Nest selection of the Great spotted woodpecker (*Dendrocopos major*) in the Oostereng

How do forest characteristics and human disturbance influence next selection of the Great Spotted Woodpecker in the Oostereng?

Picture made by Thijs Glastra

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Abstract

The Great spotted woodpecker (*Dendrocopos major*) is the most common woodpecker species in Western Europe and is a keystone species that indicates good forest health. The Dutch population is increasing as a result of natural forest management and maturing forest. However, little is known about the nest selection of the Great spotted woodpecker. More research is needed in order to reveal what forest characteristics are important in the process of nest selection. To analyze nest selection, data was collected in the Oostereng forest. Transects were walked to map woodpecker abundance. For nest sites, data was collected on a nest patch level (number of (dead) trees, tree species, average DBH, vegetation and canopy cover) , on a nest tree level (DBH, state, tree height, distance to trails) and on a cavity level (cavity height, cavity direction). Every nest location was paired to a random tree in the same forest patch, where the same data was collected with the exception of cavity level characteristics. Analysis in Rstudio with a Binary Logistic Regression model revealed that the number of dead standing trees, the DBH of the nest tree and the distance from nest trees to trails are important characteristics for nest selection of the Great spotted woodpecker. This study further describes that in the Oostereng forest, Great spotted woodpeckers prefer both dead and alive deciduous trees as nest trees. Future studies will further aid the understanding of nest selection of Great spotted woodpeckers and will benefit the conservation of Great spotted woodpecker populations and thus forest health.

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Introduction

Nest building is very diverse among bird species, ranging in design and size across and within taxa. The overarching function of the nest is that of laying eggs and raising offspring in a safe environment (Mainwaring et al., 2014). Apart from building the nest, selecting an appropriate nesting site is an important process that determines reproductive success (Rolstad, Rolstad & Stokke, 1995; Hooge, Stanback & Koenig, 1999). Nest site selection is determined by multiple factors: food availability, predation risk, intraspecific competition, availability of nest material and presence of suitable (micro)climate (Mainwaring et al., 2014).

Firstly, the availability of food for both parents and offspring is an important factor that determines nest selection (Rolstad, Rolstad & Stokke, 1995). Secondly, the risk of predation influences nest selection. Nest predation is the main cause of reproductive failure for most avian species (Forstmeier, Weiss, 2004). Risk of nest predation can be lowered through multiple approaches. One approach is the preference for nest sites away from predators or in close proximity to more aggressive species as 'guardians'. Some species prefer to nest higher above ground to reduce predation risk by mammals, whereas other species select nesting locations lower to the ground to reduce predation risk by avian predators (Forstmeier, Weiss, 2004; Mainwaring et al., 2014). A third factor that can be important for nest selection is intraspecific competition (Nilsson, 1984). Territorial birds avoid conspecifics, while other gregarious species nest in groups together. A fourth factor, the presence of nest material, could be important if the bird species has specific needs for certain nesting material like mud (Cantarero, López-Arrabé & Moreno, 2015). A fifth factor is the presence of suitable (micro)climate for rearing offspring (Tieleman, Van Noordwijk, & Williams, 2008).

One nesting strategy that takes into account these five aspects is cavity nesting. However, in addition to these factors, cavity nesters also require the presence of dead or decaying trees for food availability, excavating nest holes or for using existing holes (Gutzat & Dormann, 2018). For woodpeckers, nest selection plays a central role in their life (Pasinelli, 2007). Woodpeckers are among the most demanding cavity nesting bird species because they have specific ecological demands (Mikusiński et al., 2001). Woodpeckers will generally excavate a new breeding cavity almost every year, although some individuals will use the same cavity from the year before (Mazgajski & Rejt, 2006). The Great spotted woodpecker (*Dendrocopos major*) is the most common woodpecker species in western Europe (Piacentini & Chiatante 2022). They are found throughout Europe and are present in every forest type. Great spotted woodpeckers are less demanding than other European woodpecker species, which might explain their high abundance throughout Europe (Virkkala, 1994; Mikusiński et al., 2001; Kosinski & Kempa, 2007).

Forest characteristics can have a great influence on habitat and nest selection of woodpecker species. Basile et al. (2020) found that woodpeckers prefer breeding sites where the mean DBH (diameter at breast height) is larger than the mean DBH of the entire forest. Specialist woodpecker species such as the Three-toed woodpecker (*Picoides tridactylus*) and the White-backed woodpecker (*Dendrocopos leucotos*) need a stable population of saproxylic beetles for their food supply (Kajtoch et al., 2013). Great spotted woodpeckers prefer old deciduous forest stands as both their breeding habitat and foraging ground. Old deciduous trees are preferred nesting trees. A study by Kosinski & Kempa (2007) found that Oaks (*Quercus sp.)* were by far the favorite nesting tree species for the great spotted woodpecker, more specifically Oaks with a DBH of ca. 48 cm. The Great spotted woodpecker prefers a habitat for nesting where the forest has a closed canopy, because this offers better visual shelter from both aerial and arboreal predators (Piacentini & Chiatante, 2022). Although some aspects of their nest site preferences have been researched, there are still few studies done on the nest selection of European woodpecker species (Kosinski & Kempa, 2007; Pasinelli, 2007).

