Exploring forest bird diversity in epiphyte rich temperate deciduous forests

A case study of Söderåsen National Park

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Abstract

In this study I investigated the diversity of forest birds in relation to epiphyte richness in temperate deciduous forests, using the Söderåsen National Park in southern Sweden as a case study. My study focused on comparing the bird species richness and abundance across two site categories of forest which were previously identified as being high (Category A) or low (Category B) in epiphyte species richness. I inventoried bird species richness and abundance using point count surveys which were conducted in early spring, while focussing on those individuals that were exhibiting territorial behaviour. A total of 406 birds of 23 species were found, with 231 individuals displaying territorial behaviour. While no statistically significant differences in overall bird species richness or abundance were found between the site categories, sites with higher epiphyte richness showed higher numbers of insectivorous bird species and abundance exhibiting territorial behaviour. The red-listed Marsh Tit (*Poecile palustris*) was only found to showing territorial behaviour in the epiphyte rich site category (A). These results suggest that epiphyte rich forest may support a distinct bird community, possibly due to greater habitat complexity, although a direct causal relationship remains unconfirmed. This study highlights the ecological importance of maintaining a heterogeneous forest landscape and calls for future research, especially during periods when migratory bird species are present to clarify whether any link occurs between sites rich in epiphytes and sites rich in bird diversity.

Keywords: Beech forest, Habitat guilds, Red-listed species, Sweden, Trophic guilds, Protected areas, National Park, Söderåsen, Broadleaf, Insectivores, Forest structure, Marsh tit, Biodiversity indicators

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Abbreviations

Abbreviation	Description
VC	Forest Value cores, areas that were inventoried to have a certain diversity in species in the study by Malmqvist and Weibull (2007)
SMHI	Swedish Meteorological and Hydrological Institute
SLU	Swedish University of Agricultural Sciences

1. Introduction

Temperate deciduous forests can be found around the world in both the northern and southern hemisphere. They potentially would cover much of Europe, eastern Asia, and northeast North America. However, these regions are some of the world's most densely populated areas, and therefore, much of the temperate deciduous forests have been cleared over time. Many of the remaining forests are managed for wood production, and only a few support some of the natural conditions and disturbance dynamics that these forests naturally have the capacity to support (Savill, 2004). This has created a landscape where much of Europe's biodiversity associated with these forests is scattered and fragmented in different hotspots (Wilson and Peter, 1988). In Europe only 15 percent of forest habitats are classified as having a favourable conservation status (AEE., 2019). When looking at the biodiversity in Sweden, most red-listed species can be found in southern Sweden's temperate deciduous forest, despite its small area compared to Sweden's northern boreal forests that cover larger areas (Berg *et al.*, 1995). This indicates that conserving temperate deciduous forests is vital to ensuring the persistence of associated species in the future. Most of the areas that are classified as temperate deciduous forests are composed of broadleaf tree species. Broadleaf forests are mainly secondary forests, having developed after the logging of primeval forests or regenerating in agricultural areas that have been abandoned. They include both planted and naturally regenerated forests that can vary in management intensity (Wilson and Peter, 1988; Savill, 2004; Adams *et al.*, 2019). These forests can develop a varied stratified stand structure within them: emergent trees, canopy, subcanopy, shrub layer, and herbaceous layers. This variety in structure and layering of forests gives these types of forests the capacity to provide habitat to a high diversity of flora, funga, and fauna (Roxburgh and Noble, 2001; Currie and Bergen, 2008).

Temperate deciduous forests have an average daily temperature range varying between -30°C and 30°C, with a yearly average of 10°C. Large variations in temperature over different seasons are typical for these types of forests. Precipitation can range from 750 to 1500 millimetres yearly (Adams *et al.*, 2019; *Temperate Deciduous Forest: Mission: Biomes*, 2025). These factors, along with the seasonality that this biome has, makes these forests have a long growing season of about 6 months (Roxburgh and Noble, 2001; Currie and Bergen, 2008). These factors together create a climate that can support a variety of epiphyte species.

Britannica defines an epiphyte as "any plant that grows upon another plant or object merely for physical support." (*Britannica*, 2025). Epiphytes are often thought to be associated with tropical forests, however, they also play a vital role in temperate deciduous forest ecosystems. Temperate epiphyte communities usually consist of fern and fern allies in the southern hemisphere and Himalayas and these areas can be conceived as the most diverse in the overall diversity of vascular plants in temperate-related epiphytes. However, locally abundant epiphyte communities in temperate forests can be found elsewhere, such as in central Europe (Zotz, 2005).

The epiphytes that can be found in Europe are highly sensitive to changes in their environment and can therefore be used as an excellent indicator for both forest health and air quality (Ellis *et al.*, 2014; Flores-Argüelles *et al.*, 2022). Light availability and humidity levels can also affect epiphyte colonization and growth. Tree-related epiphyte diversity is therefore highly influenced by the availability of certain tree characteristics (Wilson and Peter, 1988; Fritz, Brunet and Caldiz, 2009; Wierzcholska *et al.*, 2024). In previous studies, that were conducted in beech (*Fagus sylvatica*) forests of southern Sweden, the age of trees has been shown to be the characteristic that affects the composition of lichens the most, alongside the characteristic of smooth bark vs moss cover. In the same study, bark pH and tree vitality were seen to be of the highest importance for the bryophyte composition (Fritz, Brunet and Caldiz, 2009). Due to the sensitivity to all these characteristics, disturbances to the forest structure and microclimates caused by, for example, forestry can greatly reduce epiphyte diversity (Nascimbene, Thor and Nimis, 2013). Old-growth forests, especially temperate beech forests, not having high levels of anthropogenic disturbance, and the related allowance for the creation of a variety of tree microhabitats, these forests can support a high variety of epiphytes and are therefore important to protect (Fritz and Brunet, 2010). The presence of epiphytes has also been shown to help enhance the structural complexity and creation of microhabitats that benefit a variety of invertebrates and other species groups, which in turn help other species groups' diversity, such as birds (Fritz, 2009; Díaz *et al.*, 2012; Wierzcholska *et al.*, 2024).

There is a variety of bird species that can be found in temperate deciduous forests. These birds can be classified in various ways, from their annual movement behaviour (i.e. migrant, resident), to classification based on diet, habitat or nesting preferences (Lopes *et al.*, 2016; Fraser *et al.*, 2017; Martin and Fahrig, 2018; Klein *et al.*, 2020). Different bird species can occupy different parts of the strata from the forest canopy to the forest floor, much like epiphytes. Birds occupy these different parts due to the niches they occupy for their foraging and/or nesting requirements. The different parts of the stratification will at the same time need to contain certain characteristics, depending on birds specific habitat requirements, such as deadwood, and large vs small diameter wood (Urban and Smith, 1989). Woodpeckers, for example, are a family of bird species that require certain tree and habitat characteristics for nesting, roosting, and foraging, but can also create important habitat features for other species. This makes woodpeckers a keystone species throughout much of their range (Mikusiński, 2006; Drever *et al.*, 2008). Black woodpeckers (*Dryocopus martius*), for example, have been described as key creators of nesting cavities in temperate beech forests (Zahner, Bauer and Kaphegyi, 2017). The cavities that woodpeckers create are then not only used by other bird species for nesting, but can also create specific microhabitats that can support a variety of epiphyte species.

Lichens play an important role in maintaining the food webs that are present in forests. Multiple studies have shown that, like in the study from (Ellis *et al.*, 2015), however, the direct correlation between epiphyte species diversity and bird species diversity has not been demonstrated as yet in temperate deciduous forests (Ellis *et al.*, 2015). There has been a study by Klein *et al.* (2020) that looked at the correlation between bird and lichen species richness, within managed boreal forests and their interaction with forest structure. Their study showed no correlation between the two taxonomic groups; however, their research was conducted within boreal forests and not specifically on the species richness effects of one taxa on the other (Klein *et al.*, 2020). Another study conducted by Uliczka and Angelstam (2000) looked at the use of bird and lichen species richness as indicators for forest conservation values. This study again did not focus directly on the effects that lichen species richness has on bird species richness, but did show that there might be a correlation between the two. The correlation between the species groups comes from the fact that both benefit from a structurally heterogeneous environment. The structural heterogeneity was provided by variation in tree species and tree ages. The same study also showed a positive correlation between the proportion of deciduous trees per stand and the number of bird species (Uliczka and Angelstam, 2000). Overall, no previous studies were found that directly considered whether areas with high lichen species richness indicate high levels of bird species richness in temperate forests. To fill this gap, studies around the subject need to occur within reasonable study areas; one of which is Söderåsen.

The study area, Söderåsen National Park, is located in the northwestern part of Skåne, in Sweden. The current shapes of the rock rift valleys in this area formed during the Younger Dryas period (Humlum, 1997). This left a landscape with deep fissure valleys, which are still present to this day. The largest of these valleys is the Skäralid Ravine. The formation made it hard for much of the forests in and around the ravine to be harvested, and thus, much of the forests in the ravine were left untouched over the years (Brunet and Isacsson, 2009). The temperate deciduous forests of Skåne are poor in tree species. This is mainly due to the scarcity of refugial areas during the ice ages in Europe (Nascimbene, Thor and Nimis, 2013). This has resulted in the temperate forests in and around the Skäralid Ravine area being dominated by mainly beech forests. Due to the forests in the rift valley being mostly left untouched, the area supports valuable biodiversity (Brunet and Isacsson, 2009). The rift valley has been protected since 1939, but to further protect the area, Söderåsen National Park was established in 2001, with the Skäralid Ravine occupying a significant part of the park. Some of the area around the ravine, which was included in the park, was previously managed for production until the 1980s-1990s (Brunet and Isacsson, 2009). However, when the park was created, forest operations were stopped, and current management is focused on restoring these areas to mainly beech forest. The park is 1625 hectares large and is currently made up of mainly deciduous broadleaf forests, of which most of the basal area is comprised of beech (Brunet and Isacsson, 2009; Naturvardsverket, 2009). The classification as a National park is the strongest protection of nature an area can get in Sweden (Naturvardsverket, 2024). Current management is focused on converting still existing spruce forests and clearcuts to deciduous forests. The park is also actively working on increasing the current amount of deadwood in the forest to a level that can be found in natural forest conditions (*About Söderåsen National Park*, no date). The area around Söderåsen has been studied for its biodiversity in the past (Brunet and Isacsson, 2009). A study conducted within the park by Malmqvist and Weibull (2007), focused on red listed species of lichen and mosses and found 62 red listed species within their study sites (Malmqvist and Weibull, 2007). A study by Thurell (2024) was built on the Malmqvist and Weibull (2007) study and looked at the presence of deadwood within the park and the difference between the unmanaged forests and historically managed forests in the park. The study showed that the amount of deadwood was overall higher within the park compared to managed forests, but not at the level that natural untouched forests would have (Thurell, 2024). Studies within Söderåsen showed that the area supports a high variety of fungi, plant, and animal species, including several red-listed lichens, mosses, and fungi (Malmqvist and Weibull, 2007; Brunet and Isacsson, 2009). It is for this reason that Söderåsen was deemed as an excellent location to study bird species richness within epiphyte species-rich areas.

