Understanding the Impact of Forest Management on Bird & Mammal Diversity

Faculty of Geosciences Utrecht University

Global Sustainability Science

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1. Introduction:

Nowadays, there is an increasing need to understand the repercussions of human activities, such as forest management, on biodiversity, considering their inducing role in triggering environmental changes and the sixth major extinction in history (Chapin III et al., 2000). Biodiversity is defined as “the sum total of all biotic variation from the level of genes to that of ecosystems” and “includes not only species and species abundance, but genetic variation within species.” (Gregory, 2006). The significance of biodiversity in the preservation of Earth’s ecosystems functioning and services have been gaining attention (Pollock et al.,2017) along with its accelerating loss (Cardinal et al., 2012). Ever since the first Earth Summit in Rio de Janeiro in 1992, human actions have been recognized as detrimental to the Earth’s ecosystems and biodiversity (Cardinale et al., 2012).

Noticeable declines in wildlife populations, such as birds and mammals, are a result of increasing and unsustainable exploitation of land (Parmesan & Yohe, 2003). Activities like deforestation and construction can disturb the natural flow of an ecosystem in a forest and pose a threat to birds and mammals. They destroy, degrade and fragment habitats, making it difficult for species to survive (Human Impacts on Biodiversity | Natural History Museum, 2021). Compelling evidence from a study conducted by Schulze et al. (2019) has shown a significant positive association between the abundance of non-migratory forest bird species in Central Europe and the quality of forest management in the last 45 years. This led to the conclusion that “sustainable forest management independent from economic conditions” should be encouraged to “mitigate the general decline of bird abundance”. Many studies show that diversity in an ecosystem is a sign of health and stability since it increases its resilience to external pressures (Tilman et al., 2014). It is, therefore, necessary to comprehend the impact of forest management on species diversity better, especially in countries where natural areas are under pressure due to human activity.

In the Netherlands, one of the World's most densely populated countries, forests require active conservation and management. The unique ecosystems have been largely affected by human action, namely "landscape alteration for food protection, urbanisation and agriculture" leaving less than 12% of the Dutch land surface natural and mostly forested (Van Dijk, 2018). These forested areas are all replanted for timber production or landscape restoration making all forests in the Netherlands non-native. Utrechtse Heuvelrug National Park hosts the second largest forest in the Netherlands and therefore is also subject to the impact of forest management.

This research project will be undertaken at Utrechtse Heuvelrug National Park, in the province outskirts of Utrecht, which hosts over 100 different species of birds such as the Great Spotted Woodpecker *(Dendrocopos major)* and the crested tit *(Lophophanes cristatus)* to the European robin *(Erithacus rubecula)* (National Park Utrechtse Heuvelrug, 2021). Apart from birds, notable mammals often found in the Utrechtse Heuvelrug forest are roe deer (*Capreolus capreolus*), foxes (*Vulpes*), rabbits (*Oryctolagus cuniculus*), squirrels (*Sciuridae*) and badgers (*Meles meles*).

Moreover, the national park of Utrechtse Heuvelrug presents three types of forests, multifunctional, nature forest, and forest reserve zones. However, it remains unclear how these different types of forest management affect species diversity on the UH.

In the context of the course 'Regional Integration Project', the research question "How do different forest management types affect species diversity in Utrechtse Heuvelrug National Park?" is addressed. The purpose of this scientific report is to understand the effect of forest management on bird and mammal diversity. More specifically, we ask 1) How are bird species richness and evenness affected concerning the 3 types of forest management? 2) How, with the application of the Shannon-Wiener Index, does species bird species diversity vary in the forest types? 3) How does mammal species' richness differ between the 3 types of forest management?

We expect to observe a significant decrease in both the bird and mammal species diversity in relation to the increase of exploitative forest management. The highest diversity is expected to be found in the forest reserve zones and the lowest in the multi-functional forest.

2. Literature Review

2.1 Forest Management Types

The multiple-use forest management planning (MUFMP) approach was created to introduce the idea of sustainable forest management, to combine the ecological and socio-economic functions (Başkent,2018). Around 75% of the forests in the Netherlands are multi-functional, they carry out: (1) social functions which include education, employment care, volunteering, recreation, and cultural heritage. (2) Ecological functions such as landscape design, water management, and research. (3) economic functions such as extracting raw materials, especially wood (Staatbosbheer, 2021).

In nature forests, the major purpose is to produce timber with regard to the sustainability of the forest, the protection of the soil, and the conservation of water (Amlesh,2016).

While in forest reserves nature is free to run its course as no interventions or activities are carried out by humans; they are set aside and protected by the government.

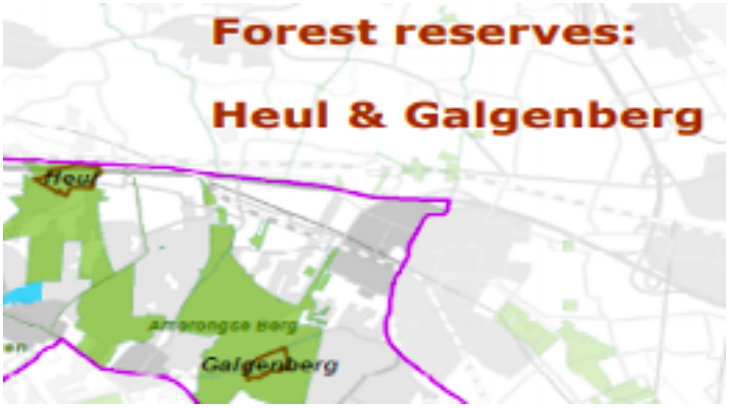

Figure 1. *This figure shows the forest reserve zones present in the National Park; Galgenberg and Heul (Staatsbosbeheer, 2021).*

Much research has focused on the various effects that different forest management has on plant diversity while there has been less research on birds and especially mammals diversity. However, according to the literature, bird populations can be affected in many ways by forest management, for example, when selective cutting is carried out and regular canopy openings are created, this can lead to higher invertebrate diversity than in forests with closed canopy, therefore indirectly influencing bird populations since invertebrates are their major source of food (Schulze, 2019). Moreover, bird species that are confined to mature forests prefer forests with canopy openings in the autumn, once the breeding season has ended (Schulze, 2019). Another important factor contributing to bird population is the amount of deadwood present in the forest (Pötzelsberger et al., 2021) since it is a habitat of many invertebrate species.

Many studies have confirmed that older forests are more important in maintaining species richness and diversity than early successional forests (Pötzelsberger et al., 2021), and according to Schulze, 2018 in Central Europe the oldest trees have been found in sustainably managed forests rather than in unmanaged ones. Furthermore, it is expected that leaving deciduous forests unmanaged would cause an eventual mono dominance of a tree species (e.g. *Fagus sylvatica* in Germany) and evidence of this event has been observed in the Semenic National Park in Romania and other forest reserves (Schulze, 2017). While in a Meditteranean context it has been observed that bird population can be negatively affected when the forest canopy becomes so dense as to block the growth of shrubs and herbaceous specie, while favouring bird predators since they have a less visual obstruction (Gil-Tena et al., 2007).

Mammals are affected by the different types of forest management and one example of this management is the removal or thinning of trees, this having a long-term effect on

ecosystems. This method not only affects the plant community, but subsequently, it affects the animals in the park. The animals in the park have an important role in dispersing seeds of plants, nutrient cycling, and also small animals such as mice are food sources for predatory mammals and birds. Unfortunately, the long and short term of tree removal is not very known (Gallo et al., 2016). Moreover, forest management such as wood production is known to modify the wildlife habitats, especially the small mammal community. (Gasperini et al., 2016). To conclude, according to Hollie et al., 2020, many studies on the past effects of different forest management on bird populations have been limited by spatial and time factors, further studies need to be conducted while keeping in mind these limitations.

2.2 Birds & Mammals - Good Indicators for Sustainable Forest Management.

Biodiversity is incredibly challenging to measure. Birds can be a 'focal species' when studying biodiversity, meaning that they can be studied as a single species covering all habitats (Gregory, 2006). Firstly, they are present in every habitat, and they easily move from one area to another in search of resources. Secondly, they are high in the food chain, which makes them a good indicator for the presence of other species in the environment such as insects. Furthermore, birds have been thoroughly studied and many people can be considered experts in study, count and analyse them (Gregory, 2006).

Mammals are used as bioindicators because they provide us with the state of the ecosystem. Small mammals are one of the best bioindicators for the terrestrial ecosystems (Koroleva et al., 1999). Animals, such as mice (Mus musculus) and voles (Microtus) are potential indicators of sustainable forest management. Their role in forests is to consume and spread the seeds of trees and plants, but also to act as a source of food. Lastly, they can respond to disturbances (Pearce & Venier, 2005).

2.3 Calculation of Species Diversity

Biodiversity is calculated with different methods like species richness, evenness, and diversity.

Species richness is the count of species present regardless of their abundance. It strongly depends on sample size, therefore is often not considered the best option to determine biodiversity when different areas are compared (Fath, 2008). Furthermore, it does not provide information regarding the rarity or dominance of some species.

Species evenness measures the relative abundance of each species. It provides information on the dominance of species, but it depends on the sample size. However, it is interesting to study species evenness as it has been related to enhancing ecosystem functioning (Orbing et al., 2014).

Finally, species diversity combines these two quantities and gives an index for the number of species in the environment and their relative abundance. A common calculation to determine species diversity is the Shannon-Wiener index as it works almost universally. This equation takes account of the species richness and the number of individuals per species. Because it relies on the proportion of individuals over the total, it works on most sample sizes (Fath,2008). All these indices can offer different insights into the ecosystem functioning in the park. We will be using them all to compare the different forest management types.

Resources like time and instruments available have been sufficient to collect all the data needed to calculate bird species richness, evenness and diversity using the Shannon-Wiener index. However, as mammals were not so commonly seen in the studied areas, we decided to only focus on the species richness for mammals, as the amount of data collected for them was not sufficient to provide concrete results as it will be seen later in the Results section.

