated that young forests with Scots pine still have significant browsing damage, and only three areas in the country reach the goal of a maximum of five percent annual damage (see Table 1 in 1.2.1. Furthermore, the organisation also claims that browsing damage to pine is today considered to be one of the most important reasons for the reduction in forest growth, resulting in large economic losses (SFA 2021f).

In Sweden there are varying densities of moose, which range from 0.5 moose per 1000 ha, to 15 moose per 1000 ha (SLU 2021b). In recent decades the moose population has undergone large changes, which has caused concern for both foresters and hunters. It has been suggested that this reduction was caused by an increased harvest (Hörnberg 2001).

Moose population density is primarily regulated by hunting, availability of fodder, predator-prey dynamics (‘The Landscape of Fear’) and forest management decisions (Ball 1999, Laundré et al. 2010, Månsson 2007, Vysinova 2010).

Indeed, studies have shown that forest management decisions, such as thinning methodology and pre-commercial thinning (PCT) will affect moose behaviour and browsing pressure (Härkönen 1998, Månsson et al. 2010).

It has been shown PCT both reduces forage availability and moose browsing, particularly when deciduous trees are targeted, (Härkönen 1998, Olsson 2008). Moreover, PCT is an important element of forest management, especially when regulating competition between Scots pine and deciduous tree species (Heikkilä and Härkönen 1996).

1.3.1. Management of moose by key interest groups

The Swedish Forest Agency (SFA)

According to the SFA (2021c) the agency has indicated acceptable and non-acceptable levels of damage-levels, which are measured annually (Table 1):

Table 1 - Damage levels categorised as assessed by the Swedish Forest Agency

Damage level	Description
Under 5%	Less than 5 % damage is a tolerable level if the damage is over several years.
Between 5-10%	Between 5 and 10 % damage can be accepted in individual years on average if damage is below 5 percent on average in the long term.
Between 10-20%	In this instance, damages are so severe that it is not enough to be close to 5 % for several years to get an acceptable multi-year average. The balance between moose and forest is in crisis and significant measures need to be put in place.
Over 20%	If the damage is above 20 %, it is in principle not possible to conduct pine forestry in the long term. The area must have several years almost completely without damage to reach 5 % in the long term. The moose population must be reduced sharply and immediately and kept at a low level for several years.

In cases where the damage-levels need improved management to reach acceptable levels, the agency recommends that landowners and hunters need to work together, by reducing the moose population and planting more pine (in suitable locations), in addition to monitoring the activities of other browsing mammals (SFA 2021d).

The Swedish Environmental Protection Agency (SEPA)

SEPA states that moose populations are managed regionally, and that in each county, there are several moose management areas where goals for the management of the population are set, for example shooting targets. However, the organisation which is the main actor in wildlife management in Sweden, also acknowledges that views of how to manage wild game varies in line with different interest groups and associated values (SEPA 2021).

The Swedish Hunters Association (SHA)

The Swedish Hunters Association (SHA) is an influential actor in Swedish wildlife management – having been granted responsibility (since 1938) from the Swedish state to carry out a considerable share of the country's wildlife management. Their tasks include maintaining sustainable wildlife management, providing information and training to hunters (Engbladh 2016).

According to the SHA, intensification of agriculture has contributed to the decline of biological diversity and acknowledges that this trend must be reversed, stating that appropriate wildlife management can be a valuable contribution, by providing wildlife management recommendations, (SHA 2016) in addition, the SHA has produced a moose management guide that outlines their vision for how issues regarding the species should be handled (SHA 2020).

Surveys carried out by the SLU researcher Fredrik Widemo, and previous research leader at the Swedish Hunters association, suggests that more than half of the hunters who participated in recent research think that the moose population is too low (SLU 2021a). From 2012 a new moose management program was introduced intended to reduce browsing damage to forests and since this time, the moose population has decreased by 20%, however, the levels of forest damage remain at approximately the same level as before (SLU 2021a).

The survey results clearly show a change in attitude amongst hunters towards the size of the moose population between 2013 and 2021 – now there is a desire to increase the numbers of moose, although a small percentage of participants (<10%) wanted to lower the moose population, around 45% of participants thought that the moose population is well-balanced ('lagom' in Swedish) (SLU 2021a).

Södra

Södra works with members, elected representatives and officials at local, regional and national level within wildlife management and participates in opinion formation on wildlife issues (Södra 2021b).

Furthermore, the association collaborates with The Federation of Swedish Farmers (LRF), other forest owners' associations and forestry companies, including the Swedish Forestry's national wildlife group and hunting organisations (Södra 2021b).

Södra's policy on wildlife issues is decided by the association's board. The policy contains guidance and direction for Södra's work in wildlife issues and was adopted by the association's board in 2014. The policy states, among other things, that (Södra 2021b):

- Södra supports SFA goals for forests and ungulates.
- Individual forest owners are responsible for wildlife management on their property.
- Game damage to growing forests must be limited, primarily through hunting.
- The browsing pressure must never be so great that it controls the choice of conifer species when regenerating (see Table 1).

- The combined effect of browsing from all ungulates such as moose, red deer, fallow deer and roe deer is considered.
- Fences and game deterrents are not accepted as general measures to cope with regenerating conifers.
- Increased leaf mixture is desirable, which contributes to biodiversity and a more versatile feed supply.
- RASE species and pine are regularly retained during forest management.
- Damage inventories (ÄBIN) must be carried out regularly and in the event of extensive game damage, the possibility of 'protection hunting' must be used.

SLU collaborated with Södra to survey and map forest damage caused by wild deer and identify how forest owners needed support to deal with the problems. The most common request was for information on how to carry out/increase hunting. Members of Södra also sought information about how to create feed for wild game, how to save already damaged trees and how to avoid unacceptable levels of damage (Bender 2017).

Blomqvist (2016) investigated the relationship between supplementary feeding and browsing damage because of findings that showed that moose who have an unbalanced diet compensate by eating a larger amount of twigs. The study highlighted the need to fill a knowledge gap about how to provide suitable supplementary feedings to ensure moose's diet is more balanced and thus leads to decreased browsing of twigs.

Another study highlights that the cover of forest floor vascular plants, a key part of ungulates' diets, has been decreasing in Sweden over recent decades (Leemans 2021). Results identified that bilberry shrubs were shorter in areas where fallow deer were present at higher densities. Which coincides with other research that highlights the challenges of deer and moose having an overlapping diet (Leemans 2021, Rautiainen et al. 2021, Spitzer et al. 2021).

Where numbers and distributions of different ungulates are increasing across Europe, and they share the same habitat and dietary preferences, this will cause moose to browse more heavily on pine because of lower availability of forest floor plants, which results in decreased values for timber production (Rautiainen et al. 2021, Spitzer et al. 2021).

High cervid densities can have a negative impact on forest floor plant densities and moreover, in regenerating clear-cuts which can cause changes in forest floor vegetation composition (Tremblay et al., 2006). Combined with current forestry practices which involve dense planting of coniferous trees under short-rotation regimes, there has been a steady decline in the appearance of ericaceous shrubs (Sayn 2021).

However, while annual growth of ericaceous shrubs was highly affected by the forest's basal area and time since clear-cutting, the effect of cervid browsing pressure does not show any significant influence (Sayn 2021).

1.4. Thesis Aim

The aim of this study was to evaluate if the Scots pine plantations can be a future pine forest, or if browsing damage may be too severe to reach the goals of the investment.

The thesis will test the hypothesis that:

- There is no difference in damage proportion in stands with a high density of Scots pine saplings compared to stands with low density

In the thesis I will investigate:

- If browsing damage on more than 20% or 50% of planted seedlings is enough to potentially change the species composition in young plantations
- If the natural regeneration of both broadleaves and conifers will fill the gaps in plantations with low density of Scots pine
- The goals and the reasoning of the forest owner when they regenerated the stands
- What the forest owners consider as required measures to reach the set goals for the stands

2. Methods

In this study, I made an inventory of 22 young stands which were regenerated by planting Scots pine four-six years ago. The stands were managed by the forest owner association Södra Skogsägarna (an economic association who represent forest owners in southern Sweden) and the stands were surveyed by the author, with approval of the forest owners. In addition, forest owners were interviewed regarding their aim with the regenerations and to gain an insight into their perspectives about the possibility to combine Scots pine plantations with the population of moose.

After both types of surveys and data collection had been concluded, statistical analysis was carried out to conclude if the null hypothesis (outlined in Section 1.4), was accepted or rejected.

2.1. Study area

The study area was chosen based on forest stands that were originally planted with Scots pine between 2016 – 2018 and managed by Södra Skogsägarna, in Jönköpings län, Kalmar län and Kronobergs län (Figure 3).

Södra carry out an annual planting survey of their newly planted stands. The stands are randomly selected from all coniferous plantations made each spring. In these surveys 15 to 30 circular sample plots (2.83 m radius) are systematically placed out in a grid. The plot centres are marked with a plastic stick and the coordinates are recorded with a GPS to re-measure the plots after three years.

In this survey, a subsample of the stands from the Södra planting survey was inventoried during October and November 2021. The subsample was made by the criteria of age and location, giving an approximate height of the planted seedlings, now saplings, to be 2 meters. Furthermore, the stands, which were planted on intermediate sites, had to be planted partially or fully with Scots pine, had not yet been pre-commercially thinned. Due to restrictions and policy by Södra Skogsägarna, only forest owners who gave permission to be contacted by SLU was finally approached and included in the survey. This resulted in a final number of 22 stands for the survey (Figure 3). 19 of the stands were owned by private forest owners, one stand was owned by Kalmar Kommun, one owned by Södra, and one owned by Sveaskog.