Current trends and threats

In the Netherlands, the number of Great spotted woodpeckers is increasing. One of the reasons for this increase entails forest stands that have grown older, resulting in more suitable habitat and consequently suitable nesting locations for the woodpeckers (Kosinksi, 2006; Sovon, n.d.). For feeding, they prefer forest patches that contain dry/dead wood with many insects, which are present in old and unmanaged forests. Another reason for the increase relates to forest management in the Netherlands which has changed from almost exclusively production forest to a more natural approach of forest management, whereby potential nest trees and availability of dead wood and thus food availability have increased (op Akkerhuis et al., 2005; Angelstam et al., 2003; Sovon, n.d.).

Despite the positive population trend in the Netherlands, Great spotted woodpeckers face several threats. First, some forest management practices can have detrimental effects. Woodpeckers depend on old trees for their nests and dead wood for feeding on insects (Virkkala, 2006). Forest practices where old trees are cut down and where dead wood is removed from the forest can cause a local decline in woodpeckers (Piacentini & Chiatante, 2022; Mazgajski & Rejt, 2006).

Another threat for the great spotted woodpecker is habitat fragmentation. Forest patch size influences the breeding success of the Great spotted woodpecker. Reproductive success in Poland was found to be lower in small forest patches (<10 ha) than in large forest patches(<100 ha) (Mazgajski & Rejt, 2006). Possible cause of the decline in breeding success in small patches is the possibility of increased predation pressure – for example by Pine marten (*Martes martes*) (Mazgajski, 2002) – or increased intraspecific competition (Mazgajski & Rejt, 2006).

Finally, human disturbance can influence nest selection. In temperate forests, rising spring temperatures result in an increase of human recreation in the forest (Bartczak et al., 2012). Spring is an important period for the woodpeckers, as they are establishing their territory (Bötsch et al., 2017). The presence of humans can thus result in lower habitat quality (Reed & Merenlender, 2008). Birds will avoid areas with a lot of recreational activity if neighboring areas are less disturbed by recreation (Bötsch et al., 2017). Density and species richness of birds decreases closer to trails in a forest with high recreation pressure (Bötsch et al., 2018). Walking trails also indirectly influence bird abundance because they fragment the landscape (Bötsch et al., 2018).

Importance of research

Woodpeckers are important to study for a number of reasons. First of all, woodpeckers can be regarded as keystone forest species. They are sensitive towards any changes in their habitat and their presence can be used as a general indicator for forest biodiversity and quality (Mikusiński et al., 2001). Woodpeckers are also so-called ‘ecosystem engineers’. They change their environment by making new cavities every year which results in a large amount of cavities within the forest. The cavities that are no longer used by the woodpeckers provide a nesting place for secondary cavity-nesters (Piacentini & Chiatante, 2022). As the presence of woodpeckers can be used as an indicator for forest biodiversity, assessing and researching them can be useful for forest restoration practices (Virkkala, 2006). Woodpecker abundance thus also indicates the biodiversity of other bird species in managed forests (Drever & Martin, 2010). Therefore, they are also an excellent species to study the effect of human disturbance on bird abundance and nest selection.

Research questions

The main research questions are as follows:

- What forest characteristics determine nesting sites of the Great spotted woodpecker (*Dendrocopos major*)?
- What is the influence of human disturbance on nest selection of the Great spotted woodpecker (*Dendrocopos major*)?

And as sub question, related to the second research question:

- How does the distance to walking trails influence nest locations of the Great spotted woodpecker (*Dendrocopos major*) ?

Hypotheses

The forest characteristics that determine the selection of nesting sites are expected to be a combination of tree species, canopy cover, DBH and number of dead standing trees in the area around the nest site. Tree species, because Great spotted woodpeckers have a strong preference for deciduous tree species such as Oaks (Kosinski & Kempa, 2007). Large living deciduous trees are expected to be used most (Piacentini & Chiatante, 2022; Kosinski & Kempa, 2007). DBH, because Great spotted woodpeckers prefer large diameter trees as nest trees (Kosinski & Kempa, 2007; Piacentini & Chiatante, 2022). The number of dead standing trees, because that is where Great spotted woodpeckers forage on insects (Mikusiński et al., 2001).

Regarding the influence of human disturbance, it is expected that the Great spotted woodpecker will avoid nesting sites neighboring directly to active forest practices such as fellings and thinnings, as woodpeckers prefer a closed canopy for safety against predators (Piacentini & Chiatante, 2022). Furthermore, it is expected that a close distance to walking trails influences nest site selection for the Great spotted woodpecker negatively (Catalina-Allueva & Martin, 2021). A small negative impact is expected, as cavity breeding birds are less affected by human recreational disturbance because their excavated cavity also acts as shelter, which lowers the effect of disturbance compared to an open cup nester (Bötsch et al., 2017).

Methods

Study system: Oostereng forest

Data was collected in the Oostereng forest, a small forest just outside of Wageningen (685 ha, 51°59'56.1"N 5°43'00.9"E) that has been used for research by Wageningen University and Research (WUR). Firstly, this forest area was chosen because it is densely populated with Great spotted woodpeckers (based on data from Waarneming.nl), which increased the probability of finding sufficient individuals and nesting sites. Secondly, because the forest is compact, it is easy to walk and collect data throughout the forest in a short amount of time, which made the forest very suitable to walk daily transects repetitively. Lastly, the forest has a range of different tree species and habitats, which provided a great testing arena to study what forest characteristics are important for the Great spotted woodpecker.