Current studies might suggest a correlation may occur between epiphyte species richness and bird species richness within temperate deciduous forests and in particular beech forests. This is due to their common need and preference for structurally complex, old, and tree species-rich forests. This type of forest is often associated with old-growth forests and thus suggest the correlation between the two groups' species richness is due to their common habitat preference, and not the groups directly affecting each other (Moning and Müller, 2009; Storch *et al.*, 2023). Other research, however, might suggests that there is a possibility that the two groups do affect each other directly. A study done by Nadkarni and Matelson (1989) showed that some bird species use epiphytes for foraging as well as a source of food and nesting material. However, this study was conducted in neotropical forests and thus may not be directly relevant to the temperate deciduous context (Nadkarni and Matelson, 1989).

Relations between species are a key factor to consider for forest conservation strategies and forest management (Muys *et al.*, 2022). As much of the natural vegetation cover in Europe consists of temperate deciduous forest, and biodiversity conservation has become an important European goal, this study can provide the knowledge needed to help guide future forest management in Europe.

The aim of this study was to determine whether bird species richness differs between areas previously established as being high vs low in epiphyte species richness, within a temperate deciduous forest. There was the possibility that epiphyte species richness and bird species richness directly affect one another; however, answering this question is outside the scope of this thesis. In other words, I evaluate whether a pattern occurs in the data, but I do not evaluate the underlying processes or drivers. I hypothesized that there would be a slight difference between the two sites; specifically, that the sites with the higher epiphyte diversity would show higher bird diversity. To evaluate bird diversity, I used the point-count method for surveys, and evaluated my results in terms of bird species richness, bird abundance, and specific taxa of interest (i.e. woodpeckers, red-listed forest species). Due to the timing of the thesis, I was limited to conducting surveys of the resident (early spring) bird diversity, and could not thoroughly include migrant species that arrive later in the spring.

2. Materials and methods

This study was based on two previous inventories and an inventory conducted by the author. A species inventory with Forest Value Cores (VC's) was conducted on behalf of the County Administrative Board of Skåne county, by Andreas Malmqvist and Henrik Weibull at Naturcentrum AB (Malmqvist and Weibull, 2007). The identification of species was assisted by cooperating experts. A secondary inventory was conducted by Gustav Thurell, as a Master's thesis, on deadwood amounts in the value cores previously determined and inventoried in the species inventory by Andreas Malmqvist (Thurell, 2024). A final inventory of bird diversity was conducted by the author, Luuk Breeker.

2.1 Study Area

The study area was located in the temperate zone of southern Sweden (56.0388° N, 13.2515° E). The area was fully within the boundaries of the Söderåsen national park in the province of Skåne. The park was established in 2001 and occupies 1625 hectares. The park falls within the administration of the Länsstyrelsen Skåne and is protected as a National Park, but also within Natura 2000 (Lansstyrelsen.se, 2025). Throughout the spring, a variety of migrating bird species occur within the park. This is due to species arriving to breed in the area or moving through to go further North or Eastwards to start breeding (Wirdheim, n.d.).

2.1.1 Inventory of Forest Value Cores

Between 2002 and 2003, an extensive inventory of nature value cores was carried out within Söderåsen National Park (Malmqvist and Weibull, 2007). These value cores were determined with the help of colour orthophotos, in combination with visits to a large amount of candidate stands. During these visits, assessments were conducted on valuable structures such as dead wood, old trees, moss and lichen-rich cliff walls, and any findings of red-listed and other rare species (Malmqvist and Weibull, 2007). During the inventories, wood living insects, fungi, birds, vascular plants, mosses, and lichens were inventoried with a particular focus on the lichen species. The lichen inventories were conducted in a more systematic way than the other groups. In the report, only red-listed bird species were noted, and during the inventories, no targeted or systematic focus was allocated to inventorying these species (Malmqvist and Weibull, 2007).
The goal with the lichen inventory was to enhance knowledge about the park for both public attraction and to help with future management decisions within the park.

After the inventory, the VC’s were subsequently allocated into two Categories, Category A or Category B, which was done according to the Naturvårdsverkets guidelines (Malmqvist and Weibull, 2007):

- **Category A**: "Sub-areas with a documented occurrence of significantly many red-listed species, signal species, and other protected species for the natural type. In normal cases, the presence of older trees, large trees, deciduous trees, and dead wood characterizes the sub-area." (Malmqvist and Weibull, 2007)

- **Category B**: "Sub-area where no or only a few red-listed species have been found but where a significant presence of older and/or large trees, deciduous trees, and dead wood as well as signal species and other protected species justifies classification as a value core." (Malmqvist and Weibull, 2007)

In the report, it was noted that “Due to the high natural values in the national park, the bar has been set quite high for a stand to qualify as a value core” (Malmqvist and Weibull, 2007). The categorisation was done with the help of the national park administration to “assure a good resolution of the material” (Malmqvist and Weibull, 2007). As the lichen survey is focused on the lichens and mosses, and this was the only structured biodiversity survey thus far conducted, the park managers lacked additional knowledge about other species groups in the park. By conducting a targeted bird survey within Söderåsen NP, knowledge about the park’s bird diversity will be expanded.

2.1.2 Inventory of dead wood in value cores

In April of 2021, a deadwood inventory was conducted in Söderåsen (Thurell, 2024). This inventory was carried out with the goal of filling knowledge gaps about deadwood development in the park. The inventory focused on two different types of sites that were derived from the VC study. In the inventory, these two different categories were:

- **Category A**: Areas that were mostly undisturbed beech forests that had been protected for a longer period of time.

- **Category B**: Older historically managed beech forests that at the time of the inventory had been protected for 20 to 30 years.

The hypothesis in Thurell (2024) was that “The amount of dead wood is larger in A-value areas compared with B-value areas that have been previously managed” (Thurell, 2024). To confirm the hypothesis, 50 sample plots were inventoried. 25 of the plots were randomly distributed within the VC’s, and 25 outside. The inventories were then conducted according to the field instructions of the Swedish National Forest Inventory. With these instructions, all deadwood that had a diameter larger than 10 cm and was believed to have grown within the sample plot was noted. Each sample plot had a 10-meter radius, resulting in 314 square meters of inventory area per plot. For each deadwood piece that met the requirements, a certain set of variables was noted: the status of the deadwood, meaning if the deadwood was a standing dead tree or stump or was lying on the ground, diameter, length, species, and degree of decomposition (Thurell, 2024).

2.2 Bird surveys

The inventory of birds done by the author was conducted over three weeks, starting on the 28th of March and finishing on the 12th of April 2025 in Söderåsen National Park. The inventories were done in the form of point count surveys in two separate area types previously categorised in the VC report. These categories are the A and B categories previously mentioned in 2.1.1 Inventory of Forest Value Cores.

2.2.1 Point count bird survey plots

For this study, I used the point count survey method. The point count survey method involves a surveyor standing stationary while noting observed birds within a designated circular plot around the surveyor. These plot surveys are then repeated over an area to estimate the abundance of birds (Bibby, Burgess and Hill, 1992). In my surveys, the circular plots were designed to have a radius of 30 meters. For the selection of my point survey plots for the bird survey, maps were used from the VC report that specified the locations of the category A and B areas. To find proper plot locations within A and B areas, a set of requirements was made to select the plot locations that would provide the most accurate data possible while still being practically possible to use for the bird surveys. For example, in some cases, category A or B areas overlapped in part with steep embankments that were too difficult to descend or ascend during early morning bird surveys. In such cases, the survey point was placed as proximate as possible to the map-designated survey point location. For each category A and B, 6 sites were selected prior to going into the field (i.e. using the maps) that were large enough to contain 4 plots while at the same time ensuring that the survey points were not too close to another site or opposing category. To do so, circles with a radius of 30 meters were created digitally and placed onto the map to see where survey points could fit within the site. The plot edges were also at least 30 meters away from each other to spread the survey effort throughout the A and B categories and help distinguish whether a bird was within or outside each survey area, while also trying to prevent bird territories from overlapping over multiple plots. This resulted in at least 90 meters between different plot centres within the same site. These locations were then entered into Avenza Maps, which is a mobile mapping app, and physically visited to confirm they were practically suitable for use as bird survey locations. These plot visits were done the day before the surveys, and if during these visits it was found that the location was unusable, the point was moved to a location that still met the requirements as close as possible to the original location. If the location was then deemed to meet the requirements, the location was marked with red and yellow tape to ensure the survey's points could be easily found again and to ensure that repetition of surveys was done in the same location during subsequent resurveys of the same plot. The location coordinates were also noted down within Avanza Maps once the location was deemed appropriate. For guidance in some plots at the edge of the 30 meters green tape was used to mark the edge of the plot. With the requirements set, 12 sites were determined, of which 6 were A sites and 6 were B sites, and in each site 4 plots were placed as can be seen in *Figure 1*.

