

“Does background traffic noise disturbance affect woodpecker abundance?” – A case study from the Ville Forest (Brühl, Germany)

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Abstract

In regards to background anthropogenic disturbances that impact forested habitats, noise pollution from traffic is one of the most significant issues. Studies have shown that the acoustic signals used by birds are increasingly masked by traffic noise. Masking of signals important to territory defence and mate attraction may have a negative impact on reproductive success, and may ultimately exclude species from suitable breeding habitat. Woodpeckers, which are birds in the *Picidae*, are one group of birds which rely heavily on acoustic signaling. This study looks at the impact which traffic noise has on Woodpecker abundance by analyzing how the number of nesting cavities differ between areas subject to different levels of disturbance, based on the assumption that the greater the number of observable cavities, the greater the abundance of Woodpeckers within that particular area. Data collection was carried out in four parcels of the Ville Forest, located in Brühl, Germany. Within each of the four forest parcels, five 100m long line transects were measured at randomly selected locations throughout the area, with any Woodpecker cavity observable within approximately 10m either side of the transect line recorded. The amount of dead/decaying trees (i.e. snags) in each transect was also recorded. The results indicate that noise disturbance is an insignificant factor in regards to the number of Woodpecker cavities observed, however the amount of snags within the area was shown to be of significance ($p=0.007$). This indicates that traffic noise disturbance does not impact the excavation of cavities as long as there is suitable habitat available, with the environmental suitability of potential habitat of much greater importance when Woodpeckers choose an area for excavating nesting cavities. Traffic noise tends to have most energy at frequencies below the critical bird communication range, so therefore masking of Woodpecker acoustic signals is unlikely to occur. This study, however, suggests that despite traffic noise not being a negative factor, there may potentially be other aspects to traffic which may influence habitat selection in Woodpeckers, such as visual disturbance of passing vehicles.

Keywords: Woodpeckers, anthropogenic, cavities, biodiversity, traffic noise, habitat, environment, snags, disturbance, forest, pollution

1. Introduction

In any natural environment, anthropological disturbances can have a profound effect on locally residing organisms (*Francis et al. 2009*). It is well documented that major sudden disturbances such as deforestation negatively impact forested habitats, however one aspect which is often not highlighted as much is the ecological impact of smaller background disturbances. These can be defined as smaller scale human disturbances which are a constant occurrence over a prolonged period of time. In regards to background

anthropogenic disturbances that impact forested habitats, noise pollution from traffic is one of the most significant issues. In relation to birds, noise pollution is known to often reduce nesting species richness and lead to different avian communities through altered species interactions (*Francis et al. 2009*). Studies have shown that the acoustic signals used by birds are increasingly masked by traffic noise (*Halfwerk et al. 2011*). Masking of signals important to territory defence and mate attraction may have a negative impact on reproductive success, and depending on the overlap in space, time and frequency between noise and vocalizations, such impact may ultimately exclude species from suitable breeding habitat (*Halfwerk et al. 2011*). Woodpeckers, which are birds in the *Picidae* family that are found in woodland habitats worldwide (*Winkler et al. 1995*), are one group of birds which rely heavily on acoustic signaling. A key behavioral characteristic of Woodpeckers is that through using their chisel-like bill, woodpeckers drum powerfully upon trees (*Virkkala, 2006*). This drumming is primarily used for excavating nesting cavities, however it is also done as a means of communication. Males drum in late winter to establish and defend a territory, both sexes drum as part of courtship, and either sex may drum to solicit mating, to summon a mate from a distance, or in response to an intruder near a nest (*The Cornell Lab of Ornithology, 2015*). Therefore, noise disturbances may have a significant ecological impact upon Woodpeckers by masking these acoustic signals.

Noise disturbance not only impacts organisms individually, but can also result in irreversible changes to the functioning of the ecosystem as a whole. One such way in which disturbances can impact the entire ecosystem is through the effect on keystone species. Keystone species are defined as species that have a disproportionately large effect on the communities in which they occur, and play an important role in the functioning of the ecosystem (*Bednarz et al. 2004*). If a keystone species was to be negatively affected by anthropological disturbances, then subsequently any additional species that rely upon them within the ecosystem are to be likewise effected. Woodpeckers are an example of a keystone species, as the cavities they excavate in trees form habitat which is highly suitable for many other woodland species. Abandoned nesting cavities are regularly used as nests or roosts for small owls, ducks, swifts, bluebirds, swallows, wrens, and small mammals that do not excavate holes themselves (*Bonar, 2000*). Species such as these which use cavities created by others for nesting or roosting are called 'secondary cavity users', with the population of secondary cavity using birds often being determined by the availability of abandoned Woodpecker nesting holes (*Bonar, 2000*). This means that due to its role as a keystone species, the prevalence of Woodpeckers in woodland areas can be used as an indicator for the overall level of biodiversity of secondary cavity user species (*Virkkala, 2006*). If noise disturbance was found to be a significant factor in reducing the abundance of Woodpeckers, this could have an ensuing negative impact on the entire ecosystem, as reduced Woodpecker populations will in turn result in fewer nesting cavities being excavated, and subsequently lead to lower populations of secondary cavity user species.