3. Methods

3.1. The Study Area

The Utrechtse Heuvelrug National Park lies in the Dutch province of Utrecht. The total area of the National Park is around 10.000 hectares and is covered in heathlands, grasslands, floodplains and forests (Nationaal Park Utrechtse Heuvelrug, n.d.). Figure 2. shows the location of Utrechtse Heuvelrug in The Netherlands. In addition, figures 3. and 4. give an overview of more specific locations in the area; each dot symbolises a bird count location. Different colours symbolise different types of forest management.

Source: freevectormaps.com/netherlands

Source: www.np-utrechtseheuvelrug.nl

Figure 2. *Location of The Utrechtse Heuvelrug.*

Figure 3. *First map represents the specific locations in the forest reserve zones (the purple dots).*

Figure 4. *Second map represents the specific locations in the multifunctional forest (the red dots) and the nature forest (the green dots).*

3.2. Study Design: Birds

To count the species present in the Utrechtse Heuvelrug, the area will be sampled using the line transect method. The transect method takes only a small segment compared to the

natural area allowing larger territories to be covered. This also makes observations easier to collect and is less time and resource-intensive than other more elaborate methods such as point counts (Greene, 2012). Despite the small sample size, this method gives an accurate representation of the biodiversity present in the area (Helle & Pulliainen, 1983).

Line transect sampling involves an observer slowly traveling alongside a designated line recording all birds seen or heard. A transect line of 100 meters in length was chosen; the width extended 20 meters on each side of the transect. The duration needed to walk the transect was 20 minutes, this allowed the observers to stop, listen and recheck data if needed. One of the main motivations of using this method concerns the double-counting of birds, this is a relatively minor issue as observers are continuously moving (Greene, 2012).

A line was created by using a starting coordinate of the transect and walking a 100-meter line while using a map, 'GPS fields area measure' application and a compass. A visual representation of the transect method can be seen in figure 5. where the dots represent all birds present in the forest and the circled dots represent birds that were identified and counted. Birds only within the transect range were counted and not all dots are circled due to possible errors, mainly because not all birds present were identified and some remained hidden in surrounding vegetation.

Multiple transects within a particular habitat type were required for measuring biodiversity, therefore 10 different sample sites for each type of forest management were chosen meaning 30 sites in total; each site had a unique identification number and a separate data sheet, and the transects were chosen using a simple random sampling method. The sample size is relatively large therefore it reduces sampling errors and gives a better representation of the community. Lastly, a table of the fieldwork planning, starting point coordinates and the fieldwork maps can be seen in Appendix 1.

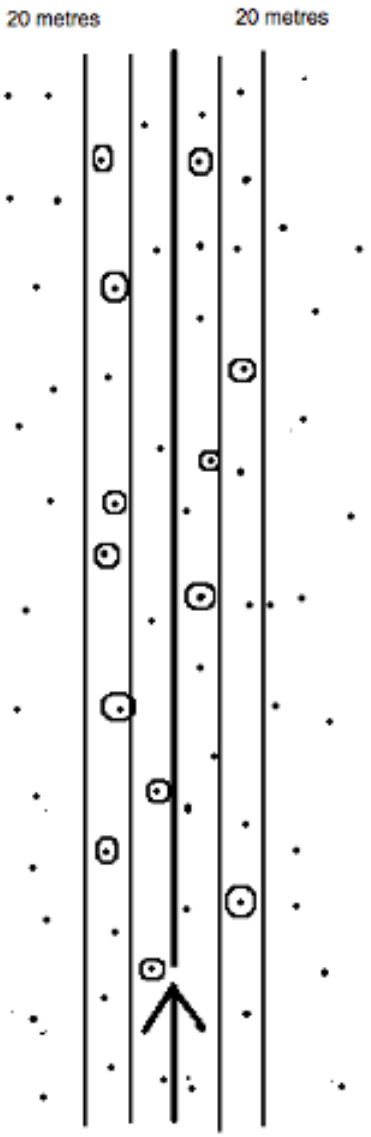

Figure 5. *Visual representation of the transect method.*

3.3. Data Collection: Birds

Fieldwork was conducted in the period from the 1st until the 4th of June 2021, the number of individual birds was registered against the independent variables of the three forest management types.

A data sheet (Appendix 3.) with the most common bird species in the area was made using tools like 'avibase.bsc-eoc.org' and 'https://waarneming.nl'. Another document was

made with all the species including visual data, key characteristics, and their sounds (Appendix 2.). The observers learnt and practised the information beforehand to obtain accurate surveying. Bird activity is the highest in the morning therefore the fieldwork was conducted starting at 6:00 and was finished after all the transects had been completed.

The fieldwork data was entered into an Excel spreadsheet as soon as possible and was securely stored on google drive, allowing easy access. Before finalizing the data, missing information and errors were checked, for example, listening to the recordings. All information can be seen in the excel spreadsheet in Appendix 7.

3.4. Data Analysis: Birds

Data regarding species richness and evenness was analyzed using the Shannon-Wiener index (calculated in Excel). To calculate this index number of individuals per species and the total number of individuals spotted are needed. The formula goes as follows:

$$H' = -\Sigma p_i * \ln p_i$$

Where p_i is the number of individuals per species over the total of individuals.

$$J' = H'/\log(S)$$

where S is the number of species counted.

The species evenness is determined with a value between 0 and 1 where 1 represents the complete evenness (Fath, 2018). After calculating the index, a value close to 1 was considered as good management, and a value close to 0 as bad management.

The average of the bird species richness for each management type were compared and analysed using SPSS. It was used for the purpose of statistical analysis in order to obtain the explanatory P-values of the variables.

The groups, determined by the management type, have been compared using the Kruskal-Wallis statistical test or the ANOVA test, The ANOVA test will be used in case of

normal distribution, while the Kruskal-Wallis test will be used when the results are not normally distributed (McCrum-Gardner, 2007). These tests are used to compare the scale variables of more than two groups. The richness and evenness have been compared using a Kruskal-Wallis test, while the diversity was studied through an ANOVA.

3.5. Mammal diversity

Methods used for measuring mammal diversity were different and conducted online mainly due to lack of camera traps and one of the observers not being able to perform fieldwork. The data was collected with the help of a website called Waarneming.nl, which provided the sights seen and registered by other observers.

The remote member studied 3 of the points used for the transects and placed the coordinates into the map provided by the site (see Appendix 3.). For each transect point the smallest radius of 1 km was used, as it was the smallest radius provided. However, two of the forests were close to each other, therefore in order to avoid overlapping it was decided that the Nature Forest and the Multifunctional Forest would be studied together as one group. Hence, the mammals for both of the forests were counted together, making the results better to understand.

Moreover, the time frame of the study design was changed, because mammal sightings are not as frequent compared to birds. Thus, the data was collected from the beginning of the year, to ensure a sufficient amount of data.

4. Results

4.1 Birds: Species Richness

In total, a number of 279 individuals were observed of 28 species. Of those individuals the European Robin *(Erithacus rubecula)* and the Common Chaffinch *(Fringilla coelebs)* were

the species with the highest observations. In particular 44 and 41 individuals were counted in all the transect sites respectively as seen in Appendix 5.

The forest reserve and the multi-functional forest presented the same number of total species richness,which was 20 for each, but for the nature reserve, the total species richness was slightly lower at 19 as presented in Appendix 6. Contrary to the expected outcome, the highest number of individuals, 102 were observed in the multi-functional forest, and the lowest, 84, in the forest reserve. The number of individuals in the nature forest slightly increased to 95 compared to the forest reserve.

In Figure 6. The box plot exhibits the distribution of the data averages. The lowest value for average species richness accounts for the multifunctional forest and ranges from 4-10 with a median value of 7. For the forest reserve (borerevaat) the species richness ranges from 5-12 with a median value of 6 and for the nature forest (natuurboss), species richness ranges from 5-12 with a median value of 7.5.

As can be observed in Appendix 8. The significance obtained from the Shapiro-Wilk test ($p= 0.046$) is below 0.05, so the data significantly deviates from a normal distribution. This is also illustrated visually in the histogram in Appendix 8.

The results of the Kruskal Wallis test demonstrate that the type of forest management has no significant effect on the richness of the bird species ($p= 0.483$) as observed in Appendix 9. Therefore, the relation between the forest management types and bird species richness is concluded to be insignificant, and the null hypothesis is accepted.

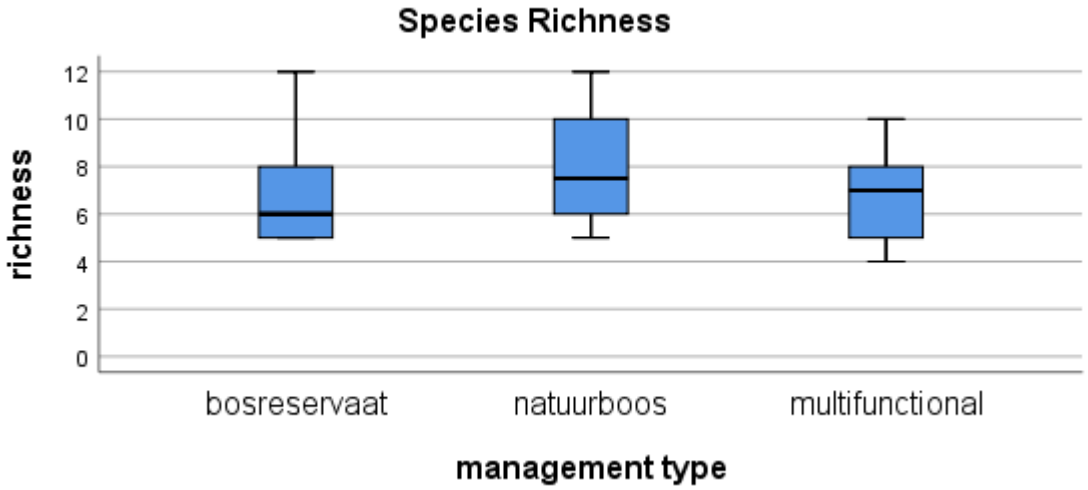

Figure 6. *Species Richness index compared in the three different forest management types.*

4.2 Birds: Diversity & Evenness

As mentioned in the methods section, the species diversity and richness showed a not-normal distribution and were compared using the Kruskal-Wallis statistical test. The diversity results were normally distributed and were analysed using the ANOVA test.