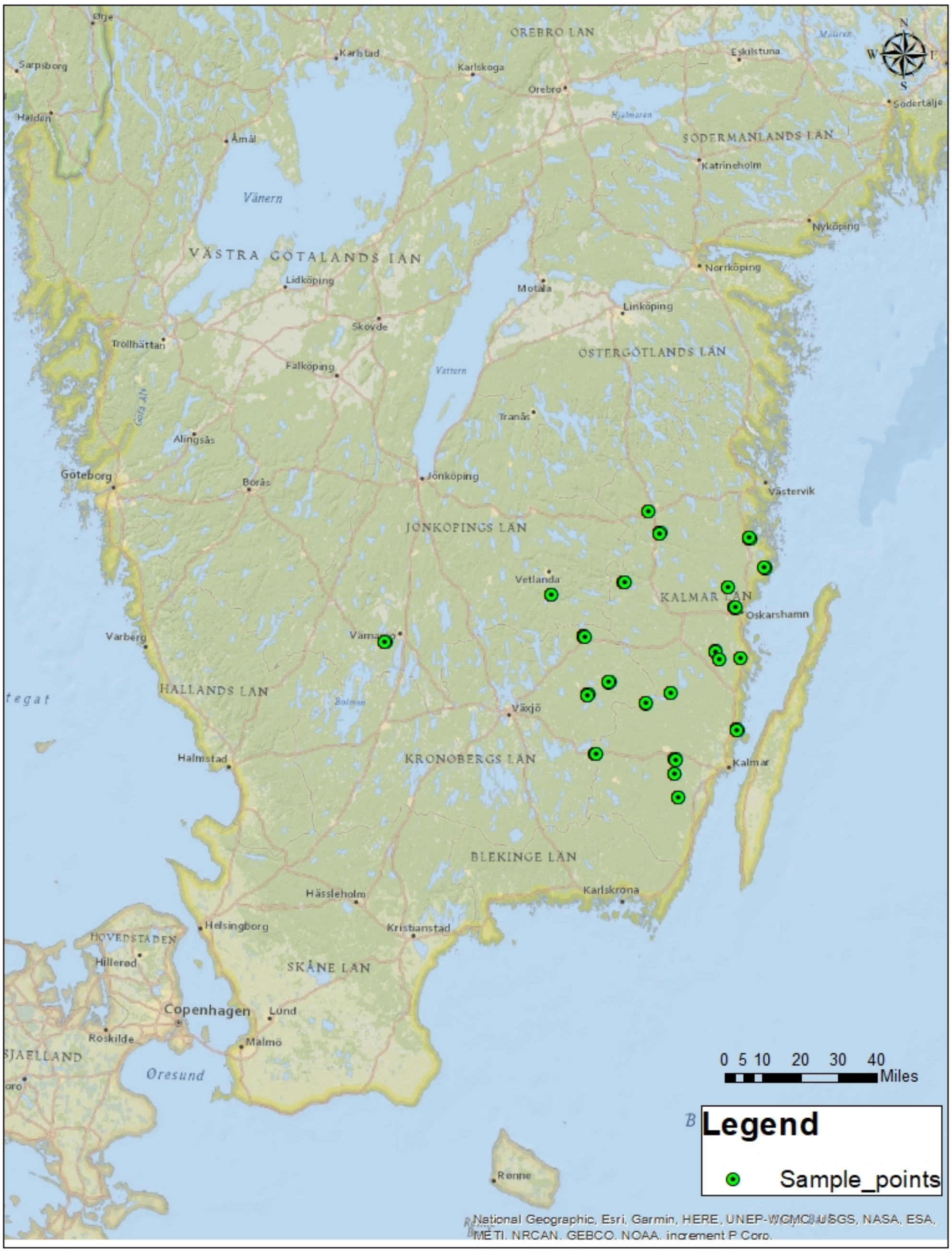

Figure 3 – Location of the 22 stands included in the survey.

2.2. Experimental design

2.2.1. Surveys of young forest stands

Sample plots (Figure 4) from the first survey were re-measured (on average 25 sample plots per stand). The plots were relocated using the coordinates from the first inventory and the plastic sticks representing the sample plot centre. If a plot could not be remeasured due to obstacles such as dangerous terrain, waterbodies or sample points that were placed in roads etc, they were relocated at the surveyor’s discretion.

The original sample plot size (2.83 m radius) was maintained. In each plot the following variables were recorded: number of saplings of Scots pine, Norway spruce, birch and a fourth category for all other tree species. Tree height (all species) and damage levels for pine and spruce only.

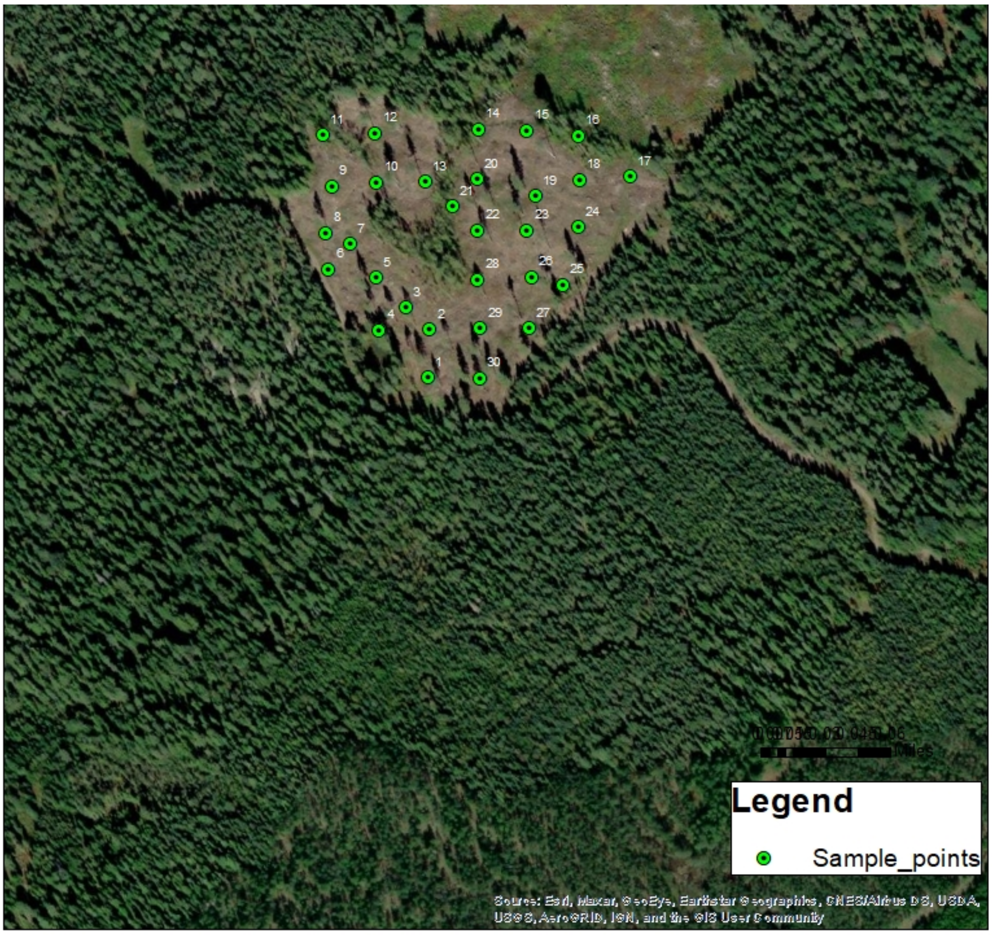

Figure 4 – example of a stand and how the sample plots are distrubted. The numbers related only to the plot count, bearing no further signficance.

2.2.2. Damage categorisation

The proportion of damaged saplings were used to describe browsing damage at plot level (e.g., if 1/10 pines were damaged, the damage level was 10%). A sapling was counted as damaged if it had been clearly browsed by an ungulate, indicated by broken twigs or branches (with chewed ends), broken or chewed at the top of the main stem or clear damage to the bark of the main stem (loss of bark or shaped by browsing e.g., not straight). All visible damage was recorded to reflect upon browsing impact on future crop trees. By recording damage to side shoots (e.g., twigs and branches) the method employed in this study differs to the methodology employed in ÄBIN and by the SFA (Section 1.1.3.) and thus are not compared directly to ÄBIN or SFA results. Furthermore, ÄBIN surveys are carried out at the end of the winter period e.g., starting in April, whereas the damage surveys for this study were conducted in October and November.

2.2.3. Damage calculation

The mean value for damage was calculated at stand level by taking the average of damage recorded at sample plots. The overall mean damage value for all 22 stands combined was calculated by taking the average damage value of all stands individually.

2.2.4. Estimating the Future Dominant Tree

After the data from the surveys of young forests had been concluded, it was used to calculate hypothetical scenarios that would allow us to estimate changes to stand species composition and count the future dominant tree; based on possible thinning decisions or assumptions about how different degrees of damage would influence stand development e.g., if browsing damage is too severe for pine stands to develop into intended monocultures.

