The Hazel Dormouse (*Muscardinus avellanarius*) in Schleswig-Holstein and Hamburg, Germany

Monitoring presence and temporal activity and assessing species interactions and habitat preferences of the hazel dormouse with camera traps

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Hamburg | Behörde für Umwelt und Energie

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Leeuwarden, 15st of May, 2018

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Bachelor thesis Wildlife Management 2017
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Picture title page: Lena Horst and Nina Villing, 2017
Hazel dormouse on baited wooden board, captured on 16th of September, 2017

Preface

While conducting this thesis, many people helped us with their support, be it of intellectual, financial, or motivational nature. We collected more data than anticipated – consequently, we had to spend a lot of time with the sometimes very exhausting work of data preparation. Receiving support and interest in our work from different backgrounds helped keep the work exciting, as it reminded us how very curious we were ourselves, about the results of our analysis and the contribution it might make to hazel dormouse research and conservation.

We want to thank Dr. Björn Schulz of the Stiftung Naturschutz Schleswig-Holstein, for giving us lots of advice and information, providing the unexpectedly high number of camera traps and ensuring financial support. We are very glad to have had such a kind and motivated mentor, who did not hesitate to include us in other hazel dormouse-related activities, like the search for hazel dormouse summer nests in December 2017. We are still constantly staring into shrubs and bushes, in hopes of finding another nest.

Dr. Nina Klar of the BUE (Behörde für Umwelt und Energie, Hamburg) was vital for our project, as she was the one who helped initiating the project. She established valuable contacts for us, provided us with information and advice, as well as financial help. We are very grateful for that.

We also want to thank Sven Büchner, whom we met during the search for hazel dormouse nests. He helped us with his insight in this species' characteristics, answered our sometimes surely a bit dull questions, gave us valuable tips and information and endowed us with his very helpful book.

We are thankful for the support and enthusiasm for the subject, our tutors Theo Meijer and Marcella Dobbelaar showed us, but also for the sometimes perplexing criticism that helped us define our goals and look at the subject from different perspectives. Additionally, the correct application and interpretation of the statistical tests and results would not have been possible without the guidance and infinite patience of Mr. Henry Kuipers.

Special thanks go out to Andreas Henkel of the administration of the National Park Hainich, Thuringia. If he had not introduced one of us, Lena Horst, to the hazel dormouse as study species during an internship in his department in 2016, this project would probably never have existed. By giving the opportunity to try out different methods to monitor hazel dormice within the National Park, the corner stone was laid, which ultimately led to this study in 2017.

Last, but not least, we want to thank our understanding friends and families. They bore with us, when we sat in front of our computer screens, clicking through hundreds of thousands of photos only to wake up out of the zombie-like state, when a hazel dormouse appeared, and start running through the house squealing, trying to force everyone to look at it.

We are glad we were able to carry out this project, we could not have done it alone.

Thank you.

Lena Horst & Nina Villing,
Hamburg & Leeuwarden, 11th of April, 2018

Summary

This research report investigates the presence of hazel dormice (*Muscardinus avellanarius*) in isolated roadside habitats in eastern Hamburg and the neighbouring western Schleswig-Holstein. Camera traps were used with the aim to gain more knowledge regarding possible influences on hazel dormouse presence. Where found to be present, activity patterns, including temporal activity, first appearance, and amount of occurrences per camera site were assessed. The effects of the occupation of other species on the focal species' presence and the correlation between select environmental parameters and hazel dormouse presence were tested as well. Hazel dormice are classified as endangered in both Hamburg and Schleswig-Holstein. To effectively implement conservation efforts, knowledge of the species distribution and biology are important. Other commonly used non-invasive methods are not suitable to determine temporal activity patterns or species interactions. Three zones of interest, two in Schleswig-Holstein along the A24 and one in Hamburg, around the district Billwerder, were divided up into 43 areas within which, with one exception, two camera sites each were chosen. Due to limited equipment, the ultimately 85 camera sites were surveyed gradually for 14 nights each from the 7th of August 2017 until the last camera traps were taken down on the 23rd of October 2017. In total 349,920 photos were taken, of which the data from the 17 sites with hazel dormouse detection were analyzed further. Ultimately 1.5 % of the original total and 9.9 % of the pictures processed recorded hazel dormice. Hazel dormouse presence was detected to the north and south along an approximately 2.68 km stretch of the A24 motorway, and findings of previous years further to the east along the A24, around the crossing with the federal highway B404, were reconfirmed. No occurrences were documented in Hamburg. Because of camera malfunctions and frequently low amounts of occurrences at several successful sites, hazel dormouse presence cannot be entirely dismissed at the unsuccessful sites. The mean number of trapping nights to first detection was 5.88 (± 4.55). The earliest first detection took place only hours after installation and the latest was 13 days. Two of the 17 successful sites were responsible for 95 % of all hazel dormouse pictures. Temporal activity of the focal species shows three clear peaks: the first after dawn, the second around midnight and the third before dusk. At 11 out of the 17 successful sites, hazel dormice were only recorded during one of the 14 sampling nights. The sites 058 and 059 stood out again, because hazel dormice were recorded in 13 out of 14 sampling nights. The four remaining sites recorded the focal species on respectively 3, 4, 5, and 6 days. The most frequently recorded species, appearing on 77.8 % of the pictures on hazel dormouse sites, were the on photo indistinguishable species wood mice (*Apodemus sylvaticus)* or yellow-necked mice (*A. flavicollis),* merged as "*Apodemus* species". *Apodemus* species were found to have a slightly negative effect on hazel dormouse presence, with the chance of hazel dormouse occupancy at sites where *Apodemus sp.* are not present being 1.28 times larger than at sites where they are. Analysis of correlation between hazel dormouse presence and habitat parameters suggested that presence of hazel within 20 m of the camera site (Cramer's V = 0.366; $p = 0.012$), placement of the baited board directly in hazel (Cramer's V = 0.587; $p < 0.001$) and size of forested area (Cramer's V = 0.562; $p = 0.002$) were heavily associated with hazel dormouse presence. Using camera traps as survey method for hazel dormice proved to be useful when one wants to investigate activity patterns and species interaction using a non-invasive technique on hazel dormice in their natural habitat. While it is also a useful tool for determining presence of the focal species, the increased financial budget, investment of time and susceptibility to malfunction of the method have to be taken into account. These disadvantages limit the use of this instrument to implementation on a smaller scale and make it more prone to oversights than conventional methods. For presence determination on a larger scale, the commonly applied practices of using nest boxes and tubes as well as searching for nests and gnawed nuts are more feasible and less likely to return false negatives.

