Bird diversity in fast-growing stands of hybrid aspen, poplar, and birch in Skåne

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Master's Thesis • 30 credits
Swedish University of Agricultural Sciences, SLU
Southern Swedish Forest Research Centre
Euroforester
Alnarp, 2024

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Credits:	30 Credits
Level:	Second cycle, A2E
Course title:	Master's thesis in Biology
Course code:	EX0986
Programme/education:	Euroforester
Course coordinating dept:	Southern Swedish Forest Research Centre
Place of publication:	Alnarp
Year of publication:	2024
Cover picture:	Matts Lindbladh
Copyright:	All featured images are used with permission from the copyright owner.
Keywords:	Fast-growing broadleaves, short-rotation forestry, birch, hybrid aspen, poplar, bird diversity, bird abundance, Southern Sweden

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Abstract

Due to climate change mitigation, the need for wood for energy production is increasing. In response, fast-growing broadleaves, among them silver birch (*Betula pendula*), hybrid aspen (*Populus tremula* × *P. tremuloides*) and poplar (e.g. *Populus trichocarpa* × *P. maximowiczii* (OP42)) are being planted mainly on former agricultural land as short-rotation plantations. Since these plantations are sometimes treated as agricultural land, the silvicultural measures are different compared to normal production forest systems. Furthermore, of these tree species, only birch is considered native to Sweden. Differences in the homogeneity of stand structure, and variation in the use of native, hybrid and non-native tree species, could cause differences in bird community composition and abundance. These differences could be of relevance to forest biodiversity outcomes.

This study analysed the difference in bird diversity, considering species richness and abundance, between the three aforementioned tree species. Furthermore, the study investigated the extent of influence on bird diversity from stand characteristics: stand size, basal area, quadratic mean diameter, understory vegetation, and dead wood volume. I surveyed 18 fast-growing broadleaf stands located in Skåne; first the vegetation was measured, and second, bird data was collected in the early spring. For the bird data I conducted point count surveys in all three stand types, with results restricted to individuals showing territorial behaviour (singing, nesting behaviour).

A total of 29 bird species and 333 individual birds were detected, four of which are listed as near-threatened, and one as endangered according to the Swedish Red List. Most species encountered were habitat generalists and residents. The highest bird species richness and bird abundance were counted in birch stands, followed by hybrid aspen, and then poplar stands, within which I counted the lowest bird species richness and abundance. The highest species richness among broadleaf-associated species and migrants was found within hybrid aspen stands. My results indicate that tree species and basal area had an impact on bird diversity. For the other vegetation measures, no significant effect on the bird composition was found. Nevertheless, these measures gave insights into stand structure, which showed a greater heterogeneity in the exotic tree species than expected and therefore, can explain the relatively high bird diversity in hybrid aspen plantations. This result also suggests that further research is needed to test the influence of vegetation measures on bird diversity in fast-growing plantations. Additionally, a potential effect of the surrounding landscape was found, indicating that further research is needed to understand how surrounding environmental conditions may influence bird composition in the surveyed stands.

All of these findings have implications for our understanding of how tree species choice and the management of short-rotation plantations of fast-growing broadleaves can alter bird diversity and abundance.

Keywords: Fast-growing broadleaves, short-rotation forestry, birch, hybrid aspen, poplar, bird diversity, bird abundance, Southern Sweden

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Abbreviations

BA	Basal area
DBH	Diameter at breast height
FGB	Fast-growing broadleaves
GHG	Greenhouse gas
GLM	Generalised Linear Model
Hasp	Hybrid aspen
QMD	Quadratic mean diameter
SLU	Swedish University of Agricultural Sciences
SRF	Short-rotation forestry

1. Introduction

The negative consequences of anthropogenic climate change for biodiversity and human lives require that the mitigation of greenhouse gas (GHG) emissions takes place. One possible measure is to replace the usage of fossil fuels with low greenhouse gas emitting energy sources (Rivas Casado et al. 2014; Roberge et al. 2016). In order to promote this mitigation action, the current energy policy within the European Union requires that member states increase their share of renewable energy sources by 45% by 2030 (Ciucci 2023). In Sweden, a more ambitious goal has been adopted to reduce GHG emissions by 63% relative to 1990 levels by the year 2030 (Ministry of the Environment 2020).

One possible way to reduce the use of fossil fuels is via the usage of fuelwood as an energy source (Bouget et al. 2012). For this and other reasons, the global demand for wood has increased over recent decades and is expected to continue to increase this century (Betts et al. 2010). Consequently, the harvesting pressure on natural forests will increase, which could be minimized by the implementation of an intensified forestry system, growing genetically improved seedlings of fast-growing broadleaves (FGB) in short-rotation forestry (SRF) plantations (Betts et al. 2010; Tullus et al. 2012; Heilmayr 2014).

One important motivation for tackling climate change is the direct negative effects on animals and plants, making the biodiversity crisis worse (Pereira et al. 2024). For example, bird migration and reproduction are influenced by shifting weather conditions and land use changes (Crick 2004; Fraixedas et al. 2020). Measures to protect biodiversity from these impacts have already been conducted but do not seem to be sufficient. Sweden, for example, managed to increase the protected forest area, but the protected habitats provided remain highly fragmented (Felton et al. 2020). To define and estimate the impact of environmental changes on wildlife in certain areas, well-studied taxonomic groups like birds are commonly used as indicators (Uliczka & Angelstam 2000; Gregory 2006; Roberge & Angelstam 2006; Lindbladh et al. 2017). Since birds are highly mobile species, they react quickly to habitat changes by colonizing new areas (Karačić 2005; Knowlton et al. 2021). Furthermore, the visual and acoustic detection and identification methods used to survey birds are relatively easy to carry out (Lindbladh et al. 2017; Fraixedas et al. 2020). For this reason, the present work will focus on the abundance of birds in

SRF systems as a means to understand the potential implications for this important component of forest biodiversity resulting from the widespread implementation of this form of plantation forestry.

Despite the measures to protect biodiversity, some losses in the abundance of species are visible, due to intensification in both forestry and agriculture. Therefore, the abundance of many bird species is currently declining in Europe and Sweden (Söderström & Pärt 2000; Berg 2002b; Wretenberg et al. 2006; Chiatante et al. 2019; Ram et al. 2023). Intensification seems to mainly affect habitat specialists since the number on the Red List has increased lately (Berg 2002b). Habitat generalists seem to be less affected by intensification (Ram et al. 2017), which could be explained by the usage of different habitat types available in near surroundings (Söderström & Pärt 2000). Since public awareness of biodiversity is increasing and the ongoing decline in bird species should be limited according to the Sustainable Development Goals, the implication of FGB plantations also meets some resistance, likely due to concerns regarding to the negative effects of forestry intensification on biodiversity (Pedroli et al. 2013; Felton et al. 2021).

1.1 Fast-growing broadleaves and their ecology

1.1.1 Use of fast-growing broadleaves

In Sweden, the term FGB often includes the tree species silver birch (*Betula pendula*), aspen (*Populus tremula*), poplar (mainly *Populus trichocarpa* × *P. maximowiczii* (OP42)), hybrid aspen (*Populus tremula* x *P. tremuloides*), and willow (*Salix sp.*) (Tullus et al. 2012; Taeroe et al. 2015; Böhlenius et al. 2021). With the exception of silver birch and aspen these tree species are all considered exotic by the Swedish Forestry Act and cannot be grown on more than a limited percentage of forest land due to restrictions by certifiers like the Forest Stewardship Council (Böhlenius et al. 2021). Therefore, FGB are usually grown on arable land as energy crops, for which they are often expected to rapidly produce large amounts of biomass (Tullus et al. 2012; Jastrzębska 2020).

The management of FGB differs depending on the tree species, but in general, plantings are commonly designed to be even-aged with a dense spacing of one or several FGB species (Flaspohler & Webster 2011; Böhlenius et al. 2021). When established on arable land, FGB plantations are not considered a forest by law, but agricultural crops, hence, the use of herbicides and soil preparation is not limited and often used in the establishment phase (Weih 2008; Böhlenius et al. 2021). Due to the fast growth, thinnings are often not carried out before the final harvest (Arbez 2001). Final harvests are conducted in winter, after a rotation length of approximately 30 years (Tullus et al. 2012, Döpke et al. 2013). Due to the lower biomass production of birch compared to hybrid aspen and poplar, it takes longer for birch to reach the harvesting age, which results in longer rotation periods (Böhlenius et al. 2021). In general, during the research, I found less guidance provided regarding the management of birch stands as SRF. If the plantation is grown as an energy crop on arable land, the harvest needs to be carried out between 8 to 20 years of rotation (European Commission 2022). Overall, FGB plantations can be seen as an intensification in forest management that are in some situations comparable with agricultural systems rather than forestry systems (Arbez 2001; Calladine et al. 2018; Felton et al. 2020).

In Sweden, the plantation of hybrid aspen and poplar species was supported by the government after the storm Gudrun (Felton et al. 2016a). The data report of the National Commission of fast-growing trees in Sweden states that in 2019 there existed 1703 ha of poplar and 727 ha of hybrid aspen grown as SRF throughout the country (Adler et al. 2021). For birch, I could not find data regarding the proportion grown specifically as SRF in Sweden.

1.1.2 Effects on bird diversity

Overall, the impact that plantations have on the surrounding landscape depends on tree species selection, the resulting stand structure, and their associated management (Flaspohler & Webster 2011; Liu et al. 2014). It is important to mention that FGB plantations cannot substitute for natural forests in terms of species richness due to their simplified structure (Schulz et al. 2009; Flaspohler & Webster 2011). This simplified structure creates, for example, different or limited food resources and habitats, which can result in a deprived bird species composition within FGB plantations compared to natural forests (Calladine et al. 2018).