Four different scenarios were applied to investigate how different management decisions such as thinning selection (e.g., prioritising Scot's pine or prioritising the tallest tree in the stand regardless of species) will influence the future development of the stands, and to investigate if browsing damage of more than 20% or 50% of planted seedlings is enough to potentially change the species composition in young forests, and if natural regeneration of both broadleaves and conifers will fill the gaps in plantations with low density of Scots pine.

The scenarios assumed a chosen strategy in the pre-commercial thinning (PCT), carried out in each sample plot and retaining one sapling per plot. The theoretical PCT made it possible to assess the stand tree species composition for each scenario, using the sum of all plots to represent the stand.

In **Scenario 1 – Scots pine prioritisation**: PCT was used to retain as much of pine as possible in the stand, regardless of sapling heights. If there was a pine in the sample plot, all other trees were removed, and one pine was retained. If there was no pine sapling present in the sample plot, then the highest sapling was retained, regardless of species.

In **Scenario 2 – highest sapling prioritisation:** only the highest sapling was retained in each sample plot regardless of tree species and all other saplings are removed. If more than one sapling was equal to the maximum height, then priority was given based on species in the following order: Scots pine > Norway spruce > birch > other tree species.

In **Scenario 3 – >50% damage to pine:** it was assumed that pine saplings in plots with pine damage greater than 50% would not be able to develop and compete with saplings of other tree species. If the plot had a damage level< 50 %, the strategy from Scenario 1 was followed. If not, the strategy from Scenario 2 was followed.

In **Scenario 4 – >20% damage to pine:** it was assumed that pine saplings in plots with pine damage greater than 20% would not be able to develop and compete with saplings of other tree species. If the plot had a damage level< 20 %, the strategy from Scenario 1 was followed. If not, the strategy from Scenario 2 was followed.

Calculating the future dominant tree

In this study a threshold of 65% of a single tree species is used to determine if a species can be considered dominant and therefore a monoculture, the same limit used in Swedish National Forest Inventories (NFI) (Nilsson, 2013).

The results section will show calculations to highlight if any of the scenarios above result in expected monocultures from a single species.

2.2.5. Data output and statistical analysis of fieldwork

Statistical data analysis was performed using Microsoft Excel (Version 14.5.5). for calculating mean and standard deviation at stand level for the following variables: stem density (stems ha^{-1}), height (m) and damage (%) (only for pine and spruce).

Mean is used to calculate the most common or average value whilst standard deviation informs us about the spread of dispersion of the results of a given measured variable.

To test the study hypothesis a t-test was used to see if the group of stands with lower pine density (<1500 stems ha^{-1}) have the same browsing damage as the group of stands with higher pine density (>1500 stems ha^{-1}). The hypothesis was rejected on the reference level p-value >0.05.

A threshold of above or below 1500 stems ha^{-1} has been used in this study when researching how regeneration failure of Scots pine changes the species composition of young forests, as it also used in other studies, (Ara et al. 2021).

The tree species composition was calculated first on plot level as a proportion of each species in number of saplings of the total, per plot. Thereafter the species composition on stand level was calculated as the average of the plots. A t-test was used to show if there is any significant difference in the number of Scots pine-dominated stands (>65%) when comparing the use of different PCT options between Scenarios 1 and 3 and between Scenarios 1 and 3, as Scenario 1 focuses on pine prioritisation, the main species of interest in this thesis.

2.3. Data collection - questionnaire

Descriptive statistics were used to analyse forest owners' responses about how browsing damage had affected Scots pine plantations and if the results obtained from field data showed that species composition had deviated from their original aims.

The questionnaire was five questions with multiple-choice answers for each question:

1. What was the original goal for your forest stand?

a) Maximise production value
b) Create a balance between production value and recreational values
c) Maximise recreational values e.g., hunting, berry/mushroom picking
d) Other – describe

2. Who do you turn to for guidance on regeneration and future management?

a) The owner / yourself
b) Forest advisors e.g., Södra
c) Others around me e.g., neighbours, friends or relatives
d) Newspapers or the internet
e) Other

3. How does browsing damage affect your management of the forest stand?

a) Significantly
b) A lot
c) Not a lot
d) Not at all
e) I don't know

4. How do you balance production goals against environmental goals?

a) 100% production
b) 75% production / 25% environmental
c) 50% production / 50% biodiversity
d) 25% production / 75% environmental
e) 100% environmental

5. Which of the following options would help to achieve your initial goals for your forest stand?

a) Increased hunting
b) Increased moose population
c) Increased pine density
d) Increase the number of trees belonging to RASE species
e) Greater subsidies for protection against browsing e.g., fencing, physical barriers
f) None of the options listed help to achieve my initial goals

The questionnaire was sent to participating forest owners via email and hyperlink following the completion of fieldwork. The forest owner was sent a questionnaire in Swedish, and both questions and answers are translated into English in this thesis. The questionnaire in the original language can be found as Appendix 2.

3. Results

3.1. Surveys of selected young forest stands

The overall mean density of Scots pine in 22 surveyed stands was 1616 ± 828 stems ha^{-1} with a mean height of 1.1 ± 0.6 m (Table 2). The overall mean density was 1358 stems ha^{-1} when considering all tree species.

There were no empty plots in the whole survey, all sample plots had at least one sapling of one of the four species categories (pine, spruce, birch or other tree species), except for Stand 16 which had no Norway spruce and fewer trees than all other Stands (Appendix 1). Scots pine, Norway spruce and birch were the predominant species in all stands, but broadleaves were also recorded in most stands either as either mature retention trees or as minor regeneration. Most commonly oak (*Quercus spp*), and occasional aspen, (*Populus tremula*), hazel (*Corylus avellana*), rowan (*Sorbus aucuparia*), salix (*Salix spp*.), sycamore (*Acer pseudoplatanus*), and rarely the coniferous species juniper (*Juniperus communis*).

Table 2 – Summary of key results including stem density (stems ha^{-1}) represented as overall mean and standard deviation (±), height (m) and damage (% of density) for all species recorded. Damage was only recorded for Scots pine and Norway spruce.

Tree species	Stem density (Stems ha^{-1})	Height (m)	Damage % (% of density)
Scots pine	1616 ± 828	1.1 ± 0.6	25 ± 15
Norway spruce	822 ± 603	0.9 ± 0.7	1 ± 0.2
Birch	2755 ± 1731	1.6 ± 0.6	-
Other sp.	238 ± 306	0.3 ± 0.4	-

3.1.1. Development of planted pine seedlings

General results related to planted pine seedlings

The survey mean density of Scots pine was 1616 ± 828 *stems* ha^{-1} with a mean height of 1.1 m ± 0.6 m (Table 2).

The highest stand density of Scots pine was 4080 stems ha^{-1}, whilst the lowest average for a stand was 160 ha^{-1}. The highest stand mean pine sapling height was 2.1 m.

The highest mean browsing damage for a stand was 58% of the pine saplings, while the average for the whole survey was 25%. The lowest browsing damage found was 0 % (occurred in one stand only, which featured very few trees and less than the average number of sample plots).

There was no significant difference in the damage proportion in the low or high density stands (t-test p= 0.5). Therefore, the null hypothesis is accepted. 13 of 22 stands had less than an average of 1500 stems ha^{-1} of Scots pine with a mean damage level of 27 %. The damage level for stands with higher density was 23%.

3.1.2. Development of competing tree species (Norway spruce, birch and other)

General results related to Norway spruce

The survey mean density of Norway spruce was 822 ± 603 *stems* ha^{-1} with a mean height of 0.9 m ± 0.7 m (Table 2).

The highest mean stand density of Norway spruce was 1947 stems ha^{-1}, and the lowest was 0 stems ha^{-1} (one stand only). The highest mean spruce height was 3.3 m.

The highest mean browsing damage for a stand was 5% of the spruce saplings, while the average for the survey was 1%. The lowest browsing damage found was 0 % (multiple stands).

General results related to birch

The survey mean density of birch was 2755 ± 1731 *stems* ha^{-1} and a mean height of 1.6 m ± 0.6 m (Table 2).

The highest stand density of birch was 6933 stems ha^{-1}, and the lowest was 53 stems ha^{-1}. The highest mean birch height was 2.8 m. Browsing damage was not recorded for birch trees.

General results related to other tree species

The survey mean density of other tree species was 238 ± 306 stems ha^{-1} and a mean height of 0.3 m ± 0.4 m (Table 2). The highest stand density of other tree species was 994 stems ha^{-1}, and the lowest was 0 stems ha^{-1} (three stands). The highest mean other tree species height was 1.6 m. Browsing damage was not recorded for other tree species.

Species composition in the stands

Birch was the most dominant tree species in the stands, both in terms of mean height and stem density. The species composition in the survey was on average a pine proportion of 33%, spruce 14%, birch 46% and other tree species 7% (Figure 5).