Data collection

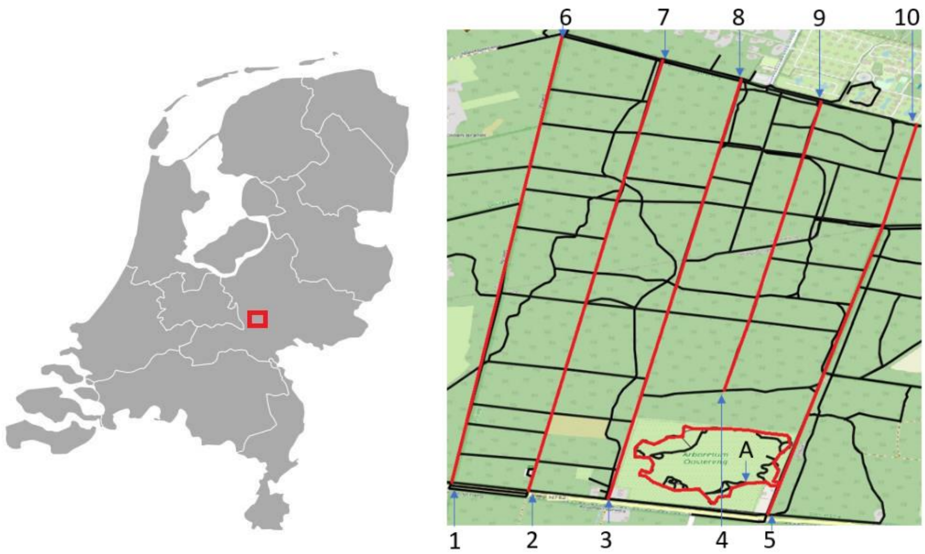


Figure 1: The Netherlands with the Oostereng forest location highlighted in the red square, the map on the right shows the different transects in red, numbered from 1 to 10 and A for the Arboretum route.

During March , April and the beginning of May 2023, line transects were walked between dawn and 12:00 PM from the South of the forest towards the North and vice versa. To avoid bias, transects were chosen randomly on the day of the fieldwork with a random number generator in Google. In total, there were five South to North transects, numbered 1-5, and five North to South transects, numbered 6-10. Each of these numbered transects were walked five times during the data collection period. The Arboretum Oostereng, labelled as A in figure 1, was also walked through five times.

Every time a Great spotted woodpecker was spotted when walking these transects, the observation was recorded in Obsmapp, which saved the exact GPS location of the observation. During the first two months of data collection, cues that possibly indicated nest building sites were noted down to maximize the discovery of occupied nests in the breeding season. From May until the beginning of June, nests were discovered and data was collected around each nest tree.

Forest characteristics were measured for nest locations, but were also measured for paired locations: a location where no occupied nest was present. The GPS coordinates of these paired locations were generated by a random GPS generator (Random Location Generator (geographic coordinates)). In this generator, GPS boundaries around a nest location were set in order to create a paired location within the forest patch surrounded by trails, so that the paired location is located in the same forest patch as the nest location. These paired locations were in close proximity to the nest location, but at least 20 meters from the nest tree. With the implementation of these paired locations, it was possible to analyze what characteristics are important for the nest selection the Great spotted woodpecker.

The measured characteristics were divided into three different categories: Nest patch level, nest tree level and cavity level (Di Sallo & Cockle, 2022).

Nest patch level

The following characteristics were measured on a nest patch level, which is the area within a radius of 10 meters from the nest tree: Canopy cover (%), where an aerial picture was taken in order to assess the percentage of coverage. Canopy cover was measured on the same day (22th of May) for all trees, when foliage was fully developed. Vegetation cover (%) was also visually assessed on the 22th of May. Furthermore, number of trees with DBH >10 cm within a radius of 10 meters from the nest tree were counted and measured (Kosinksi & Kempa, 2007).

Nest tree level

The following characteristics were measured on a nest tree level: Tree Species (Piacentini & Chiatante, 2022; Di Sallo & Cockle, 2022; Kosinski & Kempa, 2007), State (Alive or dead) (Di Sallo & Cockle, 2022; Kosinski & Kempa, 2007), Part of tree (trunk or branch) (Kosinski & Kempa, 2007), DBH (Di Sallo & Cockle, 2022; Kosinski & Kempa, 2007) and tree height (Di Sallo & Cockle, 2022; Kosinski & Kempa, 2007), which was measured with a Nikon Forestry Pro II Laser Rangefinder/Hypsometer.

Cavity level

The following characteristics were measured at a cavity level: Cavity height (Di Sallo & Cockle, 2022) and facing direction of cavity entrance (Kosinski & Kempa, 2007)

Figure 2: The different levels of data collection, with from left to right: Nest patch level, nest tree level and cavity level

Data analysis

All data was gathered in Excel as input for further analysis.

For data analysis, Rstudio (version 2023.06.0) was used. To answer the main research question: *What forest characteristics determine nesting sites of the Great spotted woodpecker (Dendrocopos major)?*, a binary logistic regression was used to analyze what forest characteristics influence nest site selection and to analyze if the nest location and the paired nest location characteristics show significant differences. The forest characteristics that were analyzed in the binary logistic regression model are summarized in Table 1.