4.2.1 Species Diversity Across Transects

The ANOVA test comparing diversity across the three different management types showed that there is no significant difference in the three sets of values. The graph below (Figure 7.) shows a small difference in the means, although the probability that this is given by chance is quite high (significance value of 0.40).

Therefore, we should accept the null hypothesis and state that there is no significant difference in species diversity across the three different forest management types.

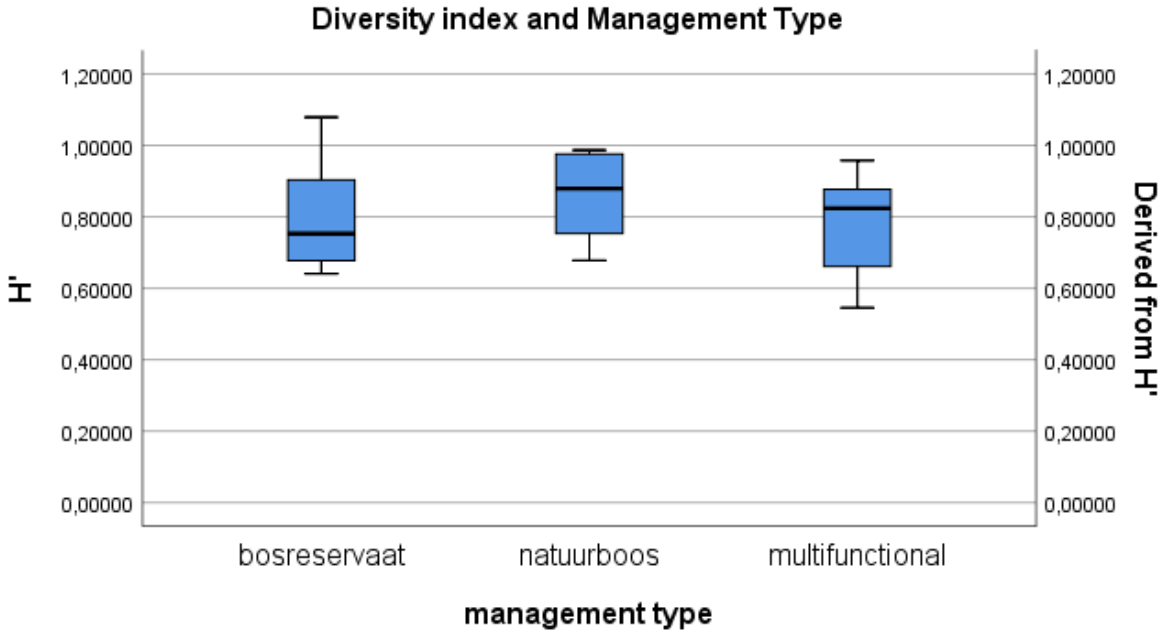

Figure 7. *Diversity index compared across the forest management types*

4.2.2 Species Evenness

From the Shannon Index we can see that the evenness of bird species has high values in almost all spots.

We can see from the statistical analysis that the average evenness value in the transects was 0.96, with a range from 0.74 to 1; as the values are close to 1 we can say that most of the species were even in number.

The Kruskal-Wallis test showed that there is a significant difference between the evenness values across the three management types.

In the Nature Forest transect, the average of the J' was 0.99. In the forest reserve the average was 0.98, and in the multifunctional forest the average was 0.93.

As we can see from the graph in Figure 8. below, the multifunctional management forest has, in fact, a lower evenness mean compared to the nature forest and the forest reserve.

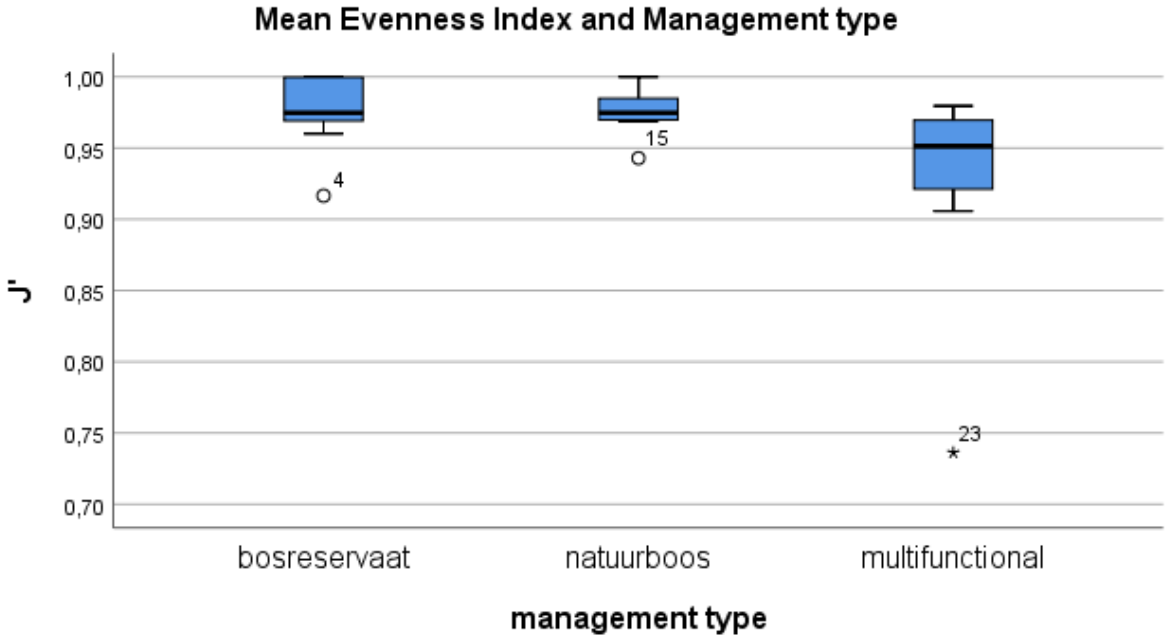

Figure 8. *Evenness index and management types. Note that the y-axis starts from 0.7, to better show the difference between the values in the three management types.*

4.3 Mammals: Species Richness

The data obtained for the mammals in the park presented in Figure 9 was not as much as we expected to find from the beginning of the year. Blue represents the number of mammals in the forest reserve, while yellow represents the mammals in both Nature and multifunctional forest. The bar chart clearly shows the different mammals in the 2 categories. In particular, the European roe deer is very common in the forest reserve, while bank vole is more common in the other two types of forests. Moreover, it can also be seen that some mammals such as the European rabbit and the long-tailed field mouse (Apodemus sylvaticus) are not present in the forest reserve, they are present only in the nature and multifunctional forest. Lastly, the European hare *(Lepus europaeus)* is not very common in either of the 3 forests,as the number of sights were low in either of the forests.

Through the online fieldwork we were able to identify which of the forests had more biodiversity by looking at the species richness. The species richness in the forest reserve is 4 while for the other two forests combined the richness was 6.

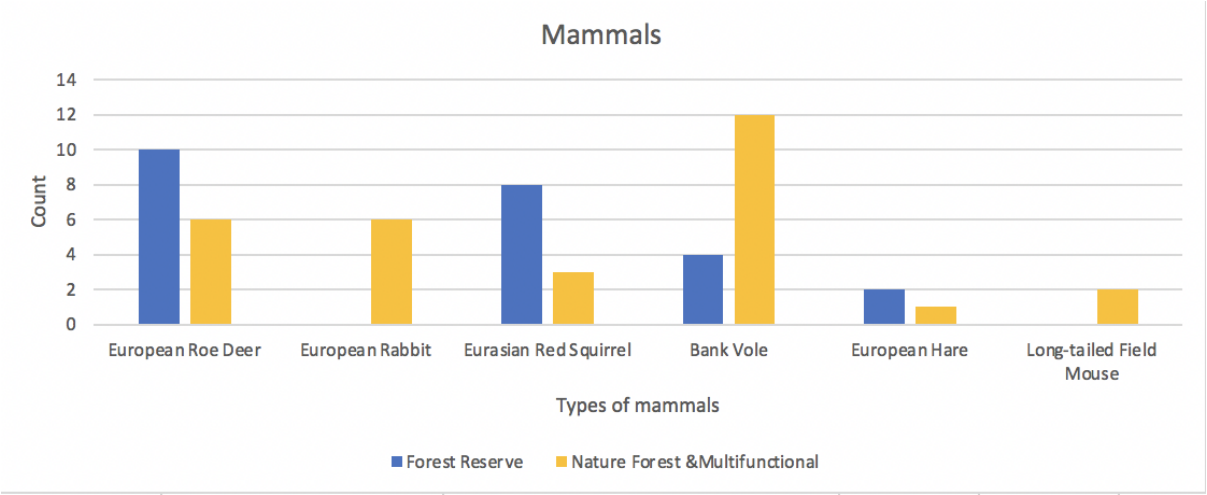

Figure 9. *Graph showing the different types of mammals in the 3 types of forest management*

5. Discussion

5.1 Discussion on Avian Species

The purpose of the main research question was to understand the effects of different forest managements on birds and mammals diversity in the Utrechtse Heuvelrug National Park. The results regarding the avian species indicate that the different forest management types have no significant effect on species richness, even though more individuals have been counted in the natural forests, the difference was not as notable. Also, there was no significant difference in species diversity across the different management systems.

In accordance with a great part of the literature it was expected that the managed forests would have a higher species richness due to higher environmental heterogeneity (Tamme et al., 2010). However, environmental heterogeneity can also have negative effects such as reducing beetle species richness and therefore influencing their predator, birds. This

should be considered in the context of nature conservation and forest management (Tamme et al., 2010).