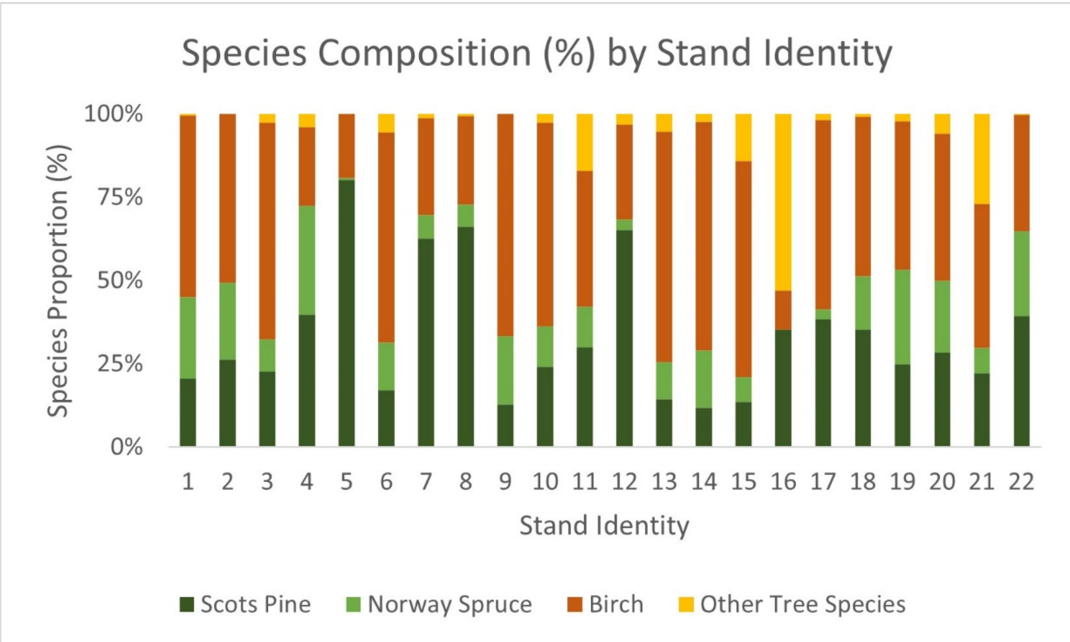

Figure 5 - Species composition measured represented as a percentage in each stand.

3.1.3. Scenario Results

The four scenarios for PCT strategies resulted in four different tree species compositions in the survey.

In Scenario 1, the pine preference scenario, the outcome after PCT was pine dominated stands, on average 82 % pine (Figure 6). In Scenario 2, where the leading tree in term of tallest sapling in each plot, was retained, the tree species composition of the stands changed. In this scenario birch became the dominant tree species (44%) (Figure 7). Pine represented 31% of the species proportion in Scenario 2 – a decrease of around 62% from Scenario 1.

In the two following scenarios the damage level in each plot was considered in the PCT strategy. In Scenario 3, the pine priority was replaced with the tallest tree if the damage level exceeded 50 %. Few stands were subject to pine damage levels > 51%. Pine represented 70% of the species proportion in Scenario 3, a reduction of 15 % compared to Scenario 1 (Figure 8).

In Scenario 4 the accepted damage level was as low as 20 %, which resulted in a further decrease in pine proportion (Figure 9). Pine represented 55% of the species proportion in Scenario 4, a decrease of 33% compared to Scenario 1.

Do the scenarios lead to any trees being dominant or formation of monocultures?

Scenario 1 would lead to 20/22 stands being Scots pine monocultures (>65% of stand composition). Scenario 2 would lead to only 2/22 stands being Scots pine monocultures. Scenario 3 would lead to 14/22 stands being Scots pine monocultures and Scenario 4 would lead to 6/22 stands being Scots pine monocultures.

T-test results show a significant difference in the number of Scots pine-dominated stands when comparing the use of different PCT options between Scenarios 1 and 3 (t-test p value = 0.01) and between Scenarios 1 and 4 (t-test p value = < .001).

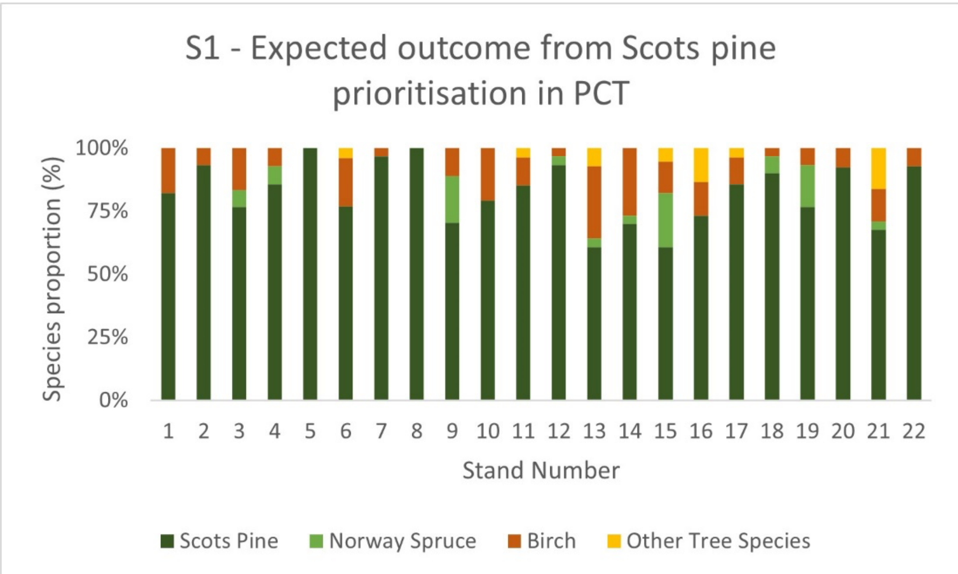

Figure 6 – Species composition measured represented as a percentage in each stand, where pine is prioritised in PCT selection.

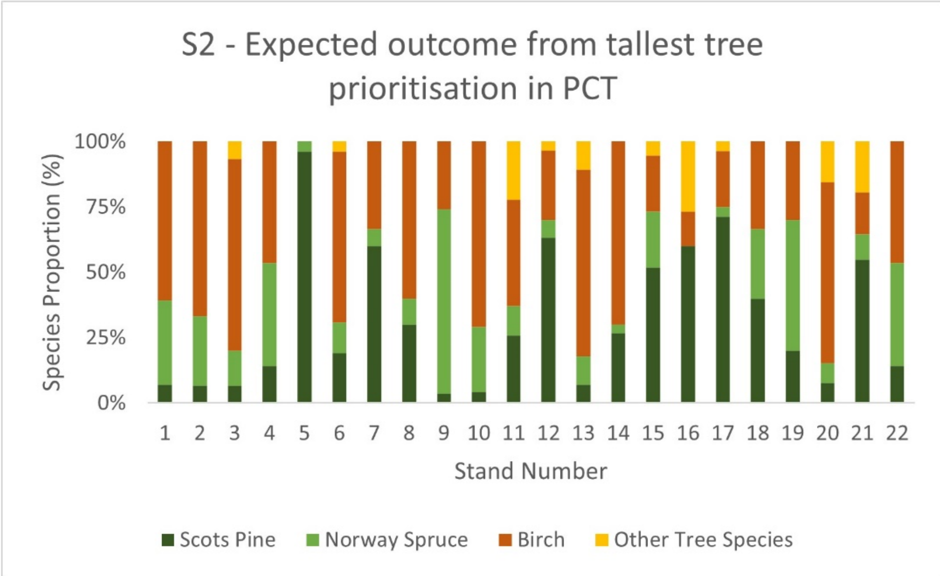

Figure 7 - Species composition measured represented as a percentage in each stand when the tallest sapling regardless of species is retained.

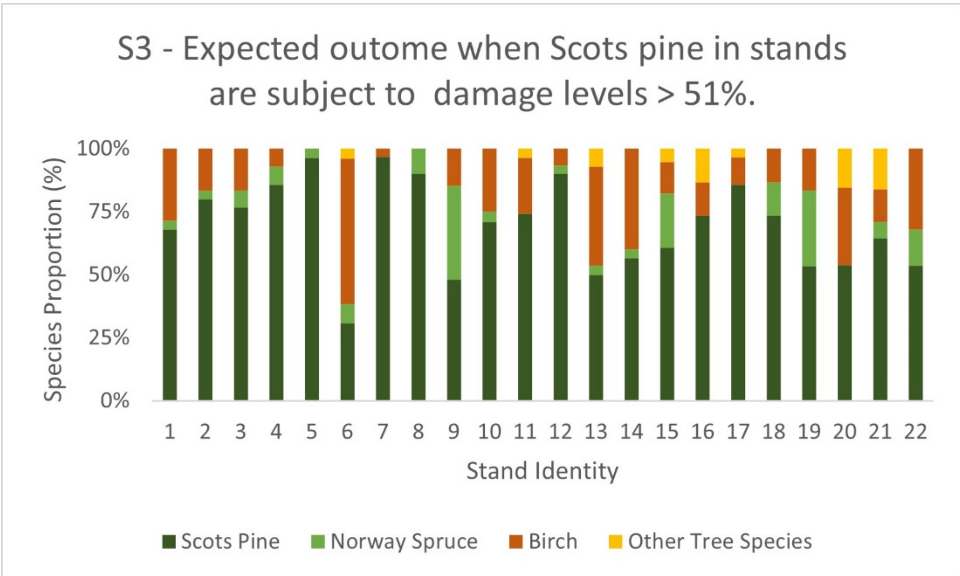

Figure 8 - Species composition measured represented as a percentage in each stand in stands that are subject to pine damage levels > 51%.