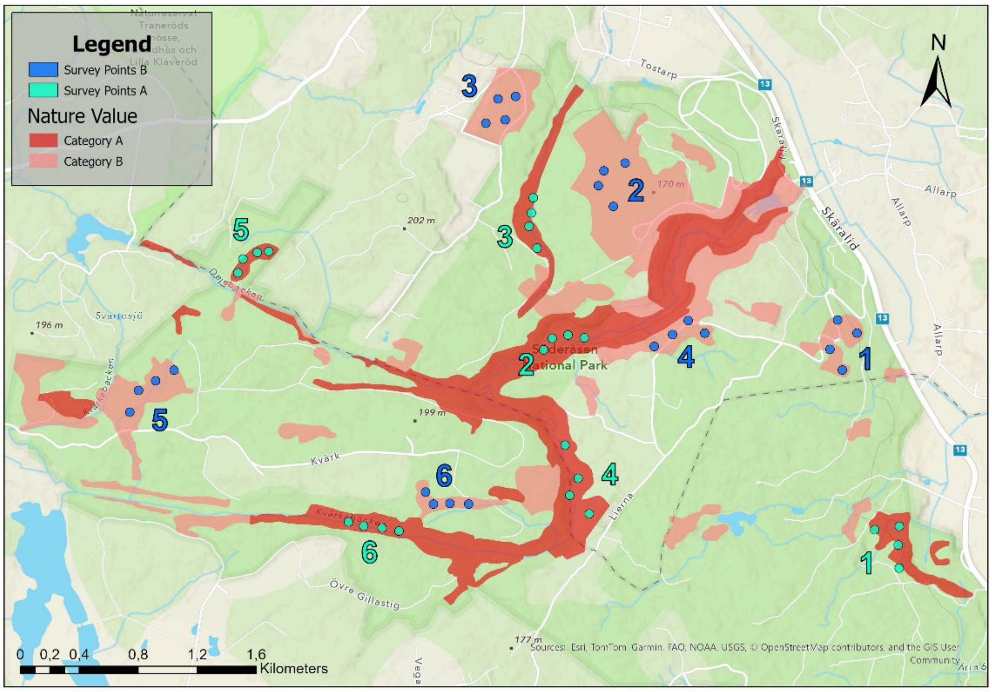
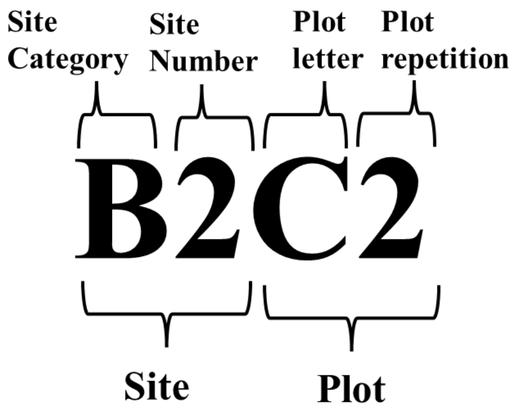


Figure 1. Map showing A and B site categories and the survey point numbered by site. [ArcGIS map])

Each of the site and plot locations was then given a code. The code, consisting of four digits, starts with an A or B for the category of the site, followed by the number of the site. Following this, is the plot letter with the repetition of the plot for the day. This then creates the full code where the first two digits tell the site location and the second part, which plot and which repetition of the day the survey was in.



2.2.2 Species inventory

To inventory the species, surveys were done in each of the predetermined plot locations. The surveys were started at sunrise, for which the time was sourced from the app created by the Swedish Meteorological and Hydrological Institute (SMHI), set on the nearby Ljungbyhed location. When ordering the surveys, I alternated between starting categories and plot order over the survey days to reduce possible bias from e.g. surveying more category A sites earlier in the morning than category B sites. Two sites with the same site number where surveyed after each other, and this was repeated in the same morning. This resulted in two sites surveyed each day two times, with this site routine being repeated during a subsequent visit six to seven days later. I conducted my bird surveys in a total of 12 days over three weeks, for which each of the 12 sites were inventoried 4 times. To reduce variability between the repeated surveys, surveys were only conducted in suitable weather conditions to reduce variability in bird activity and detectability during the surveys. Suitable weather conditions were classified as minimal wind and precipitation. Minimal wind was classified with max wind speeds staying below 14 m/s and average wind speeds staying below 10 m/s. However, due to the weather station being located outside the park these higher wind speeds where not observed by the surveyor. Minimal precipitation was classified with precipitation below 0.5 mm per hour.

At the start of each site survey the date, site code, site order, temperature, sky condition, wind strength, and start time were noted down, with the help of the SMHI app, at the first plot. After these variables were noted down the survey started. In each plot I stood on the previously determined location and listened and looked for any birds within the 30 meter radius of the survey points for 6 minutes. During the survey four different types of interactions were noted.

1. **Songs:** Vocalisations that are typically long and complex, that are generally associated with territorial, courtship and mating behaviour of birds.

2. **Calls:** Vocalisations that are typically shorter and often serve as a warning to others and are used by some flocking birds to keep in contact with each other.

3. **Visuals:** Bird seen within the survey plot area.

4. **Drums:** Fast and repetitive striking of a woodpecker's bill against a substrate to establish territory and/or attract mates.

These interactions where then noted per individual (Mya, 2014). If birds engaged in any other behaviour e.g. nesting behaviour, or if anything notable happened during the survey time, this was noted as well. During each survey audio recordings of the survey were made with the help of the Merlin app made by CornelLab. The app provides bird species identification based on their vocalisations with the help of vocalisation recognition software integrated in the app.

When walking into a survey point on occasion some individual birds would be disturbed and e.g. fly out of the survey point. These birds were also noted. After each plot was surveyed the finish time of the site was noted and any temperature or wind strength changes were noted with the help of the SMHI app.

2.2.2.1 Special notations

During the surveys certain bird species outside of the plot would also get noted as present but not in the plot, but only if the birds were found to be within the site but not the plot. This was done for all woodpecker and predatory bird species. This data was then not used in the species diversity data of the plots but as additional data which will be mentioned in the results. These birds were still noted because of the fact that they occupy much larger territories and are also important indicators of biodiversity.

2.3 Data analysis

All statistical analyses were done in RStudio (Version 2024.04.2). To be able to use the data within RStudio the data collected in the point count bird surveys was put into Microsoft Excel, in a format recognised by RStudio.

For the data analysis two different types of data were used. The data that was collected in the point count survey, and data collected from online sources about the species that were noted during the point count survey. For each of the noted species during the point count survey the red list status was gathered from the 2020 Rödlistebedömning on the Artfakta website. The trophic classification of each species was also gathered from Artfakta (SLU, 2025). There were three trophic classifications which were noted for the bird species; granivores (birds feeding predominantly on seeds), insectivores (birds feeding predominantly on insects), and omnivores (birds with no predominant diet) (Burin *et al.*, 2016). To distinguish the field collected behavioural data between territorial and nonterritorial behaviour, each species territorial behaviour was noted. For most of the species territorial behaviour constituted singing except for the woodpecker species and the Jay (*Garrulus glandarius*). The woodpecker species and Jay do not sing and show territorial behaviour in other ways. The woodpeckers drums to establish territory and the Jay uses calls (Mikusiński, 2006). For the Hawfinch (*Coccothraustes coccothraustes*), both the call and song were classified as territorial behaviour, because of the extreme difficulty distinguishing between the two. Species were also categorized in terms of their respective forest preference. These preferences were allocated based on the species general preference of forest habitat. The species were divided in three preferences; broadleaf, or conifer for species preferring forest habitats compiling for the majority of trees from these groups, or generalist species that have no particular preference. This classification data was sourced from Felton *et al.* (2021) for the majority of species encountered during the bird surveys. However the classification for Grey wagtail (*Motacilla cinerea*), Stock dove (*Columba oenas*), Green Woodpecker (*Picus viridis*), and Hawfinch were not present in (Felton *et al.*, 2021). The missing data was collected from the following sources; Grey wagtail (Tyler and Ormerod, 1991), Stock dove (Kosiński *et al.*, 2011), Green Woodpecker (Gorman, 2020), and Hawfinch (BirdLife, 2025). The data which was collected in the field about woodpeckers outside of the survey plots was also put into a format recognised by RStudio.

The data that was collected included four surveys for each site. Out of these four surveys the species count was taken to establish the species present in each site. To calculate species abundance per site, encounter counts were taken from the repetition data. For each species, the repetition with the highest number of encounters was used to represent its abundance at that site. This approach was taken as research indicates that maximum abundance better correlates with true bird abundance than mean abundance data from repeated surveys (Toms *et al.*, 2006). RStudio was then used to plot the data into bar charts so that visual comparison could be made of the results. For the bar charts depicting mean values error bars representing 95% confidence intervals were added to illustrate variation across sites. The created bar charts were then categorized in three major categories being species counts, abundance counts, and woodpecker and Threatened species. Within the Threatened species graphs a particular focus was placed on the Marsh tits (*Poecile palustris*) due to this species being the only one that is classified as threatened in part due to habitat loss. Other threatened species recorded during the study were either classified as such due to disease, or also in part due to habitat loss, but their broader geographic ranges mean their presence is less directly relevant to the specific survey sites (SLU Swedish Species Information Centre, 2024). To assess whether the observed differences between territorial bird abundance or species richness between the site categories could be attributed to random variation, or if they reflect underlying differences between the two site categories a Mann-Whitney U test was used. The Mann-Whitney U test was performed in RStudio, and an approximate effect size (r value) was also calculated in RStudio.

A map was also created in ArcGIS, with the help of the GIS layers for the A and B sites from the study by Malmqvist and Weibull (2007). The coordinates that were noted in the field with Avanza Maps were then exported from the app as a separate layer and added into ArcGIS. The point layer was then manipulated with the buffer tool in ArcGIS to create 30-meter plots to scale. The symbology was then altered of the layer to visualize the plots, and numbers were added to visualise site numbers.

3. Results

A total of 406 birds of 23 bird species were noted over the surveys (Table 1).