This study will look at the impact which anthropogenic noise disturbance, specifically traffic noise, has on Woodpecker abundance. This will be done by analyzing how the number of nesting cavities differ between areas subject to different levels of disturbance, based on the assumption that the greater the number of observable cavities, the greater the abundance of Woodpeckers within that particular area. The results of this study will hopefully bring to light the impact which traffic noise has on the excavation of Woodpecker nesting cavities, and subsequently whether other species in the ecosystem may also be negatively impacted due to the Woodpeckers role as a keystone species.

1.1 Study area

Data collection was carried out in four parcels of the Ville Forest. This forest is located between Brühl and Erftstadt, and is 66 ha in area. Out of these 66 ha, approximately 20 ha has been protected since 1978 as “strict nature reserve/wilderness area” according to the International Union for Conservation of Nature (IUCN). The remaining 46 ha are categorized as “habitat/species management area”, in which only sustainable forestry is allowed. Within the Ville Forest, the oldest trees are approximately 200 years old. The Old Forest Naturwaldzelle is part of the Natura 2000 project, which is an important component of the European Nature and Biodiversity Policy (LANUV NRW 2013, ec.europa.eu 2013). The Old Forest consists mainly of deciduous trees, such as beech (*Fagus*), oak (*Quercus*), birch (*Betula*) and European hornbeam (*Carpinus betulus*). Most areas of the Ville Forest were deforested for the exploitation of lignite between the end of the 19th century and the beginning of the 20th century. The restoration process of these areas began in the 1920s, and was finally completed after the last mine was closed in 1984 (Kremer 1999, Forschungsstelle Rekultivierung 2011). Since 1961, restoration measures are based on scientific theories, and include the mixing of hardwood forests under poplar-nurse crop, and techniques to avoid soil compaction (Uwe Schölmerich, Regionalforstamt Rhein-Sieg-Erft, personal communication, June 25, 2012).

The study area is composed of four separate forest parcels within the Ville Forest (Naturschutzgebiet Ententeich, Stiefelweiher, Naturschutzgebiet Entenweiher and Pingsdorfer Weiher, as seen in Figure 1). Habitat structure of all four parcels is comparable. They include lakes (Stiefelweiher 1.2 ha; Ententeich 1.7 ha; Entenweiher 5 ha, Pingsdorfer Weiher 3.6 ha) accompanied by surrounding reed belts and swamp areas. Tree species composition (*Salix*, *Populus*, *Alnus*) adjacent to the banks of the lakes is nearly identical. All four biotopes are situated within deciduous forest areas interspersed with pine trees, larches and spruces.