According to the Shannon-Wiener Index calculations all the different types of forest presented high species evenness and the test showed that there is a significant difference in the values. Overall, the multifunctional forest has a slightly lower evenness, meaning that there is higher disproportion between the number of individuals within each species present in this forest compared to the others. In other words, some species dominate the sites more than others. The European robin and the common chaffinch were the most common birds in every forest management type, except for the nature forest where the common chiffchaff had more counts than the European robin. This is not surprising since these birds are among the most common in the Netherlands and they are generalist species, meaning that they can live in different forest habitats and are able to thrive in disturbed ones (Staude 2021).Moreover, since the European Robin is a resident bird its population could also be favoured by climate change,in fact, according to Richardson et al., 2013 climate change is favouring non-migratory birds while disadvantages migratory ones. Even though this is invalid for the Common chiffchaff since it is a migratory bird, an increasing number of individuals are inhabiting Europe all year round without migrating (Trust, 2021).

Despite the transect method being an accurate method of surveying, there are still possible sources of error. One of the main disadvantages was the observer's ability to identify species; As most birds are detected and identified by call, high levels of observer skill and experience are required to identify birds accurately whilst on the move (Greene, 2012). It is important to point out that several individuals of one species were only noted when heard or seen both at the same time. This most likely influenced the result, especially on species evenness. Furthermore, most of the recordings were based on the earring of the male call of the species. Other chatting or sounds were missed and undetected mainly due to sound similarities between species.

Overall, the data suggests that the results were insignificant. However, the results obtained were not the only one presenting no big differences in the species richness and

evenness between managed and unmanaged systems in this specific subject. According to Gil-Tena et al., 2010, the study that was conducted on changes in structure of managed forests did not provide significant results. The explanation for this was that it was difficult to see big changes in bird species due to the lack of bigger spatial scales. This confirms to some extent that in our findings there was no significant difference in the bird species due to limited time and the area of fieldwork not being large enough.

In fact, many studies had temporal limitations, according to Laiolo et al., 2004 disturbance due to management activities influencing avian species more during the winter than during the breeding season. Furthermore, according to Raupp et al. 1988 and Hunter, 1991 the distribution of food resources for birds, such as insects, in deciduous forests changes with seasons, even causing niche shifts. For accuracy, repeated visits are recommended because bird abundance and visibility vary (Hostetler, 2016), unfortunately, we don't have the resources available for such extensive collection of data. Given these phenomena, further studies should be conducted across seasons to understand these differences.

The transect lines had to be independent, meaning non-intersecting and non-overlapping. Unfortunately, spatial limitations were experienced due to transects being too close to each other. Data could therefore have been replicated, meaning that the same individual birds could have been counted in different transects, which were next to each other. Many studies such as Rajkumar & Wijesundara, 2014 avoided pseudoreplication by keeping the transects at a minimum distance of 100 m between each other, while our transects were less than 60 meters apart.

Our study was also limited due to the lack of necessary information, such as the succession of vegetation in the 30 sites. Therefore, our assumption was that the forest reserve contained the oldest vegetation, since no activities such as thinning and cutting are carried out there. Given this assumption, studies such as Gil-Tena et al., 2007 confirms that forests in a more developed stage may benefit bird species richness by providing more dead

wood and cavities, however, our results noted that forest reserves did not have a higher species richness compared to the other forests.

Our assumption could be countered by other studies such as Schulze, 2018 which affirms that in Central Europe the oldest trees have been found in sustainable managed forests rather than in forest reserves which are left unmanaged.

Furthermore, it needs to be taken into account that the data collected in our forest reserve cannot be representative for other reserves in the Netherlands. This is due to the presence of a highway next to the forest reserve zones; the closest transect to the highway at around 150 meters and the furthest away only around 350 meters. The influences of the highways have been demonstrated by experimental studies, which reveal that they lead to deterioration of the habitat quality of some breeding and wet meadow birds, this can negatively affect breeding birds by lowering avian population densities along the roads (Cuperus & Foppen, 2003).

5.2 Discussion: Mammals

As can be seen in the result section the nature reserve has less species than the nature and multifunctional Forest, which can mean that it is a more disturbed forest. This is happening because the area of the reserve is near a highway, infrastructure that disturbs the forest's ecosystem. On the other hand, a higher species richness means that the two forests are more populated by mammals than reserves which would further correlate with the findings of bird species. The birds were more prominent in the nature forest than in the other two forests. This could conclude that the nature forest is the least disturbed of the 3.

Looking further into the abundance of mammals in the forest, we were able to analyse how some mammals can indicate disturbance in an ecosystem. One of the mammals is the European roe deer which can clearly be seen in high numbers in the nature reserve compared to the other two forest management. One reason for this difference is that the deer is a game animal, and it is being hunted, explaining why there are lower numbers of

deer in unprotected areas of the park. Another animal is the bank vole. This small mammal is known to be an indicator of heavy metal contamination of the environment, leading to the conclusion that the environment in the nature and multifunctional forest is contaminated (Zakrzewska, 2010).

A limitation to the mammal data collection method was the inability to do real fieldwork because of the absence of camera traps to capture the movement of mammals. Hence, we had to gather our data through a website which presented other people's observations. A disadvantage of the website is that the smallest radius provided from a midpoint was too big, resulting in overlapping two of the three forests and making it difficult to properly separate the two forests.

6. Conclusion

The aim of this study was to assess how bird and mammal diversity varies in relation to different forest management types present in the Netherlands in the Utrechtse Heuvelrug National Park; the multifunctional forest management, natural forest management, and the forest reserve. More precisely, the species richness and species evenness for birds and species richness for mammals were calculated.

After examining the data and the following results regarding the avian species, we concluded that different types of forest management have no significant difference on the species richness. While looking at the mammals, we concluded that there was only a slight difference in the species richness as the nature and multifunctional forest had more species than the nature reserve.

These results contributed to the existing literature on the effects that forest management has on bird and mammal species, and to the limited number of studies which have compared different forest managements.

The main limitations of our fieldwork were that the transects sites provided were too close to each other, making it difficult to be more accurate with our results. Another limitation

was the inexperience in recognizing bird sounds as there were many birds that needed to be learnt in a short period of time. Also, we did not have enough time to gather solid data, we should have needed to do that across different seasons. The highway was too close to one of the forests, which again resulted in disturbing the biodiversity in the park and making it difficult to recognize bird's sounds and collecting more data. Finally, during the online fieldwork, it was difficult to be precise with the website used to collect the information because the smallest radius provided from a midpoint was too big, therefore resulting in two of the forests: Nature and the Multifunctional Forest to overlap.

We are unable to conclude that our results are accurate due to many limitations, and they can only be representative for deciduous forest with a similar biodiversity.

Further research should be conducted in order to understand the different effects that these types of forest management have on bird and mammal species. A comparison of the same type of management carried out in different geographic locations with varying biodiversity is important in comprehending how different species react to the management system. Finally, studies should not always be aimed at comparison but also in finding casual relations.

7. Relevance and Integration Possibilities

In the Utrechtse Heuvelrug the three different forest managements have a different impact on the health of the forest, biodiversity and ecosystem services. Nonetheless, these impacts are caused by the perceptions of the residents and forests on forest management, making our subtopic focused on how these types of sustainable management impacted the birds and mammals from the park.

Our findings are important because it allowed us to gain a more in-depth insight about the impacts of different forest management on bird and mammal species. The literature review helped us understand what type of management is the most common in the Netherlands and how this is influencing birds and mammals abundance, how they are used

as bioindicators in the park, and finally how it is possible to calculate species diversity by using species richness. However, the research focused on a specific area, as most of the research was made as an overview of the forests in the Netherlands and of mammals and birds everywhere in the world, we focused on only an area of the Utrechtse Heuvelrug National Park. This helped us in closing some of the gaps found in the literature.

Nonetheless, the results that were presented in the report are important because they provide insight and accurate source of information for any further research about sustainable forest management which may be conducted by other researchers, leading to new research questions.

From a different point of view, the results could affect the other sub-topics such as woody plant species diversity (1A), invasive alien species(1C), forest perceptions by residents(1E) and forest management perceptions by foresters(1F). The first two sub-topic, 1A and 1C, conducted research on how forest management affected forest structure and woody species diversity and the impact of invasive species, respectively. As a result, their findings could affect our own research because the different types of forest structure and woody plant species influence the mammal and bird species. However, the next two of these 4 sub-topics were related with the forest perceptions by residents and foresters on sustainable management. Hence, both could have been affected by the results we provided because their view on forest management would change. For example, if our results showed that the biodiversity is being affected in a negative way by the forest management in the park, these two stakeholders would change their strategies and views to diminish the impacts.

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9. Annexes

Appendix 1. Fieldwork planning schedule; the table of coordinates; maps of the coordinates.

Fieldwork times for our groups research: (end times were indicative)

	Tuesday	Wednesday	Thursday/Saturday
Kristiana + partner Laurens (FW79 fieldwork)	6:00 - 11:00 which sites: transect ID 11 transect ID 12 transect ID 13 transect ID 14 transect ID 15		6:00 - 11:00 which sites: transect ID 31 transect ID 32 transect ID 33 transect ID 34 transect ID 35
Agnese + partner Thijs (FW78 fieldwork)	6:00 - 11:00 which sites: transect ID 16 transect ID 17 transect ID 18 transect ID 19 transect ID 20		6:00 - 11:00 which sites: transect ID 46 transect ID 47 transect ID 48 transect ID 49 transect ID 50
Vasileia + partner Thom (FW77 fieldwork)		6:00 - 11:00 which sites: transect ID 6 transect ID 7 transect ID 8 transect ID 9 transect ID 10	
Federico + partner Maya (FW76 fieldwork)		6:00 - 11:00 which sites: transect ID 1 transect ID 2 transect ID 3 transect ID 4 transect ID 5	
Alexia + partners Sarah, Barbora and Kam (OFW86 online)	working on data on mammals	6:00 - 7:00	