The stand structure of FGB plantations differs between the tree species planted, but is often described as being homogenous or simplified. For example, young aspen stands in the US were considered low in structural heterogeneity by Jarvi et al. (2018). With increasing age, the structure of FGB plantations can become more varied due to differences in the heights of the tallest trees and the development of a richer understory. As a result, the increased structural heterogeneity correspondingly provides increased foraging opportunities and nesting sites for birds (Riffell et al. 2011; Czaloun 2012; Randlane et al. 2017) which can consequently result in an increase in the bird species richness as the plantation ages (Gruss & Schulz 2011; Lindbladh et al. 2017). The increasing age and structure of FGB plantations also seems to influence bird community structure, as found by a study from Germany that describes a shift from open-land bird species to shrubland species as FGB plantations age (Döpke et al. 2013). The increased structure found in older plantations can, however, have a negative effect on bird abundance. For example, another study from Germany suggests that the lower light conditions found in mature poplar plantations were suboptimal, as indicated by increasing bird abundance towards the lighter edges (Bielefeldt et al. 2008).

The tree species used can also vary in their suitability as habitat for different bird species, depending on the specific characteristics of tree species. For example, poplar plantations may be more suitable to woodpeckers and other bird species that depend on decaying trees and dead wood in their habitat. Due to the low density of the wood of poplar trees, excavators can carve holes out of healthy, relatively young trees (Wesolowski et al. 2018). Also, the wood of aspen (*Populus tremula*) is often preferred by excavators to create holes (Wesolowski & Martin 2018). Despite this potential, some studies report a lack of breeding holes in poplar plantations, likely due to the low rotation age (Kartanas 2010; Gruss & Schulz 2011).

Relative to arable fields and conifer plantations, FGB plantations can support a rich ground flora, which may even host a limited number of endangered species (Karačić 2005; Jastrzębska 2020). This understory can serve as a shelter and foraging resource for birds (Döpke et al. 2013). Furthermore, it influences the morphology of the birds (Villard & Foppen 2018). In those FGB stands that are fenced, the exclusion of browsing activity by large herbivores can result in a higher structural diversity in the understory (Felton et al. 2016b). In a study that contrasted the bird communities of four- to eight-year-old hybrid aspen and Norway spruce plantations, Lindbladh et al. (2014) found that the hybrid aspen stands contained a higher bird diversity. Similar results were found for stands with an increased relative proportion of birch compared to otherwise Norway spruce-dominated production forests (Felton et al. 2011, 2021).

In summary, habitats linked to old trees and large amounts of dead wood cannot be expected to be provided by FGB plantations, due to their low harvesting age. However, FGB stands may positively influence the avian diversity in a simplified agricultural landscape by creating a less homogenous landscape (Berg 2002a; Schulz et al. 2009; Flaspohler & Webster 2011). Additionally, FGB plantations can help to connect forest areas in otherwise agriculturally dominated landscapes and may therefore benefit even forest specialists like the Marsh Tit (*Poecile palustris*) (Chiatante et al. 2019).

1.2 Objectives of the thesis

The thesis analyses the diversity of bird species in stands of birch, hybrid aspen, and poplar grown in SRF systems in Skåne in Southern Sweden. To analyse the impacts of the forest structure on bird diversity, surveys estimating basal area and species richness in trees and understory were conducted. Additionally, the dead wood volume and stand size was also considered as potential influencing factors.

I had the following objectives:

- To find out how bird diversity differs between the three surveyed tree species stand types, considering that only birch is native to Sweden.
- To investigate whether and to what extent the stand characteristics assessed influence the species richness and abundance of birds in FGB plantations.

The following hypothesises were tested:

- The bird community abundant in silver birch will be richer compared to the stands of other tree species, as exotic tree species can provide conditions and resources that are less beneficial to native fauna (Calladine et al. 2018).
- The abundance of the bird community in less dense stands like silver birch will be richer compared to denser stands, as very high vegetation density can negatively affect habitat usage by birds (Bielefeldt et al. 2008).
- The most abundant habitat usage category amongst birds will be generalists in all three stand types, as these species are less affected by habitat changes than specialists, due to their ability to make use of a range of habitat types (Söderström & Pärt 2000; Ram et al. 2017).

2. Material and methods

2.1 Study area

The present work was conducted in the county of Skåne in Southern Sweden. Skåne is located in the temperate oceanic climate zone of Sweden and has a mean annual surface temperature of 8.35°C, as calculated between the years 1901 - 2022. The mean annual precipitation is 800 mm/year, as estimated in the same time period (Climate Knowledge Portal 2021).

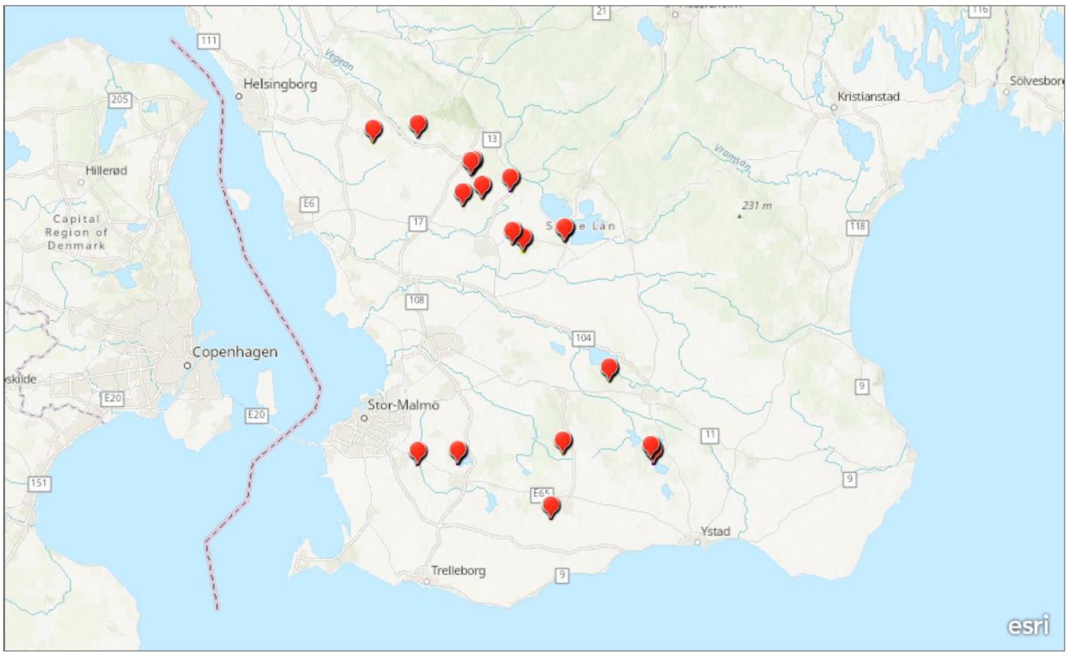
In Sweden, forests account for 70% of the land cover (Felton et al. 2021), which amounts to 27.9 million ha, of which 23.5 million ha are productive forest land (Roberge et al. 2023). In Sweden, forests with a growth over one m^3sk/ha a year are defined as productive forest land (Roberge et al. 2023). The main area of the productive forest area is planted with 40.2% Scots pine, 27% Norway spruce, and 12.8% birch (the most used broadleaf tree), almost exclusively managed using a clear-cutting system of even-aged stands to produce timber, pulp wood, and energy wood (Felton et al. 2021; Roberge et al. 2023). Other broadleaves make up 7.6 % of Sweden's productive forest area (Roberge et al. 2023).

Skåne's landscape mainly consists of a mosaic of arable and forest land (Berg 2002b). In absolute area, 462 000 ha of Skåne are covered by arable land and 434 000 ha are forested, of which 425 000 ha consists of production forests (Roberge et al. 2023). The production forest area in Skåne, unlike that of Sweden, consists of 33.4% Norway spruce, 9.0% Scots pine, and a higher proportion of broadleaves with 43% (Roberge et al. 2023). Most forest in Skåne is owned by individual owners (323 000 ha), 39 000 ha belong to companies and 72 000 ha to other forest owners (Roberge et al. 2023).

2.2 Stand selection

The stands were selected from a database provided by a PhD thesis project within the research programme “Trees for Me”, which is investigates the biodiversity implications of FGB plantations. This data base provides a list of SRF plantations of hybrid aspen, poplar, and silver birch in Sweden that were older than 20 years, with some exceptions, and larger than 0.1 ha. For my study, only stands located in Skåne were considered during the process of stand selection (Figure 1), due to logistical and time constraints.

The selected stands were chosen to help ensure a minimum threshold size of habitat was available to influence the bird species encountered within the stand, and to facilitate their survey. All stands with a size lower than 0.53 ha were excluded to reduce the influence of edge effects on bird activity (Felton et al. 2021). Stands larger than 7 ha were excluded, as available stands above this size were substantially larger, few in number, and did not encompass all three tree species stand types of interest. Regarding stand age, no limit was selected due to the low number of available stands left after filtering for the stand size. After the selection, all stands were sorted into clusters, consisting of two stands in reasonable driving distance of one another to help facilitate the bird survey design that involved surveying two stands per morning (Table 1).



Esri, CGIAR, N Robinson, NCEAS, USGS | Esri, TomTom, Garmin, Foursquare, FAO, METI/NASA, USGS

Figure 1. A map showing the location (red points) of all surveyed study stands in Skåne, southern Sweden.

Table 1. A list of the surveyed stands describing the tree species, bird survey day and stand size. The year of establishment is given for all stands, where reliable information was available.