Forest characteristic	**Description**
Nest/paired patch level	
Canopy cover	Percentage between 0 and 100
Vegetation cover	Percentage between 0 and 100
Average DBH	Average DBH of all trees (DBH > 10 cm in the nest patch, with exception to the nest or paired tree
Number of trees	Number of trees with a DBH larger than 10 cm
Number of tree species	Count of every tree species present
Number of dead standing trees	Count of all dead trees that are still standing
Nest/paired tree level	
DBH	In centimeter
Tree species	Species of the nest or paired tree
Tree height	In meter
Tree state	Alive or dead
Tree type	Broadleaved or coniferous
Distance from tree to trail	In meter

Table 1: The different forest characteristics that were tested in the binary logistic regression model

AIC values were calculated for each combination of characteristics in the model in order to determine the model with the best fit. A VIF test was done in order to assess collinearity between different independent variables. Variables were deleted if collinearity was higher than 10. The model with the lowest AIC was used for further analysis.

To answer the sub question*: How does the distance to walking trails influence nest locations of the Great spotted woodpecker (Dendrocopos major) ?* and determine the possible influence of human disturbance on nest site selection, QGis (version 3.16.2-Hannover) was used to submit all the GPS locations of Great spotted woodpecker sightings and nest locations. Here, the function distance from point to road was used to calculate the distances between (paired) nest locations and trails. To further investigate the influence of distance from (paired) nest locations to trails, distance was added as an independent variable in the binary logistic regression model.

Results

In total, 16 nests were found with the help of 294 Great spotted woodpecker observations (Figure 3).

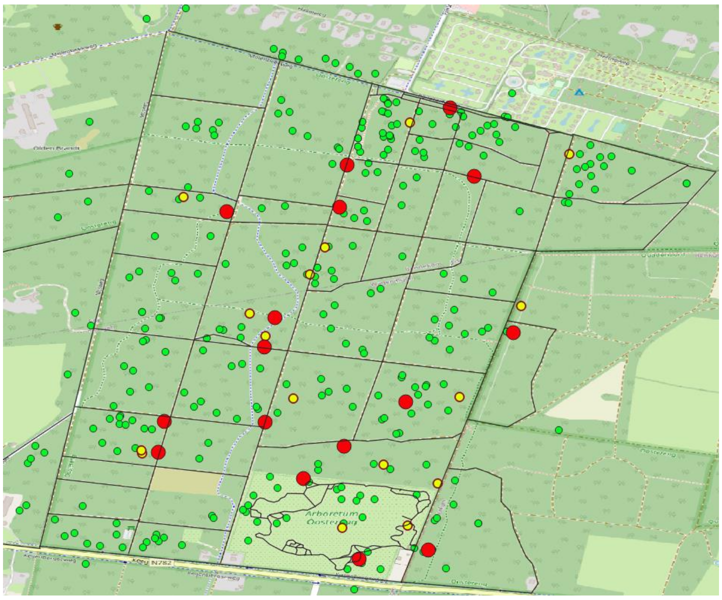


Figure 3: This map shows the Oostereng forest with in green: all the Great spotted woodpecker observations, in red: all the nest locations and in yellow: all the paired locations

Model outcomes

Model	AIC	Difference between Null and Residual deviance
1: Nest/paired tree ~ DBH + N dead standing trees + Canopy cover + Distance from trail	31.93	22.428
2: Nest/paired tree ~ DBH + N dead standing trees + Canopy cover	36.33	16.029
3: Nest/paired tree ~ DBH + N dead standing trees + Vegetation cover	37.32	15.038
4: Nest/paired tree ~ DBH + Height	43.94	6.425

Table 2: Different combinations of characteristics in the model and their AIC value and difference between Null and Residual deviance. The lower the AIC, the better the model. The higher the difference between Null and Residual deviance, the better the model

The GLM test was done to see which variables influence nest selection. The nest or paired location was set as a dependent variable, the different forest characteristics were all added to the Generalized Linear Model (GLM). Variables were tested for collinearity and were deleted if collinearity was higher than 10.

Model 1 had the lowest AIC value (Table 3, 31.93).

Model 1	Nest/paired tree ~ DBH + N dead standing trees + Canopy cover + Distance from trail			
	Estimate	Standard Error	Z value	Pr(>|z|)
(Intercept)	-8.88934	3.65509	-2.432	0.01501
DBH	0.06823	0.03468	1.967	0.04914
Number of dead standing trees	3.19472	1.19101	2.682	0.00731
Canopy cover	0.07801	0.04119	1.894	0.05821
Distance to trail	-0.08487	0.04183	-2.029	0.04243

Table 3: The statistical outcomes of Model 1, where DBH, number of dead standing trees and distance to trail are all significant with P <0.05