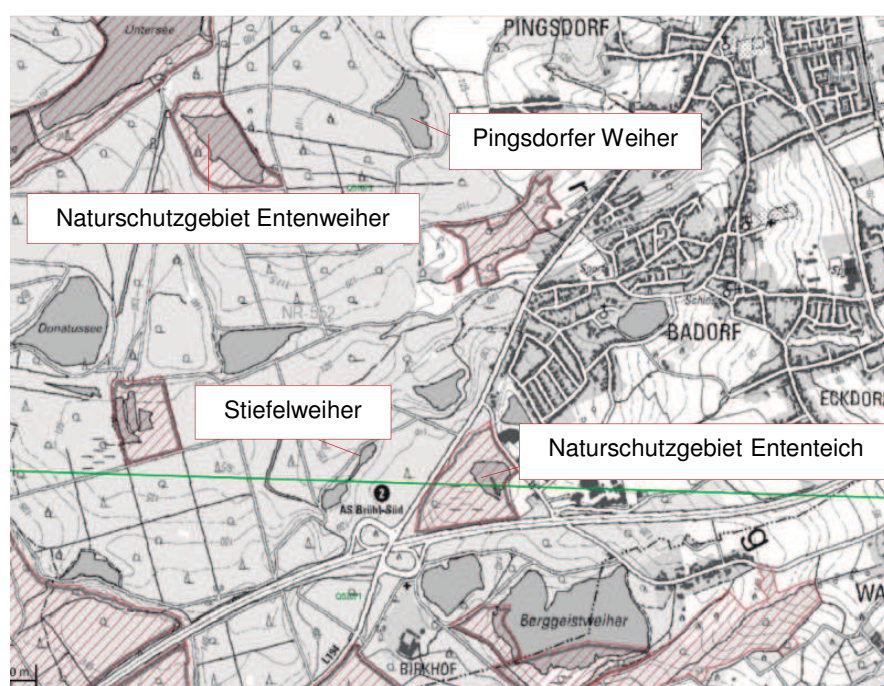


Figure 1: Location of the four forest parcels within the study area in the Ville Forest

(Reference: Naturschutzgebiete und Nationalpark Eifel in NRW - Karten – Naturschutzgebiete (n.d.). Available from <http://www.naturschutzinformationen-nrw.de/nsg/de/karten/nsg>)

Differences occur in each of the forest parcels in regards to the level of anthropogenic disturbance that they are subject to. Naturschutzgebiet Ententeich is affected by high noise pollution from traffic and the theme park Phantasialand. This reserve is enclosed by the country road L194 from north-west to south- west by the Autobahn 553 in the south, and the theme park located in the east. Stiefelweiher is affected by moderate background traffic noise emitting from the L194 in the east at a distance of approximately 300 metres, and from the autobahn 553 in the south-east at a distance of 100 to 150 metres. Naturschutzgebiet Entenweiher and Pingsdorfer Weiher are located further away from streets and housing and have no traffic noise pollution.



Figure 2: Suitable woodpecker habitat (© Linzmeier)

1.2 Study species

Six woodpecker species can be found in and around the Ville Forest: Black Woodpeckers (*Dryocopus martius*), Great Spotted Woodpeckers (*Dendrocopos major*), Middle Spotted Woodpeckers (*Dendrocopos medius*), Lesser Spotted Woodpeckers (*Dendrocopos minor*), Grey-Headed Woodpeckers (*Picus canus*) and Green Woodpeckers (*Picus viridis*). All of these species nest in cavities, have strong bills for drilling on trees and long sticky tongues for extracting insects from the bark, which form the main part of their diet. Woodpeckers can drill their beaks at a rate of up to 20 times a second, and up to 12,000 times a day (Winkler *et al.* 1995). One distinctive feature of Woodpeckers is that they have zygodactyl feet, which is a formation of two sharply clawed toes pointing in each direction, helping them to grasp the sides of trees and balance whilst they drill their bills against the trunk (Bock, 1999). This differs to most birds that have one toe pointing back and three pointing forward on each foot.

In addition to this, Woodpeckers also have distinguishably stiffened tail feathers, which they press against the tree surface for helping to support their weight whilst they drill cavities (Hoyt, 1957). Male and female woodpeckers work together to excavate a cavity nest, which is used to incubate eggs for about two weeks. Breeding season for Woodpeckers is generally between March – June, with the majority of new nesting cavities excavated before the onset of the breeding season in February/March. Nests usually consist of between 2-5 eggs. When a woodpecker hatches, one parent brings food to the nest whilst the other stays with the young. The young generally leave the nest after 25 - 30 days (Winkler et al. 1995).

Tree species, tree diameter, tree condition, and the surrounding tree density are all natural factors which can affect whether a woodpecker chooses a specific location for a nesting cavity. Most species have a preference towards excavating nesting cavities in standing dead or decaying trees (i.e. snags), as the wood is often much softer to drill through in comparison to wood in live trees. The availability of snags within an area is therefore considered a key factor as to the abundance of nesting Woodpeckers. In regards to the habitat requirements of the aforementioned six woodpecker species, Great Spotted Woodpeckers (*Dendrocopos major*) are very widespread, being generalists that occur wherever there are trees with sufficient growth to accommodate nest cavities. Lesser Spotted Woodpeckers (*Dendrocopos minor*) are also generalists; however they have a preference towards old deciduous woodland rich in deadwood near to water bodies (Riemer, 2009). Black Woodpeckers (*Dryocopus martius*) are widespread, however studies have shown a preference towards mature forest stands characterised by tall and large diameter trees, high volumes of coarse woody debris, and dense canopy cover (Khanaposhtani et al. 2012). Middle Spotted Woodpeckers (*Dendrocopos medius*) are restricted to mature deciduous forests, especially areas with mixed oak and hornbeam (Kosinski, 2006). Grey-Headed Woodpeckers (*Picus canus*) and Green Woodpeckers (*Picus viridis*) prefer semi-open landscapes such as forest edges, riverine, swampy and marshy woods (Winkler et al. 1995). It should be noted, however, that due to the complexity of making distinctions between cavities made by different Woodpecker species, this study looks at the abundance of Woodpeckers in general as opposed to species specific abundances.

