Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Skogsmästarskolan

Effects of active and passive conservation on forest structure and bird diversity in Färna Ecopark

Effekter av naturvård genom aktiv skötsel och av att lämna naturvårdsskog orörd på skogens struktur och fågelfaunans diversitet i Färna Ekopark

ARVID SANDSTRÖM

Examensarbete i skogshushållning, 15 hp
Serienamn: Examensarbete /SLU, Skogsmästarprogrammet 2021:01
SLU-Skogsmästarskolan
Box 43
739 21 SKINNSKATTEBERG

Tel: 0222-349 50

Effects of active and passive conservation on forest structure and bird diversity in Färna Ecopark

Effekter av naturvård genom aktiv skötsel och av att lämna naturvårdsskog orörd på skogens struktur och fågelfaunans diversitet i Färna Ekopark

Arvid Sandström

Handledare: Grzegorz Mikusiński, SLU Skogsmästarskolan

Examinator: Eric Sundstedt, SLU Skogsmästarskolan

Omfattning: 15 hp

Nivå och fördjupning: Självständigt arbete (examensarbete) med nivå och fördjupning G2E med möjlighet att erhålla kandidat- och yrkesexamen

Kurstitel: Kandidatarbete i Skogshushållning
Kursansvarig institution: Skogsmästarskolan
Kurskod: EX0938
Program/utbildning: Skogsmästarprogrammet

Utgivningsort: Skinnskatteberg
Utgivningsår: 2021

Omslagsbild: Bäck med bäverfördämning som rinner genom Färna Ekopark. Bilden tagen sommaren 2020 av Arvid Sandström på mark som ägs och sköts av Sveaskog.

Elektronisk publicering: https://stud.epsilon.slu.se

Serietitel: Examensarbete/SLU, Skogsmästarprogrammet
Delnummer i serien: 2021:01

Nyckelord: Biodiversity, deciduous forest, avifauna

SLU
Sveriges lantbruksuniversitet
Skogsvetenskapliga fakulteten
Skogsmästarskolan

Abstract

Voluntary set-asides are an important part of the conservation of forest species in Sweden. Set aside stands are either treated passively by leaving them untouched (in Swedish abbreviated as NO) or with active, often invasive maintenance (NS). Färna Ecopark is an area with 2 822 hectares productive forest, since 2005 dedicated to conservation of biodiversity and contain both NO and NS forest stands. The forest has a distinctly high proportion of deciduous trees for the region and most stands being subject to conservation are treated to maintain this distinction.

My study aims to examine what effect the two different modes of conservation treatment has had on forest structure and their local assemblage of forest birds. The forest structure in eleven NO stands and ten NS stands was measured and compared to each other as well as with ten coniferous production stands in the same area and of a similar age. Bird survey data from the same stands were also examined and compared.

I found that the NO stands were more structurally diverse, had a greater proportion of deciduous trees and had local bird assemblages richer in species when compared to the production stands. I could also demonstrate a correlation between forest structural diversity and bird species richness across all treatment groups. The studied NS stands showed great variation between stands in several aspects of forest structure and bird assemblage composition. There were also more bird species observed exclusively in the NS stands compared to the other treatment groups. Likely, this variation is a result of the greater variation in the form of treatment that different NS stands have received. It also made the NS stands hard to study as a group and no statistically significant differences were found between them when compared to the other groups of stands in the study. Therefore, I have concluded that to make inferences concerning the effects of active conservation maintenance, a greater sample of stands is required, and they should be subdivided by the way stands have been maintained.

Keywords: Biodiversity, deciduous forest, avifauna.

Sammanfattning

Frivilliga avsättningar är en viktig del av naturvården i den svenska skogen. Avsättningarna kan antingen tillhöra målklass NO (naturvård orörd) eller NS (naturvård skötsel). Färna Ekopark är ett område i Västmanland på 2822 ha produktiv skogsmark varav större delen avsattes 2005, både som NO och NS områden. Skogen i Färna har en högre andel lövträd än vad som är typiskt för området och en stor del av skötseln är avsedd att bevara och utveckla det särdraget.

Syftet med den här studien är att undersöka vilken effekt som indelningen i målklasserna har haft på skogsbestånden och på de fåglar som lever i dem. Skogsstrukturen i elva NO bestånd och tio NS bestånd har inventerats och jämförts med varandra och med skogsbestånden i tio produktionsbestånd från samma område och av liknande beståndsålder. Fågelinventeringsdata från samma bestånd har också undersökts och jämförts mellan beståndsgrupperna.

Det framgick att NO bestånden hade större diversitet i sin skogsstruktur, hade en större andel lövträd och innehöll fler fågelarter jämfört med produktionsbestånden. Det gick även att påvisa ett positivt samband mellan diversitet i skogsstruktur och lokal artrikedom av fåglar. NS bestånden som ingick i studien uppvisade stor variation sinsemellan både i termer av skogens och fågelfaunans sammansättning. Denna variation är sannolikt ett resultat av att skötseln av de enskilda NS bestånden varierat mycket. Det gör också NS bestånden svåra att studera som grupp och inga statistiskt signifikanta skillnader mellan dem och de andra beståndsgrupperna kunde finnas i denna studie. NS bestånden innehöll dock ett större antal olika fågelarter än de andra beståndsgrupperna. Slutsatsen av detta är: för att studera effekten av naturvårdsskötsel så behöver en större grupp NS bestånd undersökas och bestånden bör delas upp efter vilken typ av skötsel som utförts i dem.

Nyckelord: Biodiversitet, lövskog, naturvårdsskötsel.

Foreword

Many thanks to Dariusz Graszka Petrykowski who collected the bird data. I would also like to thank all the people who have worked on Färna Ecopark. It is truly a beautiful forest. Finally, I thank Grzegorz Mikusiński for giving me the opportunity to work on this exciting project and for all his help and guidance.

Contents

Introduction

Voluntary set asides by forest owners in Sweden constitute an important complement to formally protected forests in preserving structures important for biodiversity and amount to roughly the same area (Simonsson, Östlund & Gustavsson 2016). Both organisations of forest certification that operate in Sweden (FSC and PEFC) require certified forest owners to make voluntary set asides (FSC 2020; PEFC 2017). They also require a forest management plan that classifies forest stands by management goal. Forest stands that are set aside for conservation fall into classes NS (where local conditions or conservation goals warrant active maintenance of the stand) and NO (conservation stands that are left untouched). In result, most forest areas set aside by forest owners for conservation of biodiversity are "labelled" as belonging to one of two distinct modes of treatment: active (NS) or passive (NO). It is important to predict how these two ways of treating conservation stands affect the structure of the forest and biodiversity.