Logistic regression figures

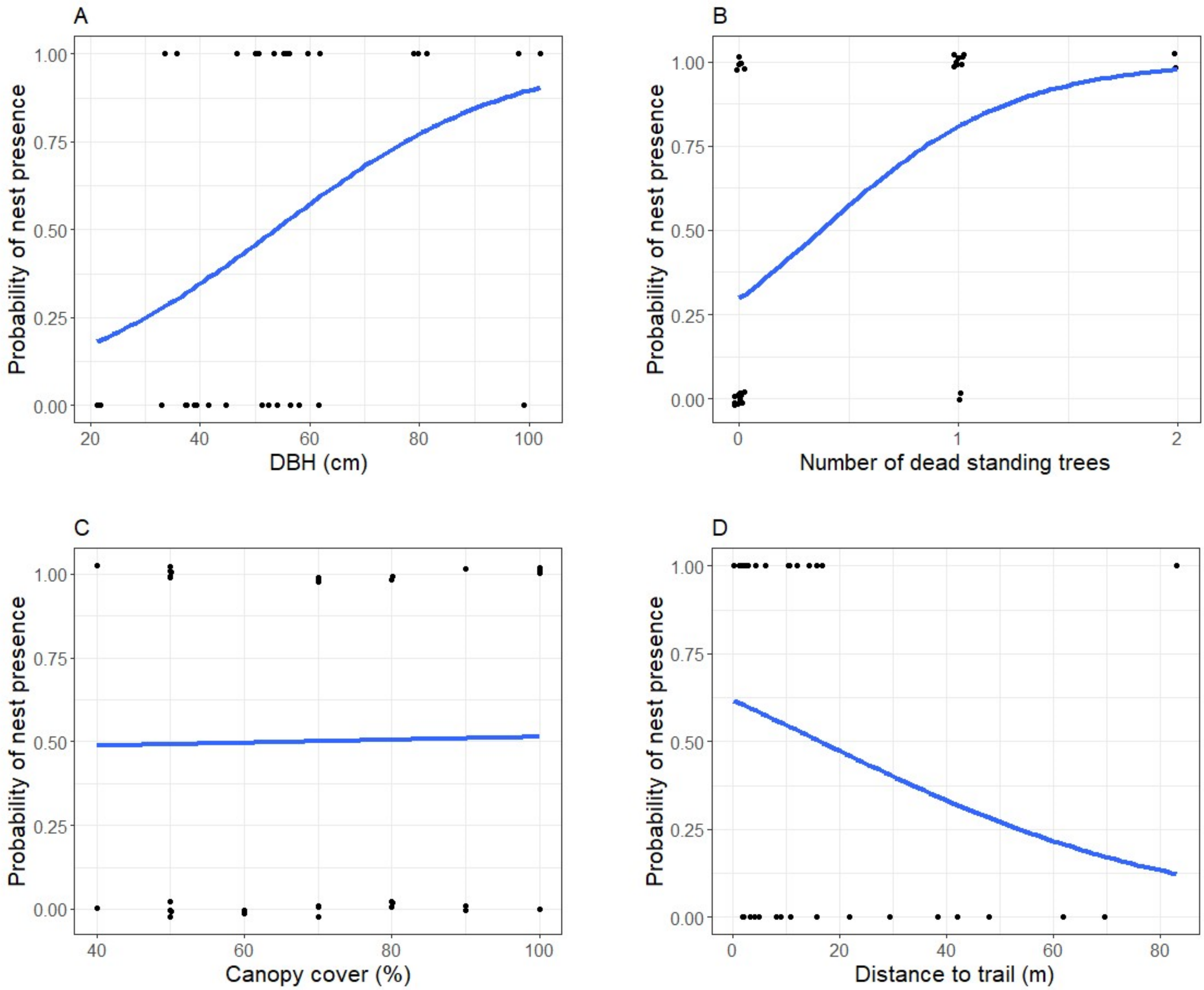
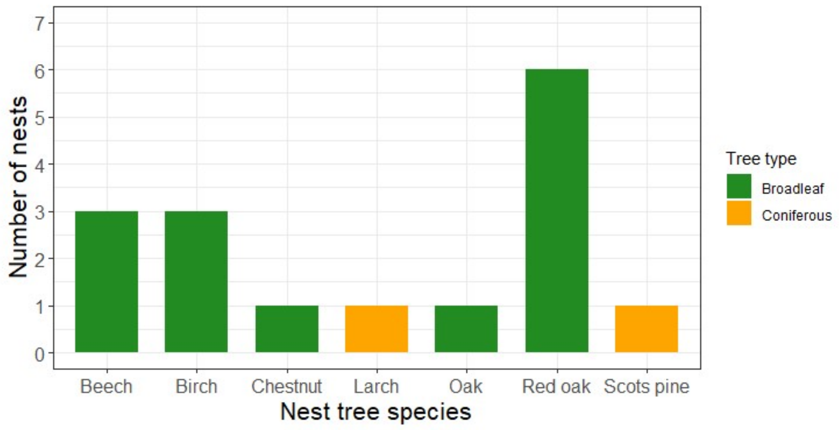


Figure 4: This graph shows the logistic regression between the probability of nest presence and the DBH, number of dead standing trees, canopy cover and distance to trail of the nest or paired tree. A shows that the probability of nest presence increases as the DBH increases with P < 0.05. B shows that the probability of nest presence increases as the number of dead trees increases with P < 0.05. For C, canopy cover (%) P is not significant (0.058) and the graph doesn't show a clear increase or decrease in probability of nest presence. D shows that the probability of nest presence decreases when the distance to trail increases with P < 0.05.

In this model, the presence of Great spotted woodpecker nests was positively influenced by the DBH of the nest/paired tree (GLM, z-value = 1.967, p = 0.049, Figure 4A). The presence of Great spotted woodpecker nests was positively influenced by the number of dead standing trees in the nest patch (GLM, z-value = 2.68, p = 0.0073, Figure 4B). The presence of Great spotted woodpecker nests was nearly significantly influenced by the canopy cover in the nest patch (GLM, z-value = 1.894, p = 0.06, Figure 4C). The presence of Great spotted woodpecker nests was negatively influenced by the distance from the nest/paired tree to a trail (GLM, z-value = -2.029, p = 0.042, Figure 4D).