Id point	Type of forest management	Longitude	Latitude	Coordinate
1	bosreservaat (forest reserve)	5°26'21.46"E	52°3'0.824"N	52°3'0.824"N 5°26'21.46"E
original 2	bosreservaat	5°26'24.238"E	52°3'1.576"N	52°3'1.576"N 5°26'24.238"E
new 2	bosreservaat	5°26’20.168’’E	52°2’54.423’’N	52°2’54.423’’N 5°26’20.168’’E
original 3	bosreservaat	5°26'18.94"E	52°3'0.815"N	52°3'0.815"N 5°26'18.94"E
new 3	bosreservaat	5°26’14.908’’E	52°2’54.086’’N	52°2’54.086’’N 5°26’14.908’’E
original 4	bosreservaat	5°26'23.57"E	52°3'0.549"N	52°3'0.549"N 5°26'23.57"E
new 4	bosreservaat	5°26’19.174’’E	52°2’52.581’’N	52°2’52.581’’N 5°26’19.174’’E
5	bosreservaat	5°26'25.236"E	52°2'59.76"N	52°2'59.76"N 5°26'25.236"E
6	bosreservaat	5°26'36.068"E	52°3'1.091"N	52°3'1.091"N 5°26'36.068"E
7	bosreservaat	5 °26'40.56"E	52°3'0.883"N	52°3'0.883"N 5°26'40.56"E
8	bosreservaat	5°26'36.51"E	52°2'58.933"N	52°2'58.933"N 5°26'36.51"E
9	bosreservaat	5°26'40.156"E	52°2'59.603"N	52°2'59.603"N 5°26'40.156"E
10	bosreservaat	5°26'37.879"E	52°3'0.178"N	52°3'0.178"N 5°26'37.879"E
11	natuurboos (nature forest)	5°14'17.58"E	52°10'56.545"N	52°10'56.545"N 5°14'17.58"E
12	natuurboos	5°14'20.502"E	52°10'57.063"N	52°10'57.063"N 5°14'20.502"E
13	natuurboos	5°14'24.599"E	52°10'56.4"N	52°10'56.4"N 5°14'24.599"E

original 14	natuurboos	5°14'20.925"E	52°10'55.574"N	52°10'55.574"N 5°14'20.925"E
new 14	natuurboos	5°24'04.26"E	52°18'20.04"N	52°18'20.04"N 5°24'04.26"E
original 15	natuurboos	5°14'17.335"E	52°10'54.644"N	52°10'54.644"N 5°14'17.335"E
new 15	natuurboos	5°23'59.39"E	52°18'11.87"N	52°18'11.87"N 5°23'59.39"E
16	natuurboos	5°14'14.153"E	52°10'56.746"N	52°10'56.746"N 5°14'14.153"E
17	natuurboos	5°14'11.061"E	52°10'56.691"N	52°10'56.691"N 5°14'11.061"E
18	natuurboos	5°14'10.816"E	52°10'55.201"N	52°10'55.201"N 5°14'10.816"E
19	natuurboos	5°14'14.324"E	52°10'55.514"N	52°10'55.514"N 5°14'14.324"E
20	natuurboos	5°14'13.077"E	52°10'53.766"N	52°10'53.766"N 5°14'13.077"E
31	multifunctional	5°13'34.18"E	52°11'5.627"N	52°11'5.627"N 5°13'34.18"E
32	multifunctional	5°13'36.527"E	52°11'2.932"N	52°11'2.932"N 5°13'36.527"E
33	multifunctional	5°13'33.371"E	52°11'6.853"N	52°11'6.853"N 5°13'33.371"E
34	multifunctional	5°13'41.334"E	52°11'2.468"N	52°11'2.468"N 5°13'41.334"E
35	multifunctional	5°13'43.357"E	52°11'1.315"N	52°11'1.315"N 5°13'43.357"E
46	multifunctional	5°14'4.43"E	52°11'50.573"N	52°11'50.573"N 5°14'4.43"E
47	multifunctional	5°14'2.596"E	52°11'49.304"N	52°11'49.304"N 5°14'2.596"E
48	multifunctional	5°14'2.788"E	52°11'45.999"N	52°11'45.999"N 5°14'2.788"E
49	multifunctional	5°14'3.003"E	52°11'44.202"N	52°11'44.202"N 5°14'3.003"E
50	multifunctional	5°14'4.546"E	52°11'37.141"N	52°11'37.141"N 5°14'4.546"E

Transects Map South
(points 1-10)

group1B

Transects Map
Points 11-20

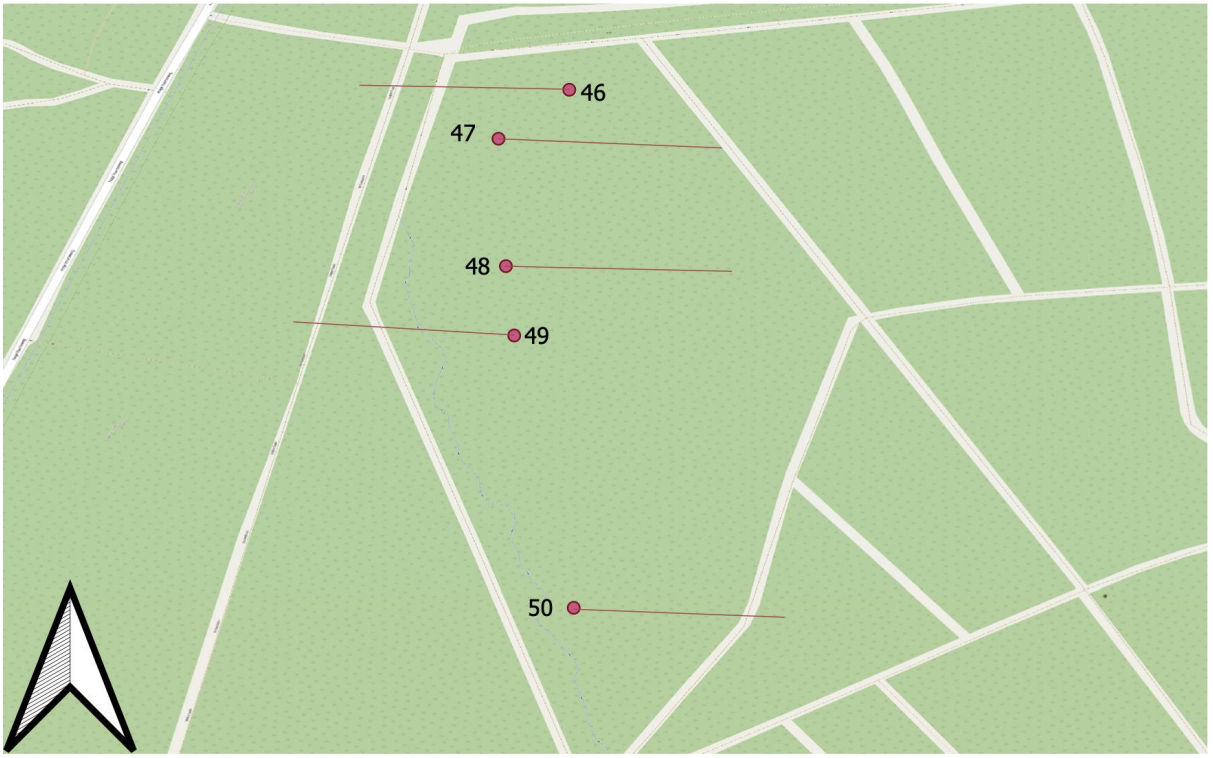
group1B

Transects Map
Points 31-35

group1B

Transects Map
Points 46-50

group1B



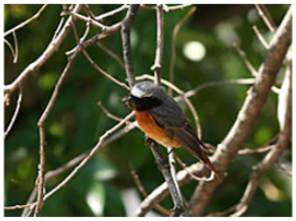
Appendix 2. List with all the species and their characteristics

European pied flycatcher - *Ficedula hypoleuca*

-This is a 12–13.5 centimetres (4.7–5.3 in) long bird. The breeding male is mainly black above and white below, with a large white wing patch, white tail sides and a small forehead patch. The Iberian species *iberiae* (known as **Iberian pied flycatcher**) has a larger forehead patch and a pale rump. Non-breeding males, females and juveniles have the black replaced by a pale brown, and may be very difficult to distinguish from other *Ficedula* flycatchers, particularly the collard flycatcher, with which this species hybridizes to a limited extent.
-Sound: https://www.xeno-canto.org/species/Ficedula-hypoleuca

Great spotted woodpecker - *Dendrocopos major*

-An adult great spotted woodpecker is 20–24 cm long, weighs 70–98 g and has a 34–39 cm wingspan. The upperparts are glossy blue-black, with white on the sides of the face and neck. Black lines run from the shoulder to the nape, the base of the bill and about halfway across the breast. There is a large white shoulder patch and the flight feathers are barred with black and white, as is the tail. The underparts are white other than a scarlet lower belly and undertail. The bill is slate-black, the legs greenish-grey and the eye is deep red. Males have a crimson patch on the nape, which is absent from the otherwise similar females. Juvenile birds are less glossy than adults and have a brown tinge to their upperparts and dirty white underparts. Their markings are less well-defined than the adult's and the lower belly is pink rather than red. The crown of the juvenile's head is red, less extensively in young females than males.
-Sound: https://www.xeno-canto.org/explore?query=Dendrocopos%20major%20



Common redstart - *Phoenicurus phoenicurus*

-The common redstart shows some affinity to the European robin in many of its habits and actions. It has the same general carriage, and chat-like behaviour, and is the same length at 13–14.5 cm long but slightly slimmer and not quite as heavy, weighing 11–23 g. The orange-red tail, from which it and other redstarts get their names, is frequently quivered. The male in summer has a slate-grey head and upperparts, except the rump and tail, which, underwing coverts and axillaries are orange-chestnut. The forehead is white; the sides of the face and throat are black. The wings and the two central tail feathers are brown, the other tail feathers bright orange-red. The orange on the flanks shades to almost white on the belly. The bill and legs are black. In autumn, pale feather fringes on the body feathering obscures the colours of the male, giving it a washed-out appearance. The female is browner, with paler underparts; it lacks the black and slate, and the throat is whitish.
-Sound: https://www.xeno-canto.org/explore?query=Phoenicurus%20phoenicurus