1.3 Hypothesis

This study will aim to test the following research hypothesis; background level traffic noise disturbance will have a statistically significant affect towards the abundance of woodpecker cavities across the Ville Forest as a whole. It is therefore expected that out of the four study areas, areas with low levels of noise disturbance will have higher numbers of observed cavities in comparison to areas with greater levels of noise disturbance. Furthermore, noise disturbance will be equally as significant a factor in contributing towards Woodpecker abundance as the availability of snags, which is known to be a key environmental determinant as to the number of excavated nesting cavities within an area.

2. Methodology and experimental design

The four previously described forest parcels, Naturschutzgebiet Ententeich, Stiefelweiher, Naturschutzgebiet Entenweiher and Pingsdorfer Weiher, were used as the sites for data collection in this study, with each of the forest parcels being known habitat for Woodpeckers. To classify the forest parcels in regards to their level of background traffic noise disturbance, a ranking of 1 indicates the highest level of disturbance, whilst a ranking of 3 indicates the lowest level of disturbance. In relation to the aforementioned research hypothesis, it is expected that a forest parcel with a disturbance ranking of 1 will have the lowest number of excavated cavities, whilst a forest parcel with a ranking of 3 will have the highest number of cavities. Naturschutzgebiet Ententeich was given a disturbance ranking of 1 (high traffic noise), Stiefelweiher was given a disturbance ranking of 2 (moderate traffic noise), whilst Pingsdorfer Weiher and Naturschutzgebiet Entenweiher were both given a disturbance ranking of 3 (no traffic noise). Traffic noise can be defined as engine noise from passing vehicles on nearby roads. The level of noise described in each area and the assigned disturbance ranking are based on prior expert knowledge of the forest.

Within each of the four forest parcels, five 100m long line transects were measured at randomly selected locations throughout the area. A portable GPS device was used in order to measure a distance of 100m, and to mark the exact coordinates of each transect location. Even though the selection of the transect locations within each of the four forest parcels was random, care was taken to ensure that the chosen transect locations accurately portrayed the variation in environmental composition across the entire area, and that there were no barriers in the way that would potentially block the transect from extending 100m in a straight line. Along the 100m line transect, the surveyor walked at a slow pace and recorded any Woodpecker cavity observable within approximately 10m either side of the transect line. Only nesting cavities were recorded, with foraging holes or tracks discounted.

In addition to observing nesting cavities in each transect, observations were also made as to the amount of nearby snags. A value of 1 was given to transects which contained a high quantity of snags (more than 5 snags with a diameter >50cm per transect), whilst a value of 0 was given to transects containing minimal or no snags (less than 5 snags with a diameter >50cm per transect). The amount of snags in each transect should point out whether background traffic noise disturbance is of greater or lesser importance to Woodpeckers in comparison to the environmental suitability of an area when choosing a location to excavate a nesting cavity. The amount of snags was chosen for this particular additional environmental variable, as it is known that Woodpeckers have a preference towards excavating cavities in

snags, and with restricted time availability it was simpler to observe the number of snags in comparison to choosing other potentially suitable environmental variables such as tree species or tree diameter.

Data was collected from mid-January to mid-February 2016 from five transects of one different forest parcel each day, so after four days all five transects in each of the forest parcels had been sampled. This process was repeated until all five transects in each of the four forest parcels had been sampled three times in total. The total number of unique individual nesting cavities observed in each transect across the three repeat visits was the resultant data which was used for subsequent analysis.