Descriptive results

Nest/paired tree state, nest/paired tree type, nest/paired tree species, cavity height and cavity direction couldn't be modelled due to the low sample size of only 16 nests and no other sample locations for comparison. For descriptive purposes, different descriptive results were visualized.



species. The two colours represent the tree type: broadleaf or coniferous.

Woodpecker nests were found in 7 different tree species (Beech, Birch, Chestnut, Larch, Oak, Red oak and Scots pine), Red oak (*Quercus rubra*) was the most common with 6 of the 16 nests, X^2 (6, N = 16) = 9.37, p = 0.15. Broadleaved trees were favorite, 14 of the 16 nests were located in a broadleaved tree, X^2 (1, N = 16) = 9 p = 0.0027)

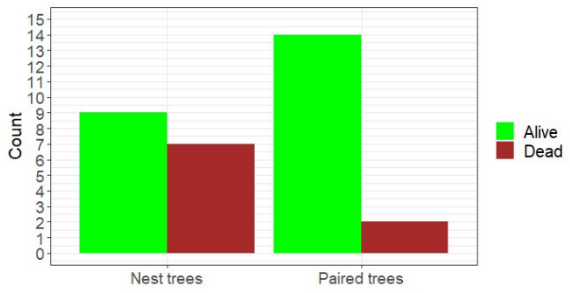


Figure 6: This bar graph shows the number of nest and paired trees for the two tree states: dead and alive

Tree state for the nest trees was mostly evenly distributed, X^2 (1, N = 16) = 0.25, p = 0.61, in total there were 9 alive and 7 dead trees.

When looking at a Windrose diagram, the different facing directions for the nest locations can be visualized.

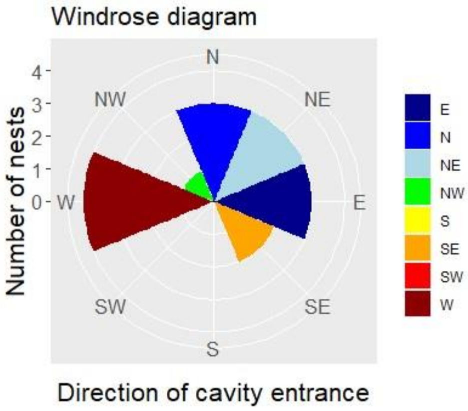


Figure 7: This Windrose diagram shows the different directions of cavity entrance and their count from 0-4

Most Southern facing directions were absent, while the western and eastern regions were clearly represented, X^2 (7, N = 16) = 8, p = 0.33.

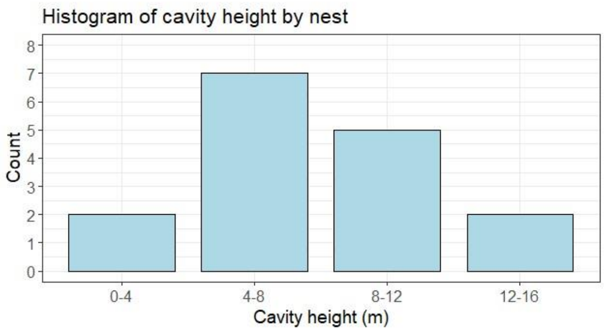


Figure 8: This histogram shows the count of 4 different cavity height classes: 0-4 m, 4-8 m, 8-12 m, 12-16 m

Cavity height differed between 2-14 meters, most nests were in the range of 4-8 meters above ground level, X^2 (3, N = 16) = 4.5, p = 0.21.

Discussion

The purpose of this thesis was to assess what forest characteristics influence the process of nest selection of the Great spotted woodpecker in the Oostereng forest. The results showed that nest tree DBH, number of dead standing trees on a nest patch level and distance to trails are important characteristics for nest selection.

It was expected that the nest tree DBH would be an important characteristic for nest selection, because research has shown that Great spotted woodpeckers prefer trees with a large diameter of ca 48 cm. (Kosinksi et al., 2007). Furthermore, Hebda (2017) found that Great spotted woodpeckers prefer larger diameter trees with a median of 50 cm. Pasinelli (2007) and Basile et al. (2020) have shown that Great spotted woodpeckers nest in trees that have on average a significantly larger DBH than surrounding trees. As expected, DBH was significant in the regression model with a median of 56 cm. for the nest trees. The probability of a nest location increased with an increasing tree DBH and the DBH of paired and nest trees differed significantly. As indicated by Pasinelli (2007) and Basile et al. (2020), maybe not absolute DBH, but relative DBH could be the driver behind nest selection of Great spotted woodpeckers. In most nest patches found in this thesis, the DBH of the nest tree was higher than the average DBH of the surrounding trees.

It was expected that the number of dead standing trees on a nest patch level would be an important characteristic for nest selection, with an increasing preference when the number of dead standing trees increases, because research has shown that Great spotted woodpeckers are strongly dependent on the availability of dead standing trees for foraging and nesting (Kosinksi et al., 2007; Pasinelli, 2007). As expected, this characteristic was significant in the regression model, where the probability of a nest location increased with an increasing number of dead standing trees on a nest patch level. Dead wood increases overall biodiversity and is home to many invertebrates that are part of the diet of the Great spotted woodpecker. Moreover, it is known that Great spotted woodpecker populations decrease in size when availability of dead standing trees decreases (Czeszczewik et al., 2013).