Table 1. All bird species encountered over the time of the surveys

Species	***Forest preference***	***Site category***	***Swedish Red List Category***	***Trophic classification***
Black Woodpecker	Broad/Conifer	B	Near Threatened (NT)	Omnivore
Blackbird	Broad/Conifer	A, B	Least Concern (LC)	Omnivore
Blue Tit	Broadleaf	A, B	Least Concern (LC)	Insectivore
Brambling	Broad/Conifer	A, B	Least Concern (LC)	Granivore
Chaffinch	Broad/Conifer	A, B	Least Concern (LC)	Granivore
Chiffchaff	Broadleaf	A	Least Concern (LC)	Insectivore
Goldcrest	Conifer	A	Least Concern (LC)	Insectivore
Gray Wagtail	Broad/Conifer	A	Least Concern (LC)	Insectivore
Great Spotted Woodpecker	Broad/Conifer	A, B	Least Concern (LC)	Omnivore
Great Tit	Broad/Conifer	A, B	Least Concern (LC)	Insectivore
Green Woodpecker	Broadleaf	B	Least Concern (LC)	Insectivore
Greenfinch	Broad/Conifer	B	Endangered (EN)	Granivore
Hawfinch	Broadleaf	A, B	Least Concern (LC)	Granivore
Jay	Broad/Conifer	A, B	Least Concern (LC)	Omnivore
Marsh Tit	Broadleaf	A, B	Near Threatened (NT)	Insectivore
Nuthatch	Broadleaf	A, B	Least Concern (LC)	Insectivore
Redwing	Broad/Conifer	B	Near Threatened (NT)	Omnivore
Robin	Broad/Conifer	A, B	Least Concern (LC)	Insectivore
Song Thrush	Broad/Conifer	A, B	Least Concern (LC)	Omnivore
Stock Dove	Broad/Conifer	A	Least Concern (LC)	Granivore
Treecreeper	Broad/Conifer	A, B	Least Concern (LC)	Insectivore
Woodpigeon	Broad/Conifer	B	Least Concern (LC)	Granivore
Wren	Broad/Conifer	A, B	Least Concern (LC)	Insectivore

A total of 231 individual birds belonging to 18 species exhibited territorial behaviour during the surveys within the allocated plots.

3.1 Species richness

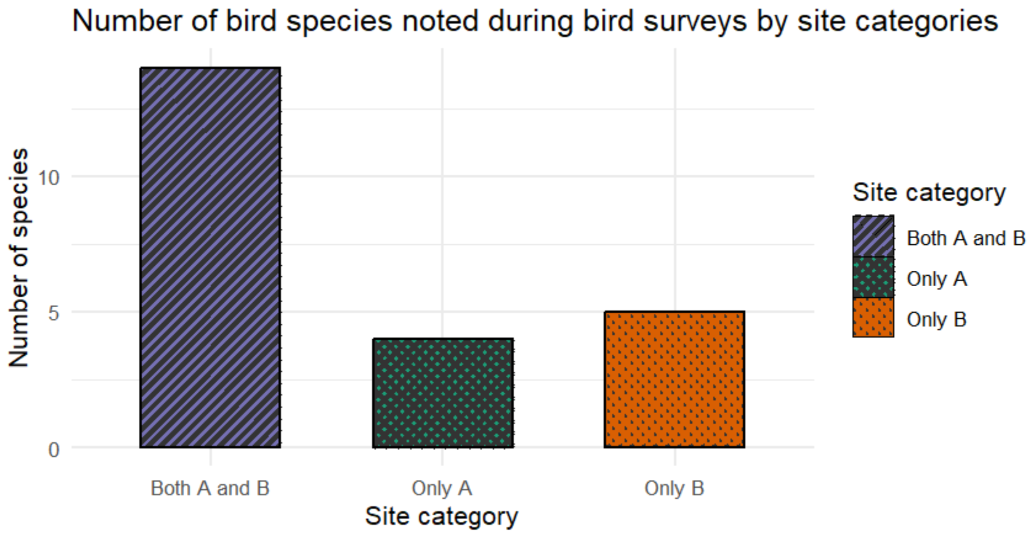


Figure 2. Number of bird species noted during bird surveys by site categories.

In both categories A and B 14 species where found, A had 4 species unique to the category, B had 5 species unique to the category (*Figure 2*). This makes a total for category A of 18 species, and in category B a total of 19 species (*Appendix Figure 16*). The most common species in the A site category was the Chaffinch (*Fringilla coelebs*), having 36 individuals noted. The second most common bird species in A was the Blue tit (*Cyanistes caeruleus*) with 18 individuals, and the Wren (*Troglodytes troglodytes*) as third most common in A with 17. The most common species for the B site category was the Brambling (*Fringilla montifringilla*) with 47 individuals, following the Chaffinch with 38 individuals. The Great tit (*Parus major*) was the third most common in the B site category with 19 individuals.

Figure 3. Total number of bird species found showing territorial behaviour over all sites per site category.

When looking at the number of species that showed territorial behaviour per site category, 17 species were found in the A site category, and 12 species were found in the B site category (*Figure 3*).

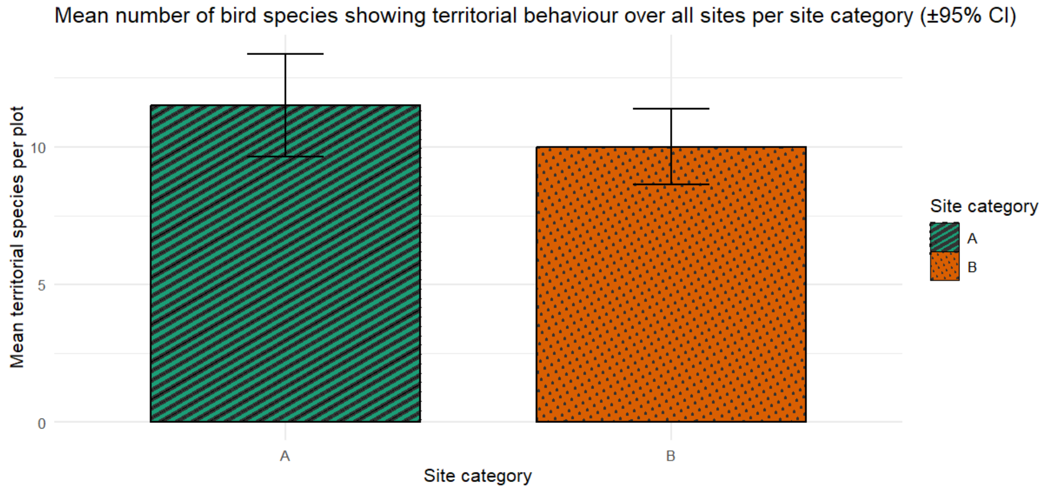


Figure 4. The mean number of bird species (±95% CI) across the six sites found for the two site categories.

The mean number of territorial bird species over all sites of the same category was for the A category 11.5 species and 10 species in the B category (*Figure 4*).

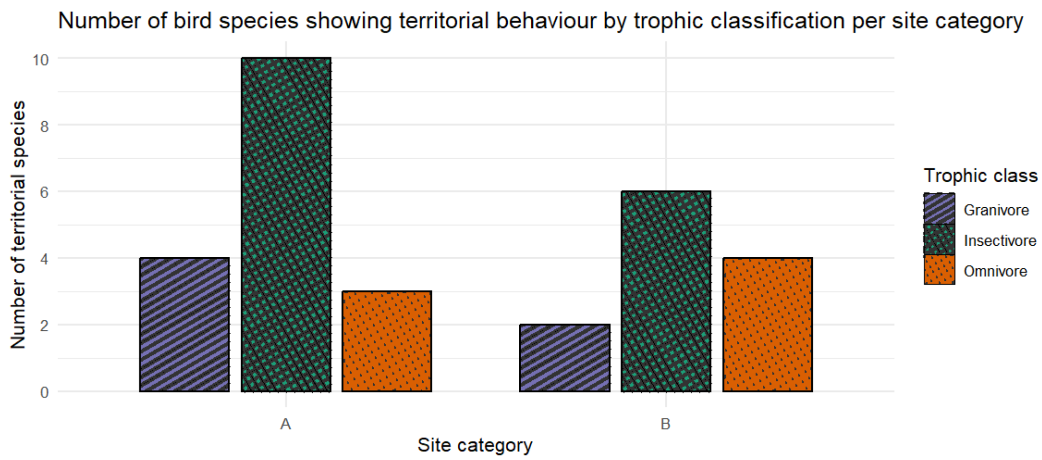


Figure 5. Number of bird species showing territorial behaviour by species trophic classification per site category.

In site category A 4 granivore, 10 insectivore, and 3 omnivore species showed territorial behaviour. In site category B 2 granivore, 6 insectivore, and 4 omnivore species showed territorial behaviour (*Figure 5*).

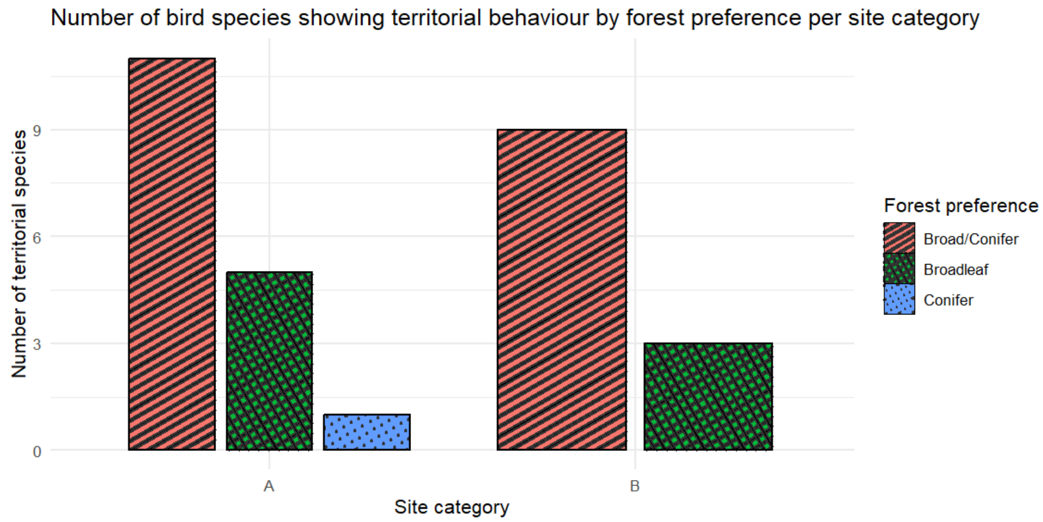


Figure 6. Number of bird species showing territorial behaviour by species forest preference per site category.