Table of Contents

Introduction

The hazel dormouse (*Muscardinus avellanarius*) is listed on Appendix III of the Bern Convention and Annex IV ('European protected species') of the EU Habitats and Species Directive (Hutterer, Kryštufek, Yigit, Mitsain, Meinig, and Juškaitis, 2016). While the latest assessment for The IUCN Red List of Threatened Species (IUCN, 2017i) has returned a global categorization of 'Least Concern', a decline in population numbers observed in recent surveys indicates a future problem for this species (Bright, Morris, and Mitchell-Jones, 2006; Büchner, Lang, and Jokisch, 2010). Regardless of local status, member states of the EU Habitats and Species Directive are required to report on the conservation status of habitats and species (Art. 6, 12, 16 and 17 of the Directive), and in case of Annex IV-species a strict protection regime has to be implemented across their natural range (European Union, 2017). The hazel dormouse is a small mammal found across most of Europe and northern Asia Minor that hibernates in nests near the ground between the months of October and May (PTES, 2017). Hazel dormice live in dense, thick vegetation and generally avoid even small interruptions in cover, making the animal quite elusive (Mortelliti, Santarelli, Sozio, Fagiani, and Boitani, 2012). To fulfil the requirements of the EU Habitats and Species Directive, local authorities of member states therefore employ several different techniques to survey the species and find the best ways to aid its conservation.

The most commonly applied hazel dormouse monitoring methods are live-trapping (Berg and Berg, 1999), track tunnels (Mills, Godley and Hodgson, 2016), hair tubes (Capizzi, Battistini and Amori, 2009), checking nest boxes/tubes (Bright and MacPherson, 2002) and searching for natural nests (Foppen, Verheggen and Van der Meij, 2002) or gnawed hazelnuts (Bright, Mitchell and Morris, 1994). Live-trapping and searching for natural nests are the only methods leading to an actual visual record, but as they involve possible disturbance or handling of the animals, they are not only invasive, but also often complicated because of local regulations and necessary handling permits (Bright et al., 2006). Track tunnels, while comparably labour- and cost-inexpensive, present the difficulty of distinguishing species and are more suited to identifying composition and relative abundance of small-mammal species in general (Glennon, Porter and Demers, 2002). Hair tubes, also requiring little labour, provide reliable identification, but also have a low detection rate (Capizzi et al., 2009), while searches for gnawed hazelnut shells are impractical where hazel is absent, not heavily-fruiting or influenced by other foragers. These survey techniques have resulted in a successful detection of hazel dormouse activity, habitat preference and population trends over the last few decades all over Europe, such as in Belgium (Verbeylen, 2012), the Netherlands (Foppen, et al. 2002), Lithuania (Juškaitis and Šiožinytė, 2008), Italy (Capizzi et al., 2009) and Austria (Resch, Blatt and Slotta-Bachmayr, 2015).