Site	Species	Survey Day	Size	Planted
Sångletorp	Birch	2	1.17	
Vomb	Birch	4	2.7	
Skarhult	Birch	4	7.4	1980
Höör2	Birch	5	0.6	
Trolleholm59h	Birch	7	1.1	1996
Jordkull	Birch	9	3.7	1992
Skabersjö12	Hybrid Aspen	1	2.9	1995
Svenstorp	Hybrid Aspen	2	1.7	1991
Snogeholm	Hybrid Aspen	3	0.63	1992
Ellinge	Hybrid Aspen	6	0.53	1993
Trollenäs5	Hybrid Aspen	7	1.35	2001
Trolleholm78x	Hybrid Aspen	8	0.54	1996
Skabersjö67e South	Poplar	1	5.2	2008
Bellinga	Poplar	3	6.7	
Höör1	Poplar	5	0.6	
Eslöv	Poplar	6	5.8	
Trolleholm355c	Poplar	8	1.36	2000
Knutstorp2T	Poplar	9	0.87	2005

2.3 Vegetation survey

In each stand, four centrally located points were established with ArcGIS. They served as central points for both the vegetation analysis and the bird survey. For the vegetation analysis, the area in a radius of 10 m around each point was surveyed. The plots were placed at a distance from stand edges to reduce the influence of edge effects on the bird survey results (Felton et al. 2021). Due to the large variation in stand size, the survey points in stands over 5 ha were located approximately 50 m from the stand edges, which also helped to ensure the even distribution of survey plots within the stand. However, in stands smaller than 1 ha, the distance to the edges could not be higher than 20 m. Each survey point was located within 40 m to 60 m from the next survey point, depending on the overall size and shape of the stand. In the selected plots, the tree species were identified and the diameter at breast height (DBH) for all trees larger than 4 cm at 1.3 m height was measured using the Arboreal Forest app (Arboreal AB 2023). Based on these measures, the app then calculated the basal area (BA) and quadratic mean diameter (QMD). To reduce measurement errors when taking DBH, the trees were measured from two sides (Sveaskog Förvaltning AB 2021).

In addition, the abundance of understory vegetation was measured by counting the number of plants higher than 0,3 m and < 4 cm DBH (Lindbladh et al. 2020). This provided a measure of the shrub layer which can have an important influence on bird diversity in production forest stands (Felton et al. 2021). The dead wood volume was quantified within a radius of 5 m from the survey point, by measuring the diameter of logs and snags with the Arboreal Forest app (Arboreal AB 2023). The decay class was allocated using guidelines from Canada´s National Forests Inventory. The index includes 5 decay classes, ranging from hard intact bark and wood texture in class 1, to partly missing bark and partly decaying wood in class 2. Class 3 is defined by a trace bark and larger pieces that are partly decaying. Class 4 includes logs with no bark, consisting of small, blocky pieces. Class 5 is defined by logs without bark and a texture of small wood pieces (Forest Inventory Committee 2008).

2.4 Bird survey

The bird surveys were done by using the point count method (Bibby et al. 2000) which is an efficient means of providing an index of bird species richness and abundance that is correlated with the true abundance of the present bird species (Toms et al. 2006). In addition, point counts are best suited for a combination of bird survey and habitat assessment in forested survey sites (Bibby et al. 2000). However, the results must be interpreted with caution since there are limitations in the detectability of bird species with distinct behaviour when using multi-species survey approaches (Johnson 2008). Therefore, a variety of approaches were used in order to minimize possible detection errors.

To reduce concerns that birds further from the observer will go undetected relative to birds closer to the observer, I restricted the survey to only those birds within 20 m from the survey point (Johnson 2008). The distance in the field was calibrated by using a laser range finder (Felton et al. 2021). Within the chosen survey area, the birds that occur are likely to be identified, since the distance often used for similar bird surveys is between 30 and 40 m (Lindbladh et al. 2014; Felton et al. 2021). The distance of the survey points to the forest edges varied, due to the need to include stands as small as 0.53 ha. This is 0.03 ha larger than the 0.5 hectares encompassed by four 20 m radius bird survey points. In these few cases, the bird area surveyed included the majority of the stand area, as circular plots could not be placed without overlapping edges. Therefore, these data must be analysed with caution regarding bird species abundance. The distance between the survey points was limited to a maximum of 40 m, to reduce the risk of bird abundance inflation when surveying large stands that may extend over a variety of environments (Lindbladh et al. 2022). Furthermore, this approach minimizes the risk of double counting, since the movement of birds between survey points can still be estimated (Felton et al. 2021).

I surveyed each study stand twice per day in the early spring from the 18th to the 27th of March 2024. The survey period was chosen to coincide with annual peaks in the singing activity of breeding resident bird species (Bibby et al. 2000). Migrant passerines have not arrived in large numbers in Southern Sweden, but the limited time to conduct this thesis did not leave the possibility for a second survey in late spring. I started by surveying the southernmost stands to reduce negative influence of colder temperatures on bird activity. The surveys were started at dawn, approximately 6:00 am, and finished around 9:30 am. This period coincides with the daily peak in bird vocal activity (Bibby et al. 2000). The two stands surveyed a day, were visited alternately to reduce bias in the surveying time, which could occur if bird singing activity was more active in the early rather than late morning on a given day (Felton et al. 2021). Furthermore, the order of stands was arranged to ensure that each stand type (birch, hybrid aspen, poplar) was visited first equally often. All surveys were conducted in suitable weather, meaning almost no wind, and minimal rainfall, to reduce the influence of environmental elements on the detectability and activity of birds (Bibby et al. 2000).

All surveys were conducted by a single observer, who was experienced with bird identification and survey methods, as a measure to decrease observer bias (Jarvi et al. 2018). Since the survey was conducted by one person, a recorder (Song Meter Micro by Wildlife Acoustics) was always placed one metre away from the observer, recording the whole survey period. The audio was used as a backup for bird identification, which provided the chance to relisten the bird voices in case of uncertainty in species identification. Each point was surveyed for five minutes after a one-minute pause to reduce the influence of the observer's arrival on bird behaviour (Bibby et al. 2000). Bird activity during the pause, for example, warning calls or flight response, was included in the count (Bibby et al. 2000). The identification of birds was mostly made acoustically rather than visually. In cases of uncertainty regarding the number of individual birds collectively encountered between survey points within a stand, the most conservative abundance estimate for each species was used (Lindbladh et al. 2014; Felton et al. 2021). Only birds engaging in territorial behaviour, such as songs, nest attendance, or territorial fights, were included in the survey for the purpose of increasing the probability that the bird occurrence was linked to the vegetation conditions present (Felton et al. 2021). Birds that were observed when flying over a stand were not included in the analysis (Lindbladh et al. 2014). The summed abundance for each species in each stand was estimated by using the highest abundance value of all four surveys since the true avian abundance is correlated with the highest abundance rather than the average abundance (Toms et al. 2006).

2.5 Bird ecological characteristics

I used descriptions of the habitat requirements, migratory status, and nest sites of all bird species specified by Felton et al. (2021) to classify the observed species according to their ecology. For birds not mentioned by Felton et al. (2021), the classification given in Artfakta.se (2024) was used, where the Red List status for each species was also checked.

The classification of forestland-associated species was based on Felton et al. (2021) and classified birds as either "conifer specialists", like European Crested Tit (*Lophophanes cristatus*), "broadleaf specialists", like the Eurasian Blue Tit (*Cyanistes caeruleus*), or as "forest generalists", like Eurasian Siskin (*Carduelis spinus*). Farmland birds were classified by using the habitat type definition given by Artfakta.se (2024), since Felton et al. (2021) focused on forestland species, and did not mention farmland-associated species like Woodlark (*Lullula arborea).*

In general, it is important to mention that many bird species use forests as nesting sites, shelter, and foraging substrate. Nevertheless, the forests in which they might occur are not necessarily considered as their main habitat (Berg 2002b). For example, forest bird species like the Woodpigeon (*Columba palumbus*) can be dependent on foraging in agricultural land (Blondel 2018; Calladine et al. 2018; Mikusinski et al. 2018).

In addition, the species observed were classified according to their migratory status (i.e. migrants, partial migrants, and residents) and nest site preference (i.e. above-ground nesters, cavity nesters, and ground nesters), by using the bird ecological characteristics provided by Felton et al. (2021) and, with missing species data found in Artfakta.se (2024).

The classification for each bird species observed during the survey period is given in Table 2.

2.6 Data analysis

The data analysis was conducted in R (version 4.3.3) (R Core Team 2024), RStudio (Posit Team 2024), and Microsoft Excel (Microsoft Corporation 2018).

The species richness (S) and abundance (A) was calculated for each stand and each forest type. This data was then used to calculate Shannon's Diversity Index (H') in Excel.

The following equation was used:

$$H' = \sum_{i=1}^{S} p_i \ln(p_{i)}$$

Shannon's Evenness (E) was then calculated in order to compare the species richness of the different stand types by using the following equation:

$$E = \frac{H'}{\ln(S)}$$

In the above equations S is representing the number of species encountered in the stand and p_i describes the proportion of individuals of one (the i^{th}) species.

To estimate the impact of stand type and vegetation characteristics on the bird species richness and bird abundance, Generalized Linear Models (GLM) of the R package stats were used. To model both response variables, a Poisson distribution and log-link function were used for the bird species richness and a Gaussian distribution for the bird abundance. GLMs were done for the following measures: tree species, stand size, stand BA, QMD, shrub layer, and dead wood volume.

All GLMS were checked for overdispersion by using the check_overdispersion function in the package performance and by checking for patterns in the residuals, visible in plots of the Pearson residuals against the fitted values.