Färna Ecopark is a partially set aside forest in central Sweden and is owned by state forest company Sveaskog. It was dedicated to conservation of biodiversity in 2005. As in other ecoparks, more than half of the productive forest area is managed for conservation of biodiversity, with stands classified both as NO and NS. There are also stands managed with a production goal. However, these are managed with stricter environmental considerations than regular production stands outside of ecoparks (Sveaskog 2005). An important conservation goal in Färna Ecopark is to increase the amount of deciduous forest habitats. For this reason, treatments in the NS stands are mainly directed at selectively thinning out spruce to enhance development and recruitment of deciduous trees. Controlled burning is also applied in some stands as well as filling in ditches to restore wet areas (Sveaskog 2005). Some deciduous stands or mixed stands rich in deciduous trees have also been assigned to the NO treatment in the ecopark; in places where local conditions make this beneficial to conservation goals.

In this study, the effects of the two modes of conservation treatment were first assessed by measuring and comparing the forest structure in NS and NO stands fifteen years after the ecopark has been established. Coniferous stands managed for production of woody biomass in the same ecopark were also examined as a reference, (this group includes stands from both the PG and PF class where production is the goal). The examined stands were all older than 60 years. Second, bird survey data from the same stands was examined and compared between the different stand groups to gauge the effects of treatments on local biodiversity. Deciduous trees are rare in Swedish production forests (Mikusiński & Angelstam 1999; Mikusiński, Angelstam & Sporrong 2003) and several species of birds are dependent on them (Jansson & Andrén 2003). Bird species and populations may also respond positively to increases in variables of forest naturalness, such as the amount of dead wood and layer stratification (Ram et al. 2017). A combination of forest structure and bird data should therefore be a useful tool to assess the level of success in the specific goal of Färna Ecopark to increase and enhance deciduous habitats, and a more general goal to increase the naturalness in Swedish forests. The purpose of my study is to:

1. Assess the differences in forest structure and bird assemblage composition between the three groups of stands i.e., NO, NS and stands with a production goal (PG and PF).
2. Provide implications for conservation planning based on testing of three predictions concerning the links between forest treatment, structure, and bird assemblage composition.

Predictions

In studies from North America, forests with tree fall gaps in the canopy showed an increase in bird species adapted to forage in the tree foliage (Blake & Hoppes 1986; Martin & Karr 1986). However, a study of tree-fall gaps in Finnish boreal forest by Forsman et al. (2013) failed to reproduce these results. Too see if the gaps created by treatments in the NS stands have had a positive effect for arboreal foraging bird species, I tested the following prediction:

(i) the active maintenance of the NS stands has led to a more open forest structure providing more habitat for arboreal foraging bird species when compared to the untouched NO stands.

One of the main conservation goals of the Färna Ecopark is enhancing biodiversity linked to deciduous trees. I will therefore assess what to what extent conservation stands serve this purpose by testing the second prediction:

(ii) NS stands, as well as deciduous-oriented NO stands, will contain more bird species specialised in a deciduous forest habitat, and fewer species specialised to a coniferous forest habitat, than the production stands.

Finally, disregarding the management goals (i.e. NO, NS, PF) I looked at the extent to which habitat structural diversity can be associated with species richness for forest birds. In relation to that, I predicted the following:

(iii) forest stands with a greater structural diversity provide habitat for bird assemblages richer in species.

Methods

Study area

Färna Ecopark is a forest landscape 4 004 hectares in size, 2 822 hectares of which are productive forest land producing at least 1 cubic metre of wood per hectare per year. It is located in south-central Sweden in the province of Västmanland. The forest was largely set aside from regular commercial production in 2005 and 60.8 percent of the productive forest land is being managed solely for conservation purposes (Sveaskog 2005), 23.5 percent belongs to the forestry goal class NO and 37.3 percent to NS. Not all forest stands in the NO or NS class were of high conservation value in 2005; forest stands in both classes are also treated to restore such values.

The forest consists mainly of Scots pine *(Pinus sylvestris),* Norway spruce *(Picea abies)*, downy and silver birch *(Betula pendula* and *B. pubescens).* The proportion of deciduous trees in Färna was already noticeably high in 2005 in a region with general deciduous forest scarcity. Because of this, an important conservation aim is to further increase the amount of deciduous and mixed forest habitats to create a deciduous-rich forest landscape (Sveaskog 2005).

Management goal classes

Common classification used in Swedish forestry management planning are PG, PF, NO and NS. In class PG, forests are managed with the goal of producing woody biomass where general environmental considerations are taken in operations. These include leaving buffer zones towards lakes and wetlands, exempting bogs from forestry, and leaving individual trees of high conservation value and artificially created high stumps in final felling. PF (production with strengthened considerations) are production forests where environmental consideration is required on a greater proportion of the forest stand than is typical for PG. In Färna Ecopark, the division line between PG and PF is drawn when considerations amount to at least 15 percent green tree retention in final felling (Sveaskog 2005). NO (conservation forests left untouched) and NS (actively maintained conservation forests) are set aside from commercial production. NS forests maintained in operations, often (but not always) using the same tools and machines as commercial forestry operations. However, the goal of the operations are not production of woody biomass but to benefit local conservation values, either by removing elements that threaten the conservation values of that forest, such as encroaching spruce in a deciduous stand, or by mimicking natural disturbance regimes by e.g. prescribed burning.

Forest stands

In total, 31 forest stands in Färna Ecopark were examined in this study. These were divided into three treatment groups corresponding with their management goal class; eleven stands representing NO, ten stands representing NS, and ten representing production goal stands. The third group consisted of 8 PF and 2 PG stands combined (hereafter called P). All stands are at least 60 years old. The production stands are managed through even-aged forestry of spruce, pine or a mix thereof. Windfall trees, which are usually harvested in PG and PF stands, are left in the forest in Färna Ecopark except for when massive amounts are created by storms (Sveaskog 2005). These stands should therefore on average contain more dead wood than other production stands in the region.

The treatment of the NO and NS stands in the study aims at restoring or preserving either a deciduous forest type (four of the NO and five of the NS stands), or mixed forest type (seven of the NO and five of the NS stands). Eight of the NO and five of the NS forest stands were initially judged as having high conservation values already in 2005, other NO and NS stands are treated with the goal to restore high conservation values either passively (NO) or actively (NS).

Study plots and sample areas

To compare the forest stands with each other, the forest structure were studied on circular plots of equal size and shape, and entirely situated within the stand's boundaries. The study plots were created by taking the fixed center point from the bird surveys in each stand for and drawing a 50-meter radius around it. This resulted in circle of 0.785 hectares (one stand was eliminated from the study because this radius reached outside of the stands boundaries). The bird data used in the study included only observations from within this radius.

The forest structure in each study plot was sampled by taking measurements on living and dead trees on six smaller areas, these were circular and 100 square meters in size, making a total of 7.6 percent of the study plot. The sample areas were laid out using the center and the compass as references. One sample area was placed in the center of the plot and the other five along lines going from the center to the edge at 72 degrees from each other. Two of the sample areas were placed half-way between the center and the edge and the remaining three were placed touching the edge. The two areas to be placed half-way were randomized and the same pattern used in all study plots. The resulting placement can be seen in figure 1.