The application of several of the described methods has yet to lead to a definitive determination of hazel dormouse presence in Hamburg, Germany, where the only signs that the species is present are low numbers of isolated natural nest discoveries during extensive searches in the area (Ebersbach, 2015[a]). The neighbouring state, Schleswig-Holstein, on the other hand, has an extensive history of several occurrences over the last decade, partly through nest findings, of which a large amount was found in the green corridors along highways and on traffic islands (Schulz, Ehlers, Lang and Büchner, 2012; Schulz, pers. comm.). The hazel dormouse is classified as endangered in both states (Schäfers, Ebersbach, Reimers, Körber, Janke, Borggräfe and Landwehr, 2016; Borkenhagen,

2014) and both the Department of Environment and Energy Hamburg (BUE) and the Stiftung Naturschutz Schleswig-Holstein are involved in the effort of determining hazel dormouse presence and distribution in the area (Ebersbach, 2015a; Borkenhagen, 2014). Both organisations seek to gain knowledge regarding whether the so far discovered hazel dormouse activity continues along roadside habitats towards Hamburg and whether the species has populated isolated areas in the vicinity of previous dormouse detections (Schulz, et al., 2012). Two regions, one across the border of Eastern Hamburg and the south-west of Schleswig-Holstein and one in the south-east of Hamburg, were chosen for this survey. In Schleswig-Holstein, the roadside forests bordering the north and south of ca. 40km of the A24 motorway, where nests were previously documented (Schulz, et al., 2012) and recently seen (Schulz, pers. comm.), were chosen. In Hamburg, the forests in the neighbourhood of Billwerder was chosen to be surveyed, where nests were last found in 2012 (Haak, 2012). Given that an extensive utilization of conventional methods between 2011 and 2014 failed to provide more than sporadic signs of dormouse presence in Hamburg (Ebersbach, 2015a), an assessment without relying on the previously used techniques may prove more successful. The authorities in question are also interested in general information that sampling via indirect signs cannot provide, such as influence of and interaction with other mammalian species.

Camera traps have been shown to be a time-effective and reliable way of detecting small mammals (Di Cerbo, and Biancardi 2013). While rarely used for surveying dormice and comparably costly, this method has also shown promise in regard to the study species (Mills et al., 2016). Although this instrument allows for assessment of daily activity patterns (Panchetti, Amori, Carpaneto, and Sorace, 2004), the focus of camera trap studies surveying hazel dormice has so far only been on seasonal activity instead of daily. Camera traps also make it possible to monitor whether the presence of other species at the camera sites and the surrounding habitat has any bearing on the likelihood to encounter this animal. Additionally, while distribution (Capizzi et al., 2009), abundance (Bright and Morris, 1990) and nest-site preferences (Panchetti, Sorace, Amori, and Carpaneto, 2007; Juškaitis R., 1997[a]) of hazel dormice within certain habitat types have been the subject of study, no habitat assessment has previously been done in connection to dormouse presence detected via camera traps. The list of habitat requirements for an area to be considered suitable for the species is still quite broad and variable (Bright, Morris, and Mitchell-Jones, 2006), and presence or absence of the most commonly named criteria seem to be able to reliably predict whether the hazel dormouse is also present or absent (Bright, Morris, and Mitchell-Jones, 2006).

A small pilot study, carried out by one of the authors of this report, Lena Horst, employing camera traps over the months of July-September 2016 in the National Park Hainich, Thuringia, recorded dormice within 2-4 days of implementation in 6 out of the 16 camera trap locations. During said study dormice were also shown to seemingly be deterred from accessing the baited board when *Apodemus* subspecies were present, often lingering in the vegetation around the site, only very rarely approaching the closer proximity and never feeding at the same time. Repeated presence of raccoons at 9 of the 16 camera sites was also associated with lower chance of hazel dormice presence overall, although it is uncertain whether this was due to their mere presence or them and other medium-sized mammals simply depleting the bait before hazel dormice could become interested in it. At 3 of the 6 hazel dormouse sites, raccoons were recorded as well. Two of these sites were frequently visited by raccoons and hazel dormice were only recorded once, never visiting the board again. At the third site (16_03) hazel dormice were recorded 375 times and a single raccoon visited the site in between hazel dormouse records once, but did not access the board with bait and never came back.

According to literature and the experience from the pilot study, several hypotheses can be made about factors that may influence the hazel dormouse (see figure 1).