The category A had 11 species that are classified as generalists, 5 broadleaf preference species, and 1 species of bird preferring conifer forest that showed territorial behaviour. The category B had 9 species that are classified as generalists, and 3 broadleaf preference species of bird that showed territorial behaviour (*Figure 6*).

There were not any large differences between the A and B site categories in bird species. However, a small difference between the sites can be seen. The A site category had the greatest number of species that showed territorial behaviour, and the A site category also showed a higher number of insectivore bird species.

A Mann-Whitney U test was performed to compare territorial bird species richness between site category A and site category B.

There was not a significant difference in territorial bird species richness between the two site categories; $z = 22$, $p = 0.5655$, $r = 0.185$.

3.2 Bird abundance

The A site category had 173 bird individuals noted. The B site category had a total of 233 birds noted (*Appendix Figure 19*).

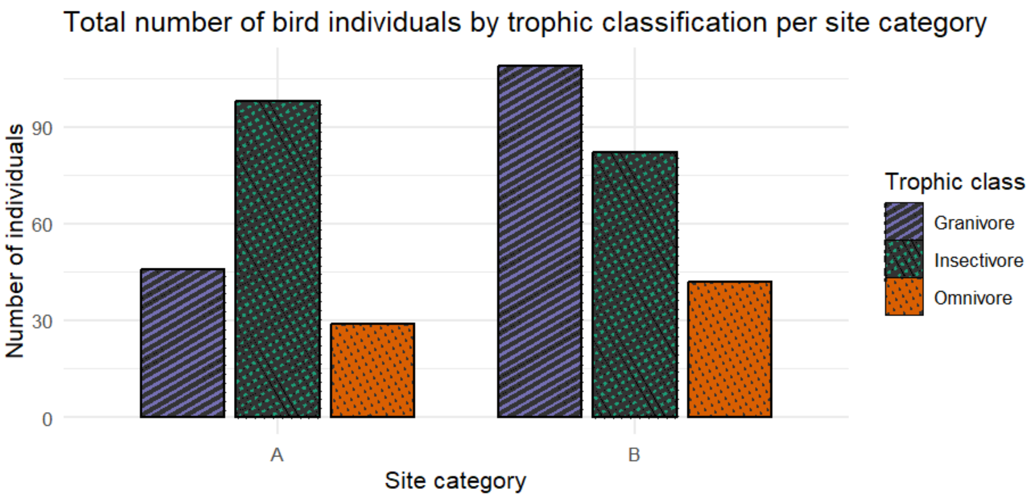


Figure 7. Total number of bird individuals by trophic classification per site category (including non-territorial).

The A site category had 96 granivore birds, 202 insectivore birds, and 46 omnivore classified birds. The B site category had 174 granivore birds, 165 insectivore birds, and 51 omnivore classified birds. The B site category had more granivore birds than the A site category (*Figure 7*).

Figure 8. Total number of bird individuals showing territorial behaviour per site category.

When looking at the abundance of birds showing territorial behaviour 119 birds were noted in the A site category, and 112 birds were noted in the B site category. Between the different site categories, the difference in prevalence was not noteworthy (*Figure 8*).

Figure 9. Mean number of territorial bird individuals per site category.

The mean number of territorial birds over all sites of the same category was for the A category 19.8 individuals and 18.7 individuals in the B category (*Figure 9*).

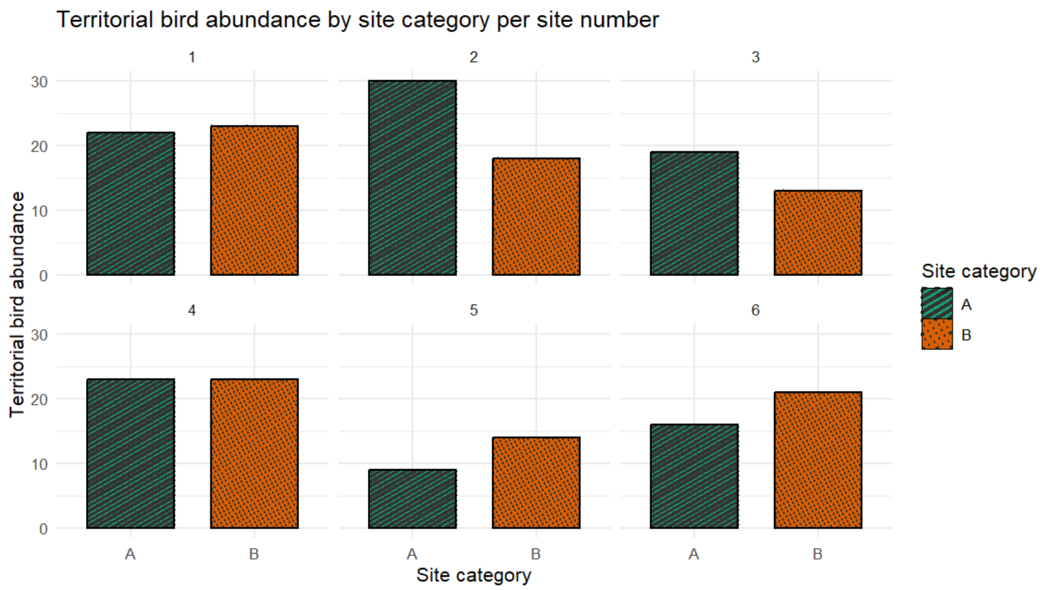


Figure 10. Territorial bird abundance by site category per site number.

The subdivided individual sites territorial bird abundances can be seen here with a variety in outputs between the different sites (*Figure 10*).

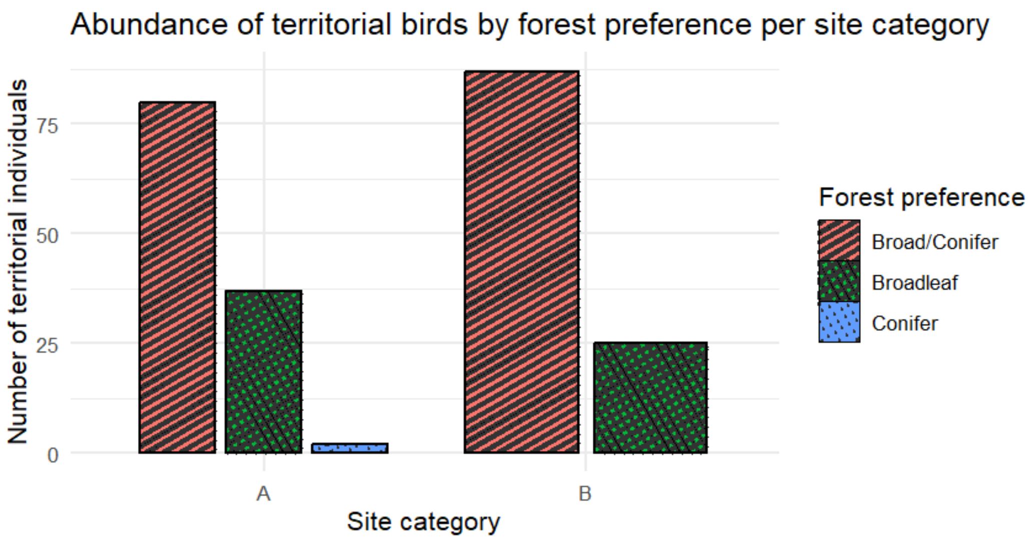


Figure 11. Number of bird individuals showing territorial behaviour by forest preference per site category.

In the A site category 80 generalist, 37 broadleaf preferred, and 2 conifer preferred birds were noted showing territorial behaviour. In the B site category 87 generalist, and 25 broadleaf preferred birds were noted down showing territorial behaviour. No large differences between the site categories can be noted (*Figure 11*).

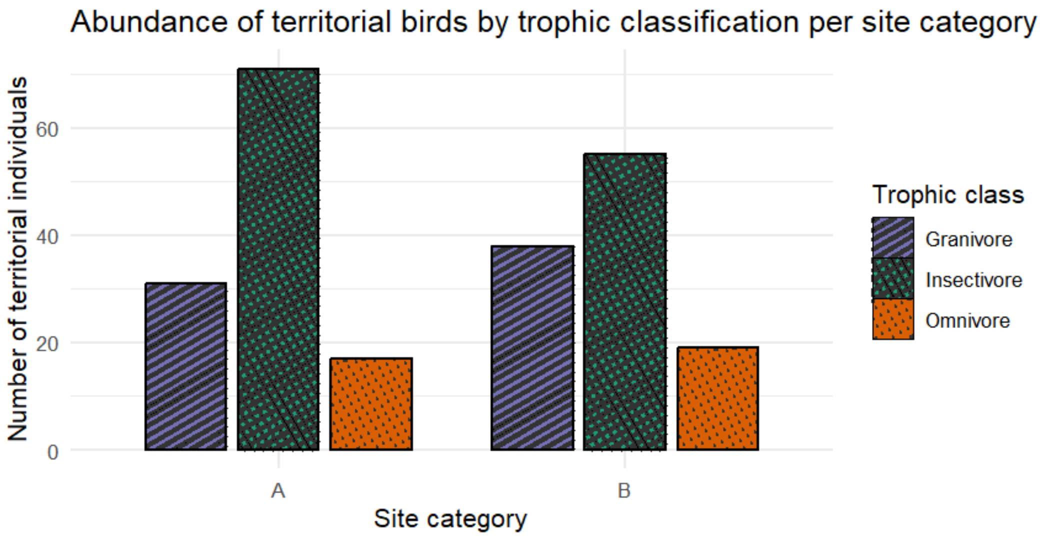


Figure 12. Number of bird individuals showing territorial behaviour by trophic classification per site category.

The site category A had 31 granivore, 71 insectivore, and 17 omnivore birds that showed territorial behaviour. The site category B had 38 granivore, 55 insectivore, and 19 omnivore birds that showed territorial behaviour. When only looking at the territorial birds the difference between site categories A and B in the amount of granivores is no longer noteworthy, however the difference between the categories in insectivore abundance is now larger (*Figure 7 and 12*).

A Mann-Whitney U test was performed to compare territorial bird abundance between site category A and site category B.

There was not a significant difference in territorial bird abundance between the two site categories; z = 20, p = 0.8089, r = 0.092.