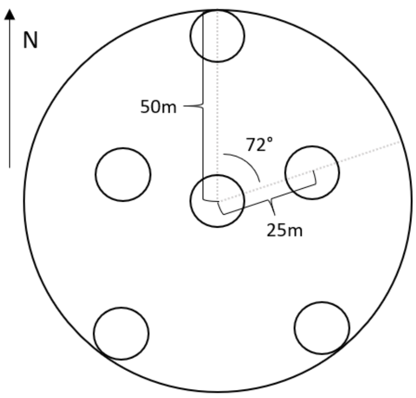

Figure 1. The placement of the sample plots, not to scale.

Data collection and processing

In each sample area, the tree species, diameter at breast height (DBH, measured at 1.3 meters from the ground) and tree height were recorded for living trees (with a DBH over 1 cm and height over two meters) and dead trees, or parts of dead trees (DBH over ten centimeters). DBH was measured to the nearest centimeter and height to the nearest meter, this means that the smallest trees possible to record had a DBH of 0.5 cm and a height of 1.5 meters. Silver birch and downy birch were collectively recorded as a birch. From this data, the basal area (m^2/ha, total and for each tree species) was estimated for each study plot. Forest stand diversity was estimated from the same data (for details see below).

To get a list of all tree species present on each study plot, species that were spotted during data collecting anywhere on the study plot were recorded (but not measured). The presence of shrub species was recorded in the same way. No extra time was allocated for this visual inventory.

The structure of the under- and midstory was examined by dividing the measured trees into three height-classes (≥2 and ≤ 6 meters, ≥7 and ≤10 meters, ≥11 and ≤14 meters) and calculating the basal area for each height class. The number of deciduous trees in the understory was found to be low on most plots, and differences in deciduous basal area in the understory were dependent on only a few trees. Therefore, the recruitment of deciduous trees on the study plots were examined by looking at the total number of deciduous trees below 14 meters in height.

Volume of dead wood

The volume of coarse dead wood (DBH ≥ 10 cm) was calculated (in m^3/ha) for each study plot by measuring DBH and height (or length) for all standing and downed dead trees, found on the six sample plots. Volume functions for that tree species were then used to calculate the volumes (appendix 1). One dead great sallow *(Salix caprea)* was found and its volume was calculated using the function for aspen. DBH and length of downed dead trees have been measured if their stump was found on the sample plots and their volumes calculated using the same formulas.

Trees that have broken off somewhere in the middle have been measured in both ends whenever possible, and their volume calculated as a truncated cone. If it was not possible to measure both ends, the volume of the tree was calculated using DBH and the height to where it has been broken off using the same functions as the whole trees. Their volumes were therefore slightly underestimated. The volumes of broken off treetops were also calculated using formulas for whole trees, with the diameter 1.3 meters from the base as DBH and the length of the treetop as its height. It is assumed that this will be more accurate than calculating the volume of the treetops as cones.

Leaf area index

The leaf area index (LAI) is a measurement of foliage density defined as area of foliage divided by area of ground. It was measured using a LI-COR LAI-2200 plant canopy analyzer. This instrument estimates leaf area index by comparing data from wide angle optical sensors under clear sky and under the canopy. It calculates the density of the canopy from the amount of light it lets through (LI-COR, Inc. 2012). The instrument does not distinguish between foliage and other obstacles blocking the sky. Because of this it is not the true foliage area being measured, but the area of all the canopy, including tree trunks and limbs from living and dead trees alike. The LAI was calculated from eight readings below the canopy per study plot. Because of the wide angle of the optical sensors, it is likely that some of the readings “spilled out” of the 50-meter radius. The LAI value for each study plot is therefore the average LAI for an area slightly larger than the plot itself.

Stand diversity

In order to compare the diversity of the forest stands it needed to be quantified. Bacaro et al. (2014) propose that this can be done by calculating an index they call Shannon´s recursivity derived from the distribution of tree species and tree diameter. Shannon’s recursivity is based the function of Shannon-index (or Shannon-entropy), which is used as an expression of diversity. Shannon index H in a dataset of S components, is calculated from the proportion p of each component as:

$$H = -\sum_{i=1}^{S} p_i \times \ln(p_i)$$

Shannon´s recursivity is the sum of the Shannon-index of tree species and diameter distribution. To calculate this, DBH was divided into 10-cm classes, and the percentage of basal area was used as proportion p.

Statistics

Differences in variables of forest structure and bird assemblage composition between groups of study plots have been tested for, (by testing the null hypothesis that the distribution for that variable is the same across all treatment groups), using the Kruskal-Wallis H test in the IBM SPSS statistics program. Where the null hypothesis was rejected, pairwise post hoc-tests with Bonferroni correction were used to determine which of the groups were significantly different from each other. A correlation between forest stand diversity (quantified as above) and bird species richness across all study plots was tested for by calculating the Spearman rank correlation coefficient across all study plots. Both methods are non-parametric and do not require the variables tested to be normally distributed.

Data have been plotted using Microsoft Excel. When making boxplots in that program it calculates and excludes outliers automatically. Excel defines an outlier as lower than the 1st quartile value or higher than the 3rd quartile value by more than 1.5 times the difference between those quartile values.

Bird data

The bird data examined was collected by Dariusz Graszka Petrykowski during the spring of 2020. Petrykowski made in total three surveys in each stand during the periods: 1st to 10th April; 2nd to 12th May and 28th May to 13th June. This allowed for encapsulating resident birds and migrants being active vocally at different parts of spring. Each survey lasted 25 minutes, divided into five-minute blocks, during which all birds seen or heard was recorded along with distance and direction from the inventory centre. The surveys were performed in the morning hours i.e. from about 30 minutes after the sunrise until 10:00 a.m. All observations of birds judged to be farther away than 50 meters from the center point were removed. One observation of a common gull *(Larus canus)* was also removed since it is a non-forest species, as well as one observation of ten whooper swans *(Cygnus cygnus)* flying by.

Richness, abundance and functional groups

To examine the composition of the bird assemblages in different treatment groups the richness, meaning the number of different bird species, and abundance, meaning the number of individual birds, was gathered from the bird data. The species richness on each study plot was assessed by counting all the different species observed in that plot in any of the three inventories. The abundance of each species was estimated by using the highest number of observed individuals of that species in a single 5-minute interval. Because of the small area examined (50-meters radius), only one individual of most bird species was observed at a time. Species richness was therefore used as the variable for describing bird assemblages.

The bird species observed were divided into functional groups using appendix 5.1 in Mikusiński et. al. (2018). The functional groups describe the bird's behaviors and traits in diet, nest types, mode of foraging, and migratory pattern. One bird species can be represented in several functional groups in the same category if for example it has more than one way of foraging for food. To compare the availability of habitat structures in the different forest treatment groups, the richness of bird species in various functional groups was analyzed in two ways. First by comparing the richness of bird species by mode of foraging (aerial, arboreal, understory and ground), as this makes for a cross-section of the local habitat. Secondly, by comparing the richness of resident birds and cavity nesters, as those functional groups are known to be disadvantaged by modern forestry practices (Helle & Järvinen 1986)(Eggers & Low 2014). One bird species might also be represented in more than one group of migratory patterns if they behave differently in different parts of their geographic range. In those cases, Staav & Fransson's compendium of Nordic birds (2007) was used to determine if that bird species bird species is resident in Västmanland.