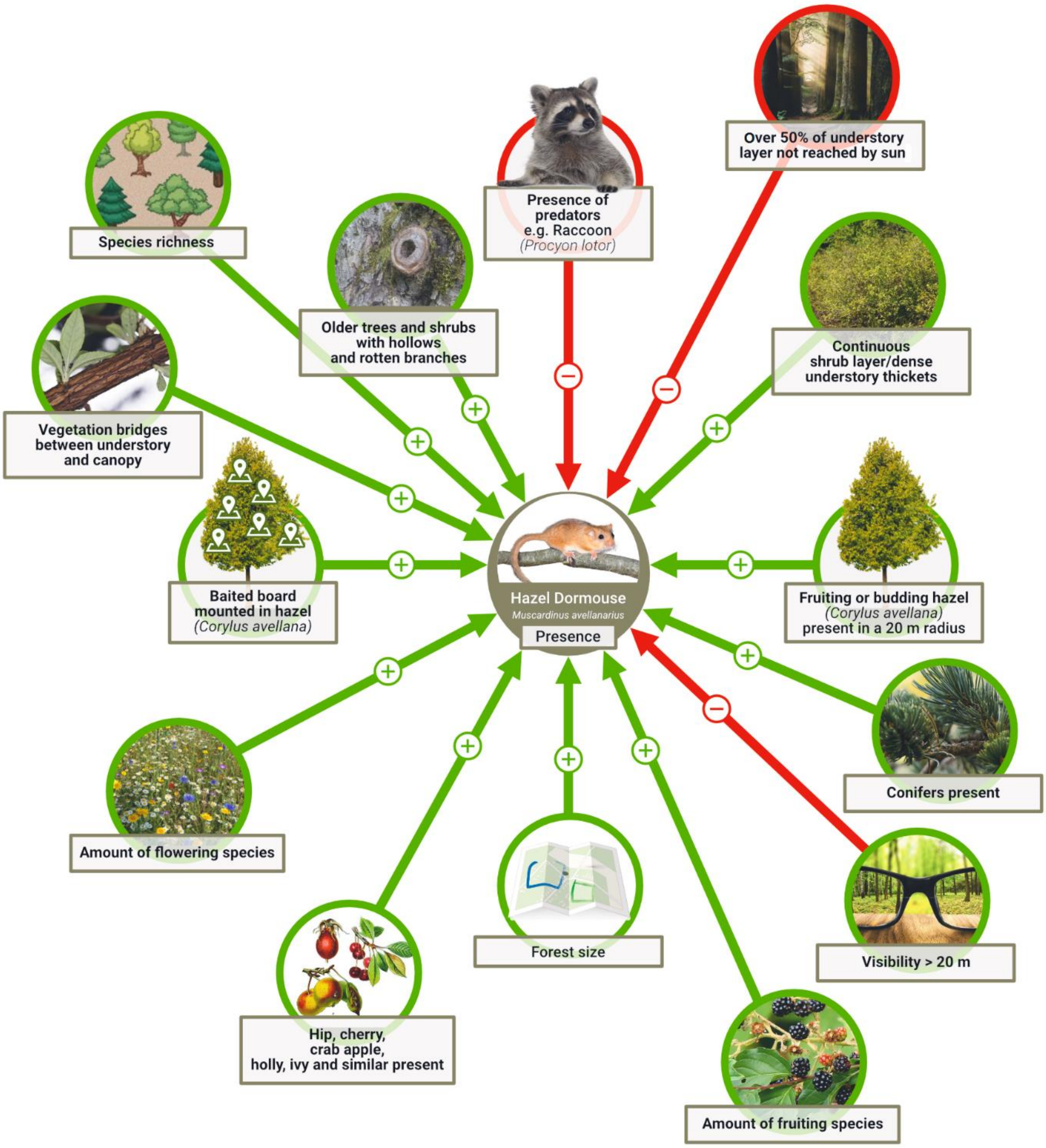

Figure 1: Conceptual model of possible influences of habitat parameters and other mammal species on hazel dormouse presence

In order to effectively organize and direct future hazel dormouse conservation efforts to ultimately fulfil the requirements placed by the EU Habitats and Species Directive, knowledge about the factors that favourably or unfavourably influence the species across its distribution range is vital. The aim of this study is therefore to help understand hazel dormouse biology and distribution to improve conservation efforts.

The goal is to determine hazel dormouse presence in two different areas across Hamburg and Schleswig-Holstein, as well as to assess activity patterns, interspecies interactions with other mammals and of the influence of the most important habitat requirements where the species is present.

The main and sub research questions are as follows:

1. **Where in isolated roadside habitats with a size of at least 0.5 ha within the study areas of Schleswig-Holstein and Hamburg are hazel dormice present?**

2. **What are the recorded activity patterns of hazel dormice at the camera sites?**

   2.1 What is the average amount of time until first appearance of hazel dormice at camera sites?
   2.2 During which times of the night are hazel dormice most recorded at camera sites?
   2.3 How many nights and across how many occurrences were hazel dormice recorded at camera sites?

3. **What influence does the presence of other mammal species at the camera sites have on hazel dormouse presence?**

4. **What is the correlation between select environmental parameters and hazel dormouse presence at the camera sites?**

1. Material and Methods

To answer the research questions, camera traps facing wooden boards with bait were employed. In order to find spots with high potential for hazel dormouse activity within the chosen areas, a score system based on several vegetation features and food availability was developed.

This chapter describes the study species, the study area, used materials, the methods utilised for area selection and camera site placement within the selected areas, as well as the time schedule used.

1.1. Study Species

This study focusses on the hazel dormouse and its presence within the study area. Furthermore, the time when it is most likely to be detected via camera trap is investigated, which is directly linked to the biology of the hazel dormouse.

1.1.1. Biology

The hazel dormouse, also known as the common dormouse, is a small mammal of the family of dormice. Its fur is bright golden-brown with a lighter cream-colour on the underside. Hazel dormice have a head-body length of 60 – 90 mm, while the furry tail is 55 – 80 mm long (Macdonald and Barrett, 1999; see image 1).

Its weight ranges from 15 to 35 g and the lifespan can be up to 6 years. The large black eyes match the nocturnal life of the hazel dormouse and, despite not having a thumb, it can oppose one toe or finger respectively, to be able to hold onto thin twigs and rapidly climb through vegetation. Even plain and steep trees are no problem to climb for this small rodent (Deutsche Wildtier Stiftung, 2016).