Tree pipit - *Anthus trivialis*

-This is a small pipit, which resembles meadow pipit. It is an undistinguished-looking species, streaked brown above and with black markings on a white belly and buff breast below. It can be distinguished from the slightly smaller meadow pipit by its heavier bill and greater contrast between its buff breast and white belly. Tree pipits more readily perch in trees.
-Sound: https://www.xeno-canto.org/explore?query=Anthus%20trivialis

Common cuckoo - *Cuculus canorus*

-The common cuckoo is 32–34 centimetres long from bill to tail, with a tail of 13–15 centimetres and a wingspan of 55–60 centimetres The legs are short. It has a greyish, slender body and long tail, similar to a sparrowhawk in flight, where the wingbeats are regular. During the breeding season, common cuckoos often settle on an open perch with drooped wings and raised tail. There is a rufouscolour morph,, which occurs occasionally in adult females but more often in juveniles.
-Sound: https://www.xeno-canto.org/explore?query=Cuculus%20canorus

Willow warbler - *Phylloscopus trochilus*

-It is a typical leaf warbler in appearance, 11–12.5 cm long and 7–15 g weight. It is greenish brown above and off-white to yellowish below; the wings are plain greenish-brown with no wingbars. Juveniles are yellower below than adults. It is very similar to the chiffchaff, but non-singing birds can be distinguished from that species by their paler pinkish-yellow legs (dark brown to blackish in chiffchaff), longer paler bill, more elegant shape and longer primary projection (wingtip). Its song is a simple repetitive descending whistle, while the contact call is a disyllabic 'hoo-eet', distinct from the more monosyllabic 'hweet' of chiffchaffs.
-Sound: https://www.xeno-canto.org/explore?query=Phylloscopus%20trochilus

Common chaffinch - *Fringilla coelebs*

- The common chaffinch is about 14.5 cm long, with a wingspan of 24.5–28.5 cm and a weight of 18–29 g. The adult male of the nominate subspecies has a black forehead and a blue-grey crown, nape and upper mantle. The rump is a light olive-green; the lower mantle and scapulars form a brown saddle. The side of head, throat and breast are a dull rust-red merging to a pale creamy-pink on the belly. The central pair of tail feathers are dark grey with a black shaft streak. The rest of the tail is black apart from the two outer feathers on each side which have white wedges. Each wing has a contrasting white panel on the coverts and a buff-white bar on the secondaries and inner primaries. The flight feathers are black with white on the basal portions of the vanes. The secondaries and inner primaries have pale yellow fringes on the outer web whereas the outer primaries have a white outer edge.
- Sound: https://www.xeno-canto.org/explore?query=Fringilla%20coelebs

European goldfinch - *Carduelis carduelis*

-The average European goldfinch is 12–13 cm long with a wingspan of 21–25 cm and a weight of 14 to 19 g The sexes are broadly similar, with a red face, black and white head, warm brown upper parts, white underparts with buff flanks and breast patches, and black and yellow wings.
-Sound: https://www.xeno-canto.org/explore?query=Carduelis%20carduelis

Eurasian nuthatch - *Sitta europaea*

-The adult male of the nominate subspecies, *S. e. europaea* is 14 cm long with a 22.5–27 cm wingspan. It weighs 17–28 g. It has blue-grey upperparts, a black eye-stripe and whitish throat and underparts. The flanks and lower belly are orange-red, mottled with white on the undertail. The stout bill is dark grey with a paler area on the base of the lower mandible, the iris is dark brown and the legs and feet are pale brown or greyish. Most other members of the *S. e. europaea* group differ only in detail from the nominate form, often with respect to the hue of the underparts, but *S. e. arctica* is quite distinctive. It is large, pale, has a white forehead and a reduced eye-stripe, and it has more white in the tail and wings than any other subspecies. Nuthatches move on trees with short leaps, and do not use their tails for support. In flight, they have a characteristic appearance, with a pointed head, round wings and a short, square tail. Their flight is fast, with wings closed between beats, and is usually of short duration.
-Sound: https://www.xeno-canto.org/explore?query=Sitta%20europaea

Great tit - *Parus major*

- The great tit is large for a tit at 12.5 to 14.0 cm in length, and has a distinctive appearance that makes it easy to recognise. The nominate race *P. major major* has a bluish-black crown, black neck, throat, bib and head, and white cheeks and ear coverts. The breast is bright lemon-yellow and there is a broad black mid-line stripe running from the bib to vent. There is a dull white spot on the neck turning to greenish yellow on the upper nape. The rest of the nape and back are green tinged with olive. The wing-coverts are green, the rest of the wing is bluish-grey with a white wing-bar. The tail is bluish grey with white outer tips. The plumage of the female is similar to that of the male except that the colours are overall duller; the bib is less intensely black, as is the line running down the belly, which is also narrower and sometimes broken. Young birds are like the female, except that they have dull olive-brown napes and necks, greyish rumps, and greyer tails, with less defined white tips.
- Sound:

Common blackbird - *Turdus merula*

-The common blackbird of the nominate subspecies *T. m. merula* is 23.5 to 29 centimetres in length, has a long tail, and weighs 80–125 grams The adult male has glossy black plumage, blackish-brown legs, a yellow eye-ring and an orange-yellow bill. The bill darkens somewhat in winter. The adult female is sooty-brown with a dull yellowish-brownish bill, a brownish-white throat and some weak mottling on the breast. The juvenile is similar to the female, but has pale spots on the upperparts, and the very young juvenile also has a speckled breast. Young birds vary in the shade of brown, with darker birds presumably males. The first year male resembles the adult male, but has a dark bill and weaker eye ring, and its folded wing is brown, rather than black like the body plumage.
-Sound:

Eurasian blue tit - *Cyanistes caeruleus*

The Eurasian blue tit is usually 12 cm, long with a wingspan of 18 cm. for both sexes, and weighs about 11 g. A typical Eurasian blue tit has an azure-blue crown and dark blue line passing through the eye, and encircling the white cheeks to the chin, giving the bird a very distinctive appearance. The forehead and a bar on the wing are white. The nape, wings and tail are blue and the back is yellowish green. The underparts is mostly sulphur-yellow with a dark line down the abdomen—the yellowness is indicative of the number of yellowy-green caterpillars eaten, due to high levels of carotene pigments in the diet. The bill is black, the legs bluish grey, and the irides dark brown. The sexes are similar, but under ultraviolet light, males have a brighter blue crown. Young blue tits are noticeably more yellow.
-Sound:

+

Common chiffchaff - *Phylloscopus collybita*

- The common chiffchaff is a small, dumpy, 10–12 centimetres long leaf warbler. The male weighs 7–8 grammes , and the female 6–7 grammes The spring adult of the western nominate subspecies*P. c. collybita* has brown-washed dull green upperparts, off-white underparts becoming yellowish on the flanks, and a short whitish supercilium. It has dark legs, a fine dark bill, and short primary projection (extension of the flight feathers beyond the folded wing). As the plumage wears, it gets duller and browner, and the yellow on the flanks tends to be lost, but after the breeding season there is a prolonged complete moult before migration. The newly fledged juvenile is browner above than the adult, with yellow-white underparts, but moults about 10 weeks after acquiring its first plumage. After moulting, both the adult and the juvenile have brighter and greener upperparts and a paler supercilium.
- Sound:

Short-toed treecreeper - *Certhia brachydactyla*

-The short-toed treecreeper is 12.5 centimetres long and weighs 7.5–11 g It has dull grey-brown upperparts intricately patterned with black, buff and white, a weak off-white supercilium and dingy underparts contrasting with the white throat. The sexes are similar, but juveniles have whitish underparts, sometimes with a buff belly.
-Sound:

Common buzzard - *Buteo buteo*

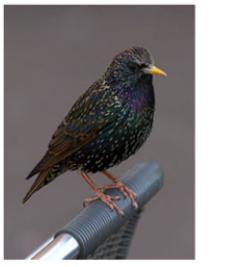
-The common buzzard is a medium-sized raptor that is highly variable in plumage. Most buzzards are distinctly round headed with a somewhat slender bill, relatively long wings that either reach or fall slightly short of the tail tip when perched, a fairly short tail, and somewhat short and mainly bare tarsi. They can appear fairly compact in overall appearance but may also appear large relative to other commoner raptorial birds such as kestrels and sparrowhawks .The common buzzard measures between 40 and 58 cm in length with a 109–140 cm wingspan .Females average about 2–7% larger than males linearly and weigh about 15% more. Body mass can show considerable variation. Buzzards from Great Britain alone can vary from 427 to 1,183 g in males, while females there can range from 486 to 1,370 g.
-Sound:

Common swift - *Apus apus*

- Common swifts are 16–17 cm long with a wingspan of 38–40 cm and entirely blackish-brown except for a small white or pale grey patch on their chins which is not visible from a distance. They have a short forked tail and very long swept-back wings that resemble a crescent or a boomerang.
- Sound:

European robin - *Erithacus rubecula*

-The adult European robin is 12.5–14.0 cm long and weighs 16–22 g with a wingspan of 20–22 cm . The male and female bear similar plumage; an orange breast and face (more strongly coloured in the otherwise similar British subspecies *E. r. melophilus*), lined by a bluish grey on the sides of the neck and chest. The upperparts are brownish, or olive-tinged in British birds, and the belly whitish, while the legs and feet are brown. The bill and eyes are black. Juveniles are a spotted brown and white in colouration, with patches of orange gradually appearing.
-Sound:



Common starling - *Sturnus vulgaris*

-The common starling is 19–23 cm long, with a wingspan of 31–44 cm and a weight of 58–101 g. Among standard measurements, the wing chord is 11.8 to 13.8 cm, the tail is 5.8 to 6.8 cm, the culmen is 2.5 to 3.2 cm and the tarsus is 2.7 to 3.2 cm. The plumage is iridescent black, glossed purple or green, and spangled with white, especially in winter. The underparts of adult male common starlings are less spotted than those of adult females at a given time of year. The throat feathers of males are long and loose and are used in display while those of females are smaller and more pointed. The legs are stout and pinkish- or greyish-red. The bill is narrow and conical with a sharp tip; in the winter it is brownish-black but in summer, females have lemon yellow beaks while males have yellow bills with blue-grey bases.-Sound:

Eurasian jay - *Garrulus glandarius*

- The Eurasian jay is a relatively small corvid, similar in size to a western jackdaw (*Coloeus monedula*) with a length of 34–35 cm and a wingspan of 52–58 cm. The nominate race has light rufous brown to a pinkish brown body plumage. The whitish throat is bordered on each side by a prominent black moustache stripe. The forehead and crown are whitish with black stripes. The rump is white. The complex colouring on the upper surface of the wing includes black and white bars and a prominent bright blue patch with fine black bars. The tail is mainly black.
- Sound:

Barn swallow - *Hirundo rustica*

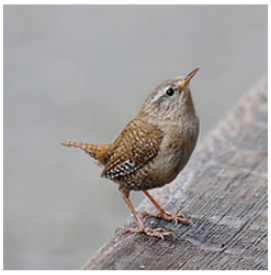
-The adult male barn swallow of the nominate subspecies *H. r. rustica* is 17–19 cm long including 2–7 cm of elongated outer tail feathers. It has a wingspan of 32–34.5 cm and weighs 16–22 g. It has steel blue upperparts and a rufous forehead, chin and throat, which are separated from the off-white underparts by a broad dark blue breast band. The outer tail feathers are elongated, giving the distinctive deeply forked "swallow tail". There is a line of white spots across the outer end of the upper tail. The female is similar in appearance to the male, but the tail streamers are shorter, the blue of the upperparts and breast band is less glossy, and the underparts paler. The juvenile is browner and has a paler rufous face and whiter underparts. It also lacks the long tail streamers of the adult.
-Sound:

Common whitethroat - *Curruca communis*

-The common whitethroat is one of several *Curruca* species that has distinct male and female plumages. Both sexes are mainly brown above and buff below, with chestnut fringes to the secondary remiges. The adult male has a grey head and a white throat. The female lacks the grey head, and the throat is duller. The whitethroat's song is fast and scratchy, with a scolding tone.
The hoarse, a little bit nasal call sounds like *wed-wed* or *woid-woid*. The warning cry is long-pulled, rough *tschehr* which resembles that of the Dartford warbler.
-Sound:

European crested tit - *Lophophanes cristatus*

- The European crested tit is an easy tit to recognise, for besides its erectile crest, the tip of which is often recurved, its gorget and collar are distinctive. It is, like other tits, talkative, and birds keep up a constant *zee, zee, zee, similar to that of the coal tit.*
- Sound:



Eurasian wren - *Troglodytes troglodytes*

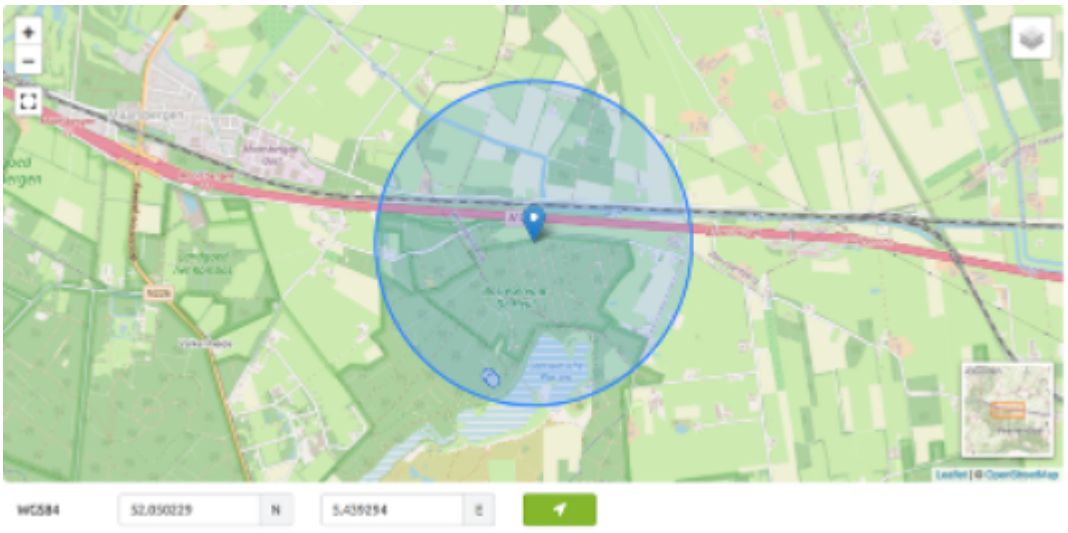
-The Eurasian wren is a plump, sturdy bird with rounded wings and a short tail, which is usually held cocked up. The adult bird is 9 to 10 cm in length and has a wingspan of 13–17 cm. It weighs around 10 g. It is rufous brown above, greyer beneath, and indistinctly barred with darker brown and grey, even on the wings and tail. The bill is dark brown and the legs are pale brown, the feet having strong claws and a large hind toe. Young birds are less distinctly barred and have mottled underparts. The plumage is subject to considerable variation, and where populations have been isolated, the variation has become fixed in one minor form or another.
-Sound:

Common wood pigeon - *Columba palumbus*

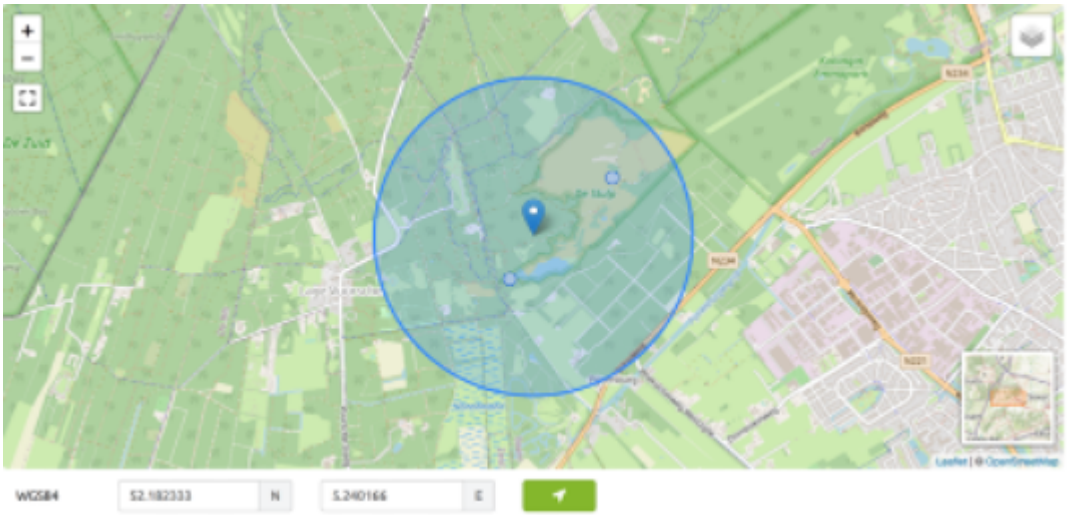
-The three Western European Columba pigeons, common wood pigeon, stock dove and rock dove, though superficially alike, have very distinctive characteristics; the common wood pigeon may be identified at once by its larger size at 38–44.5 cm and weight 300–615 g, and the white on its neck and wing. It is otherwise a basically grey bird, with a pinkish breast. The wingspan can range from 68 to 80 cm and the wing chord measures 24 to 25.4 cm. The tail measures 13.8 to 15 cm, the bill is 1.9 to 2.2 cm and the tarsus is 2.5 to 2.8 cm. Adult birds bear a series of green and white patches on their necks, and a pink patch on their chest.
-Sound:

1. https://www.xeno-canto.org/explore?query=Ficedula%20hypoleuca
2. https://www.xeno-canto.org/explore?query=Dendrocopos%20major
3. https://www.xeno-canto.org/explore?query=Phoenicurus%20phoenicurus
4. https://www.xeno-canto.org/explore?query=Anthus%20trivialis
5. https://www.xeno-canto.org/explore?query=Cuculus%20canorus
6. https://www.xeno-canto.org/explore?query=Phylloscopus%20trochilus
7. https://www.xeno-canto.org/explore?query=Fringilla%20coelebs
8. https://www.xeno-canto.org/explore?query=Carduelis%20carduelis
9. https://www.xeno-canto.org/explore?query=Sitta%20europaea
10. https://www.xeno-canto.org/explore?query=Parus%20major
11. https://www.xeno-canto.org/explore?query=Turdus%20merula
12. https://www.xeno-canto.org/explore?query=Cyanistes%20caeruleus
13. https://www.xeno-canto.org/explore?query=Phylloscopus%20collybita
14. https://www.xeno-canto.org/explore?query=Certhia%20brachydactyla
15. https://www.xeno-canto.org/explore?query=Buteo%20buteo
16. https://www.xeno-canto.org/explore?query=Apus%20apus
17. https://www.xeno-canto.org/explore?query=Erithacus%20rubecula
18. https://www.xeno-canto.org/explore?query=Sturnus%20vulgaris
19. https://www.xeno-canto.org/explore?query=Garrulus%20glandarius
20. https://www.xeno-canto.org/explore?query=Hirundo%20rustica
21. https://www.xeno-canto.org/explore?query=Common%20whitethroat%20%20
22. https://www.xeno-canto.org/explore?query=Lophophanes%20cristatus
23. https://www.xeno-canto.org/explore?query=Troglodytes%20troglodytes
24. https://www.xeno-canto.org/explore?query=Columba%20palumbus

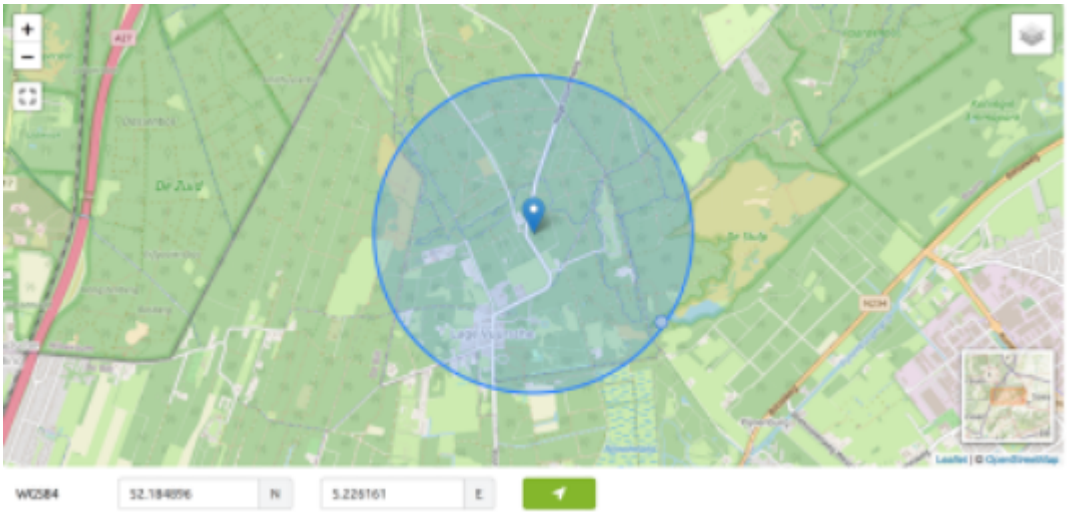
Appendix 3. Maps of the online fieldwork (Waarneming.nl)



Map of the Nature Reserve



Map of the Nature Forest



Map of the Multifunctional Forest

Appendix 4. The Datasheet.