It was expected that the canopy cover of the nest site would be high, because Great spotted woodpeckers prefer a closed canopy for better protection against avian predators (Piacentini & Chiatante, 2022). Although not significant the canopy cover was included in the best regression model. A possible explanation for this result is that when Great spotted woodpeckers establish their territories in early spring (Piacentini & Chiatante, 2022), the broadleaved trees don't have their foliage yet, which means the Great spotted woodpeckers probably don't know exactly yet what the canopy cover will be after they choose a nest tree.

It was expected that nests were more likely to be found away from walking trails, because cavity nesters had a lower number of nests close to trails with high levels of human recreation (Bötsch et al., 2017). However, the characteristic distance to trail was significant in the regression model. The opposite of what was expected was found, the probability of a nest location decreases when the distance to a trail increases. A possible explanation for this result is that recreation on trails can reduce predation risk (Miller, 1998). Another factor that could have played a role in the location of the nests was the fact that many large Red oaks were present along the walking trails. As Red oak were the most common nest tree of the Great spotted woodpecker in the Oostereng, this could have influenced the distance to trail characteristic. A last factor that may have influenced this result is that cavity nesting provides privacy (Bötsch et al., 2017). Having a private nest/hideout may decrease the effect of disturbance, even when continuous recreational activities take place nearby.

It was expected that the favorite nest tree type would be broadleaved, and more specifically, an Oak species. The descriptive results indicate that broadleaved species were indeed used most and Red oak (*Quercus rubra*) was the most common nest tree species in the Oostereng. Literature confirms that Oak species are the most common nest tree for Great spotted woodpeckers most (Piacentini & Chiatante, 2022; Kosinski & Kempa, 2007)

Shortcomings and biases

In this thesis, shortcomings and biases can be identified for the way data was gathered and analyzed . Firstly, there might be a bias in determining the random GPS coordinates for the paired locations. The paired locations were determined by creating random GPS locations within the forest patch of the nest location, surrounded by walking trails. However, in the statistical analysis, all nest and paired locations were put together without linking the nest locations to the corresponding paired locations. Because the paired locations were chosen within the same patch as the nest tree, it could have resulted in less significant differences between nest and paired locations, because the forest type and thus tree composition is similar, at least for the corresponding nest and paired location. For future research, it would be best to randomize the GPS coordinates completely by using the boundaries of the entire forest instead of a forest patch within the forest. In that way, it will be sure that the GPS coordinates for the paired locations are truly random. Secondly, tree state, tree type, tree species, cavity height and cavity direction couldn't be modelled because the sample size was too small and there were no other forest locations to compare them to. Thirdly, the transects were walked from North to South and vice versa, but not from West to East and East to West. Although the entire forest has been searched for nest locations, there could be a possibility that a nest location stayed unnoticed throughout the fieldwork, as not every part of the forest has been looked at as intensely as the direct surroundings of the transects.

Conclusion

This thesis has provided insights into the characteristics of nest selection of the Great spotted woodpecker (*Dendrocopos major)*. The number of dead standing trees, the DBH of the nest tree and the distance from the nest tree to a trail are important predictors for nest selection of the Great spotted woodpecker. The number of dead standing trees in a potential nest patch and the DBH of potential nest trees influences nest selection positively. Increasing distance from a walking trail to a nest negatively influences nest selection of the Great spotted woodpecker.

To determine which characteristics are important on a nest tree and cavity level, multiple forests should be used for analysis to get a sufficient sample size for further statistical analysis. Future research on nest selection of Great spotted woodpeckers will tell us more about these characteristics. Further analysis on the relationship between nest selection and absolute and relative DBH preferences and the relationship between human disturbance and nest distance from walking trails could be useful to further understand the nest selection process of the Great spotted woodpecker. With future research, we will understand the process of nest selection of the Great spotted woodpecker better and this will help with the conservation of not only the species, but also forest health in general.

References

op Akkerhuis, G. J., Wijdeven, S. M. J., Moraal, L. G., Veerkamp, M. T., & Bijlsma, R. J. (2005). Dood hout en biodiversiteit; een literatuurstudie naar het voorkomen van dood hout in de Nederlandse bossen en het belang ervan voor de duurzame instandhouding van geleedpotigen, paddenstoelen en mossen (No. 1320). Alterra.

Angelstam, P. K., Bütler, R., Lazdinis, M., Mikusiński, G., & Roberge, J. M. (2003, January). Habitat thresholds for focal species at multiple scales and forest biodiversity conservation—dead wood as an example. In Annales Zoologici Fennici (pp. 473-482). Finnish Zoological and Botanical Publishing Board.

Bartczak, A., Englin, J., & Pang, A. (2012). When are forest visits valued the most? An analysis of the seasonal demand for forest recreation in Poland. Environmental and Resource Economics, 52, 249-264.

Basile, M., Asbeck, T., Pacioni, C., Mikusiński, G., & Storch, I. (2020). Woodpecker cavity establishment in managed forests: relative rather than absolute tree size matters. Wildlife Biology, 2020(1), 1-9.

Bötsch, Y., Tablado, Z., & Jenni, L. (2017). Experimental evidence of human recreational disturbance effects on bird-territory establishment. Proceedings of the Royal Society B: Biological Sciences, 284(1858), 20170846

Bötsch, Y., Tablado, Z., Scherl, D., Kéry, M., Graf, R. F., & Jenni, L. (2018). Effect of recreational trails on forest birds: human presence matters. Frontiers in Ecology and Evolution, 6, 175.