Image 1: young female hazel dormouse (photo: L. Horst, 2016)

The hazel dormouse is an arboreal woodland species and prefers dense, well developed, unshaded understoreys of deciduous woodlands, thick shrubs and the early successional stage of woody vegetation, like coppice, to live in. Even small interruptions of a few meters without connection via twigs and such between shrubs can be too much of an obstacle to overcome and will only be crossed, if absolutely necessary (Mortelliti et al. 2012). Therefore, linkage between suitable habitats is vital for hazel dormouse populations. Its diet consists of a high variety starting with pollen, buds and flowers in spring, fruit and insects in summer and nuts in autumn, to fatten up for hibernation. Hazel nuts are especially favoured by hazel dormice. They leave distinct gnawing marks on the emptied nutshells (Schulz et al., 2008).

The main mating period takes place in May, but mating can occur throughout almost the entire active period, starting right after hibernation. During mating season, especially male hazel dormice often display aggressive behaviour towards same sex conspecifics (Morris, 2011). Males can mate with several different females and are not involved in raising the young. Females also mate with different males, so it is possible to have young from different fathers in one litter. Early born females, generally born in June, are known to occasionally also breed in the same year, when they are only 60 to 80 days old (Juskaitis, 2008). Hazel dormice usually have one or two litters per year, in extreme cases three litters. After 22 to 24 days, 3 to 6 young are born in a ball-shaped nest, usually made of dry grass and leaves. They also use tree cavities and nesting boxes provided by humans (Juskaitis and Büchner, 2013). The young are born blind, deaf and naked and weigh around 2-3g. They are nursed for approximately one month and then start searching for their own territory. Sometimes the young stay with their mother for a longer period of time and during the day they often prefer to sleep in a nest with conspecifics (Deutsche Wildtier Stiftung, 2016).

The home range of the hazel dormouse is relatively small. They are usually not found more than 100 m away from their nest (Bright and Morris, 2009). Males usually have a larger home range (1.0 ± 0.05 ha) than females (0.8 ± 0.05 ha) (Juškaitis, 1997[b]). Hazel dormice tend to travel through shrubs and other rather thick vegetation and make considerable detours to avoid open ground (Bright and Morris, 2009).

Relevant predators for hazel dormice include owls, mustelids and squirrels as well as (domestic) cats. During hibernation at ground level, badgers and wild boars are a threat (Deutsche Wildtier Stiftung, 2016).

Dormice are best known for hibernating during the cold and food scarce months, as well as being able to fall into a torpid state for short times, when conditions are unfavourable for them, for example due to cold, wet weather or food scarcity. The hibernation generally occurs between October and May and takes place in nests just beneath the leaf litter on forest floors or in the base of hedgerows (PTES, 2017).

1.1.2. Distribution and Conservation

The hazel dormouse is distributed over most of Europe and northern Asia Minor. German hazel dormouse populations rapidly declined during the past decades because of habitat loss and fragmentation (Deutsche Wildtier Stiftung, 2016). The same applies to other parts of the northern range, e.g. the Netherlands, Sweden, Denmark and the United Kingdom (IUCN, 2017; see figure 2).