In order to test the significance of the effects that vegetation characteristics had on bird diversity, an ANOVA analysis was conducted for the Gaussian distributed data of the bird abundance. The Poisson-distributed data, concerning the bird species richness, was tested for significance using ANOVA with the Chi square Test function.

3. Results

3.1 Vegetation analysis

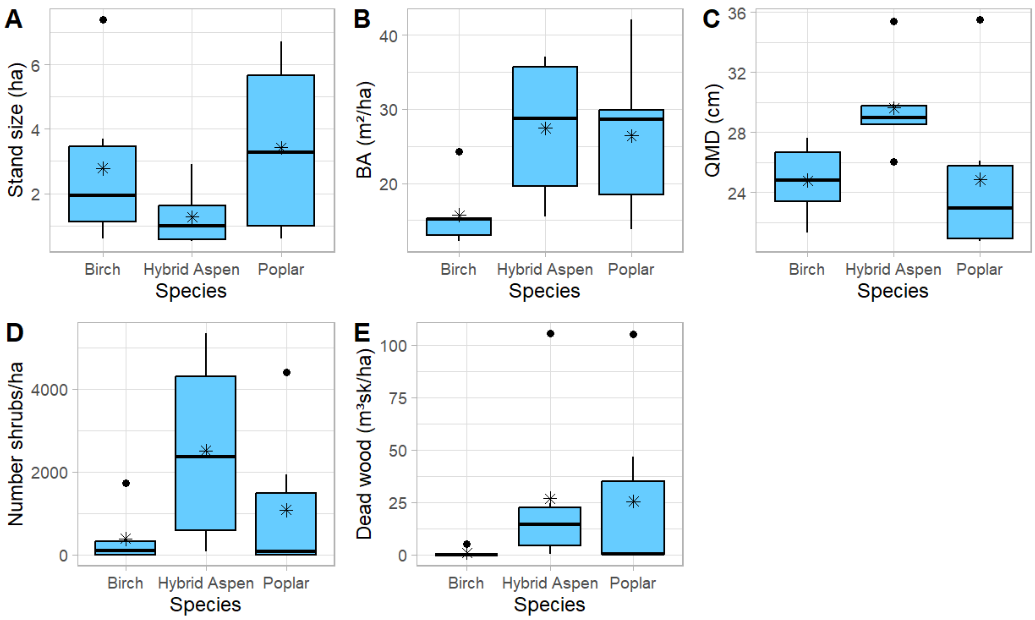


Figure 2. Boxplots showing the proportion of vegetation characteristics for each of the three tree species assessed: average stand size in ha (A), BA in m²/ha (B), QMD in cm (C). density in the shrub layer (Number of understory plants/ha) (D), and amount of dead wood in m³sk/ha (E). The boxplots present the median as a horizontal line, the mean value as a star, 25 and 75 percentiles are indicated by the box, non-outlier values are encompassed by the whiskers, and the outliers are indicated as circles.

The results of the vegetation survey can be seen in Figure 2, which summarizes vegetation characteristics for the birch, hybrid aspen, and poplar stands assessed. Hybrid aspen stands were, on average, the smallest stands and poplar stands the largest, in terms of total hectares (Figure 2). In terms of BA, there did not appear to be a large difference between hybrid aspen and poplar, but birch stands had a lower average BA at 15.72 m²/ha. Regarding the QMD, there did not seem to be large differences between poplar and birch. Hybrid aspen stands showed the highest QMD as visible in Figure 2. It is important to mention that most hybrid aspen stands were two-storied, as is visible in the data assessed from Arboreal, which showed a large number of trees with a DBH of ≤10 cm, and several trees with a DBH > 40cm. This explains the high BA of these stands compared to birch, in which few or no trees with a DBH ≤ 15cm were found. Hybrid aspen had the highest shrub density (Table 2), which were composed of hybrid aspen (*Populus tremula* x *P. tremuloides*), hawthorn (*Crataegus monogyna*), Norway spruce (*Picea abies*), and black alder (*Alnus glutinosa*). Poplar stands had the second highest stem density in the shrub layer, which consisted mostly of poplar (*Populus sp.*) (Figure 2). Birch stands had the lowest number of stems in the shrub layer (Figure 2), which consisted of silver birch (*Betula pendula*), poplar (*Populus sp.*), Norway spruce (*Picea abies*), European beech (*Fagus sylvatica*), Western red cedar (*Thuja plicata*), sloe (*Prunus spinosa*), and black elder (*Sambucus nigra*). Several hybrid aspen and poplar stands had windfalls, which resulted in a higher average volume of dead wood. A detailed description of the dead wood volume in each decay class can be seen in Figure 3.

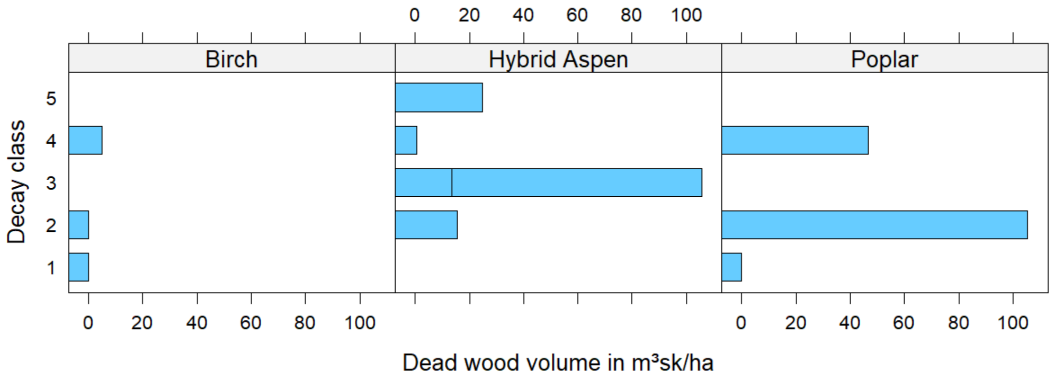


Figure 3. Bar charts showing a detailed description of the dead wood decay stage, showing the volume in m³sk/ha for each decay class, grouped by tree species stand type.

In detail results of the vegetation survey for each of the surveyed stands can be found attached in Appendix 1.

3.2 Bird survey

Table 2. All encountered birds organized by their scientific name and classified by habitat preference (B = broadleaf-associated, C= conifer-associated, B/C =generalist, F =farmland-associated), migratory status (M = migrant, PM = partial migrant, R = resident) and nest site (AG =above-ground, CN = cavity nesting, GN = ground nesting). All classifications were based on Felton et.al (2021) and Artfakta.se. Swedish Red List status is of April 2024 (artfakta.se).

Scientific Name	Common name	Habitat	Migratory Status	Nest site	Red List Status	Species Abundance		
						Birch	Hybrid Aspen	Poplar
Aegithalos caudatus	Long-tailed Tit	B	R	AG		3	0	1
Chloris chloris	European Greenfinch	B/C	PM	AG	EN	4	0	0
Carduelis spinus	Eurasian Siskin	B/C	PM	AG		2	2	0
Coccothraustes coccothraustes	Hawfinch	B	PM	AG		1	13	5
Coloeus monedula	Jackdaw	F	PM	CN		1	0	0
Columba palumbus	Common Wood Pidgeon	B/C	PM	AG		4	2	1
Dendrocopos major	Great Spotted Woodpecker	B/C	R	CN		1	6	0
Emberiza citrinella	Yellowhammer	B/C	PM	GN	NT	6	1	0

Erithacus rubecula	European Robin	B/C	M	GN		0	1	0
Fringilla coelebs	Common Chaffinch	B/C	M	AG		16	12	14
Garrulus glandarius	Eurasian Jay	B/C	R	AG		1	1	1
Lophophanes cristatus	European Crested Tit	C	R	CN		3	1	1
Lullula arborea	Woodlark	F	M	GN		1	0	0
Parus caeruleus	Eurasian Blue Tit	B	PM	CN		23	18	14
Parus major	Great Tit	B/C	R	CN		23	18	14
Periparus ater	Coal Tit	C	R	CN		3	4	1
Phasianus colchicus	Pheasant	F	R	GN		1	4	1
Phylloscopus collybita	Chiffchaff	B	M	GN		7	2	4
Phylloscopus sibilatrix	Wood Warbler	B/C	M	GN	NT	0	2	0
Phylloscopus trochilus	Willow Warbler	B	M	GN		0	1	0
Picus viridis	Green Woodpecker	F	R	CN		0	0	1
Poecile montanus	Willow Tit	B	R	CN	NT	7	0	0

Poecile palustris	Marsh Tit	C	R	CN	NT	3	4	0
Prunella modularis	Dunnock	B/C	M	AG		2	2	1
Regulus regulus	Goldcrest	C	PM	AG		5	3	1
Sitta europaea	Eurasian Nuthatch	B	R	CN		6	1	0
Troglodytes troglodytes	Eurasian Wren	B/C	R	GN		7	3	4
Turdus merula	Blackbird	B/C	R	AG		8	3	3
Turdus philomelos	Songthrush	B/C	M	AG		7	10	7

A total of 333 birds, belonging to 29 species, were observed displaying territorial behaviour during the surveys in all stands (Table 2). All collected measures of diversity (Species richness (S), Bird abundance (A), Shannon's Diversity Index (H'), and Shannon's Evenness (E)) were consistent across the three stand types in showing that the highest diversity metrics for bird communities in birch stands, with correspondingly lower figures for hybrid aspen and poplar respectively (Figure 4). The Shannon's Evenness is highest for poplar, which indicates that the populations were more equally distributed in these stands. Below, the bird species richness and abundance for the categories of habitat preference, migratory status, nest site, and Red List status are compared between the three tree species stand types assessed. Additionally, the proportions of each measure from all bird species observed in one tree species stand type are presented.