2.1 Statistical analysis

Using the data from each transect, multiple regression analysis was undertaken with this analysis enabling it to be seen how significantly each different variable affects the abundance of woodpecker cavities in the Ville forest. It also enabled a conclusion to be made in regards to whether traffic noise has a greater or lesser effect in comparison to environmental factors (i.e. amount of snags) on the abundance of woodpecker cavities. Microsoft Excel was used as the program for the multiple regression analysis. For the multiple regression analysis, the dependent variable was the number of cavities observed in each transect, whilst the two independent variables were the amount of snags and the disturbance ranking of each transect. As both of the independent variables are ordinal categorical variables, additional steps needed to be taken to enable them to be entered into the multiple regression model. When an ordinal categorical variable has more than two levels, such as with disturbance ranking, it is necessary to recode it into a number of separate, dichotomous variables, with this process called "dummy coding". A categorical variable with k levels will be transformed into $k-1$ dummy variables, each with two values of either 1 or 0. The level which is not coded is the category to which all other categories will be compared. As disturbance ranking has three levels (ranking of 1, 2 or 3), it therefore has two dummy coded variables. These two dummy variables are assigned the names "DisturbanceX1" and "DisturbanceX2". For "DisturbanceX1" a value of 1 is assigned to transects that have the highest noise disturbance ranking of 1 (i.e. Naturschutzgebiet Ententeich), whilst if they have a different ranking they were assigned a value of 0. For "DisturbanceX2" a value of 1 is assigned to transects that have the moderate noise disturbance ranking of 2 (i.e. Stiefelweiher), whilst if they have a different ranking they were assigned a value of 0. The lowest disturbance ranking of 3 (i.e. Naturschutzgebiet Entenweiher and Pingsdorfer Weiher) was chosen as the level to omit from dummy coding, so therefore in the multiple regression analysis both "DisturbanceX1" and "DisturbanceX2" will be compared in their significance against the transects with the disturbance ranking of 3 which had minimal noise disturbance. As the variable of amount of snags only had two levels which were already assigned the values of either 0 or 1, it is possible to enter it straight into the multiple regression model without the need for dummy coding.

Once the multiple regression analysis was completed, the p-values are the result which indicates whether a variable is statistically significant. If the p-value for "DisturbanceX1" / "DisturbanceX2" is <0.05 , then areas of high/moderate noise disturbance have a statistically significant difference in the number of woodpecker cavities in comparison to areas with low disturbance, and therefore the hypothesis can be accepted in saying that noise disturbance

is a significant factor. However, if the p-values for “DisturbanceX1” / “DisturbanceX2” are >0.05 , then the hypothesis can be rejected and noise disturbance is not a significant factor towards the abundance of Woodpecker nesting cavities. Similarly, a p-value of <0.05 for amount of snags indicates that the availability of snags within an area is a significant factor as to the abundance of Woodpecker cavities. The p-values for both disturbance and amount of snags can then be compared with each other, to see which factor is of greater or lesser statistical significance to the abundance of Woodpeckers in the Vile Forest.

3. Results

As detailed in Figure 2, Stiefelweiher (moderate noise, disturbance ranking 2) was the forest parcel that had the highest number of Woodpecker nesting cavities within the chosen transects, with 39 observed. Naturschutzgebiet Entenweiher (low noise, disturbance ranking 3) had 30 cavities observed, whilst Pingsdorfer Weiher (low noise, disturbance ranking 3) had 15 cavities observed. Naturschutzgebiet Ententeich (high noise, disturbance ranking 1) was the forest parcel with the lowest number of Woodpecker nesting cavities, with only 5 observed across the five different transects. It should be noted that the number of cavities observed is restricted to only the study transects, and therefore might not represent the entire area.

Figure 3: Total number of Woodpecker nesting cavities observed in each of the four study forest parcels.

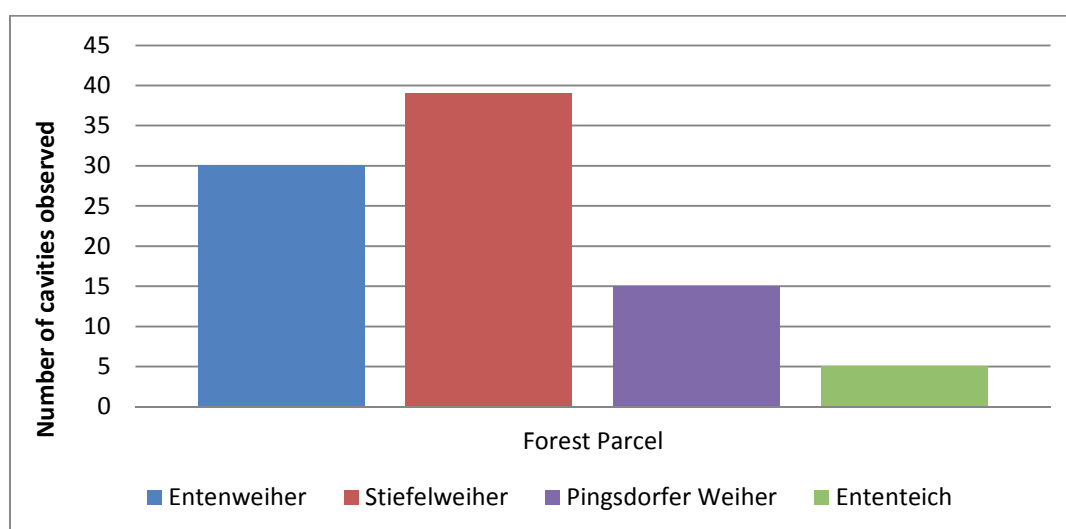


Table 1: Multiple regression results

SUMMARY OUTPUT

<i>Regression Statistics</i>	
Multiple R	0.676607542
R Square	0.457797766
Adjusted R Square	0.356134848
Standard Error	5.357344152
Observations	20