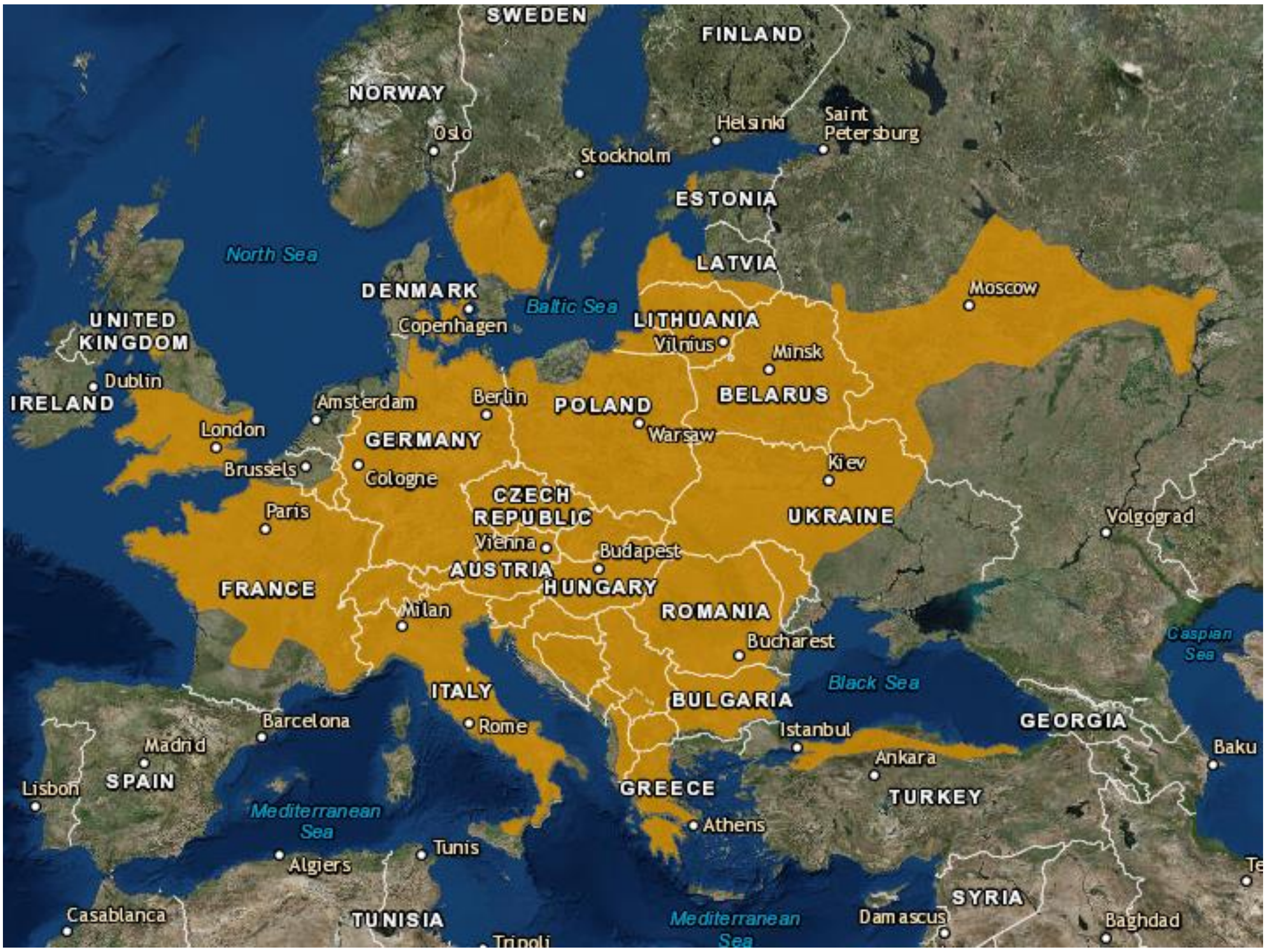

Figure 2: Hazel dormouse distribution across Europe (IUCN, 2017)

The IUCN (International Union for Conservation of Nature and Natural Resources) considers the hazel dormouse population worldwide as "least concern", meaning it is not threatened on a large scale. However, it is listed on Appendix III of the Bern Convention and Annex IV of the EU Habitats and Species Directive. In many countries this species is included on national Red Lists. In Europe the hazel dormouse is listed as least concern, but in Germany it is listed as threatened to an unknown extent (BfN). In Hamburg the hazel dormouse is listed as "category 2 – endangered", but only because there appear to be viable populations near Hamburg. Otherwise it would be listed as "critically endangered" (Schäfers, et al., 2016). In Schleswig-Holstein the hazel dormouse is listed as category 2 as well (Borkenhagen, 2014).

1.2. Study Area

The habitats chosen for this research were all isolated forested and coppice areas of over 0.5 ha along approximately 40 km of the southern and northern edge of the A24 motorway, named unit A, and in a ca. 5 km radius of the Billwerder district of Hamburg, named unit B (see figure 3, page 13). A third unit, named unit C, was chosen near Kasseburg, Schleswig-Holstein. The units were identified based on proximity to motorways respectively train tracks and vegetation. Unit C was chosen while already carrying out the study, as hazel dormouse occurrence was considered almost definitive, since the species was present there the in the recent past (Schulz, pers. comm.) and until that moment, hazel dormice were yet to be detected. To try to make sure the method works, camera traps with two different board types were employed there.

Given that the regions encompass two different states with different documentation of hazel dormouse presence, they will be described separately.