3.3 Red listed species and Woodpeckers

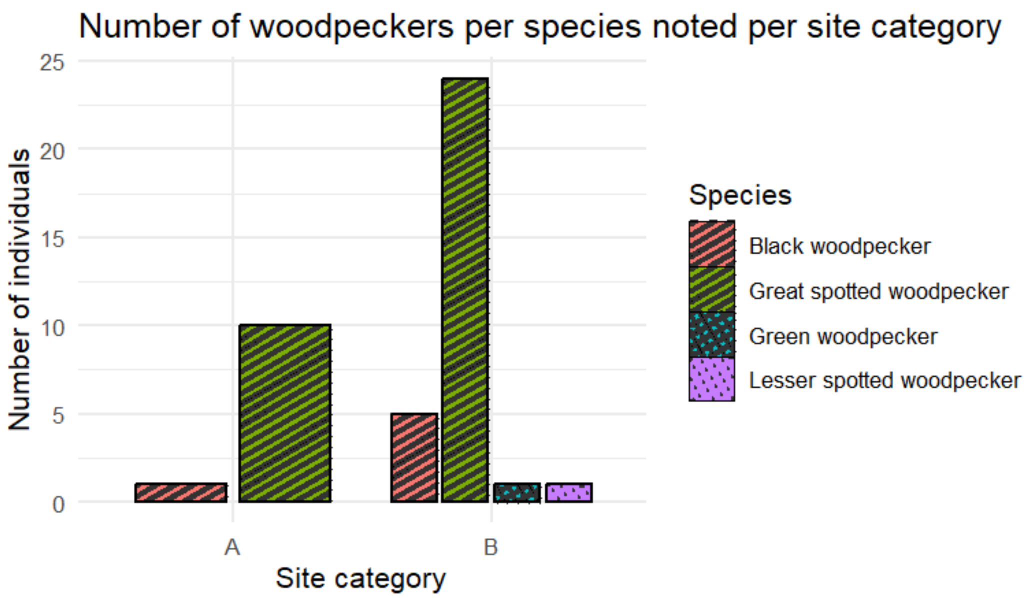


Figure 13. Number of woodpeckers per species noted per site category.

The Great spotted woodpecker and Black woodpecker were noted in both site categories. The Great spotted woodpecker was noted 10 times in category A sites and 24 times in category B sites. The Black woodpecker was noted 1 time in a category A site and 5 times in a category B site. The Green woodpecker, and Lesser spotted woodpecker (*Dryobates minor*) were both noted once each in a category B site (*Figure 13*). The total amount of woodpeckers noted in A sites was 11, and 31 were encountered in B sites.

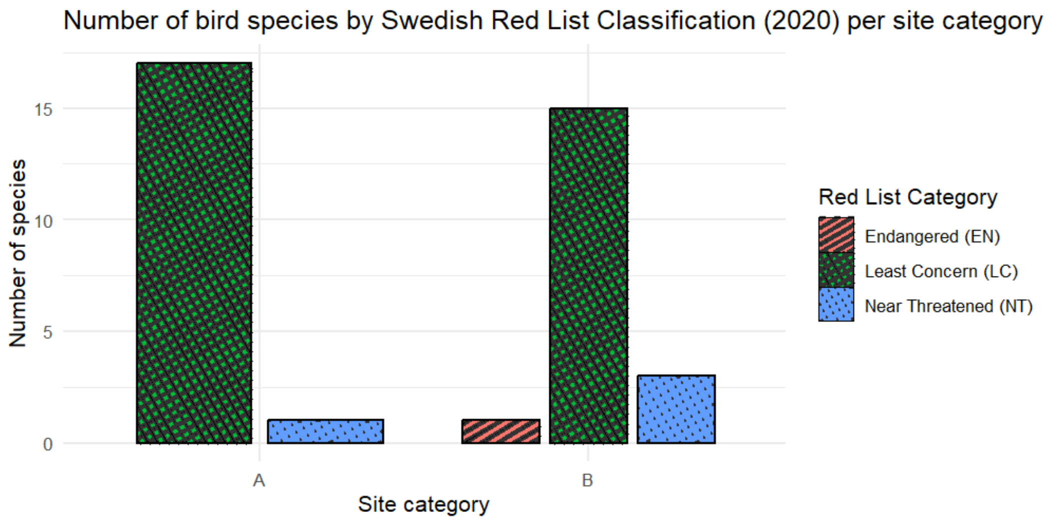


Figure 14. Total number of bird species by Swedish Red List Classification (2020) per site category.

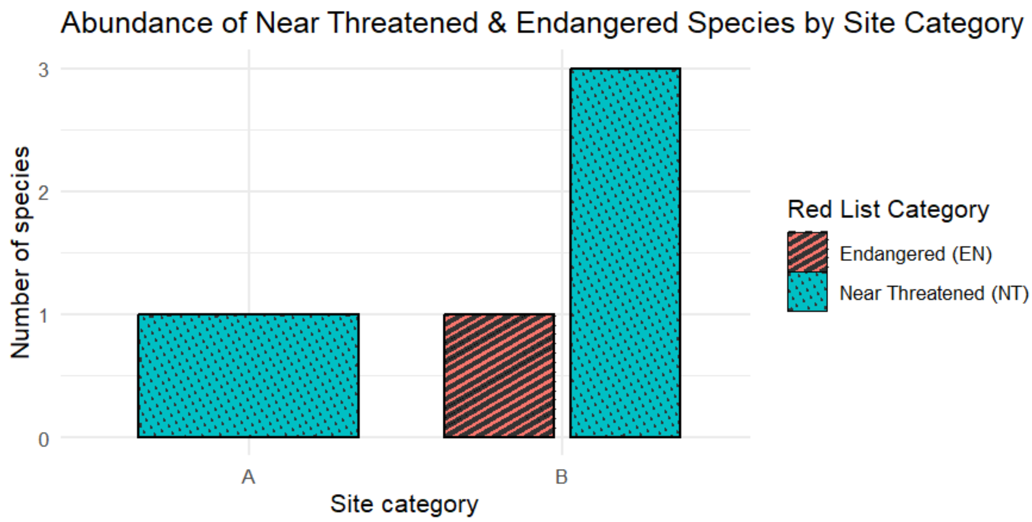


Figure 15. Total number of bird species classified as red listed by Swedish Red List Classification (2020) per site category.

Out of the species noted in the A site category, 17 were classified as Least Concern. In the B site category 15 species were classified as Least Concern (*Figure 14*). In total five red listed species were found during the surveys, four of the red listed species were classified as Near Threatened, one was classified as Endangered (*Figure 15*). Of the red listed species found, non were found in both site categories. When looking at the Marsh tit specifically (the only red listed species found showing territorial behaviour), seven were noted during the surveys in the A site category, one bird was noted in the B site category (*Appendix Figure 21*). Only in the A site category Marsh tits were observed showing territorial behaviour, with a total of 6 individuals been observed showing territorial behaviour (*Appendix Figure 22*).

4. Discussion

4.1 General findings

The results of this thesis indicate no direct relationship between epiphyte richness and the number of territorial bird species found in an area (Figure 4). There were non-territorial species that were only found in only one site category, however there was no one category with a large number of species unique to the site category (Figure 2). When territorial species were put into different classifications the number of species of each classification did have a difference between site categories. This difference could be seen with the trophic classifications where we could see a higher amount of insectivore species in the A site category that the B site category. This difference was not seen with the forest preference classification (Figure 5 and 6). This higher amount of insectivore species could be explained by insectivore species preferring areas with higher structural complexity similar to epiphytes (Fritz, 2009; Díaz *et al.*, 2012; Vergara *et al.*, 2021). For this reason, this study suggests that areas with high epiphyte richness don't have an overall higher level of bird species richness but might support a different variety of species. This suggestion that there is no difference is further supported by the results of the Mann-Whitney U test where we can also see that there is no significant difference in territorial bird species richness between the site categories. A similar result as the study by Klein *et al.* (2020) showed that epiphytic lichen richness is not correlated with bird species richness (Klein *et al.*, 2020). However, the species data represents only the presence of species, not the number of individuals.

To get a better understanding of the actual effect on the bird diversity the abundance of bird species should be looked at as well (Kempton, 1979). The difference in total abundance of birds per site category was not noteworthy (Appendix Figure 19). However, when the abundance of birds was further classified into trophic classifications a difference could be noted. When the abundance was classified into trophic classes per site category, granivore birds were seen to be almost twice as prevalent in the B site category than in the A site category. There was also a higher prevalence of insectivores but not a noteworthy amount. The abundance of omnivores was similar in both site categories (Figure 7). This difference between granivore and insectivore bird abundance between the site categories could be explained by the higher amount of structural forest layers in the A sites and the lack thereof in the B sites. Insectivore bird species prefer areas with more structural diversity, which is similar to epiphytes, which we also saw in the species number in Figure 5 (Fritz, 2009; Díaz *et al.*, 2012; Vergara *et al.*, 2021; Figure 5). The higher abundance of granivores in the B sites could be explained by the overall higher prevalence of seed food sources. This is due to the majority of the B sites comprising of old beech trees dropping large amounts of seeds, whereas the A sites contained a higher variety in tree ages and species that possibly did not provide the same abundance of food (Nielsen, 1977; Perea and Gil, 2014). However, this difference could also be due to migrant bird species moving through these areas. When bird abundance was classified according to forest preference per site category the difference between the site categories was not of noteworthy size (Appendix Figure 20). To further understand the bird diversity and importance of epiphytes to the bird diversity, the abundance of territorial birds should be looked at. The total abundance of territorial birds was not showing a large difference between the site categories, and when further looked at the mean number there was still no large difference seen (Figure 8 and 9). The territorial bird abundance by trophic classification however still showed a difference in prevalence between the abundance of insectivores between the A and B site categories. The A site category had a larger number of territorial insectivore birds than the B site category. The other trophic classification of granivores had no large difference between the site categories anymore, and the omnivores still had almost no difference between site categories (Figure 12). This is interesting as when we compare this with the previous discussed Figure 7, which showed all noted birds and not just territorial birds, the difference of granivores between the site categories was much larger (Figure 7 and 12). This change might imply that the granivore birds use the B sites just for foraging and less as territorial habitat, unlike the insectivores which showed a comparative similar difference between all birds and territorial birds noted in the different site categories. The difference between the sites could however also be explained by migrants moving through the area (Figure 7 and 12). The separation of habitat uses has been studied in some species such as the European Nightjar (*Caprimulgus europaeus*). Evens *et al.* (2018) found that the European Nightjar would connect between foraging and nesting habitats daily, and another study by Saab (1999) looking at patterns of habitat use of birds found that birds would occur more often in areas with both nesting and foraging areas (Saab, 1999; Evens *et al.*, 2018). These results, however, therefore suggest that areas with high epiphyte richness also don’t have a overall larger number of territorial birds but might support a different species makeup. This suggestion that there is no difference is further supported by the results of the Mann-Whitney U test where we can also see that there is no significant difference in the abundance of territorial birds between the different site categories.