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	387.7318182	129.2439394	4.503094852	0.017925357
Residual	16	459.2181818	28.70113636		
Total	19	846.95			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	0.218181818	2.284379222	0.095510332	0.925095488
Amount of nearby snags	7.863636364	2.554013613	3.07893283	0.007190154
DisturbanceX1	0.354545455	3.107091662	0.114108463	0.910571437
DisturbanceX2	3.3	2.93433824	1.124614727	0.277341503

The regression results shown in Table 1 indicate that as a whole, the regression model is statistically significant (F-significance of 0.0179 < 0.05). Furthermore, the R² value indicates that 45.78% of the variation in the number of Woodpecker cavities observed is explained by the variables of disturbance ranking and number of snags.

The p-values from the regression analysis indicate that at a 95% confidence level, neither high level traffic noise (DisturbanceX1, p=0.911) nor moderate level traffic noise (DisturbanceX2, p=0.278) are of statistical significance in regards to their impact on the number of Woodpecker cavities observed. Amount of snags (p=0.007), however, is shown to be of high significance in regards to its impact on the number of cavities observed. When compared against each other, the variable of amount of snags is shown to be of much higher significance towards the abundance of woodpecker cavities across the Ville Forest than the disturbance ranking variable.

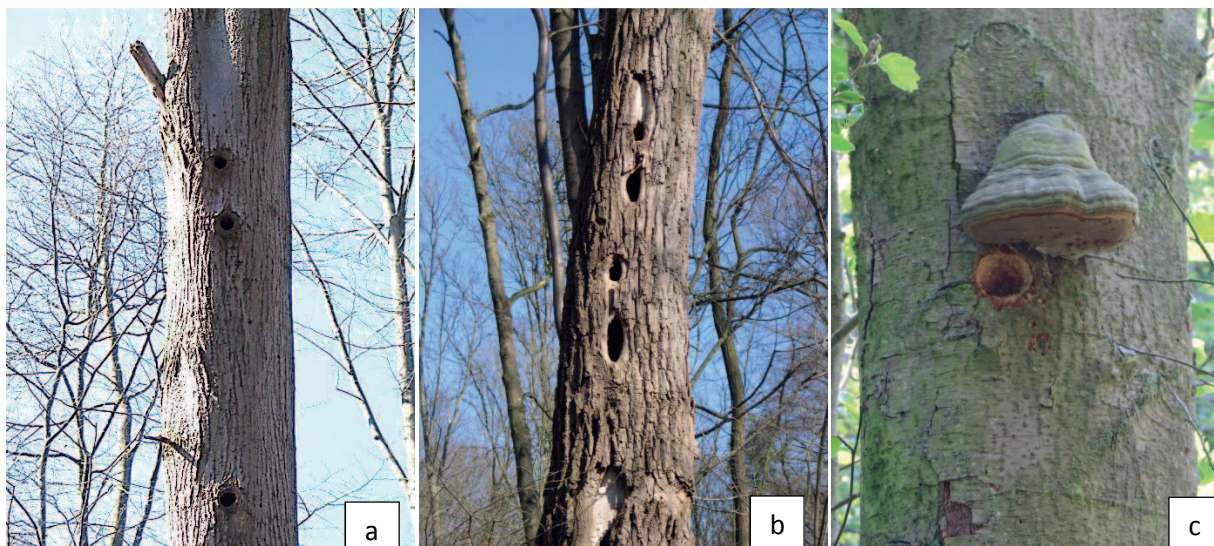


Figure 4: Cavities in the trunk of a live lime tree (*Tilia spec.*) near forest edge (a), foraging excavations in a snag near forest edge (b), cavity in a snag near lakeside (c). (© Linzmeier)