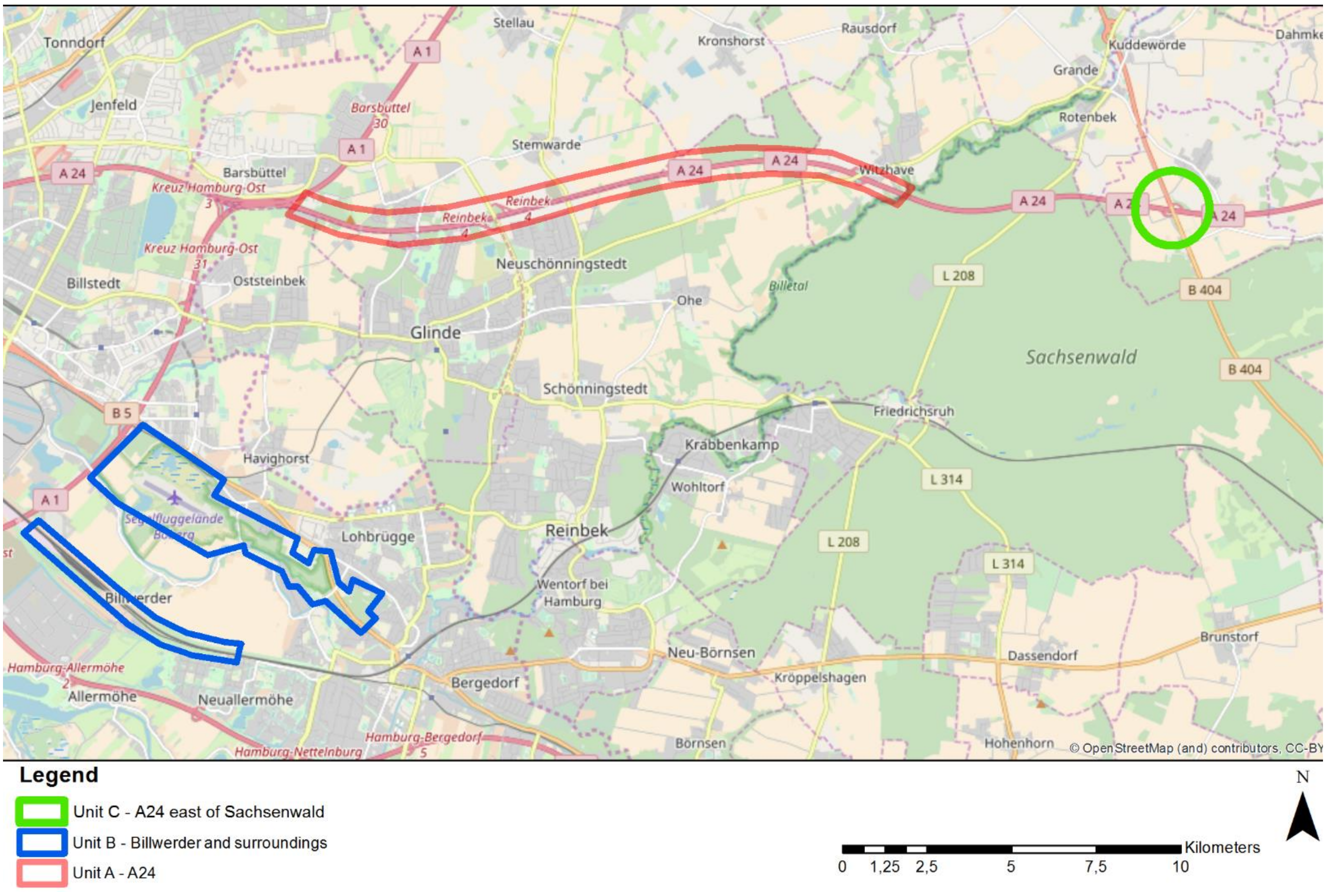

Figure 3: Location of unit A (A24), unit B (Billwerder district and nearby areas of interest) and unit C in relation to each other

1.2.1. Hamburg

The state of Hamburg, situated in northern Germany (see Appendix I), encompasses an area of 72.520 ha (Statistik Nord, 2017) of which about 8000 ha alone are made up by the city of Hamburg itself. It is a major port city connecting to the North Sea through the River Elbe and otherwise being crossed by a large amount of canals, with water accounting for ca. 3300 ha of the state (deutsche-schutzgebiete, 2000).

The whole area of Hamburg was subject of an extensive survey from May 2011 until January 2014 to determine the presence and distribution of 23 species of small mammals as well as gain information regarding their habitats, population numbers and -trends. As a result of this research, the status of the hazel dormouse in the area was determined as critically endangered, with a short-term population trend of -14.3 % (projected by data taken from 1997 - 2015) and a long-term trend of -57.1 % (projected by data taken since the 19th century) (Ebersbach, 2015[b], Schäfers *et al*., 2016). The hazel dormouse was part of this survey as the Department of Environment and Energy Hamburg had become aware of a few occurrences of the species between the 1970s and the year 2008 at the eastern border of the city (Ebersbach, 2015[a]). These reports of an Annex IV species of the Habitat Directive were cause for further investigation into possible habitat and monitoring locations to fulfil the responsibilities as a member state (European Union, 2017).

After the year 1996 (namely between the years of 2008 and 2012) hazel dormouse nests were found in 6 DGK5-Quadrants (1 : 5000), providing proof of occurrences in the district of Billwerder (see figure 4) and resulting in the verdict of the species being endangered (Schäfers *et al*., 2016). In connection with this research, a total of 250 nest tubes were deployed between 2011 and 2012 and checked for activity three times during the survey period (Ebersbach, 2012). Additionally, definitive signs of dormouse activity in the surroundings such as gnawed hazelnuts and natural nests were collected (Ebersbach, 2015[a]). While not a single occurrence of hazel dormice was recorded via the live trapping efforts directed at small rodents in the area in general, natural hazel dormouse nests were found in three locations and on one occasion a nest tube was used (Ebersbach, 2015[a]; Haak, 2012).