The additional collected data on woodpeckers showed another difference in bird diversity between the different site categories. The number of woodpeckers was larger in the B site category (Figure 13). This difference is of interest because woodpeckers in many cases are seen as indicator species for bird diversity, forest structure, and habitat connectivity over the landscape (Drever *et al.*, 2008). This difference could be explained by the higher amounts of standing deadwood found in the epiphyte poor areas by Thurell (2024). Standing deadwood is an important resource for woodpeckers for foraging and other activities which could explain this difference (Aszalós *et al.*, 2020; Thurell, 2024). However, the presence of these woodpeckers does not provide much insight into bird diversity at the microhabitat scale, particularly in the site categories studied. Instead, their presence reflects bird diversity at a broader scale, such as across the entire national park, since woodpeckers typically occupy territories much larger than the individual study sites. (Roberge and Angelstam, 2006; Drever *et al.*, 2008; Lindbladh *et al.*, 2020). Two of the Woodpecker species found are also red listed following the Swedish Red List Classification (2020). In total five red listed species were found (Figure 14 and 15). One of the more interesting red listed species found in this study was the marsh tit, because it is the only species classified as red listed due to habitat loss in Sweden compared to the other red listen species found during this study (SLU Swedish Species Information Centre, 2024). The Marsh tit was found almost solely within the A site category, and only territorial individuals were found in the A site category (Appendix Figure 21 and 22). This could mean that the epiphyte diverse areas are of high importance to this species.

4.2 Study limitations

This thesis has a variety of sources of error and limitations which affect the reliability of the presented results and the conclusions following these results. There are sources of error and limitations directly connected to the conducted surveys and those connected to the data analysis afterwards. The surveys were limited to one geographical area limiting the reliability of extrapolating these results to other regions. The time of year the surveys were done also makes the collected data mostly relevant to resident bird species, because at the time of year that the surveys were conducted, the majority of migrant bird species had not arrived in the region. The area of the survey plots also contained several roads and paths through them. During some of the surveys cars or people travelled through the survey plot possibly bumping birds or affecting their behaviour. The driving of a vehicle through the plot also occasionally created sufficient noise to impair my survey efforts. The presence of visitors to certain areas of the park can also affect bird distribution as certain areas see higher visitor numbers on average due to the presence of roads and trails. The A site categories also often contained running water which also creates sound making it harder to detect birds.

Between many of the A versus B sites, there were additional factors that differed. The tree species composition, presence of water bodies, topography, and surrounding forest composition are just some of the many factors other than epiphyte richness and diversity that differed. A good example of factors other than epiphyte richness possibly affecting data results is the site number 5A which unlike other sites was surrounded by spruce monocultures. This was because 5A was located close to the border of the park (Figure 1). To reduce the effects of these differing site factors, more site replicates would need to be found and surveyed, ideally in additional beech-dominated protected areas. The data that was used to locate epiphyte rich areas is also dated, as it was collected between 2002 and 2003. Due to this large time gap the sites may have changed sufficiently for some survey areas that were previously classified as B sites, to now possibly be classified as A sites today, and vice versa. Observer bias can also not be ignored. During bird surveys different surveyors might make different assumptions regarding the distance to a vocalizing bird, which determines whether the individual would be counted by the surveyor. The experience of the surveyor also affects the reliability of the data collected as more experienced surveyors might recognise species faster making it possible for them to focus on other individuals in the plot that are otherwise missed (Bart and James D. Schoultz, 1984; Farmer, Leonard and Horn, 2012). Observer bias does not affect the results within this study as there was only one surveyor; however, this does affect the capability of comparing this study to other previous or future studies on the subject using the same methods. There are also multiple possible sources of error in the data analysis. The generating of p values to classify differences as significant between values may have been influenced by the limited sample size, and additional data might have been needed to enable a more reliable analysis. The human error in the manipulation of the data should also be considered. The data that was collected was manually inserted into the data sheet making it possible for human mistakes. Also, the choice of formatting of the data in the data sheet used in RStudio to show results could be interpreted differently by RStudio than intended making the results skewed. All of these factors suggests that the results should be approached with a degree of caution.

4.3 Management implications

The results of this study could be used for variety of purposes. The results could be used to argue that epiphyte diversity and richness could indicate the capacity of a forest to contain a high abundance of insectivore bird territories. This in turn, if replicated by additional studies, could then guide future management of nature reserves in southern Sweden to promote insectivore bird abundance by promoting epiphyte richness, or more likely, the associated habitat feature that leads to a higher diversity of both taxonomic groups. If the Marsh tit population continues to decline in the future this study can also be used to argue for management, in temperate deciduous forest areas they are present, towards epiphyte richness to help promote the species further. The identification of forests of importance to the

Marsh tit for protection can also be helped with the results of this study. The results even though limited, show that there are bird species specific to each category, this shows the importance of a heterogeneous landscape and that heterogeny in the landscape is important to promote the overall bird species amount within the park. The results of this study can also be used specifically in Söderåsen to help future management decisions. This can be in the form of choosing where management is needed and which areas should be left alone. If the park management for example is planning on veteranisation of trees in certain areas these results could be used to determine appropriate areas. However, seeing as these results are based on resident birds, the importance of certain areas to migrant birds is not known and should thus be considered.

4.4 Conclusion and development of research

The connection between epiphyte richness and bird diversity cannot be drawn from this study, there are differences in species abundance and bird abundance between the site categories, but these are not statistically significant. To be able to demonstrate if there is truly no relationship between epiphyte richness and bird diversity future studies are necessary. These studies should then contain surveys conducted later in the spring when migratory bird species have also arrived in the area. This increase of species and total bird abundance gives the surveys a larger survey pool making any possible differences between affecting factors more pronounced in the results. The epiphyte rich sites showed a higher abundance of insectivores perhaps indicating a more structurally complex forest. The epiphyte poor sites showed a higher abundance of granivores and fewer territorial species which indicates a simpler forest habitat. The territorial presence of the Marsh tit might indicate the importance of these sites to this red listed species. The differences between the sites that could be seen, may indicate the importance of maintaining a heterogenous landscape to provide habitat for a higher bird diversity. These findings are a reminder to look outside of site-specific management and look at the needs of the landscape as a whole.

Acknowledgements

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Britannica: https://www.britannica.com/plant/epiphyte

National Parks: https://www.sverigesnationalparker.se/en/choose-park---list/soderasen-national-park/national-park-facts/

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Personal communications:

Tove Hultberg, (April 2025) 'Söderåsen National Park Management'

Appendix 1

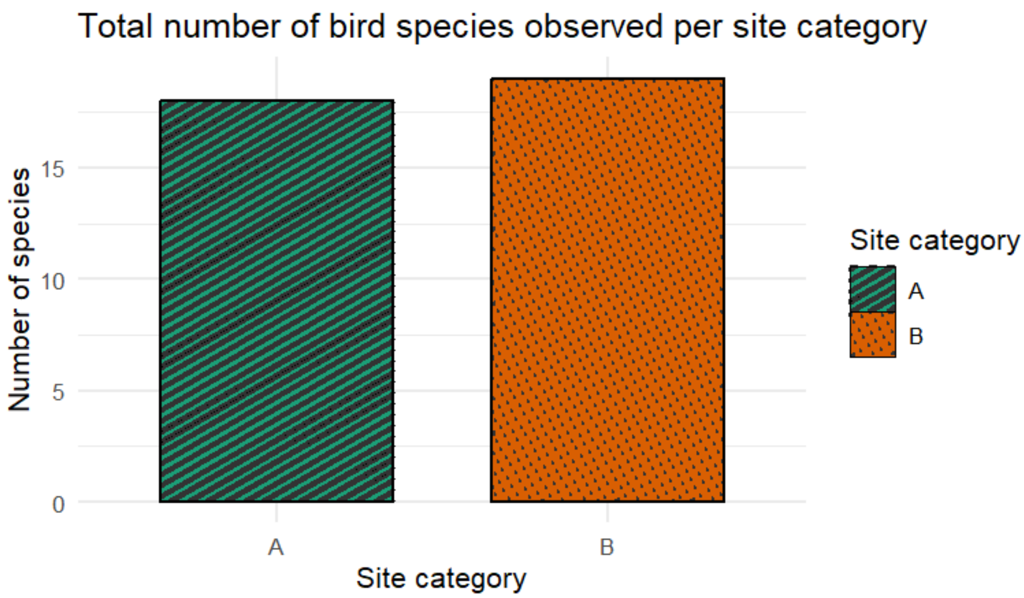

Figure 16. Total number of bird species over all sites per site category.