Even if majority of bird species can utilize different types of forest, some of them have clear affinities to either deciduous or coniferous trees. Here, a number of species specialized on these two main types of trees were selected based on the information in Ottosson et al. (2012). The richness of deciduous and coniferous forest specialist birds could then be compared between the treatment groups. The deciduous specialist species were: long-tailed tit (*Aegithalos caudatus),* marsh tit *(Poecile palustris),* lesser spotted woodpecker *(Dendrocopos minor),* European green woodpecker *(Picus viridis),* stock dove *(Columba oenas)* and Eurasian blue tit *(Cyanistes caeruleus).* The coniferous specialist species were: goldcrest *(Regulus regulus),* European crested tit *(Lophophanes cristatus)* and coal tit *(Periparus ater).*

Results

Forest structure and bird species richness

The forest on the study plots were comprised of Scots pine, Norway spruce, birches, aspen and black alder (*Alnus glutinosa*). Two NS plots also had large sallow trees, but only one dead tree was encountered in a plot and measured. Several plots in all treatment groups had heavily browsed rowan saplings *(Sorbus aucuparia)*. The shrub species encountered on the plots were juniper *(Juniperus communis),* willow *(Salix spp.)* and alder buckthorn *(Frangula alnus).*

There were no statistically significant differences in the forest density between treatment groups either in terms of basal area or LAI. But, as can be seen in figure 2a and 2b, there were a noteworthy tendency for NS plots to be less dense than the other groups, especially when compared to the NO plots. The median basal area and LAI on the NS plots (22.3 m^2/ha and LAI 2.5) were only about 70 % that of the median on the NO plots (31.7 m^2/ha and LAI 3.4).

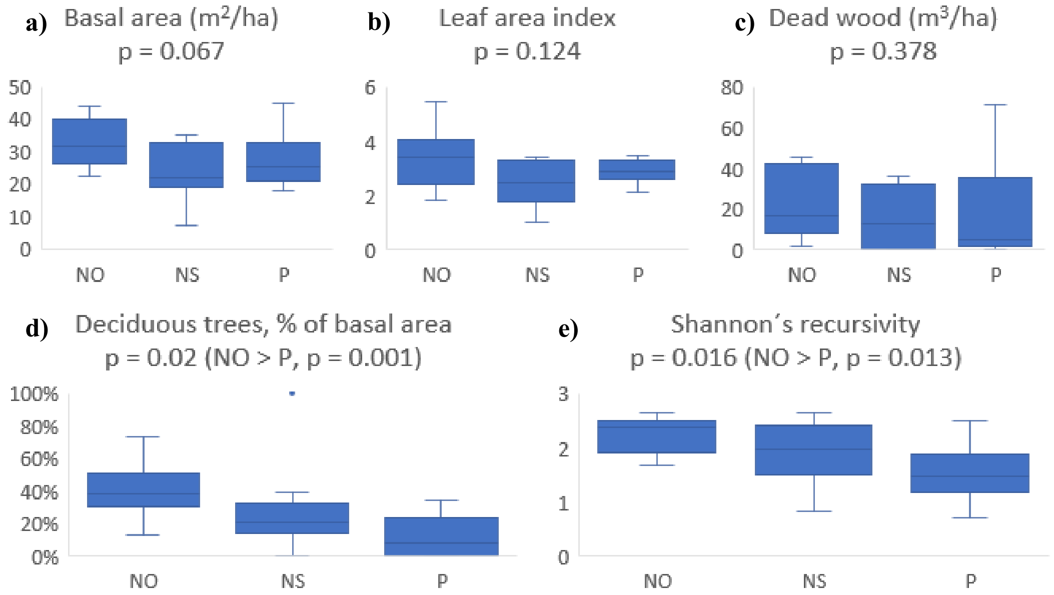

Figure 2. Forest structure variables by treatment group. The box extremities indicate the 1st and 3rd quartiles, the line inside the box indicates the median and the whisker-bars indicate minimum and maximum values. Outliers are shown as dots. One outlier from the NS group in the dead wood per hectare diagram (of 160 m^3/ha) is not visible. Below the title is the probability value for the null hypothesis that the distribution is the same across all treatment groups. Where $p < 0.05$, post-hoc test results are shown in parentheses.

Statistically significant differences were found in the proportion of deciduous trees and the Shannon´s recursivity index of forest stand diversity ($p < 0.05$). Post-hoc tests showed that these values were significantly higher in the NO plots than the P plots ($p < 0,05$), with the median being 38 % deciduous trees and an index value of 2.4 on the NO plots compared with 8.2 % and 1.5 on the P plots.

Corresponding values for the NS plots fall in between, 21 % deciduous trees and index value 2.0, and they were not significantly lower or higher than in other groups. There were no significant differences in the amount of dead wood. Much of the dead wood in NS and P was however concentrated in a few stands, which is visible by the lower median values (figure 2c).

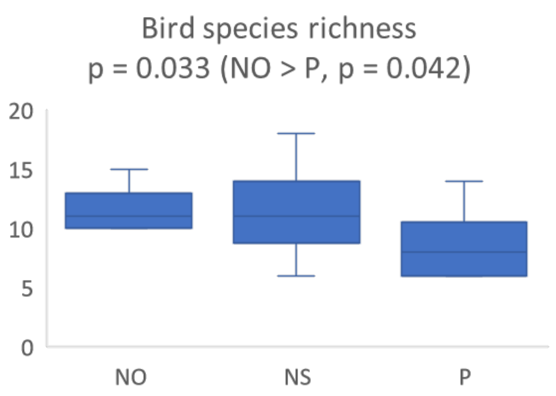

Figure 3. Bird species richness by treatment group. The box extremities indicate the 1st and 3rd quartiles, the line inside the box indicates the median and the whisker-bars indicate minimum and maximum values. Below the title is the probability value for the null hypothesis that the distribution is the same across all treatment groups, post-hoc test results are shown in parentheses.

Bird species richness in the different treatment groups are shown in figure 3. This variable was significantly different across the treatment groups ($p < 0.05$) and post hoc testing showed that NO (median 11 species per plot) had more species per plot than P (median 8 species per plot, $p < 0.05$). The post-hoc tests revealed no significant differences between NS and any other group.

Although no statistically significant differences were found between the NS plots and any of the other treatment groups, the range between minimum and maximum values were largest among the NS plots for all variables of forest structure accept leaf area index (figure 2). The same is true for bird species richness (figure 3). The median number of species is 11 on both the NO and the NS plots, but the NO plots vary between 15 species and 10 while the NS plots vary between 18 species and 6. This indicates that NS plots displays the level of variation that is larger than in other groups.

Structure of the under- and mid-stories.

There were differences in the densities of the under- and mid-story trees across the treatment groups. The NO plots had a significantly higher basal area in the middle height category compared to the P plots ($p < 0.05$). The p-value is close to the 0.05 threshold in the top height category, and as can be seen in figure 4 there is a distinct tendency for higher basal areas in that category in the NO treatment group. Regarding the lowest height category, there are no significant differences. The NS treatment group contain a few plots with relatively high basal areas in this category.