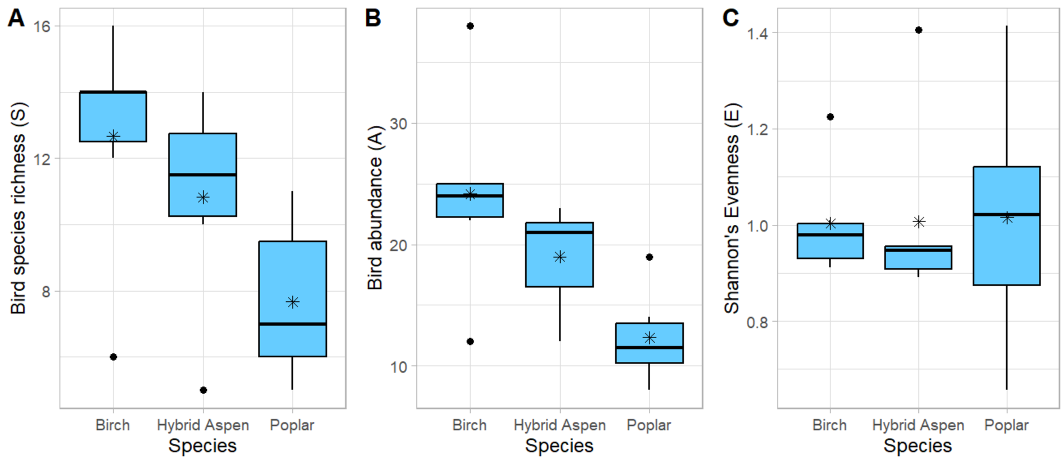


Figure 4. Boxplots of the relative bird abundance (A), bird species richness (B) and Shannon's Evenness (E) for the birds (C) displayed for each of the tree species (birch, hybrid aspen and poplar) stand types. The boxplots present the median as a horizontal line, the mean value as a star, 25 and 75 percentiles are indicated by the box, non-outlier values are encompassed by the whiskers and the outliers are indicated as circles.

With respect to the species richness of generalists, an almost equal number of species was observed in hybrid aspen and birch stands (Figure 5). The same outcomes apply when considering the abundance of these generalist bird species (Figure 5). Broadleaf-associated species showed the highest species richness in hybrid aspen stands (Figure 5), whereas their abundance was approximately double the amount in birch stands compared to hybrid aspen stands (Figure 5). Conifer-associated species showed the highest species richness and abundance in birch stands (Figure 5). Farmland-associated species were abundant in small numbers and more often encountered in hybrid aspen and birch stands than in poplar (Figure 5). These species were mainly encountered showing territorial behaviour towards the edge of the surveyed stands or in windfall gaps. The proportions of habitat preference indicate that in birch, more conifer-associated species were present relative to all species observed in birch, whereas in hybrid aspen and poplar stands, the proportion of broadleaf-associated bird species was higher than for conifer-associated species. The farmland-associated species had the lowest proportion in hybrid aspen stands and the same proportion in birch and poplar stands.

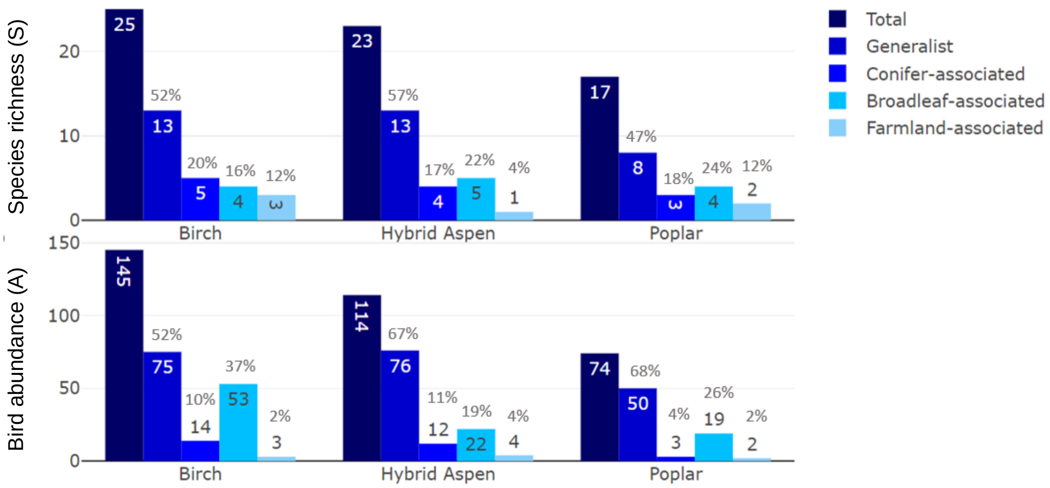


Figure 5. Bar charts of bird species richness and abundance summarized as absolute numbers by tree species and classification of habitat preference (generalist, conifer-associated, broadleaf-associated, farmland-associated). Above the absolute numbers (number within bar or below percentage), the percentage of each classification relative to the total number of bird species richness or bird abundance in each tree species stand type is given.

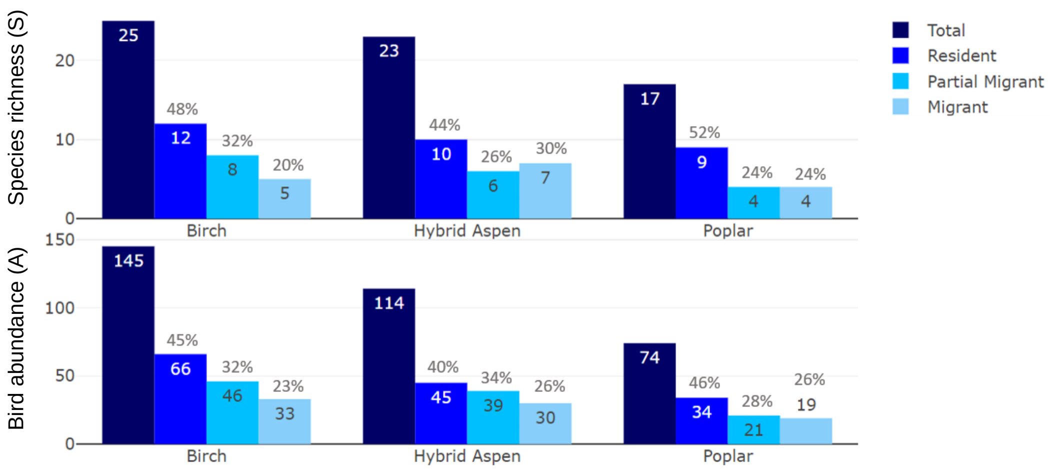


Figure 6. Bar charts of bird species richness and abundance summarized as absolute numbers by tree species and classification of migratory status (resident, partial migrant, migrant). Above the absolute numbers (number within bar or below percentage), the percentage of each classification relative to the total number of bird species richness or bird abundance in each tree species stand type is given.

An analysis of the migratory status of the bird species encountered revealed that residents and partial migrants were more abundant in birch stands (Figure 6). The highest number of migratory species were observed in hybrid aspen stands (Figure 6), whereas birch stands contained a higher number of migrants (Figure 6). The percentage of residents in birch stands relative to all observed species was highest. Similar results were found for hybrid aspen stands and poplar stands, which had the highest proportion of residents relative to all species observed in poplar. Unlike in birch, the proportion of migratory species in hybrid aspen stands is relatively high. In poplar stands the highest proportion of migrants, in terms of abundance, was observed.

With respect to nest sites, all categories occurred at their highest numbers in birch stands in terms of to both the species richness and individual abundance associated with each nesting category, followed by hybrid aspen stands and poplar respectively. Overall, the highest species richness was observed for above-ground nesters, followed by cavity nesters and lastly ground nesters (Figure 7). With respect to the abundance (Figure 7), cavity nesters were higher in abundance in birch and hybrid aspen stands than above-ground nesters and ground nesters. The proportion of above-ground nesters was highest in hybrid aspen stands relative to all observed species in hybrid aspen stands. Birch stands hosted the highest proportion of cavity nesting species relative to the bird species observed in hybrid aspen stands. Poplar species had the lowest proportion of ground-nesting species.

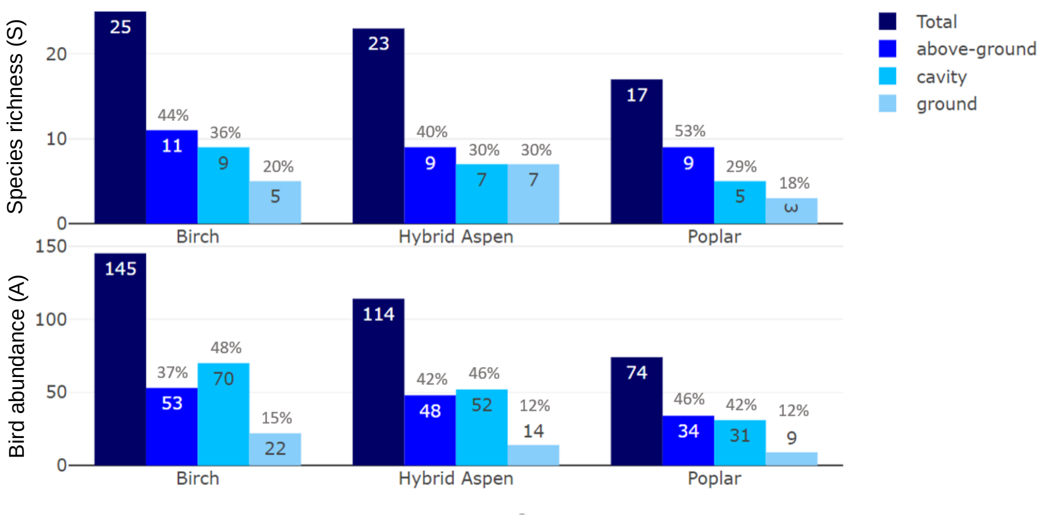


Figure 7. Bar chart of bird species richness and abundance summarized as absolute numbers by tree species and classification of nest site (above-ground, cavity nester, ground nester). Above the absolute numbers (number within bar or below percentage,) the percentage of each classification relative to the total number of bird species richness or bird abundance in each tree species stand type is given.