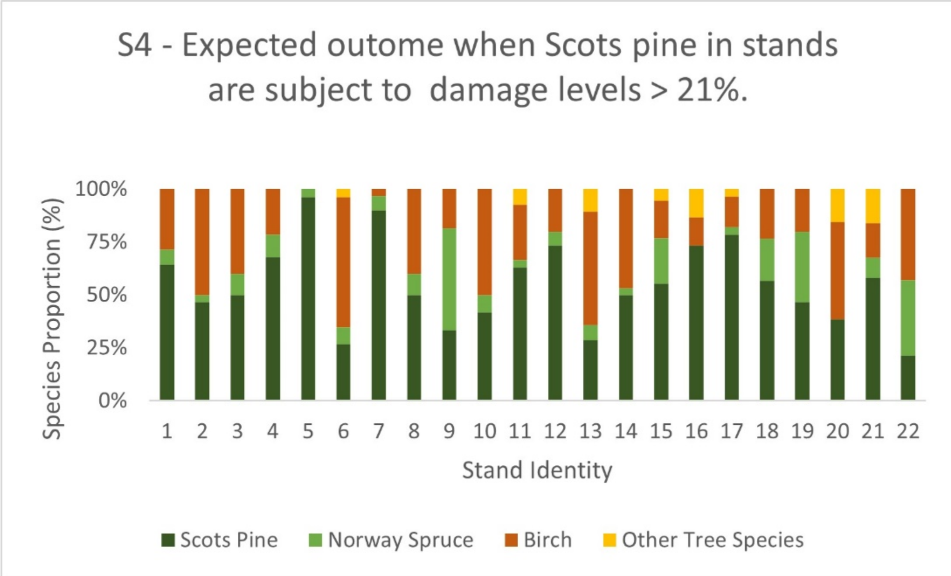

Figure 9 - Species composition measured represented as a percentage in each stand in stands that are subject to pine damage levels > 21%.

3.2. Forest owner questionnaires

3.2.1. Respondents

17 of 19 private forest owners completed the questionnaire. In total 22 stands were surveyed all belonging to different owners (Section 2.1).

Question 1

Most respondents claimed that their original goal for their forest stand was to create a balance between production and recreational values. Three answered that their original goal was to maximise production, while a single respondent answered ‘Other’, citing: to ensure the stand was like its previous habitat state and the goal for the stand depended on which stand was being surveyed when owners had more than one stand.

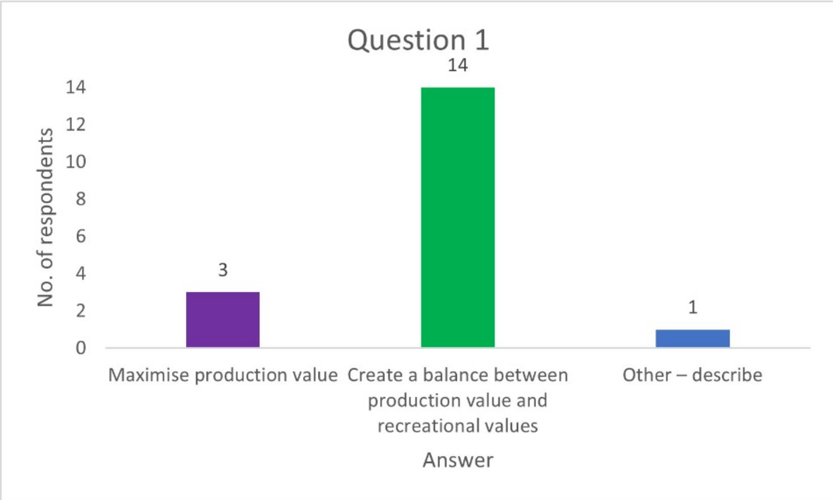

Figure 10 – Q1. What was the original goal for your forest stand?

Question 2

Most respondents answered that they used forestry advisory services for guidance on regeneration and future management of their forest stand, moreover, a high number of respondents chose to count on their own management experience. In contrary, only 1 respondent claimed to relay on newspapers or the internet (Figure 11).

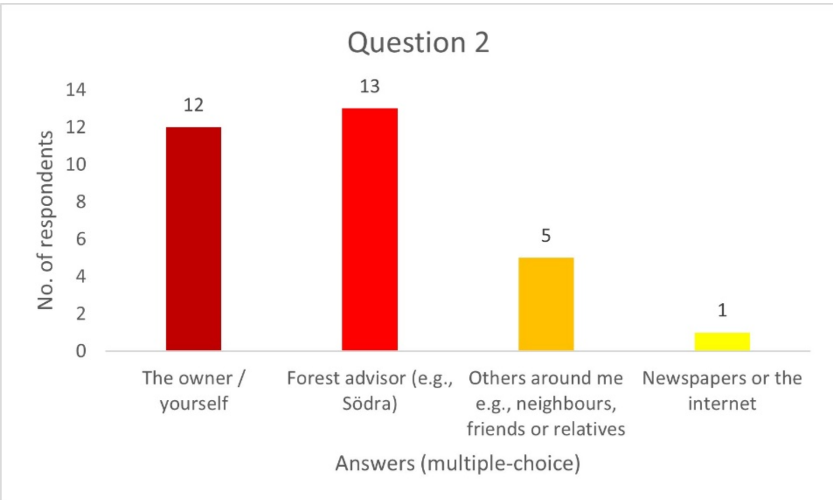

Figure 11 – Q2. Who do you turn to for guidance on regeneration and future management of their forest stand?

Question 3

Most respondents answered, ‘a lot’, while a single respondent answered ‘significantly’. The second most common answer was ‘not a lot’, while one answered they did not know (Figure 12).

Figure 12 – Q3. How does browsing damage affect your management of the forest stand?

Question 4

The most common answer from respondents on how forest owners balance production goals against environmental goals was '75% production / 25% environmental', while the second most common answer was '50% production / 50%' environmental. Two respondents answered that they aimed for 100% production, while no respondents answered that their goals were '25% production / 75% environmental' or '100% environmental' (Figure 13).

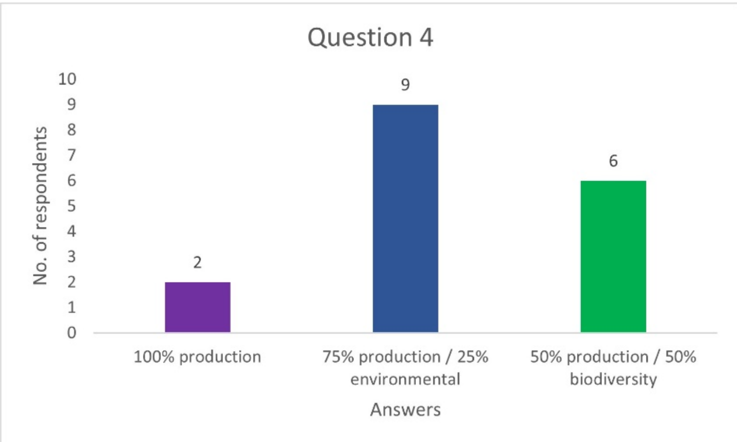

Figure 13- Q4. How do you balance production goals against environmental goals?

Question 5

The most popular answer from respondents was 'increased hunting', followed by 'greater subsidies for protection e.g., fencing'.

‘Increased pine density’ and ‘more RASE species in the landscape e.g., rowan, aspen, *Salix spp*. and oak)’ were also common answers. Only one respondent answered that ‘increased moose population’ would help them achieve their goals while some respondents claimed that none of the options listed would help them to achieve their initial stand goals (Figure 14).

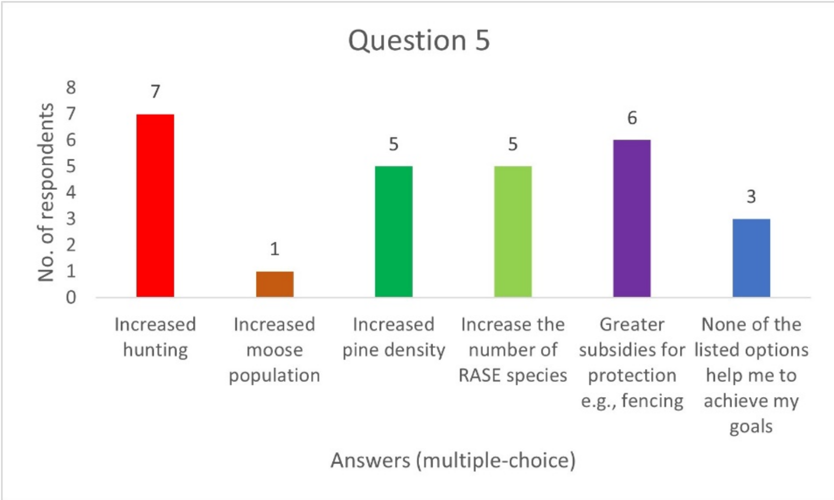

Figure 14 – Q5. Which of the following options would help to achieve your initial goals for your forest stand?

4. Discussion

4.1. General findings

In this study I conducted two surveys, one of the developments of young, planted Scots pine stands, and the other as a questionnaire for the forest owners of the stands. All the stands were planted only with Scots pine, and in densities so that if all seedlings would survive and be competitive, the stands would likely develop into Scots pine monocultures. Now, three-five years later I found no stands with sample plots without tree saplings. On the contrary, the density indicates that without any other measures all the regenerations will develop into forest stands (even if the original species planted is not dominant e.g., Scots pine), fulfilling the requirements of the Swedish Forest Agency (SFA 2020). However, two factors will most likely impact the species composition, productivity and future economy in the stand: 1) the strategy for the first competition release (PCT) and 2) the browsing pressure in the upcoming years.