Name of the observer:	GPS coordinates:	Latitude:
Date:		Longitude:
Location ID:		
Description of the area (vegetation, what kind of tree):		
Weather conditions (rain, wind, clouds, temperature):		
Time start:	Time finish:	

Bird species	**Number**	**Bird species**	**Number**
European pied flycatcher (Ficedula hypoleuca)		Common chiffchaff (Phylloscopus collybita)	
Great spotted woodpecker (Dendrocopos major)		Short-toed treecreeper (Certhia brachydactyla)	
Common redstart (Phoenicurus phoenicurus)		Common buzzard (Buteo buteo)	
Tree pipit (Anthus trivialis)		Common swift (Apus apus)	
Common cuckoo (Cuculus canorus)		European robin (Erithacus rubecula)	
Willow warbler (Phylloscopus trochilus)		Common starling (Sturnus vulgaris)	
Common chaffinch (Fringilla coelebs)		Eurasian jay (Garrulus glandarius)	
European goldfinch (Carduelis carduelis)		Barn swallow (Hirundo rustica)	
Eurasian nuthatch (Sitta europaea)		Common whitethroat (Curruca communis)	
Great tit (*Parus major*)		European crested tit (Lophophanes cristatus)	
Common blackbird (Turdus merula)		Eurasian wren (Troglodytes troglodytes)	
Eurasian blue tit (Cyanistes caeruleus)		Common wood pigeon (Columba palumbus)	
Marsh tit (Poecile palustris)		Blackcap (Sylvia atricapilla)	

Record time when the observer is not able to identify the bird (bird can later be identified from the recordings)						

Other remarks (if necessary): _____

_____

_____

_____

_____

Appendix 5. Table with the recorded total individuals for the bird species:

Bird Species	Total Individuals Observed
European pied flycatcher *(Ficedula hypoleuca)*	3
Great spotted woodpecker *(Dendrocopos major)*	13
Common redstart *(Phoenicurus phoenicurus)*	6
Tree pipit *(Anthus trivialis)*	16
Common cuckoo *(Cuculus canorus)*	1
Willow warbler *(Phylloscopus trochilus)*	0
Common Chaffinch *(Fringilla coelebs)*	41
European goldfinch *(Carduelis carduelis)*	1
Eurasian nuthatch *(Sitta europaea)*	5
Great tit *(Parus major)*	17
Common blackbird *(Turdus merula)*	11
Eurasian blue tit *(Cyanistes caeruleus)*	16
Marsh tit	7
Common chiffchaff *(Phylloscopus collybita)*	22

Short-toed treecreeper *(Certhia brachydactyla)*	11
Common buzzard *(Buteo buteo)*	1
Common swift *(Apus apus)*	2
European robin *(Erithacus rubecula)*	44
Common starling *(Sturnus vulgaris)*	0
Eurasian jay *(Garrulus glandarius)*	6
Barn swallow *(Hirundo rustica)*	0
Common whitethroat *(Curruca communis)*	2
European crested tit *(Lophophanes cristatus)*	0
Eurasian wren *(Troglodytes troglodytes)*	20
Common wood pigeon *(Columba palumbus)*	3
Coal tit (*Periparus ater)*	1
Eurasian blackcap (*Sylvia atricapilla*)	13
Eurasian magpie (*Pica pica*)	1
Carrion crow (*Corvus corone*)	10
European stonechat (*Saxicola rubicola*)	1
Song thrush (*Turdus philomelos*)	5
White wagtail *(Motacilla alba)*	2

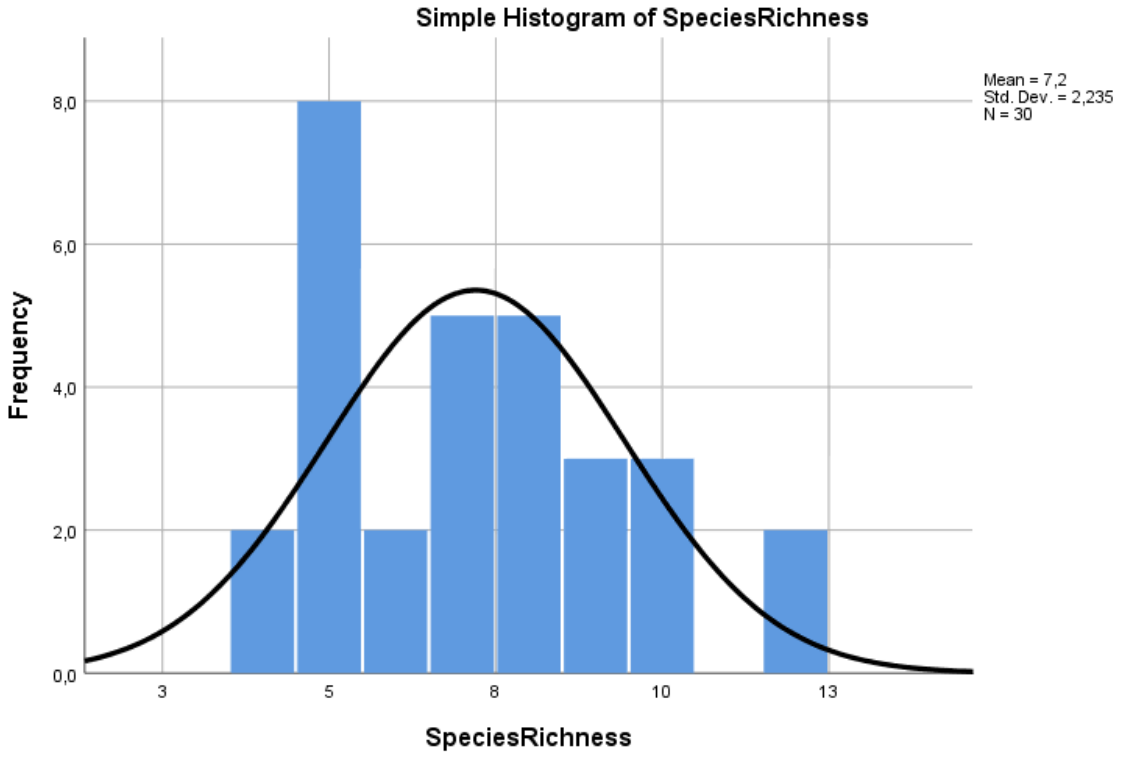
Appendix 6. Table with the bird species richness and number of individuals in each forest management type.

Forest Management Type	Species richness	N
Forest Reserve	20	84
Nature Forest	19	95
Multifunctional	20	102

Appendix 7. Table with the recorded total individuals for the mammal species.

Mammal	Forest Reserve(sights)	Nature Forest and Multifunctional Forest (sights)
European Roe Deer	10	6
European Rabbit	0	6
Eurasian Red Squirrel	8	3
Bank Vole	4	12
European Hare	2	1
Long-tailed Field Mouse	0	2
Species richness	4	6

Appendix 8. Normal Distribution test for Bird Species Richness. Visual representation with a histogram and Shapiro Wilk Test.



Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SpeciesRichness	,171	30	,025	,929	30	,046

a. Lilliefors Significance Correction

Appendix 9. Kruskal-Wallis H test for Bird Species Richness

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Richness is the same across categories of Management.	Independent-Samples Kruskal-Wallis Test	,483	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Independent-Samples Kruskal-Wallis Test

Richness across Management

Independent-Samples Kruskal-Wallis Test Summary

Total N	30
Test Statistic	1,455[a,b]
Degree Of Freedom	2
Asymptotic Sig.(2-sided test)	,483

a. The test statistic is adjusted for ties.

b. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

Appendix 10.

Excel spreadsheet - Calculation Data report.xlsx
Link:
https://solisservices-my.sharepoint.com/:x:/g/personal/f_granato_students_uu_nl/Eaafcpettzx Gt1R53lmgg8QB1XN0PqaXDiuo7JFOocaBXg?e=Y2lLdJ

example:

Site ID	European pied flycatcher	Great spotted woodpecker	Common redstart	Tree pipit	Common cuckoo	Willow warbler	Common chaffinch	European goldfinch	Eurasian nuthatch	Great tit	Common blackbird
1		1									
2			2				2				
3		1					2			1	
4							1			1	
5							2			1	
6		2		1			1			1	
7	1						3		1		
8				1			1		1	1	
9				1			2	1			
10	1			1			1		1		
Total	2	4	2	4	0	0	15	1	3	5	0
H calcul.	-0.088992134	-0.1449773	-0.088992134	-0.144977259	0	0	-0.307636892	-0.052747819	-0.119007304	-0.167939219	0
n. species total		**20**									
*H'= -pi*ln pi*											
	2	5	2	5	0	0	**18**	1	4	6	0