Regarding the Red-listed species, I observed four "near-threatened" species, Willow Tit (*Poecile montanus*), Marsh Tit (*Poecile palustris*), Wood Warbler (*Phylloscopus sibilatrix*), and Yellowhammer (*Emberiza citronella*), and one "endangered" species, European Greenfinch (*Chloris chloris*). Four Red-listed species were observed in birch stands consisting of three "near-threatened" and one endangered species. Three species classified as "near-threatened" were encountered in hybrid aspen stands and no Red-listed species were encountered in poplar stands. Except for the Marsh Tit (*Poecile palustris*) and Wood Warbler (*Phylloscopus sibilatrix*), all Red-listed species showed their highest abundance in birch stands (Table 2).

Woodlark (*Lullula Arborea*), Yellowhammer (*Emberiza citronella*), Jackdaw (*Coloeus monedula*), Willow Tit (*Poecile montanus*), and Eurasian Nuthatch (*Sitta europaea*) were exclusively encountered in birch stands (Table 2). The habitat preference and migratory status of these species did not show any clear pattern. With regard to the nesting site, a pattern in these species can be seen with two ground nesters and two cavity nesters. Furthermore, Willow Warbler (*Phylloscopus trochilus*), and Wood Warbler (*Phylloscopus sibilatrix*) were exclusively found in hybrid aspen stands. Both species are classified as migrants and ground nesters. The Green Woodpecker (*Picus viridis*) was exclusively observed in poplar stands (Table 2).

Chiffchaff (*Phylloscopus collybita*), Blue Tit (*Parus caeruleus*), Goldcrest (*Regulus regulus*), Eurasian Wren (*Troglodytes troglodytes*), Blackbird (*Turdus merula*), and Great tit (*Parus major*) were mainly encountered in birch stands. Any underlying patterns regarding migratory status or nesting sites is not apparent, as all categories are equally distributed among these species, but most of the species were classified as generalists (Table 2). The highest numbers of Hawfinch (*Coccothraustes coccothraustes*), Coal Tit (*Periparus ater*), Pheasant (*Phasianus colchicus*), and Great Spotted Woodpecker (*Dendrocopos major*), were observed in hybrid aspen. These species show no pattern in habitat preference and nest site. Nevertheless, three of four species are classified as residents. The generalists Chaffinch (*Fringilla coelebs*) and Eurasian Wren (*Troglodytes troglodytes*) were more abundant in poplar stands than in hybrid aspen (Table 2).

Songthrush (*Turdus philomelos*) was common in both birch and poplar in high numbers but showed the highest numbers for hybrid aspen stands (Table 2). The abundance of Dunnock (*Prunella modularis*) was evenly distributed between birch and hybrid aspen, but not common in poplar.

Detailed results presenting the bird species richness and abundance for each stand are attached in Appendix 2.

3.3 Effect of vegetation variables on bird species richness and abundance

Testing the effect of vegetation characteristics on the bird species richness and bird abundance with GLM and ANOVA revealed a significant effect for tree species and BA on the bird species richness and bird species abundance (Table 3 & Table 4).

The significant effect regarding tree species shows that in poplar there is a significantly lower amount of bird species and individuals compared to hybrid aspen and birch stands. With respect to basal area, the significant effect is visible especially in poplar stands with the highest basal area and the lowest bird diversity. The high basal area of hybrid aspen stands needs to be interpreted differently due to its two-storied structure.

Stand size, QMD, dead wood volume and shrub layer do not have a significant impact on bird species richness and bird abundance (Table 3 & Table 4).

Table 3. Results of the ANOVA analysis with Chi square test for the bird species richness against the vegetation characteristics assessed (Tree species, BA, stand size, shrub layer, dead wood, QMD). Significance is indicated by p-values less than 0.05.

Coefficients	Df	Deviance Residuals	Df residuals	Dev	P-value
NULL			17	22.400	
Tree Species	2	7.6232	15	14.777	0.02211
BA	1	6.3145	16	16.085	0.01198
Stand Size	1	0.019606	16	22.38	0.8886
Shrub layer	1	0.70813	16	21.692	0.4001
Dead Wood	1	1.0702	16	21.33	0.3009
QMD	1	0.049544	16	22.35	0.8239

Table 4. Results of the ANOVA analysis for the bird abundance against the vegetation characteristics assessed (Tree species, BA, stand size, shrub layer, dead wood, QMD). Significance is indicated by p-values less than 0.05.

	Coefficients	Df	Sum of square	Mean square	F-Value	P-value
Tree Species	Abundance$Species	2	422.33	211.167	6.1129	0.01144
	Residuals	15	518.17	34.544		
BA	Abundance$BA	1	235.97	235.973	5.359	0.03422
	Residuals	16	704.53	44.033		
Stand Size	Abundance$Size	1	15.58	15.581	0.2695	0.6107
	Residuals	16	924.92	57.807		
Shrub layer	Abundance$Shrub	1	10.18	10.185	0.1752	0.6811
	Residuals	16	930.32	58.145		
Dead Wood	Appendix2$DWVol	1	38.18	38.176	0.6769	0.4227
	Residuals	16	902.32	56.395		
QMD	Appendix2$DBH	1	1.85	1.852	0.0316	0.8612
	Residuals	16	938.65	58.665		

4. Discussion

In this study, I analysed the bird species richness and bird abundance in fast-growing stands of birch, hybrid aspen, and poplar in Skåne, southern Sweden. My findings indicated that the tree species selection and basal area influenced the bird population. Birch was the stand type that supported the highest levels of species richness and abundance, followed closely by hybrid aspen. Poplar supported the fewest birds. Similar results, showing that poplar hosted fewer bird species were found by other studies looking at the bird diversity in SRF plantations, mainly focused on poplar and willow (Karačić 2005; Schulz et al. 2009; Gruss & Schulz 2011; Czaloun 2012). With respect to broadleaf-associated species and migrants, both showed a greater species richness in hybrid aspen plantations. Overall, generalists showed a higher abundance and species richness throughout the stand types assessed, than specialists. Furthermore, my results indicate a negative influence of high basal area on the encountered bird community.

A study by Felton et al. (2016b) investigating the bird diversity in production and protected oak forests in Skåne, found 19 bird species and an abundance of 34 individuals in eight young (10-20 years) managed oak stands. These results can be compared to the bird diversity observed in poplar stands in my study, although the bird abundance observed in poplar stands was higher. In contrast, with respect to more mature (50-80 years) managed oak stands, Felton et al. (2016b) identified 34 bird species and 251 individuals in five stands. This suggests that when oak production stands approach maturity, they support a higher bird diversity than was found in fast-growing birch and hybrid aspen stands in my study. Considering that the stands surveyed in my study had a maximum of 30 years, an increasing vegetation structure with age (Gruss & Schulz 2011) might explain the higher bird diversity found by Felton et al. (2016b). It is important to mention that the radius used by Felton et al. (2016b) was double of that used in my study (40 m), which may explain the higher diversity observed. Furthermore, Felton et al. (2016b) surveyed both residents and migrants, during two survey periods, which very likely led to a greater bird diversity compared to my study. In addition, it is important to consider, that Felton et al. (2016b) were able to keep a 50 m distance from stand edges, and thereby likely reduced the influence of edge effects on their bird survey results.

4.1 Tree species

Regarding these overall results, I found support for the hypothesis that birch stands would show the highest abundance and species richness possibly because it is the only one of the assessed tree species that is native to Sweden. Nevertheless, some guilds like broadleaf-associated bird species or migrants showed high species richness and abundance in hybrid aspen stands. Furthermore, the proportion of all bird species observed in one stand type sometimes indicated higher proportions of guilds associated with the non-native tree species, even though the absolute numbers are lower overall, e.g. resident bird species in poplar. This indicates that the exotic tree species can also provide useful habitat to many bird species, even though these stands do not support the same level of diversity. The hypothesis regarding the benefits of native tree species was based on Flaspohler and Webster (2011), who argue that exotic tree species usually show a lower stand structure, which results in a lower abundance of birds. However, the results of the vegetation data of this study show a more diverse stand structure, in both hybrid aspen and poplar, due to the larger understory and higher volume of dead wood found in these stands. Nevertheless, looking at the species distribution in the understory, poplar stands did seem to have less heterogeneity. The difference in stand structure between my study and the one by Flaspohler and Webster (2011) could explain the high bird species richness and abundance in hybrid aspen stands, since heterogeneity in the vertical structure is an important habitat measure for many bird species (Immerzeel et al. 2014; Villard & Foppen 2018). Additionally, the gaps in hybrid aspen stands, seemingly created by windfalls, could impact the bird assemblage (Wesolowski et al. 2018), by creating a different microclimate associated with stand conditions and resources. Furthermore, hybrid aspen shares the characteristic traits of both the parent aspen species (Felton et al. 2013). Since aspen (*Populus tremula*) is native to Sweden (Karačić 2005), one could consider hybrid aspen to be phylogenetically similar to native tree species in Sweden, and therefore this tree species might provide more exploitable habitats and resources than the entirely non-European hybrid poplar. This assumption may also explain the relatively high bird species richness and abundance in hybrid aspen compared to poplar.