4.1.1. Pine damage survey methodology

As referred to in Section 2.2.2. the method employed for recording pine damage was not the same as the ÄBIN or SFA methods, as it included damaged side shoots (e.g., twigs and branches). This is also another type of study. Instead of assessing damage trends over the year on a regional or national scale, I have estimated the browsing impact on future stand development for some specific stands. My strength is the many replicates of measurements within each stand.

I believe that including side shoots can be justified on two-levels. Firstly, that the results indicate that the low height development of pines showed that they have been hindered in growth – suggesting that the observed damage from the fieldwork is negatively affecting their ability to compete with other species recorded, most notably Norway spruce and birch.

Secondly, another study included all browsing damage in their assessment. Although 75% of the damage recorded was to the leading shoot, all types of recent stem damage correlated positively with the extent of recent browsing on lateral shoot (branches) (Bergqvist et al. 2001).

In contrast to ÄBIN surveys carried out at the end of winter e.g., starting in southern Sweden in April, the surveys for this research project were carried out in October and November. It might be argued that this makes it more challenging to distinguish between older and more recent damage when recording damage levels.

Moreover, the methodology employed in this research project was designed in a way so that data collection could be collected quickly, and more stands could be surveyed. Thus, increasing the dataset from which analysis could be performed.

The criteria for the stands that were selected for surveying in this research project (Section 2 - Methods) means that the damage levels recorded are accumulated damage over several years, in contrast to ÄBIN which surveys annually. This also means that some damage will not have been recorded that ÄBIN would not have incorporated, including trees that have died. By recording browsing over several years, we see the accumulative effect of browsing and the inhibited growth of pine compared to Norway spruce.

4.2. PCT Strategy

PCT and thinnings in general allows forest owners/managers to target their preferred crop tree, thus, management decisions related to thinning will have a significant influence on the outcome of a stand.

Forest managers may look to identify a suitable thinning option that has the potential to be reduce the severity of damaging agents e.g., browsing pressure or pine weevil damage. For example, using tools such as scenario analysis or simulation programs could be a method to predict how certain levels of stand density (after initial planting or thinning), choice of tree species planted or methods to deter browsing may affect browsing pressure and influence which tree species will be dominant in the stand in the future, (Heikkilä and Härkönen 1996, Härkönen 1998, Olsson 2008).

Do the scenarios lead to any trees being dominant or formation of monocultures?

Clearly, any strategy that prioritises Scots pine retention in stands that were initially planted with this species will lead to a greater proportion of Scots pine stands and in some cases Scots pine being the dominant species. However, what the results from the scenario analyses (3.1.3.) clearly demonstrate is that to fulfil the goal of a Scots pine dominated stand, heavy intervention in terms of using PCT to remove competitive species is required. The results from Scenario 2 demonstrate that where targeted PCT is not used to prioritise pine that Norway spruce and birch will become dominant. The t-test results comparing the different PCT options between Scenarios 1 and 3 and between Scenarios 1 and 4 also show that there is the potential for significant differences in the number of Scots pine-dominated stands depending on pine damage levels (as described in Scenarios 3 and 4 in 2.2.3.). Which is consistent with a recent study that showed damage weighting had a significant impact on the proportion of Scots pine (Ara et al. 2021).

In Scenario 1, the pine preference scenario, the outcome after PCT was pine dominated stands, on average 82 % pine (Figure 8). In Scenario 2, where the leading tree in term of tallest sapling in each plot, was retained, the tree species composition of the stands changed. In this scenario birch became the dominant tree species (Figure 9).

By using PCT to retain only the highest sapling in each stand (Scenario 2), species composition becomes more varied and Scots pine becomes less competitive. Even though pine was planted intentionally, both spruce (slow growing) and birch are catching up and even superseded pine in some stands. Even though Scenarios 1 and 2 may be argued to be highly theoretical (very few forest owners would cut and remove the paid planted seedlings), they can still serve as an indicator on how well the planted pine seedlings have performed during the first years.

The relatively slow height development on the pine seedlings may indicate that they have been repeatedly or occasionally held back by damaging agents, e.g., by pine weevil or by ungulate browsers. The former of which has been identified as a major concern, as in the early growth stage Scots pine is most sensitive to biotic and abiotic stress factors (Nilsson et al. 2010). If this causes mortality of Scots pine seedlings, then this could profoundly change the trajectory of species composition of the young forest from what was originally intended, leading to a large proportion of the young stands developing develop into mixtures e.g., Norway spruce and birch (Ara et al. 2021). However, the effects the influences described above can be mitigated by site preparation (Nilsson et al. 2010).

In the absence of damaging agents, Scots pine and Norway spruce have different growth patterns and site preferences (Nilsson et al. 2010). Norway spruce is a late-successional species with slow early growth, and its growth depends on conditions in the previous year. Whereas Scots pine is a pioneer species that grows rapidly in its infancy, and this should have an early competitive advantage over Norway spruce in the initial years after planting (Nilsson et al. 2010). This is not always the case in the 22 stands surveyed for this research project. Scots pine has a poor tolerance of prolonged suppression in shady conditions (Nilsson et al. 2010), which occurred in some stands which were dominated by taller birch and spruce, mixed with Scots pine. Nevertheless, Norway spruce is considered to grow better than Scots pine in sites with intermediate to high fertility (Nilsson et al. 2010), and the stands selected for this study were of intermediate fertility.

The scenarios described here are general and simplified, e.g., stand density is not considered, which could be done in more thorough analysis. However, what Scenario 1-4 demonstrates is that different degrees of pine damage could lead to different stand outcomes in combination with precommercial thinning. Importantly, browsing pressure that leads to pine damage, will influence management decisions taken by forest owners e.g., choice of tree species, use of protection and potentially influence thinning decisions to help promote targeted species.

Scenario 3 – pine plots with >50% damage would not compete with other species

Average pine damage of >50% only occurred in one stand, and in this case PCT decisions explained in Scenario 2 would be used. In 21/22 stands had damage levels <50%, which means Scenario 1 thinning (pine prioritisation) would be employed. Overall, this would generate a pine proportion of 70% across all 22 stands.

Demonstrating that if a higher threshold for pine damage was used to determine PCT decisions then Scenario 1 PCT would be used in most stands.

Although only one stand was subject to more than 50% pine of average pine damage and this considered a positive result, it is perhaps not a suitable figure of which to base PCT decisions on. Scenario 4 explores management decisions taken in relation to damage levels that are more consistent with average damage levels recorded in Götaland in recent years (Section 1.1).

Scenario 4 - assumed that pine saplings in plots with pine damage greater than 20% would not be able to develop and compete with saplings of other tree species.

In Scenario 4 the accepted damage level was at 20% close the average levels recorded in Götaland, (Figure 2), resulting in an increase in the number of stands that would now be subject to Scenario 2 PCT. Meaning less pine prioritisation and greater variation in tree species composition, with pine now only 55% of species proportion compared to Scenario 3 which had a pine proportion of 70%.

These results would imply that where browsing damage levels are considered too high (>20% in Scenario 4) that it will have an impact of the outcome of the stand and lead to fewer pine monocultures which may conflict with the original intentions of forest owners, who aimed for pine stands. Instead, the analysis suggests these stands may develop into stands dominated by Norway spruce or a mixture of Norway spruce, Scots pine and birch.

Research carried out by LRF show that moose browsing damage levels are around 15%, which is well above the national target of 5%, prompting Södra to contact the government to highlight wildlife management problems that exist particularly in Västra Götaland, (LRF 2021).

The levels of pine damage in this research were recorded at 25%, all stands were in Götaland and are thus consistent with other results measuring pine damage levels in Götaland (Figure 2). The high levels of browsing damage to Scots pine suggest that employing Scenario 1 as a PCT method may not be optimal but does nevertheless highlight that a degree of targeted thinning or other forms of intervention may be required to ensure Scots pine plantations fulfil their owners' initial stand objectives, however, as previously mentioned the Scenario Analyses in this paper did not factor in stem densities.

Will natural regeneration of both broadleaves and conifers fill the gaps in plantations with high mortality?

Plots that were surveyed and recorded very little or an absence of pine were filled with other broadleaves and conifers. This would suggest that these tree species will also fill the gaps in plantations were high mortality of pine occurs because of browsing or other factors e.g., (resource competition, extreme weather events). It is important to stress, of course, that the spontaneous regeneration of birch and Norway spruce is not a guarantee and cannot been taken for granted. In this study made in southern Sweden, in the hemi-boreal zone and on intermediate sites and small clearcuts with short distance to seed trees. As demonstrated in our results, no stands that were surveyed contained zero trees, as natural regeneration filled any gaps left.

However, it could be that other factors supersede damage levels in terms of influencing the outcome of stand development, given the stands' current age (3-5years). For example., initial planting density, planted species choice and natural regeneration of fast-growing birch. Therefore, it would be useful to re-survey the same stands and sample plots again when the stand age has reached 10 years, as it may be a suitable timescale to reveal the influence of pine damage levels and the consequent stand outcomes. As mentioned previously different simulation programs could also be used to estimate stand outcomes.

Browsing damage will not be the only factor to affect stand regeneration, clearly PCT and thinning decisions (perhaps informed by browsing damage levels) will influence stand outcome. Nevertheless, the data from this research could be indicative in terms of damage levels alone helping to predict the future stand composition.