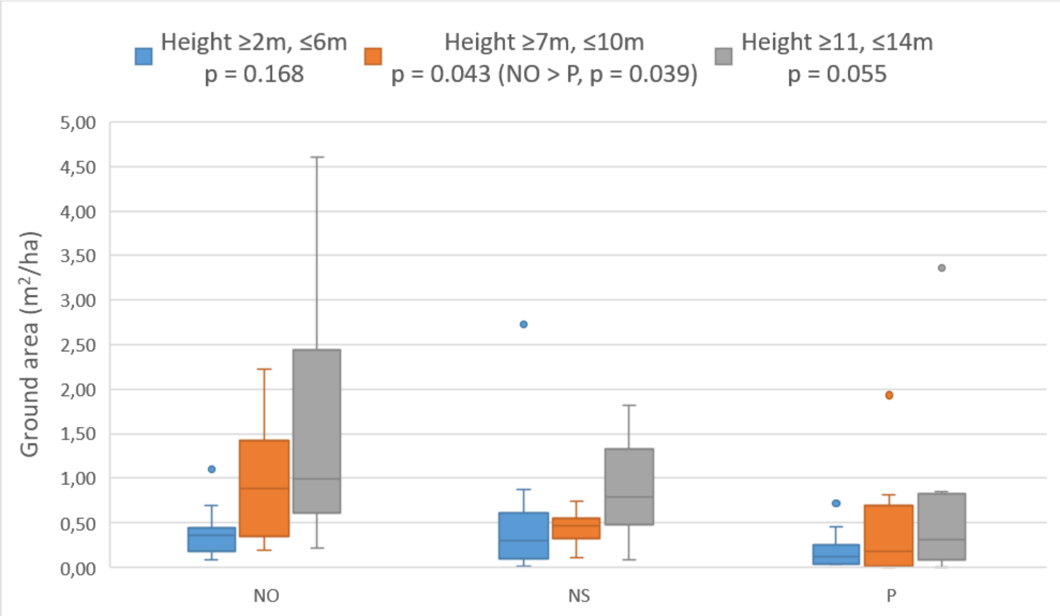

Figure 4. The basal areas of under- and mid-story trees divided into height across the different treatment groups. The box extremities indicate the 1st and 3rd quartiles, the line inside the box indicates the median and the whisker-bars indicate minimum and maximum values. Outliers are shown as dots. Below the title is the probability value for the null hypothesis that the distribution is the same across all treatment groups. Where $p < 0.05$, post-hoc test results are shown in parentheses.

Regarding recruitment of deciduous trees, there were no statistically significant results. Most plots across all treatment groups had an estimate of between 0 and 150 deciduous under- and mid-story trees per hectare. However, there were two noteworthy outliers in the NS treatment group. These plots had 1067 and 8800 deciduous trees between 2 and 14 meters per hectare. They were also among the more open of the NS plots, both having LAI well below the median (1.96 and 1.27 respectively). It is also noteworthy that ten of eleven NO plots had no deciduous trees in the lowest height category on any of their sample areas.

Bird assemblages

Although the number of different species observed per plot do not vary between NO and NS (see figure 3), NS contained more species found in just to one treatment group; 7 out of 32 species in total (Table 1). Moreover, these species were occurring on seven out of ten NS plots. The NO treatment group had 26 bird species of which two were unique to that group, the P group had 27 species of which three were unique. These treatment group unique species (table 1) were uncommon in the survey, most of them appeared on only one plot and a few species appeared on two plots.

Table 1. Bird species observed in only one of the treatment groups.

NO	NS	P
Corvus cornix	Alauda arvensis	Columba oenas
Garrulus glandarius	Bombycilla garrulus	Corvus corax
	Picus viridis	Corvus monedula
	Poecile palustris	
	Sylvia borin	
	Tetrao urogallus	
	Tringa ochropus	

Functional groups

When comparing the bird assemblages in forest being subject to different treatments in terms of functional groups, a few interesting observations could be made. In figure 4a, assemblages are compared by foraging mode. Significant differences in distribution were found in aerial foragers and ground foragers. For the aerial foragers, there were however no significant results in the post-hoc testing after Bonferroni corrections, it is only possible to say that the number of species was different across all the treatment groups ($p < 0.05$). Aerial foragers were overall very few on the plots, with the median NO and NS plot having 1 species and 0 on the median P plot. The NO plots had more ground foragers (median 9 species per plot) than the P plots (median 6 species per plot, $p < 0.05$), the median NS plot had 8 species per plot, but number of species was not significantly lower or higher than the other treatment groups. There were no significant differences in the number of arboreal foragers per plot which means that there is no support for prediction (i) in the results.

In figure 4b, bird assemblages are instead compared by the richness of deciduous and coniferous specialist species as well as cavity nesters and resident species. Deciduous and coniferous specialists showed no significant difference in distribution across the treatment groups, meaning that prediction (ii) is not supported by the results. It can however not be ruled out that deciduous specialists favor the NO and NS forests since seven out of eleven NO plots and six out of ten NS plots had at least one deciduous specialist, compared to two out of ten P plots. There was a difference in the distribution of cavity nesters ($p < 0.05$) and post hoc testing showed that NO had more cavity nesting species per plot than P (medians 3 and 1.5 species per plot). Again, NS fell in between, the median plot having 2 species, with no significant differences with any of the other plot groups. The richness of resident birds were not different across the treatment groups and the median number of species per plot were similar (six species per plot in NO and NS, five in P). But as can be read from figure 4b, there was a tendency for increased richness in the NO group compared to the others. This tendency was most visible in the 3rd quartile value, which for NO was eight species per plot compared to six in NS and P. The p value was 0.079, close to the 0.05 threshold value for statistical significance.

The comparison of bird species by foraging mode followed a similar pattern as the comparison of forest structure and bird species richness in that the values for the NS plots generally had wider ranges than the other two treatment groups. This pattern did not appear, however, again when comparing the functional groups in figure 4b.