4. Discussion

The hypothesis stating background level traffic noise disturbance will have a statistically significant affect towards the abundance of woodpecker cavities across the Ville Forest as a whole can be rejected, as the results indicate that noise disturbance is an insignificant factor (DisturbanceX1, $p=0.911$ and DisturbanceX2, $p=0.278$). The results also indicate that amount of snags within an area was a very significant factor ($p=0.007$) in regards to the number of Woodpecker cavities observed, so the hypothesis can also be rejected in saying that noise disturbance will be equally as significant a factor in contributing towards Woodpecker abundance as the availability of snags. Furthermore, despite the area with the highest noise disturbance (Naturschutzgebiet Ententeich) having the lowest number of cavities as expected, the area that had the highest number of cavities was in fact the forest parcel that had moderate noise disturbance (Stiefelweiher) as opposed to low disturbance. Therefore, the hypothesis can also be rejected in saying that areas with low levels of disturbance will have higher numbers of observed cavities in comparison to areas with greater levels of disturbance. It should be emphasized that the number of cavities observed is restricted to only the study transects, and therefore might not represent the entire area.

A possible explanation as to why traffic noise is an insignificant factor towards the abundance of Woodpeckers is that traffic noise tends to have most energy at frequencies below the critical bird communication range, so therefore masking of Woodpecker acoustic signals is unlikely to occur (Bouteloup *et al.* 2011). According to the literature, the effect of traffic noise on birds only becomes apparent above noise levels of 55 dB, which means that background level traffic noise below this level is unlikely to have any impact (Bouteloup *et al.* 2011). This accounts for Stiefelweiher, with moderate level traffic noise, having the highest number of observed cavities, as levels of traffic noise within this area would not have been above 55 dB. Even in areas with higher noise disturbance, traffic noise is unlikely to have a negative effect on communication as birds have been known to compensate for the masking effect of noise through shifts in vocal amplitude, song and call frequency, as well as temporal

shifts to avoid noisy rush-hour traffic (*Ortega, 2012*). As demonstrated by the availability of snags being a statistically significant factor towards Woodpecker abundance, it appears as if Woodpeckers primarily select areas with the highest environmental suitability to excavate nesting cavities, irrespective of the level of traffic noise it is subject to. This is further supported by the fact that several Woodpecker species, such as the Greater Spotted and Lesser Spotted Woodpeckers, are known to reside and excavate nesting cavities in gardens/parks within residential areas (*Winkler et al. 1995*), and these areas would undoubtedly be subject to moderate to high levels of traffic noise disturbance. In addition to traffic noise appearing to have no impact towards masking acoustic signals between Woodpeckers, noise disturbance is also unlikely to cause any long term physical damage. Birds are more resistant to both temporary and permanent hearing loss or to hearing damage from acoustic overexposure than humans and other mammals (*Dooling & Popper, 2007*). An additional reason as to why traffic noise does not affect Woodpeckers is that due to it being a recurrent disturbance over a prolonged period of time, birds may eventually become used to traffic noise to such an extent that it is no longer a hindrance to them (*Francis et al. 2009*). Perhaps traffic noise was initially a disturbance to birds in the Ville forest when roads were first built, however over time organisms often learn to adapt to their environment, and therefore microevolution may have resulted in birds becoming adapted to traffic noise now being a familiar aspect of their habitat.



a

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Figure 5: Humid areas lead to a progress of decay in wood (a and b) and offer an appropriate milieu for thick layers of moss (a and c). This environment meets the requirements of many arthropod species. Therefore woodpeckers do not only encounter suitable nesting sites but also face ideal foraging conditions.



b

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c

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General observations of areas in the Ville Forest outside the study area transects also support the overall conclusion that environmental suitability of nesting habitat is of greater importance to Woodpeckers when excavating cavities in comparison to the level of traffic noise. The vast majority of cavities that were observed throughout the forest were found in fairly isolated snags, as seen in Figure 3. Outside of the study transects, a number of cavities were even observed in areas with high traffic noise that had isolated snags, such as alongside the lake in Naturschutzgebiet Ententeich. This once again indicates the importance of environmental suitability, particularly availability of snags, towards the abundance of Woodpeckers. Based on general observations of the selected forest parcels in the Ville Forest, Stiefelweiher had the most isolated snags, with this high environmental suitability accounting for this parcel having the highest number of observed nesting cavities. In relation to why snags are specifically of high importance, excavating cavities in living trees is more energetically costly so therefore the softer wood of a dead tree may allow a larger cavity for a given expenditure, whilst the shorter excavation period means the possibility of earlier breeding (*Baj, 2005*). An additional general observation during the data collection was that overall, much lower numbers of cavities were observed in Naturschutzgebiet Ententeich, which had the highest disturbance ranking, in comparison to other forest parcels. This is supported by the fact that Naturschutzgebiet Ententeich had the lowest number of observed cavities in the results, with only 5 cavities observed across the five study transects. Naturschutzgebiet Ententeich is very close to the country road L194 and the Autobahn 553, however as traffic noise was shown to be an insignificant factor towards Woodpecker abundance, it is therefore likely that close proximity to traffic may influence habitat selection in Woodpeckers in other ways. Other possible effects of traffic which are known to impact birds include visual disturbance of passing vehicles, air pollution, microclimatic effects, road kill or increased attraction of predators to the roadside (*US Department of Transportation, 2011*), so it is likely that one of these factors may account for the lower abundance of nesting cavities in Naturschutzgebiet Ententeich. The other selected forest parcels in the Ville Forest are all located further away from the road and are either only affected by traffic noise or are not impacted by road disturbance whatsoever, so therefore these additional traffic effects would not cause any hindrance to Woodpeckers in these areas.