4.3. Forest owner questionnaire

The forest owner questionnaire provided information about their initial stand goals and identified what measures the forest owners believe are required to reach the set goals for their stands.

4.3.1. Q1: What was the original goal for your forest stand?

Most forest owners stated that their original intention for their stand was to create a balance between production and recreational values. A pre-requisite for surveying the selected stands was that they had been intentionally stocked with Scots pine. Most likely forest owners would have planted densely in anticipation of expected pine losses due to browsing damage or choosing to plant with pine as it would help balance their stand goals (Fahlvik et al. 2018).

If recreational values are favoured towards berry picking, then the creation or retention of pine stands will of course help with this aim. Pressure from browsing on a heavy scale, combined with minimal intervention may lead to a different forest type e.g., spruce (Edenius et al. 2002).

4.3.2. Q2: Who do you turn to for guidance on regeneration and future management?

Question 2 allowed respondents to select multiple answers, as it is likely forest owners may rely on a combination of competencies and expertise to guide their decision making.

Most forest owners stated that they sought advice for stand management from forest advisors or that they relied upon their own knowledge. This may suggest that forest advisors could potentially have a large influence on stand management decisions, but this of course should be guided by the intentions of the forest owner where appropriate. The data from respondents suggest that many forest owners are reliant on additional advice in how to meet aims, this may particularly be the case where owners want to know how strike a balance between minimising browsing damage, maximising production but demonstrate some concern for biological diversity (Feliciano et al. 2017).

The results suggest that forest owners do seek advice and given the answers provided in Question 5 and other research carried out in collaboration with Södra (Section 1.2.1), the subjects are likely related to: hunting, dealing with increased damage levels from browsing and creating alternative areas for fodder (Bender 2017).

4.3.3. Q3: How does browsing damage affect your management of the forest stand?

More than half of the respondents claimed that browsing damage influenced management decisions for their stand. However, around 30% also said that it was not a consideration. This may be reflective of forest owner goals e.g., those that would like to maximise production may favour management decisions that could reduce browsing pressure, whereas forest owners who favour recreational values or perhaps rely upon advice may feel indifferent to browsing pressure (Felton et al. 2017).

4.3.4. Q4: How do you balance production goals against environmental goals?

More than half of the respondents claimed that production and environmental goals were balanced at 75%/25%, with around 35% claiming that a 50/50 balance was used to manage their stands.

The way in which respondents answer this might be highly dependent on how one defines increasing biodiversity values. Some may argue that heavy browsing pressure will lead to mixed stands (in terms of species composition and age) in addition to larger mammals affecting the local ecosystem in terms of ground flora, spatial diversity etc. On the other hand, others may argue that excessive browsing by large mammals such as moose will disproportionately favour the regeneration of non-favoured browse species such as Norway spruce and birch (an issue well discussed within Swedish forestry), as pine and other broadleaf species are browsed and outcompeted. In addition to the fact that increased cervid numbers may affect ground flora availability (Rautiainen et al. 2021, Spitzer et al. 2021), leading to an increased intensity in which certain tree species are browsed (Section 1.2.1).

4.3.5. Q5: Which of the following options would help to achieve your initial goals for your forest stand?

Question 5 allowed respondents to select multiple answers, as it is likely forest owners may rely on a combination of methods to help achieve their initial goals for their stand.

The question and possible answers from question 5 can very much be linked to responses in question 3. Where forest owners feel that browsing has a large influence on stand management, actions such as increased moose hunting, or increased RASE species planting may be favoured. Further, this will be influenced by the desired outcomes for their forest stands (questions 1 and 4).

A survey carried out by SLU with hunters identified a changing trend towards moose numbers (SLU 2021a), (Section 1.2.1). In this study it was shown that hunters now believe that moose numbers are too low. This contrasts with the responses given by forest owners in my survey, question 5, who identify 'more hunting' as a key method to achieve their forest stand goals. Although the survey does not explicitly ask participants if they would like more moose hunting, one can assume that forest owners would consider moose to be a large proportion of ungulates that needs to be controlled (Lindqvist et al. 2014).

Although this survey was a smaller scale than the research carried out by Fredrik Widemo (see Section 1.2.1.), it does identify a potential conflict between different stakeholders regarding moose management (Sandström et al. 2013). As outlined in Section 4.4.1. creating an open forum and dialogue between all stakeholders will be critical to ensure desired outcomes are achieved for all concerned (e.g., forest owners, hunters, local authorities and forest owner associations).

Topics related to questionnaire responses in more depth

The increased planting of RASE species could fulfil two aims – reduce the browsing pressure on pine, and secondly increase tree species composition and thus biological diversity. The latter of which could become a greater requirement for future forest owners, dependent on how forest legislation and guidance develops in Sweden in upcoming years. Furthermore, it has been identified that more diverse forest stands are more resilient to external influences such as those associated with climate change (increased storms, forest fires, drought or flooding) and forest stand resistance to pests and disease (Brown et al. 2017, Boyd et al. 2013, Jónsson 2016, Prospero and Cleary 2017, Trumbore et al. 2015).

Although areas with high density of preferred deciduous tree species do not eliminate pine browsing, (Heikkilä and Härkönen 1996), the reported intake of pine reduces when broadleaves such as RASE are present (Hörnberg 1995). Lyly and Saksa (1992) reported that both the number of saplings which escaped serious moose damage and the number of saplings browsed by moose increased with an increase in stand density. Moreover, that stands subjected to repeated moose browsing will only succeed when a regeneration density of a least 4000 seedlings ha^{-1} is used. In this study the maximum average stand density recorded was 10093 ha^{-1} while the average was 5432 ha^{-1}. Nevertheless, the results from this study did not strongly demonstrate that a higher stand (pine) density leads to a significantly lower damage frequency (Section 3.1).

Some respondents answered that they would like more targeted support for protection against browsing. Incentives such as this could be considered appropriate not only for targeted pine regeneration but other species such as oak, (Bergquist et al. 2009, Dobrowolska 2006), which could be regenerated in mixed stands with pine, meanwhile promoting tree species diversity and facilitating great biological diversity within a forest landscape. The use of fencing for example has received substantial support in literature as a means of protecting trees from browsing and biodiversity degradation (Angelstam et al. 2000 and Jónsson 2016) but the high costs and need for more intensive management has also been acknowledged (Jónsson 2016 and VerCauteren et al. 2006). Moreover, the use of fencing may help young trees escape a browsing trap, especially in the case of pine where moose prefer to browse at a height of between 0.5 – 4.0m, (Olsson 2006).

4.4. Biodiversity concerns

Although the SHA has a key role in executing wildlife management goals for Sweden, it has been argued that their 'strictly anthropocentric view on wildlife management' may lead to negative outcomes for Swedish wildlife management goals, if results are orientated towards the needs of hunters instead of being balanced with biodiversity concerns (Engbladh 2016).

At stand level moose primarily encourage spatial heterogeneity by browsing patchily and exploiting existing gaps. At tree level, moose will damage individual trees and lower timber quality (according to forest production standards), (Edenius et al. 2002). However, this damage may lead to different substrate types which are essential for redlisted species who rely upon dead and dying wood, Den Herder et al. 2009).

Other research focuses on how early responses of changes to the field layer will be a key determinant of future stand development and species composition, especially where heavy browsing depletes the shrub understory, (Tremblay et al. 2006).

Research argues that ungulates have changed the distribution of native species and the composition of plant communities as well as the successional patterns and ecological processes deemed characteristic of some regions (Tremblay et al. 2006), a criticism that is also labelled at the forestry industry under current practices aimed at maximising production values, using even-aged forests (EAF) and clear-cutting as a primary method (Cherubini et al. 2018, Felton et al. 2010, Felton et al. 2020a, Felton et al. 2020b, Hedwall et al. 2010, Hedwall et al. 2011).

Regardless of the objectives related to forest management, whether that be for timber production, moose management or for recreational values, there is greater recognition of the need to include biodiversity considerations into management plans and actions.

Although moose is a keystone species (alongside Scots pine) and critical to ecosystem functioning in boreal forests (Kolstad et al. 2018); care should be taken to ensure moose numbers to not fall too low, this must be balanced against goals for the restoration of mature, deciduous forests which will play an increasingly important role in biodiversity conservation in Sweden alongside continued production forestry that prioritises coniferous trees (Angelstam et al. 2017).

4.5. Management implications

4.5.1. Different stakeholder perspectives

Hunting association, forest owners and SFA

Recent research suggests that hunters would like to see more moose. This could lead to conflicts with forest owners who want to see fewer moose (Sandström et al. 2013), and thus must be considered by decision-makers when determining the preferred moose population density. However, in the case of Götaland there is a problem with pine damage levels and perhaps increasing the number of moose will not help forest owners to achieve the SFAs targeted damage level of less than 10%.

Questionnaire responses seem to suggest a difference of opinion compared to research carried out by SLU with hunters. Although the sample size was much smaller in terms of the number of participants in my study, they were perhaps a more targeted group of forest owners (trying to regenerate Scots pine stands).

The SFA is promoting greater levels of pine regeneration (Mera Tall) and at the same time want to manage moose damage to pine, which is in general is in line with forest owner goals. As the results show, forest owners rely upon external guidance for forest owner associations such as Södra, associations such as this will not only play a key role in helping forest owners to fulfil their stand objectives but are perhaps suitably placed to help solve differences in aims between large groups such as forest owners, hunters and the SFA with their economic and intellectual capital. Edenius et al. 2002, suggests that co-management of moose and forests require appropriate monitoring programmes for both plants and animals, in addition to deep ecological knowledge regarding moose and their preferred fodder at all spatial scales.