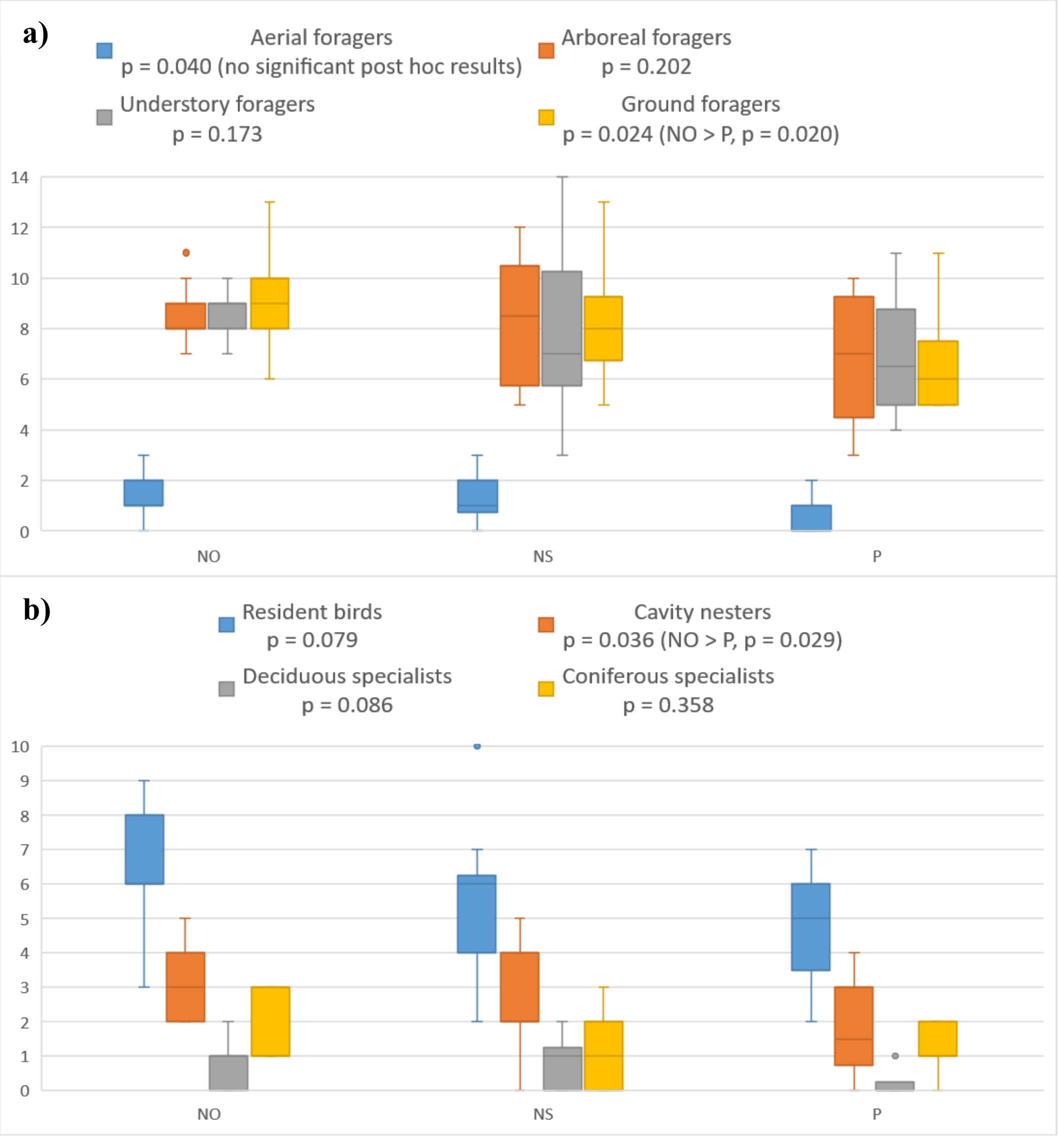

Figure 5. The number of species per plot of different functional groups divided by treatment group. The box extremities indicate the 1st and 3rd quartiles, the line inside the box indicates the median and the whisker-bars indicate minimum and maximum values. Outliers are shown as dots. Below the title of the functional group is the probability value for the null hypothesis that the distribution is the same across all plot groups. Where $p < 0.05$, post-hoc test results are shown in parentheses.

Forest diversity and bird assemblages

To test for a correlation between forest structural diversity across all treatments and bird species richness, the species richness in each stand was plotted against the index value for Shannon´s recursivity (figure 6). This plot showed a positive trend and the Spearman rank correlation coefficient for that trend was 0.33. The coefficient was significantly positive ($p < 0.05$), meaning that the results support prediction (iii).

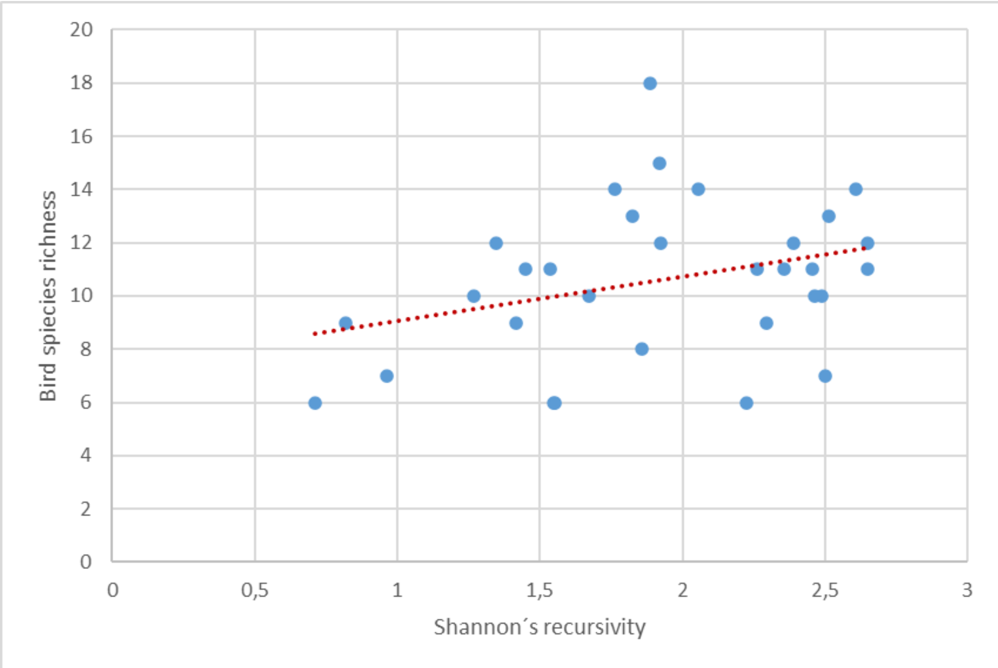

Figure 6. Plotting species richness of all stands against the index Shannon´s recursivity. Trendline is shown in red.

Discussion

The main result of my study is that goal class NO i.e. stands left untouched for conservation purposes, were in most cases statistically different from production goal classes PF and PG (here collectively P) in several structural dimensions and also, the richness and composition of breeding bird assemblages. In particular, the NO class forests studied had a significantly higher structural diversity of woody biomass. The examined variables for goal class NS were usually in between the other treatment groups and showed high variation. A correlation between forest structure diversity and bird species richness could also be demonstrated across all goal classes.

I also found a lot of variation between forest stands within the same goal class. This, as mentioned above, was especially visible in the group of stands in goal class NS. This variation, and the relatively small sample sizes apparently means that significant differences could not be demonstrated, even in instances where it appears that there should be.

The most interesting result concerning the NS treatment group is perhaps that, when compared to the other treatment groups, it shows much more variation in forest structure between stands. The reason for this is likely that the different NS stands, while receiving the same general treatment, have been subject to maintenance operations that differ greatly from stand to stand, from selective felling of a few encroaching spruce trees to nearly stand replacing cuttings. Moreover, these operations have all been applied within the last 15 years, so their effects were still clearly visible. In contrast, the NO stands were just selected based on their existing or potential conservation values in connection to deciduous trees, then left to develop freely, and the structure of P stands where the result of conventional silviculture practices.