4.2 Basal area

I also found support for my second hypothesis, namely that bird species richness and abundance in less dense stands, as with silver birch, would be higher, as we found a significant negative effect of BA on both bird species diversity metrics. Furthermore, the highest bird species richness and abundance was observed in birch stands. Correspondingly, I also found the opposite pattern, whereby high BA seemed to explain the low bird species richness and bird abundance in poplar stands, which also supported a high proportion of generalists. In contrast, birch and hybrid aspen hosted more specialists. These findings correlate with the results indicated by Bielefeldt et al. (2008), that in mature poplar plantations, birds often prefer to occupy more open habitat edges. Considering that the high BA for hybrid aspen is based primarily on many trees of a small diameter in the lower stories of the stand, the less dense stand conditions may explain why hybrid aspen has a somewhat higher bird species richness and bird abundance than poplar (Gruss & Schulz 2011). Likewise, the high species richness of ground-nesting species and farm-associated species in hybrid aspen, such as the Yellowhammer (*Emberiza citrinella*), may be explained by the gap dynamics caused by the windfalls or the proportion of neighbouring agricultural land. Birch stands also showed a high species richness and abundance of ground nesters and farm-associated species, for which the open stand structure and a grass-dominated shrub layer - providing shelter opportunities - may explain their occurrence.

4.3 Bird ecological characteristics

When looking at the habitat preference of the encountered birds, generalists were the most abundant in all three tree species stand types. This lends support to my third hypothesis. Schulz et al. (2009) also conclude that generalists were the most abundant in poplar and willow SRF plantations. Conifer- and farmland-associated species were encountered in their highest numbers in birch stands. Nevertheless, broadleaf-associated species showed a higher species richness in hybrid aspen plantations, although the abundance of birds in this category was higher in birch. Looking at the proportion of habitat preference in each stand type, generalists and broadleaf-associated species provided a higher proportion of the total bird species observed in hybrid aspen than in birch. Overall, the high relative abundance of generalists may be explained due to the stand conditions found in early spring and the poorer stand structure compared to natural forests. When there is no foliage on the trees, forests provide fewer hiding places and food, but residents that forage on bark and twigs, such as Nuthatch (Sitta europaea), Woodpeckers (*Picidae sp.*), and Marsh Tit (*Poecile palustris*) can still be abundant. The surrounding landscape plays a major role as well, since conifer-associated species can be abundant in neighbouring stands, which may explain the occurrence of conifer-associated bird species, such as Coal Tit (*Periparus ater*), Crested Tit (*Lophophanes cristatus*), and Goldcrest (*Regulus regulus*) in my surveys (Wesolowski et al. 2018). In addition, the abundance of broadleaf-associated species can not only be explained by the composition of the stands, but may also be due to landscape-level influences. Since these species are often associated with shrubs and edge habitats, they can be more abundant in a mosaic landscape of forestland and farmland (Berg 2002a) as was the case in this study.

With respect to migratory status, residents and partial migrants were most abundant in birch stands, whereas migrants showed the highest species richness in hybrid aspen stands, but a higher abundance in birch stands. When looking at the species proportions, most of the birds observed in poplar stands were residents, and the lowest proportion of migrants was observed in birch stands. The two-storied structure found in hybrid aspen stands may help to explain the higher species richness of migrants. Northern European migrants are associated with open-canopy broadleaf forests and a high number of shrubs, which provide diverse feeding opportunities, nesting sites, and protection from predators (Felton et al. 2021). These characteristics are consistent with those in the hybrid aspen stands surveyed.

The nest site categories of the observed bird species correlated with the overall finding since all categories were most abundant in birch, followed by hybrid aspen and poplar. Looking at the bird abundance of nest site classes within each stand type, the highest abundance of cavity nesters was found in birch and hybrid aspen stands. Higher dead wood volumes found in hybrid aspen stands may have affected the bird species encountered (Felton et al. 2013), especially with respect to cavity nesters, whose abundance is positively linked to the amount of dead wood (Felton et al. 2016b). Another reason for the high abundance of cavity nesters may be that several of the bird species encountered in these stands, including all woodpecker species, European Crested Tit (*Lophophanes cristatus*) and Willow Tit (Poecile montanus) can carve tree holes themselves in dead trees (Wesolowski & Martin 2018). These carved holes can then be used by other cavity nesting species like Marsh Tit (*Poecile palustris*), Blue Tit (*Parus caeruleus*), Great Tit (*Parus major*), and Nuthatch (Sitta europaea) (Wesolowski & Martin 2018). The hybrid aspen stands supported the highest abundance of Great Spotted Woodpeckers (Dendrocopos major), which may help to explain why the highest abundance of cavity nesters was also found in hybrid aspen stands. The observation of a Green Woodpecker (*Picus viridis*) exclusively in poplar may likewise be explained by the high dead wood volume. Furthermore, Chiatante et al. (2019) found a positive influence of standard rotation length and SRF poplar plantations on the abundance of the Green Woodpecker (*Picus viridis*). The high abundance of cavity nesters in birch cannot be explained by the vegetation characteristics assessed in this thesis, since only small amounts of dead wood were found. Considering the young stand age of SRF plantations, a high abundance of natural tree holes seems unlikely. The reason why cavity-nesting species were nevertheless abundant may instead be related to a preference of Great Tits (*Parus major*), in particular, to forage in birch (Rytkönen & Krams 2003), or the surrounding landscape.

4.4 Study limitations

I could not find any significant effect of the QMD on the bird species richness and abundance. An analysis of the values provided, indicated little variation between the stand types. With respect to stand size, shrub layer, and dead wood volume, one reason for the insignificance could be the small sample size, which was limited to 18 stands. When looking at the detailed data for each stand, in terms of shrub layer and dead wood, there was a large variation between the tree species stand types. This highly variable distribution explains why these characteristics were not significant as explanatory variables. Therefore, an experimental setup that contains more stands for each of the three tree species stand types, could come to a different conclusion. Additionally, the stand size could influence the results, as Dhondt et al. (2007) found a negative effect of stand sizes under 3 ha on the bird numbers observed in SRF plantations. Furthermore, environmental factors, such as previous weather, surrounding land-use, or nearby forest management activities (e.g. tree felling, woodchipper) could have influenced the outcome of the study. Such factors should be kept in mind when interpreting the significance of my results. The vegetation characteristics measured are nevertheless included in the thesis, as they provide insights into the environmental conditions provided by these stands and could be relevant to future studies. In general, and especially when considering species-specific relationships to vegetation characteristics, such as those involving woodpeckers and dead wood, many of the vegetation characteristics assessed can be important in the interpretation of results. Additionally, it is important to mention that surveys conducted in second rotation stands, may come to different results due to differences in forest structure (Calladine et al. 2018).

The ages of the assessed stands could not be reliably determined for all stands, hence, a test of the significant influence of stand age was not conducted. In this regard Gruss and Schulz (2011) argue that stand age is a less important environmental driver than tree species and height, when trying to explain bird species diversity and abundance in SRF plantations. Thus, although I could not reliably age all stands, other variables that are closely related to stand age (e.g. basal area, structural heterogeneity) were captured. Looking at the different growth rates between birch, hybrid aspen, and poplar, with hybrid aspen as the fastest growing tree species in Sweden (Tullus et al. 2012), it is obvious that certain stand structures may be present at an earlier age in hybrid aspen than in birch plantations.

The surrounding landscape can have a large effect on bird species richness and bird species abundance. For example, Schulz et al. (2009) found that the surrounding landscape made a significant difference in the species composition in SRF plantations. Considering the landscape mosaic in Skåne, an effect of the landscape on the results of my study is likely (Felton et al. 2016b). In this master’s thesis, there were no resources available to assess the surrounding landscape in detail. What was done was a comparison of the bird study results of stands smaller than one ha to larger stands in order to investigate possible distinctions, especially in the bird abundance. However, distinctions were not found. For this reason, the only information on landscape present is the mosaic structure between forest land and agricultural land (Berg 2002b). The stand size, which was found to be non-significant in this thesis, seems linked to the landscape effect and was proven significant in other studies (Gruss & Schulz 2011). This effect occurs mainly for bird species that have a large home range or are dependent on multiple habitats. For example, Chiatante et al. (2019) conclude that the occurrence of Eurasian Nuthatch (*Sitta europaea*), was explained by the landscape up to two km from the assessed forest. In the case of the stand sizes assessed in this thesis, this means that for the stands below 1 ha, the landscape could have had an important effect on the prevalence of some bird species. Looking at the home ranges of Willow Tit (*Poecile montanus*) which can vary from 5 to 15 ha (Lindbladh et al. 2020), even the largest assessed stands could be considered a minor part of the total habitat found within their territories. Some bird species, that are considered forest-dependent, like the Woodpigeon (*Columba palumbus*) or Yellowhammer (*Emberiza citronella)*, nevertheless forage on farmland (Gruss & Schulz 2011; Blondel 2018). This highlights how the surroundings of the assessed plantations can have an impact on the encountered bird species richness and abundance in this study. Considering the small average size of hybrid aspen stands, the connection between landscape and stand size may help to explain the high bird species richness of farm-associated species and ground nesters that was found.

4.5 Management implications and future research needs

Overall, the results indicate that from an ecological point of view, birch and hybrid aspen appear to provide more suitable conditions for diverse bird communities than poplar. The influence of the basal area on the bird species richness and abundance, indicate that thinnings of dense plantations might have the potential to improve the bird diversity of these stands by lowering their basal area. Even though dead wood was not associated with a significant effect on the bird community in this study overall, the fact that dead wood volume was associated with the abundance of some bird species, together with the results of other studies (e.g. Felton et al. 2013), suggest that this is still an important determinant of bird diversity. I therefore suggest that leaving dead wood in SRF plantations can positively affect the diversity of the present bird community.