Cantarero, A., López-Arrabé, J., & Moreno, J. (2015). Selection of nest site and nesting material in the Eurasian Nuthatch Sitta europaea. Ardea, 103(1), 91-94.

Czeszczewik, D., WALANKIEWICZ, W., Mitrus, C., Tumiel, T., STAŃSKI, T., Sahel, M., & Bednarczyk, G. (2013). Importance of dead wood resources for woodpeckers in coniferous stands of the Białowieża Forest. Bird Conservation International, 23(4), 414-425.

Di Sallo, F. G., & Cockle, K. L. (2022). The role of body size in nest-site selection by secondary cavity-nesting birds in a subtropical Chaco forest. *Ibis*, *164*(1), 168-187.

Drever, M. C., & Martin, K. (2010). Response of woodpeckers to changes in forest health and harvest: Implications for conservation of avian biodiversity. Forest ecology and management, 259(5), 958-966.

Forstmeier, W., & Weiss, I. (2004). Adaptive plasticity in nest-site selection in response to changing predation risk. Oikos, 104(3), 487-499.

Gutzat, F., & Dormann, C. F. (2018). Decaying trees improve nesting opportunities for cavity-nesting birds in temperate and boreal forests: A meta-analysis and implications for retention forestry. Ecology and Evolution, 8(16), 8616-8626.

Grote Bonte Specht - dendrocopos major - great spotted woodpecker, Sovon Vogelonderzoek. Available at: https://stats.sovon.nl/stats/soort/8760 (Accessed: March 13, 2023).

Hebda, G., Wesołowski, T., & Rowiński, P. (2017). Nest sites of a strong excavator, the Great Spotted Woodpecker Dendrocopos major, in a primeval forest. Ardea, 105(1), 61-71.

Hooge, P. N., Stanback, M. T., & Koenig, W. D. (1999). Nest-site selection in the Acorn Woodpecker. The Auk, 116(1), 45-54.

Kajtoch, L., Figarski, T., & Pelka, J. (2013). The role of forest structural elements in determining the occurrence of two specialist woodpecker species in the Carpathians, Poland. Ornis Fennica, 90(1), 23-40.

Kosiński, Z. (2006, January). Factors affecting the occurrence of middle spotted and great spotted woodpeckers in deciduous forests—a case study from Poland. In Annales Zoologici Fennici (pp. 198-210). Finnish Zoological and Botanical Publishing Board.

Kosinski, Z., & Kempa, M. (2007). Density, distribution and nest-sites of woodpeckers (Picidae) in a managed forest of Western Poland. *Polish Journal of Ecology*, *55*(3), 519.

Mainwaring, M. C., Hartley, I. R., Lambrechts, M. M., & Deeming, D. C. (2014). The design and function of birds' nests. Ecology and Evolution, 4(20), 3909-3928.

Mazgajski, T. D. (2002). Does the great spotted woodpecker Dendrocopos major select holes for roosting?. Polish Journal of Ecology, 50(1), 99-103.

Mazgajski, T. D., & Rejt, Ł. (2006, January). The effect of forest patch size on the breeding biology of the great spotted woodpecker Dendrocopos major. In *Annales Zoologici Fennici* (pp. 211-220). Finnish Zoological and Botanical Publishing Board.)

Mikusiński, G., Gromadzki, M., & Chylarecki, P. (2001). Woodpeckers as indicators of forest bird diversity. Conservation biology, 15(1), 208-217.

Nilsson, S. G. (1984). The evolution of nest-site selection among hole-nesting birds: the importance of nest predation and competition. Ornis Scandinavica, 167-175.

Pasinelli, G. (2007). Nest site selection in middle and great spotted woodpeckers Dendrocopos medius & D. major: implications for forest management and conservation. Vertebrate Conservation and Biodiversity, 457-472.

Piacentini, E., & Chiatante, G. (2022). Habitat selection, density and breeding of Great Spotted Woodpecker Dendrocopos major in a protected natural area in northern Italy.

Random Location Generator (geographic coordinates). Create a Random Generator - Perchance.org. (n.d.). https://perchance.org/random-location-within-region-generator

Reed, S. E., & Merenlender, A. M. (2008). Quiet, nonconsumptive recreation reduces protected area effectiveness. Conservation Letters, 1(3), 146-154.

Rolstad, J., Rolstad, E., & Stokke, P. K. (1995). Feeding habitat and nest-site selection of breeding Great Spotted Woodpeckers Dendrocopos major. Ornis Fennica, 7(2), 62-71.

Tieleman, B. I., Van Noordwijk, H. J., & Williams, J. B. (2008). Nest site selection in a hot desert: trade-off between microclimate and predation risk. The Condor, 110(1), 116-124.

Virkkala, R., Rajasärkkä, A., Väisänen, R. A., Vickholm, M., & Virolainen, E. (1994, January). Conservation value of nature reserves: do hole-nesting birds prefer protected forests in southern Finland?. In *Annales Zoologici Fennici* (pp. 173-186). Finnish Zoological Publishing Board, formed by the Finnish Academy of Sciences, Societas Biologica Fennica Vanamo, Societas pro Fauna et Flora Fennica, and Societas Scientiarum Fennica.)(Piacentini)

Virkkala, R. (2006, January). Why study woodpeckers? The significance of woodpeckers in forest ecosystems. In *Annales Zoologici Fennici* (pp. 82-85). Finnish Zoological and Botanical Publishing Board.

Waarneming.nl. Available at: https://waarneming.nl/ (Accessed: March 13, 2023).