As well as a larger variation in forest structure, the larger number of bird species that appeared on the NS plots could indicate a larger variation in available habitats in that treatment group. The habitats that those bird species depend on are dissimilar. For example, capercaillie (*Tetrao urogallus*) prefers sparse, older coniferous forest, garden warbler (*Sylvia borin)* favors dense deciduous understory, and the European green woodpecker (*Picus viridis*) are mostly found in anthropogenic landscapes containing both forest and open fields (Staav & Fransson 2007). This shows that the NS stands encompassed a lot of ecological niches used by birds with quite different requirements.

The apparent implications are that a variety in conservation maintenance operations leads to a variety of forest bird habitats, but further study is required to draw that conclusion. To efficiently study the effects of active conservation maintenance it is advisable to examine a larger sample of NS forest stands and to subdivide them by management operation, as well as scale and intensity of the operation. Initial conditions both linked to natural physiognomies, earlier silviculture measures and the stands past condition should also be discerned.

Deciduous trees

The conservation in Färna Ecopark focuses mainly on deciduous-rich stands. Therefore, I focused on deciduous-rich stands and compared them with older coniferous stands being subject to silviculture focused on production. The proportion of deciduous trees in the NO treatment group was significantly larger than in the P treatment group. This most likely is a result of stands with more deciduous trees being selected in that goal class to begin with. While the NS treatment group contained a few stands with a high proportion of deciduous trees, only half of the NS stands fulfill the Swedish forest agency's minimum requirement for deciduous-rich coniferous forest (> 20 percent of trees are deciduous)(Skogsstyrelsen 2020), compared to ten of eleven NO stands. The main reason may again be stand selection, the aim of the management of the NS stands in Färna Ecopark is directed toward increasing the deciduous component (Sveaskog 2005), therefore, it is more likely that stands with less deciduous trees to begin with would fall into that objective group. The NS group also contains more stands where the goal of the management is a deciduous dominated rather deciduous mixed forest (five deciduous and five mixed, compared to four and seven respectively in class NO). It is therefore possible that several of the NS stands have only received the first in a series of operations intended to change the dominating tree species over a long period of time.

Spruce removal by selective logging has some effect in combatting encroaching spruce but does not automatically equate to increased recruitment of deciduous trees (Hämäläinen et. al. 2020). Simply cutting away spruce has a positive effect on the regeneration of aspen, but not on birch, and the greatest positive effects for deciduous regeneration in a stand is the presence of mature trees of the same species. The largest quantities of deciduous saplings in this study were found in two NS stands. They both had mature trees of both birch and aspen growing in them and were also among the NS stands with the lowest leaf area indices, suggesting heavy management i.e. dramatic thinning of coniferous trees.

There is a common fear that protected forests in Sweden that are not exposed to a regular regime of disturbances will over time become dominated by the secondary and shade tolerant spruce. In a study by Hedwall and Mikusiński (2016) examining data gathered in protected forests from the national forest inventory (data collected from all of Sweden) largely debunks this fear, finding that tree species compositions have been relatively stable over time. However, the lack of disturbances may still pose a problem since dominance of a particular tree species are determined by site-conditions and initial tree species compositions. This does imply that when the goal is to change tree species composition, as is the case in Färna, then the undesired tree species will need to be intentionally removed. It would therefore be interesting to continue studying NS stands in Färna to see how they develop over time compared to the NO stands.

Bird assemblage composition

There was no significant difference in the number of arboreal foragers that were observed in the NS and the NO stands. This is in line with the findings of Forsman et al. (2013). The explanation they provide is that the studies that show a positive correlation between tree-fall gaps and arboreal foragers have been done in temperate forest, and most in North America. The cause for the different results in their study may be due to a difference in bird behaviour between temperate and boreal forest or between the continents. Either way, the same explanation is valid here.

The higher number of cavity nesters in the NO stands compared to P stands was an expected result. Andersson et. al. (2018) found that tree cavities were twice as common in untouched forest compared to managed forest. The more natural dynamics of untouched forest provide more stressed, dying or dead trees suitable for excavating by woodpeckers than in forests subject to manmade disturbances intended to promote growth of healthy trees. Woodpeckers also favor deciduous trees when excavating nesting cavities (Angelstam & Mikusiński 1994), which the NO stands were richer in. The NS treatment group also had stands rich in cavity nesting species. Among them also several stands with large diameter aspens that shows potential for woodpecker-rich forests. But as discussed above, the variability of the NS stands makes it hard to show any statistically significant results regarding them.

Coniferous specialists were distributed almost equally across all three treatment groups. This was not expected given the management goal to promote deciduous trees in the NO and NS treatment groups. But when looking at the results of the forest inventory, it is not surprising. Most NO and NS stands are still dominated by coniferous trees. In a review of bird indicator species that examined (among other species) two of the tree coniferous specialists, *Lophophanes cristatus* and *Periparus ater,* found that they were more common in forest stands > 50 percent coniferous trees (Lindbladh et al. 2020). Only four forest stands (one NS and three NO) in my study contain less than 50 percent conifers.

There are no clear results regarding the deciduous specialists and observations of them were relatively few. Among the species examined, only *Cyanistes caeruleus* are relatively numerous in Västmanland with an estimated 20 000 pairs (Ottosson et. al. 2012). The other deciduous specialists vary from 1 100 pairs (*Aegithalos caudatus*) to 150 pairs (*Dryobates minor*) in the region. Compared to the coniferous specialist´s estimated 9 000 pairs (*Lophophanes cristatus*), 17 000 pairs (*Periparus ater*) and 75 000 pairs (*Regulus regulus*), the deciduous specialist species are relatively rare. The inconclusive results could therefore be accounted to the small sample of forest stands in my study.

Conclusions

My study attempted to assess the effects of different modes of conservation treatments in Färna Ecopark using forest structure and breeding bird assemblages. The results show several significant differences between stands being subject to passive conservation (NO) in comparison timber production stands (PG & PF stands) that indicate the former having higher conservation values.

The stands treated with active conservation maintenance (NS) were highly variable in terms of structure and bird assemblages and the sample size proved to be insufficient for statistical analysis of that treatment group. There are however indications, mainly the higher total number of bird species, that the variability of the NS stands is linked to an increase in habitat variability. I conclude that to study the effects of active conservation maintenance it is necessary to look at NS stands not as one group (even where those stands are in the same geographical area and are being managed with similar conservation goals) but should be examined by what operations they have received.

References

Andersson, J., Domingo Gómez E., Michon,, S. & Roberge, J.-M. (2018) Tree cavity densities and characteristics in managed and unmanaged Swedish boreal forest. *Scandinavian Journal of Forest Research.* Vol. 33 pp. 233-244.

Angelstam, P. & Mikusiński, G. (1994). Woodpecker assemblages in natural and managed boreal and hemiboreal forest – a review. *Annales Zoologici Fennici.* Vol. 31 pp. 157-172.