Future research in similar stand types, but with more replicates could be conducted to assess whether dead wood has a significant impact on the overall bird species richness or only on certain species. In addition, further studies comparing the bird diversity in all FGB used in SRF plantations could be done. Many studies on bird diversity in willow and hybrid aspen SRF plantations have been conducted already (Berg 2002a; Gruss & Schulz 2011; Pedroli et al. 2013; Lindbladh et al. 2014). Hence, a comparison of these studies and studies considering other FGB could be conducted to obtain a greater picture of which stand type has a positive impact on bird diversity. Considering the landscape effect and the mosaic landscape in southern Sweden, a comparison of the bird study results and the bird diversity in the surrounding fields would enable us to see whether SRF plantations benefit the bird diversity at a landscape scale. Furthermore, investigations of the landscape influence on the bird diversity in the assessed stands may help to clarify the observed bird species composition, and especially the high bird diversity in birch, even though the vertical structure was rather low.

Conclusions

In this study, I analysed the bird species richness and abundance in fast-growing stands of birch, hybrid aspen, and poplar in Skåne, Southern Sweden. My findings indicated:

- That tree species selection influenced the bird community. Birch was the tree species with the most diverse bird community, showing the highest levels of species richness and abundance, followed closely by hybrid aspen. Poplar was the stand with the lowest bird diversity.

- That high basal area was associated with a less diverse bird community. Poplar stands with a higher basal area supported fewer birds than birch stands with a lower basal area.

- That broadleaf-associated species and migrants showed a greater species richness in hybrid aspen plantations. Generalists were the most abundant guild overall.

No significant effect was found for the QMD, shrub layer, and dead wood volume in the surveyed stands. Nevertheless, these measures describe the stand structure and indicated a higher heterogeneity in the stand structure of the exotic tree species, and the hybrid tree species, than the native tree species birch. This may explain the high bird diversity found in hybrid aspen, especially for certain bird groups. Overall, further research is needed to test the importance of specific vegetation characteristics on bird communities in SRF stands. Additionally, the results show a potential effect of the surrounding landscape on the bird communities encountered, which indicates the need for further research regarding landscape level influences.

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Popular science summary

How fast-growing trees affect bird diversity

Nina Oestereich

Biodiversity is increasingly threatened by the consequences of climate change. To combat this issue, energy sources that reduce the emission of fossil carbon, like fuelwood, are becoming more important. However, this shift puts natural forests at a higher risk of degradation and destruction. This can be avoided by planting genetically improved seedlings of fast-growing tree species. These plantations can produce a higher volume of biomass than traditional managed forests do. In Sweden, for example, silver birch, hybrid aspen, and poplar are planted in fast-growing monocultures. Of these tree species, only birch is native to Sweden. Often, fast-growing plantations are classified as agricultural land which allows management to diverge from traditional forest management, including the use of short rotation times and herbicides. However, this intensive management and use of exotic tree species can influence the biodiversity in such plantations. To measure biodiversity, it is beneficial to consider more easily detectable species that quickly react to changes in the environment, such as birds.

This study compared the bird diversity in plantations of birch, hybrid aspen, and poplar in Sweden. Additionally, it was investigated whether the structure of the vegetation influenced bird diversity. Overall, six plantations of each tree species were surveyed for their basal area to measure the density, the amount of dead wood, and the extent of the shrub vegetation. In spring, each plantation was surveyed twice for birds, showing territorial behaviour like singing.

The findings showed that the bird diversity differed between the tree species. The highest diversity was found in birch plantations, closely followed by hybrid aspen plantations and poplar plantations respectively. The basal area of the plantations seemed to play a role in the found bird diversity since a higher basal area negatively affected bird occurrence. Poplar plantations had the highest basal area of the three tree species, therefore the low number of birds encountered was not surprising. Overall, birds that are not dependent on a specific habitat were observed in highest numbers in all stands. This seems possible since these bird species can adapt to many different surroundings. The presence of dead wood and shrubs did not have a measurable influence on bird diversity. Nevertheless, this result provided information that hybrid aspen stands had a higher structural diversity than birch plantations. This seemed to influence the occurrence of birds specialised in broadleaf trees and migrant birds, which were more often found in these plantations.

These results can help forest managers to choose the right tree species for fast-growing plantations based on their effects on birds and biodiversity. This can therefore help in balancing the intensive management of such plantations and nature conservation to enhance biodiversity under a changing climate.

Acknowledgements

I would like to express my deepest gratitude to my supervisors, Adam Felton and Per-Ola Hedwall, for providing me with invaluable guidance and mentorship throughout the process of this project, which helped me develop my academic skills. Furthermore, thanks for paying attention to all the details needed to bring out the best quality in master's thesis. Special thanks to Adam for making it possible to finally include my passion for birdwatching in my studies with this project. Your knowledge and dedication have shaped the outcome of this thesis. Many thanks to PO for the guidance and feedback in all matters regarding the experimental design and data analysis of this thesis.

Special thanks go to Jamie Luna for providing me with all important information about the study stands, the contribution to the stand selection, and the support during my fieldwork.

This work would not have been possible without the cooperation of the forest owners of all surveyed stands. I would like to extend my sincere thanks to all owners and managers for giving me the permission to use the stands and for providing additional information.

Next, I would like to mention Ann Marie Ackermann, who sparked my interest in birdwatching with a club in primary school and without whom I would probably never have had the idea for this master's thesis.

Lastly, I would like to thank my family for their tremendous support, which made it possible for me to study abroad in Sweden. I would also like to thank my friends, who made the time in Sweden so special, for their encouragement, support, and patience.

Appendix 1

Table 1. Detailed results of all studied stands, giving information on the vegetation characteristics: Site name, tree species, year of establishment, size (ha), BA (m²/ha), number of understory plants/ha, dead wood volume (m³sk/ha) and decay stage, QMD (cm) and the species found in the understory.

Site	Species	Year	Size	BA	No.Underst	DWVol.	Decay	DBH	species understory
Sångletorp	Birch		1.17	15.100	0	0	0	27.30	
Skabersjö12	Hasp	1995	2.9	37.050	147.75	105.70	3	26.05	Hasp, hawthorn
Skabersjö67e	Poplar	2008	5.2	28.025	5.00	46.75	4	20.75	Poplar
Svenstorp	Hasp	1991	1.7	37.000	52.50	24.68	5	29.85	Hasp
Vomb	Birch		2.7	12.225	0	0	0	21.30	
Bellinga	Poplar		6.7	29.200	0	0.33	2	21.05	
Ellinge6	Hasp	1993	0.53	17.500	95.75	1.33	2	35.40	Hasp, hawthorn
Snogeholm	Hasp	1992	0.63	25.800	7.50	13.58	3	28.55	Hasp
Höör1	Poplar		0.6	42.125	60.50	0.23	2	20.83	Poplar
Höör2	Birch		0.6	24.275	11.50	0.05	2	22.95	Poplar
Skarhult	Birch	1980	7.4	15.275	3.50	4.95	4	27.60	Norway spruce, European beech
Trollenäs5	Hasp	2001	1.35	15.475	2.25	0.40	4	29.43	Oak, birch, Norway maple, alder, hasp
Eslöv	Poplar		5.8	13.775	138.00	0.08	2	24.83	Poplar
Trolleholm59h	Birch	1996	1.1	12.225	54.00	0.05	2	24.78	Cedar, Sambucus racemosa
Trolleholm78x	Hasp	1996	0.54	31.775	168.00	15.43	2	28.48	Hasp
Trolleholm355c	Poplar	2000	1.36	30.050	0	105.25	2	35.53	
Knutstorp2Tr	Poplar	2005	0.87	15.250	0	0	0	26.08	
Jordkull	Birch	1992	3.7	15.225	6.25	0.07	2	24.78	Sambucus nigra, European beech, Norway spruce

Appendix 2

Table 2. Detailed results for all surveyed stands regarding the bird survey, stating the site name and tree species, the bird species richness and the bird abundance, then Shannon's Diversity Index (H') and Shannon's Evenness (E).

Site	Species	Bird Species Richness	Bird Abundance	Shannon’s Index (H')	Shannon's Evenness (E)
Sångletorp	Birch	6	12	1.632630927	0.91118867
Skabersjö12	Hasp	12	21	2.375646548	0.956030501
Skabersjö67e	Poplar	8	12	2.360609114	1.135213021
Svenstorp	Hasp	5	12	1.517106397	0.942631204
Vomb	Birch	14	22	2.411205531	0.913661672
Bellinga	Poplar	6	11	1.898597999	1.059627719
Ellinge6	Hasp	14	23	2.510007618	0.951100073
Snogeholm	Hasp	12	23	2.223413108	0.894767257
Höör1	Poplar	6	8	1.926914505	1.075431462
Höör2	Birch	12	23	2.426461576	0.976479972
Skarhult	Birch	16	25	2.722385621	0.981893059
Trollenäs5	Hasp	10	15	3.236945348	1.405787503
Eslöv	Poplar	10	14	3.256575854	1.414312923
Trolleholm59h	Birch	14	38	3.235672198	1.226071203
Trolleholm78x	Hasp	13	21	2.297629615	0.895779719
Trolleholm355c	Poplar	6	11	1.175465932	0.656040028
Knutstorp2Tr	Poplar	11	19	2.024977944	0.844481395
Jordkull	Birch	14	25	2.662111953	1.008735931

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