In relation to the methodology of this study, a major strength of the data collection process is that observing nesting cavities is a simple but effective method used to acquire an estimate as to the abundance of Woodpeckers within a particular area. This is under the assumption that the greater the number of observable cavities, the greater the abundance of Woodpeckers within that particular area. As nesting cavities remain as permanent additions to trees, this method ensures that abundance studies can still be carried out at times of the year, such as winter, when Woodpeckers are not as active and may often be relatively difficult to observe. An additional strength is that this study allows for a relatively quick and uncomplicated, but nonetheless useful, conclusion to be made as to the general impact of traffic noise on Woodpeckers in the Ville Forest. This general conclusion can then provide the basis for subsequent more detailed long-term studies in the Ville Forest. A limitation, however, of this study is that due to time restraints, no physical measurements were taken to measure the actual level of traffic noise. In a more complex study this would have ideally occurred, as physical measurements would have provided a more accurate indication of the level of traffic noise a particular area is subject to.



Figure 6: *Isolated snag with excavated woodpecker cavities. (© Linzmeier)*

A probable source of error is that data collection took place in winter outside of the breeding season, Woodpeckers were yet to start actively excavating new cavities. Therefore, all of the observed cavities were from previous breeding seasons, and the results were not able to include any observations from recently excavated cavities. Furthermore, due to the complexity of making distinctions between cavities made by different Woodpecker species, another weakness of this study is that it does not give species specific abundances. It should be noted that occasional logging is carried out across each of the four forest parcels, however this disturbance takes place outside the breeding season and does not impact the excavation of Woodpecker nesting cavities.

In regards to the statistical analysis, a weakness of the multiple regression approach is that it is based on the assumption of there being no multicollinearity between variables, however in reality, natural variables are rarely completely independent from one another. For example, the amount of snags variable is possibly linked to the noise disturbance variable, as areas with high traffic noise are further developed meaning that the majority of old decaying trees - especially those located at forest edges - are most probably deforested in these areas. Therefore, this potential multicollinearity between variables could possibly impact the final result of the analysis.

In this study the multiple regression analysis only explains 46% of the variation in the number of cavities observed within each forest parcel, with more than half of the variation unaccounted for. There could therefore be additional variables not used in the model, such as tree species, tree diameter or climatic factors, which may potentially be important in explaining the remaining 54% of the variation in number of cavities observed within the multiple regression model.

5. Conclusion

In summary, the results of this study indicate that traffic noise appears to be an insignificant factor for Woodpeckers, with the environmental suitability of potential habitat of much greater importance when choosing an area for excavating nesting cavities. Therefore, traffic noise disturbance does not impact the excavation of cavities as long as there is suitable habitat available. In regards to Woodpecker conservation, efforts should focus on protecting highly suitable habitat, particularly isolated snags, as opposed to mitigating traffic noise levels. The results also demonstrate that the Ville Forest ecosystem as a whole is not negatively affected due to the Woodpeckers role as a keystone species, as they are still able to excavate cavities in the presence of traffic noise which can then subsequently be used as a habitat by secondary cavity user species. This study, however, suggests that despite traffic noise not being a negative factor, there may potentially be other aspects to traffic which may influence habitat selection in Woodpeckers when in very close proximity to roads. Therefore, further development of roads may potentially lead to a reduction in the number of species residing in areas directly nearby. Naturally there is the need for a certain level of anthropogenic disturbance in forested environments near to human settlements, such as the Ville Forest, however if this disturbance can be restricted to primarily just background level traffic noise as opposed to direct harm to the forest, then man and nature may be able to peacefully coexist.

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