Bacaro, G., Ricotta, C., Marignani, M., Torri, D. & Chiarucci A. (2014) Using Shannon's recursivity to summarize forest structural diversity. *Forests, Trees and Livelyhoods.* Vol. 23 pp. 211-216.

Blake, J. G. & Hoppes, W. G., (1986) Influence of resource abundance on use of tree-fall gaps by birds in an isolated woodlot. *The Auk.* Vol. 103 pp. 328-340.

Eggers, S. & Low, M. (2014) Differential demographic responses of sympatric Parids to vegetation management in boreal forest. *Forest Ecology and Management*. Vol. 319 pp. 169–175.

Forman J. T., Reunanen, P., Jokimäki, J., Mönkkönen, M., (2013) Effects of canopy gap disturbance on forest birds in boreal forests. *Annales Zoologici Fennici.* Vol. 50 pp. 316-326.

FSC (2020). *The FSC national forest stewardship standard of Sweden.* Bonn: FSC International Center.

Hämäläinen, K., Junninen, K., Halme, P. & Kouki, J. (2020) Managing conservation values of protected sites: How to maintain deciduous trees in white-backed woodpecker territories. *Forest ecology and management.* Vol. 461 art. no. 117946.

Hedwall, P.-O. & Mikusiński, G. (2016). Sprucification in protected forests: Myth or veracity? Clues from 60 yrs survey data. *Applied Vegetation Science.* Vol. 19 pp. 371-380.

Helle, P. & Järvinen, O. (1986) Population Trends of North Finnish Land Birds in Relation to Their Habitat Selection and Changes in Forest Structure. *Oikos.* Vol. 46 pp. 107–115.

Jansson G., Andren H. (2003) Habitat composition and bird diversity in managed boreal forests. *Scandinavian Journal of Forest Research.* Vol. 18 (3) pp. 225-236.

LI-COR, Inc. (2012). *LAI-2200 plant canopy analyzer – instruction manual.* Lincoln, Nebraska: LI-COR incorporated.

Lindbladh, M., Hedvall, P.-O., Holmström, E., Petersson, L. & Felton, A (2020) How generalist are these forest specialists? What Sweden´s avian indicators indicate. *Animal Conservation.* Vol. 23 pp. 762-773.

Martin, T. E. & Karr, J. R. (1986). Patch utilization by migrating birds: resource oriented? *Ornis Scandinavica.* Vol. 17 pp. 165-174.

Mikusiński, G. & Angelstam, P. (1999). Man and deciduous trees in boreal landscape. In: Kovar P. *Nature and Culture in Landscape Ecology. Experience for the 3rd Millenium*. Prague: The Karolinum Press, pp. 220-224.

Mikusiński, G., Angelstam, P. & Sporrong, U. (2003). Distribution of deciduous stands in villages located in coniferous forest landscapes in Sweden. *Ambio*. Vol. 32 pp. 520-526.

Mikusiński G., Villero, D., Herrando, S. & Brotons, L. (2018) Macroecological patterns in forest bird diversity in Europe. In: Mikusinski, G., Roberge J.-M. & Fuller, R. J. *Ecology and Conservation of Forest Birds.* Cambridge: Cambridge University Press, pp. 137-183.

Ottosson, U., Ottvall, R., Green, M., Gustafsson, R., Haas, F., Niklas, H., Lindström, Å., Nilsson, L., Mikael, S., Svensson, S. & Tjernberg, M. (2012) *Fåglarna i Sverige: antal och förekomst.* Halmstad: Swedish Ornithological Society.

PEFC (2017). *PEFC Sweden forest standard. (*PEFC SWE 002:4). Stockholm: Svenska PEFC ekonomisk förening.

Ram, D., Axelsson, A.-L., Green, M., Smith, H. G. & Lindström, Å., (2017). What drives current population trends in forest birds – forest quantity, quality or climate? A large scale analysis from northern Europe. *Forest Ecology and Management.* Vol. 385 pp. 177-188.

Rytter, R. (1998) *Löv och lövblandbestånd – ekologi och skötsel.* Oskarshamn: Skogforsk. (Skogforsk redogörelse, 1998:8).

Simonsson, P., Östlund, L. & Gustafsson, L. (2016). Conservation values of certified-driven voluntary set-asides. *Forest Ecology and Management.* Vol. 375 pp. 249-258.

Skogsstyrelsen (2020). *Lövrik Barrnaturskog.* https://www.skogsstyrelsen.se/miljo-och-klimat/biologisk-mangfald/nyckelbiotoper/biotoptyper/lovrik-barrnaturskog/ [2021-04-21]

Staav, R. & Fransson, T. (2007) *Nordiska Fåglar.* 4. Edition. Stockholm: Prisma.

Sveaskog (2005). *Ekoparksplan Färna – maj 2005.* Stockholm: Sveaskog.

Appendix 1

Formulas for the volumes v (dm^3) of trees from DBH d (cm) and height h (m).
Formulas from:
Rytter, R. (1998) *Löv och lövblandbestånd – ekologi och skötsel.* Oskarshamn: Skogforsk. (Skogforsk redogörelse, 1998:8).

Pine

$$v = 10^{-1,38903} * d^{1,84493} * (d + 20)^{0,06563} * h^{2,02122} * (h - 1,3)^{-1,01095}$$

Spruce

$$v = 10^{-1,02039} * d^{2,00128} * (d + 20)^{-0,47473} * h^{2,87138} * (h - 1,3)^{-1,61803}$$

Birch

$$v = 10^{-0,84627} * d^{2,23818} * (d + 20)^{-1,06930} * h^{6,02015} * (h - 1,3)^{-4,51472}$$

Aspen

$$v = 0,01548d^2 + 0,03255d^2h - 0,000047d^2h^2 - 0,01333dh + 0,004859dh^2$$

Black alder

$$v = 0,1926d^2 + 0,01631d^2h + 0,003755dh^2 - 0,02756dh + 0,000499d^2h^2$$

Publicering och arkivering

Godkända självständiga arbeten (examensarbeten) vid SLU publiceras elektroniskt. Som student äger du upphovsrätten till ditt arbete och behöver godkänna publiceringen. Om du kryssar i **JA**, så kommer fulltexten (pdf-filen) och metadata bli synliga och sökbara på internet. Om du kryssar i **NEJ**, kommer endast metadata och sammanfattning bli synliga och sökbara. Fulltexten kommer dock i samband med att dokumentet laddas upp arkiveras digitalt.

Om ni är fler än en person som skrivit arbetet så gäller krysset för alla författare, ni behöver alltså vara överens. Läs om SLU:s publiceringsavtal här: https://www.slu.se/site/bibliotek/publicera-och-analysera/registrera-och-publicera/avtal-for-publicering/.

☒ JA, jag/vi ger härmed min/vår tillåtelse till att föreliggande arbete publiceras enligt SLU:s avtal om överlåtelse av rätt att publicera verk.

☐ NEJ, jag/vi ger inte min/vår tillåtelse att publicera fulltexten av föreliggande arbete. Arbetet laddas dock upp för arkivering och metadata och sammanfattning blir synliga och sökbara.