Deer prefer *Vaccinium* as a food source, which can result in a shift of moose browsing preference from *Vaccinium* to Scots pine in areas where deer are present in high numbers (Spitzer et al. 2021). Therefore, controlling the deer population might be an important element in trying to influence moose browsing behaviour. However, current moose management in large parts of its range does not consider that there is a resource overlap between increase sympatric deer and changing moose foraging preferences, (Spitzer et al. 2021).

Den Herder (et al. 2009) argue that at low densities, the effect of moose on pioneer trees may be smaller than that of other herbivores or the fire–management regime, thus further research may be needed to conclude if controlling moose population alone will significantly affect regeneration in pine plantations.

Olsson (2006) argues that to deal with significant moose damage in pine stands, it is required that decision makers have knowledge of the spatial distribution of the damage and minimising damage to butt logs should be targeted.

Management of competing tree species and subsequent thinning is also an important consideration if regeneration of pine is preferred and the targeted crop tree for production forestry is Scots pine. Most stands surveyed were dominated by birch regeneration or retained birch. Birch competes with pine and thus requires pre-commercial thinning to prioritise Scots pine, especially as birch is less preferred as a source of fodder for browsing species (Bergström & Hjeljord 1987 and Härkönen et al., 1998). Starting with a high stem density of Scots pine may be a preferred option to reduce the proportion of pine browsed in addition to providing more management options when determining thinning and PCT decisions (Olsson 2008).

The use of retention trees and prescribed burning has been promoted in recent years (Djupström and Weslien 2019, Gustafsson et al 2020, Valkonen et al. 2002) as appropriate management alternatives to promote biodiversity and enhance regeneration of deciduous trees (where this is relevant to forest objectives) and reduce damage from moose and other herbivores (Den Herder et al. 2009).

However, some research suggests that retention trees could substantially reduce wood production (Djupström and Weslien 2019, Elfving and Jakobsson 2006), findings that would prove unpopular with forest owners, even if other benefits are highlighted. More research is needed in this topic.

SEPA (2021) claim that to determine appropriate management goals, it is essential to create a positive dialogue between those who live in affected areas, authorities and other relevant stakeholders, a view also supported by forest owner representatives (Södra 2021b).

Suggested methods to combat increased browsing pressure includes fencing, the use of chemical repellents, and the utilisation of aluminium tags attached to the top of the seedling to physically block the moose from browsing (Saursaunet et al. 2018).

Providing alternative forage resources for ungulates has also been suggested e.g., fodder fields (Månsson 2015), alongside leaving residues (including treetops) post thinning and clear-cutting, (Edenius et al. 2013, Heikkila and Harkonen 2000, Saursaunet et al. 2018).

To maintain Scots pine plantations and reduce browsing

Much research and debate has been carried out to identify management methods to increase total timber production whilst minimising browsing damage.

However, Angelstam et al 2000 suggest three key practical methods that can be employed:

1) reduce moose densities through hunting
2) to increase the amount of available fodder e.g., additional feeding – alongside changes in forestry management choices
3) or alternatively to reduce the availability of food for browsers in combination with physical protection for trees e.g., fencing.

The correct option will be an individual choice based on site conditions, local moose population density, desired outcomes and critically – economic factors.

5. Conclusion

The null hypothesis that there is no difference in damage proportion in stands with a high density of Scots pine saplings compared to stands with low density was accepted (Section 3.1.1.).

Results from the fieldwork (Sections 3.1 and 4.2) indicated that the average damage level of Scots pine across all 22 stands was 25% and that Scots pine faces strong competition from regenerating Norway spruce, birch and other tree species. Scenario analyses employed to determine the future dominant tree in stands revealed that targeted thinning may be necessary of competing trees to ensure Scots pine plantations are realised in the future, and that damage levels of more than 20% or 50% could strongly influence which tree species becomes dominant in future stands.

Results from the forest owner questionnaire (Sections 3.2 and 4.3) indicated that forest owners' management decisions are affected by browsing damage to Scots pine and that additional guidance from forest owner associations and financial support from relevant authorities to implement additional browsing deterrents is welcomed.

6. Limitations

The first limitation acknowledged in this study is the lack of experience of the author and surveyor in assessing pine trees damaged by browsing. Although the principle and signs are simple to identify, this was the author's first experience of carrying out this task. Moreover, I assessed accumulative damage rather than distinguishing between recent and old browsing damage, as is used in the annual surveys carried out with ÄBIN. By only assessing damage one year out of many, we probably miss more damage than we detect. Earlier damage can already be masked by further growth or by seedlings be so severely damaged that they die. Future damage will also most likely appear since we are still only halfway to a stand height where damage is less prone to occur.

A second limitation is acknowledged with regards to the forest owner questionnaire. An additional question which would have made the questionnaire more comprehensive would have been to ask the forest owners what proportion of pine (%) they originally aimed for. Furthermore, when contacting the owners, it would have been easier for both parties had the author detailed exactly which stand and location surveys were carried out, as many owners owned multiple stands and thus had different aims and management methods for different stands.

A further improvement that could be made in relation to the questionnaire is with Question 3 – which asks, 'How does browsing damage affect your management of the forest stand?' Two possible answers were 'Significantly' and 'A lot' but no distinguishment was provided to determine what was the difference between the two answers or indeed, define what 'Significantly' meant.

Other studies that address similar topics of hypothesis to this paper such as ÄBIN - survey at stand level and therefore acquire a greater range of data based on the number of stands surveyed compared to this research project. However, one positive about this research project is that stands were surveyed with many plots in each stand, meaning that more of the stand variation was surveyed.

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Appendix 1 – Summary of data from fieldwork

Stand ID	No. of sample plots	Mean Scots Pine density (stems ha-1)	Mean Norway Spruce density (stems ha-1)	Mean Birch density (stems ha-1)	Mean Other Tree Species density (stems ha-1)	Mean Stand Density (stems ha-1)	Mean Scots Pine damage (% of trees)	Mean Norway Spruce damage (% of trees)	Mean Scots Pine height (dm)	Mean Norway Spruce height (dm)	Mean Birch height (dm)	Mean Other Tree Species height (dm)
1	28	1300	1543	3443	29	1579	13	0	13	15	22	1
2	30	2227	1947	4293	0	2117	23	2	11	17	28	0
3	30	1827	773	5253	200	2013	8	5	6	8	15	3
4	28	1771	1457	1057	171	1114	6	0	10	16	15	3
5	27	2533	15	607	0	789	49	0	21	1	6	0
6	26	708	585	2600	231	1031	48	1	5	11	22	5
7	30	2147	240	1000	40	857	15	0	21	4	17	1
8	10	4080	400	1640	40	1540	30	0	20	10	13	1
9	27	919	1481	4815	0	1804	26	0	8	33	20	0
10	24	1267	633	3217	133	1313	19	3	8	12	22	1
11	27	1615	652	2207	919	1348	18	0	18	13	24	16
12	30	2467	120	1080	120	947	15	2	20	3	14	2
13	28	1043	800	5000	386	1807	22	2	3	8	18	6
14	30	1187	1733	6933	240	2523	20	0	7	9	17	3
15	56	864	464	4121	900	1588	22	0	16	10	18	9
16	15	160	0	53	240	113	0	0	3	0	3	5
17	28	1757	129	2600	86	1143	27	0	16	2	14	1
18	30	1787	813	2427	40	1267	37	0	7	5	10	1
19	30	1107	1253	1973	93	1107	45	0	6	10	10	1
20	13	1785	1354	2769	369	1569	45	1	10	6	18	6
21	31	813	284	1587	994	919	21	0	10	3	9	6
22	28	2186	1414	1943	14	1389	58	4	8	12	12	0

Appendix 2 – Forest owner questionnaire (Swedish / på Svenska)

1. Vad var ditt mål med beståndet när du föryngrade?

a) Maximera produktionsvärdet
b) Skapa en balans mellan produktionsvärdet och rekreationsvärden
c) Rekreationsvärden till exempel jakt, plocka bär/svamp
d) Övrig - beskriv

2. Till vem vänder du dig för vägledning för föryngring och framtida skötsel av beståndet?

a) Ägaren / dig själv
b) Skogliga rådgivare
c) Andra i min omgivning, tex grannar, vänner eller släkt
d) Annat – beskriv

3. Hur påverkar betesskador din skötsel av beståndet?

a) Betydligt
b) Mycket
c) Inte så mycket
d) Inte alls
e) Jag vete inte

4.Hur balansera ni produktionsmål mot miljömål?

a) 100% produktion
b) 75% produktion / 25% biologisk mångfald
c) 50% produktion / 50% biologisk mångfald
d) 25% produktion / 75% biologisk mångfald
e) 100% biologisk mångfald

5. Vilka av följande alternativ skulle du anse hjälpa dig att uppnå era ursprungliga mål för beståndet?

a) Mera jakt
b) Mera älg
c) Mera tallföryngringar i landskapet
d) Mera RASE arter i landskapet (Rönn, Asp, Sälg, Ek)
e) Riktade stöd för skydd mot bete, till exempel bidrag för stängsel
f) Mitt mål nås utan något av ovanstående alternativ