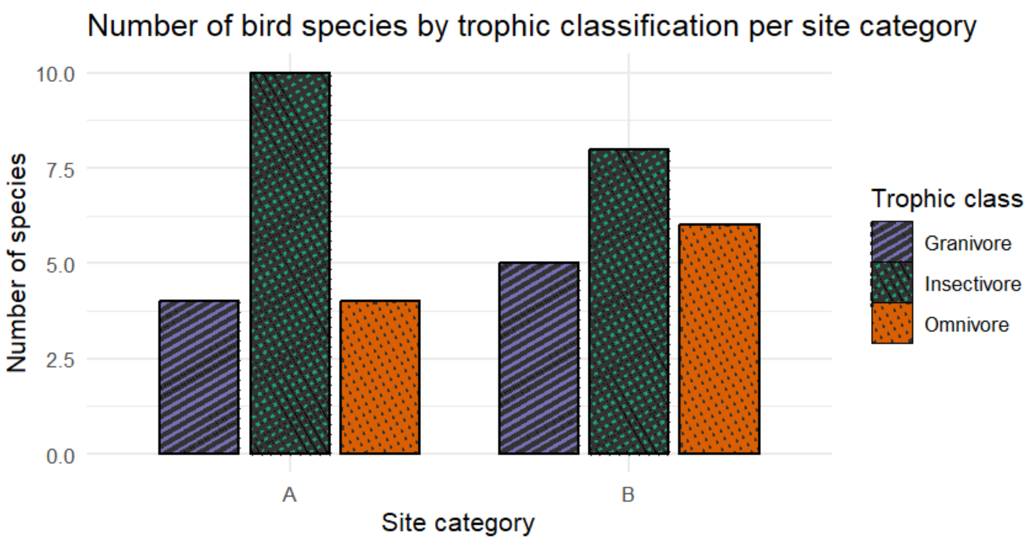

Figure 17. Number of bird species by trophic (food preference) classification per site category.

There were 4 granivore, 10 insectivore, and 4 omnivore bird species found within the A site category. In the B site category 5 granivore, 8 insectivore, and 6 omnivore bird species were found. No significant differences were found between the site categories per trophic classification (*Figure 17*).

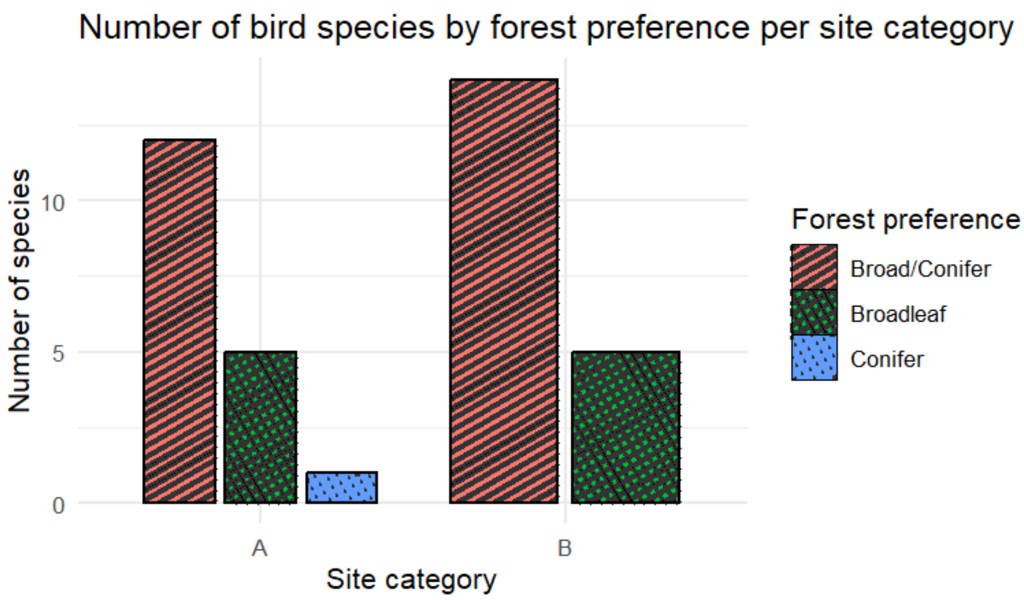

Figure 18. Number of bird species by species forest type preference per site category.

In the A site category 12 bird species were found that were generalist in forest type, 5 species with broadleaf preference, and 1 species with conifer preference. In the B site category 14 bird species were found classified as generalists, and 5 species with broadleaf preference (*Figure 18*).

Figure 19. Total number of bird individuals per site category.

The A site category had 173 bird individuals noted down. The B site category had a total of 233 birds noted down (*Figure 19*).

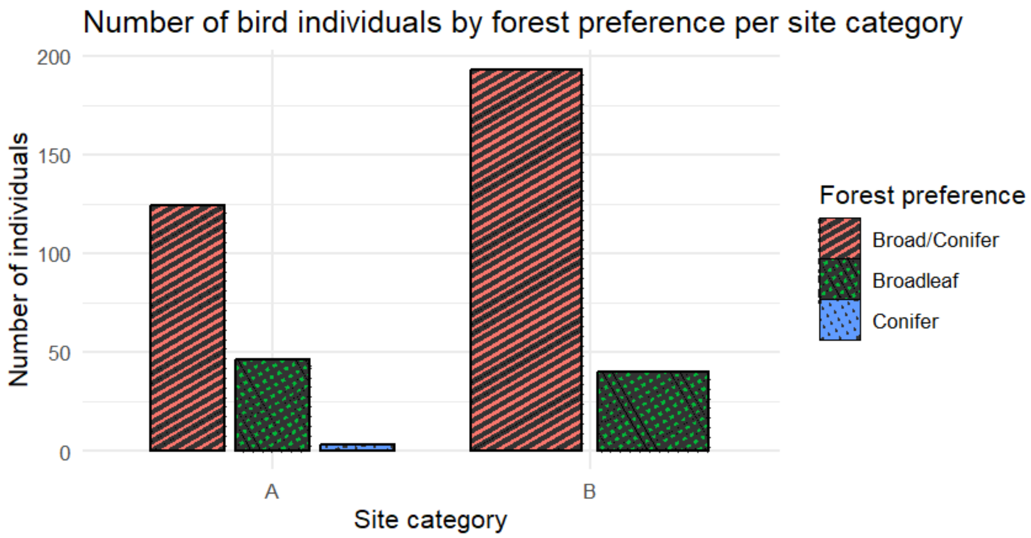

Figure 20. Number of bird individuals by forest preference per site category.

The number of generalists was 124 in the A site category, and 193 in the B site category. The number of birds classified with a preference for broadleaf forests was 46 in the A site category, and 40 in the B site category. The number of birds classified to prefer conifer forests was 3 in the A site category, and no birds in the B site category. The B site had more birds with no preference for forest type than the A site category. The difference between the site categories for broadleaf forest preferred birds was small (*Figure 20*).

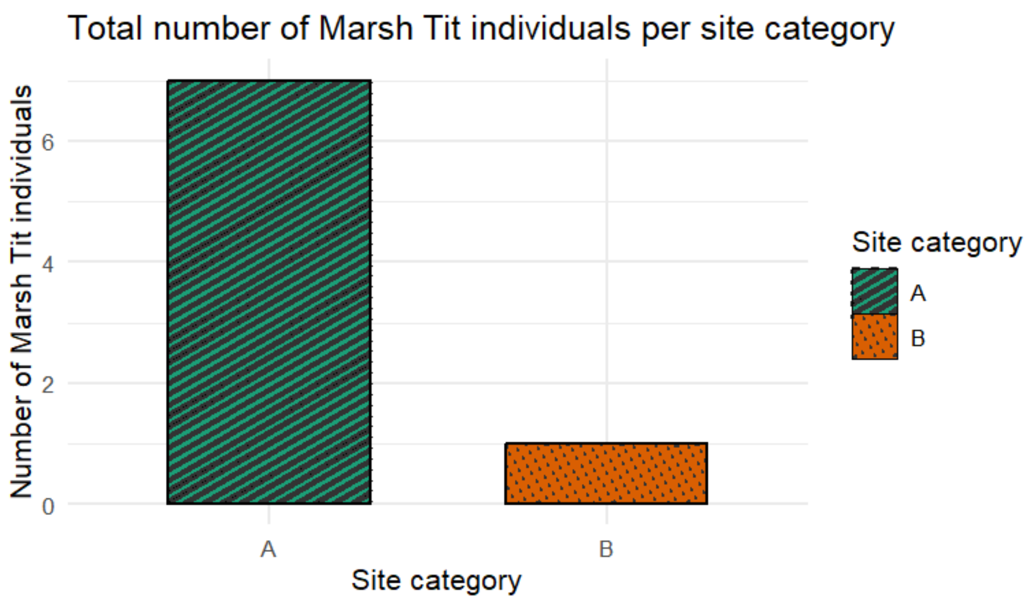

Figure 21. Total number of Marsh tits per site category.

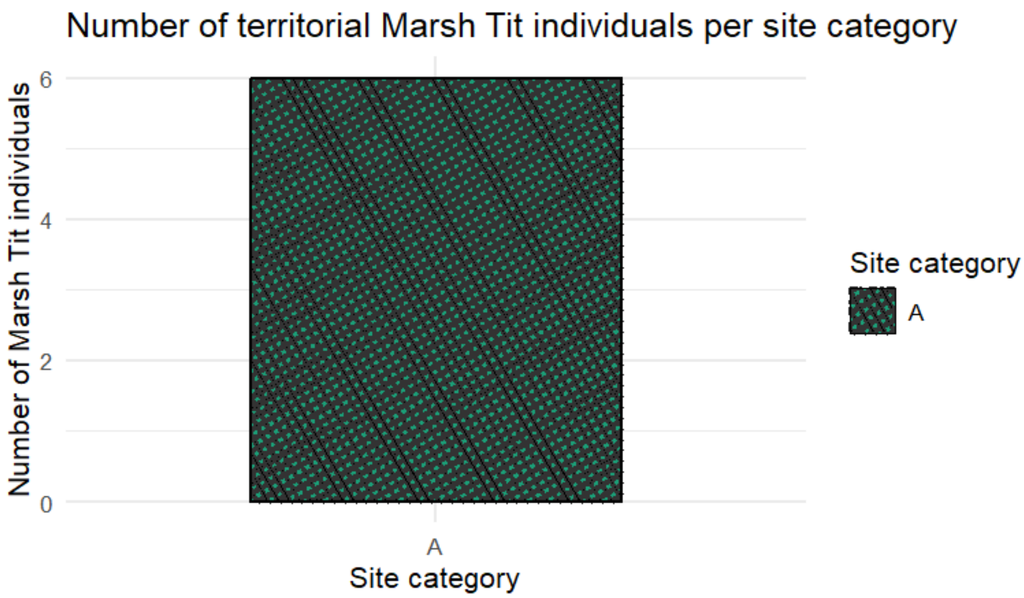

Figure 22. Total number of individual Marsh tits showing territorial behaviour per site category (Only found in site category A).

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