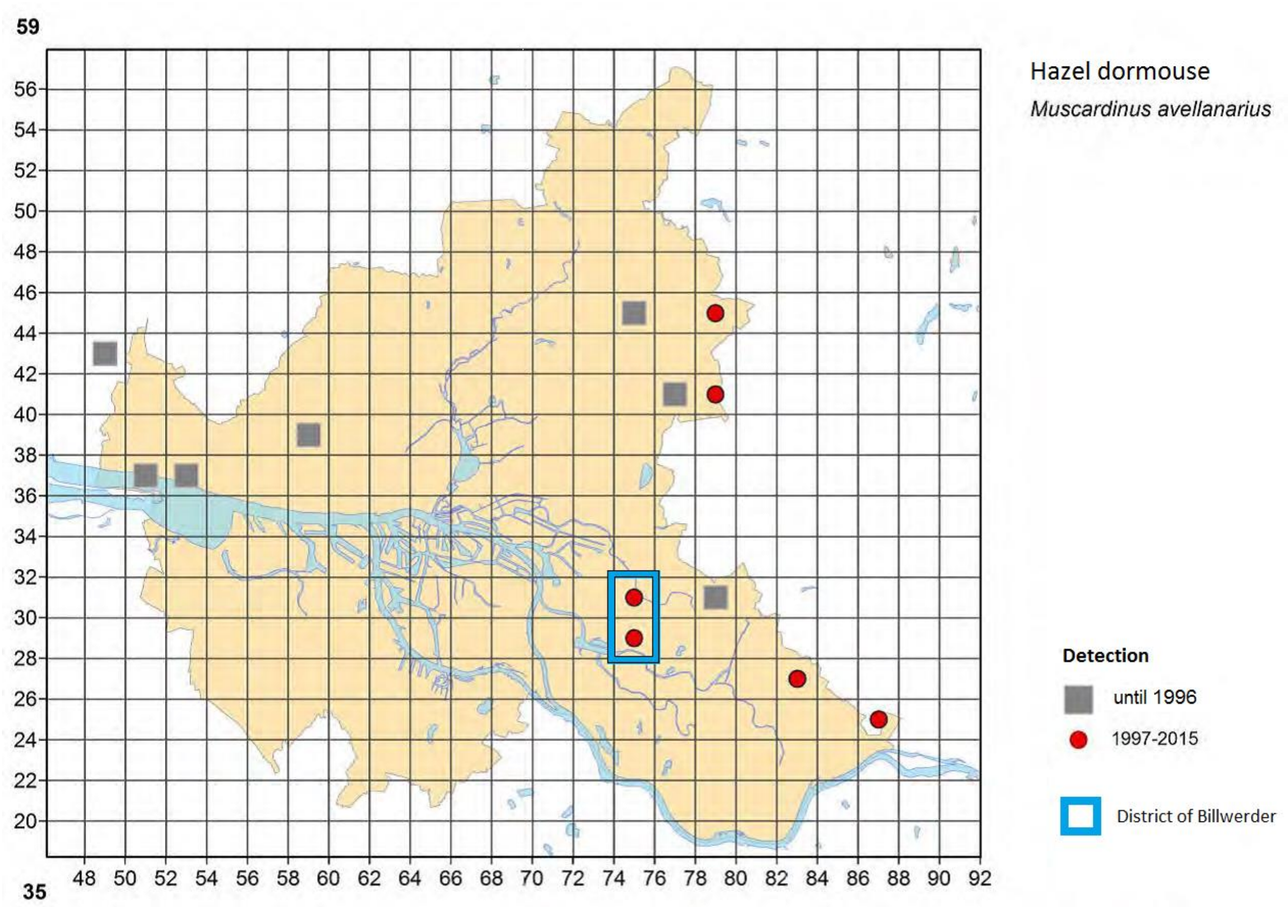

Figure 4: The six DGK5-Quadrants (2 x 2 km) of Hamburg where dormouse evidence was observed until 1996 and 1997 until 2015 (Schäfers et al., 2016)

The district of Billwerder is one of the locations where hazel dormouse occurrences have been documented and the only location where not only evidence in two quadrants, but both natural nests and the only used nest tube were found during the monitoring of 2012 (see figure 4, page 14 and Appendix II; Ebersbach, 2015[a]; Haak, 2012). The patches of forest of the neighbouring nature reserve "Boberger Niederung" as well as the forested strips running along the urban railway leading away towards the east are possible habitats along which the detected activity could continue, marking unit B (see Figure 4, page 14).

1.2.2. Schleswig Holstein

Schleswig-Holstein is Germany's northernmost state (see Appendix I) and, among others, shares a border with Hamburg in the south and Denmark in the north. In its 1,580,300-ha landmass (Statistik Nord, 2017) included are several islands, such as Helgoland, Sylt, Föhr and Amrum (Encyclopædia Britannica, 2017).

The history of the earliest scientific hazel dormouse sightings in Schleswig-Holstein starts out not quite as sparse as in Hamburg, but still low with 156 reports between the years of 1847 and 2005. Evidence of hazel dormouse presence sank from confirmation in 26 TK-25-Quadrants (1 : 25000) in

1980 to 9 Quadrants and a total of 12 findings since 2000. From that year on research claimed the species as extinct except for a few isolated populations in the southeast (Schulz *et al*., 2008).

However, in 2005/2006 the Stiftung Naturschutz Schleswig-Holstein started to incorporate private individuals and groups such as elementary school classes as voluntary field workers to search for gnawed hazelnuts all over the state (see figure 4, page 15) in the context of the project "Nussjagd"(german: nut-hunt). The results of this project suggest that the species may have been present all along and just more difficult to find, as out of over 66.000 collected nuts between 2006 and 2008 over 330 were successfully identified as dormouse-nuts, the majority having been found in the south and east of the state (see figure 5, page 16; Schulz *et al.*, 2008).

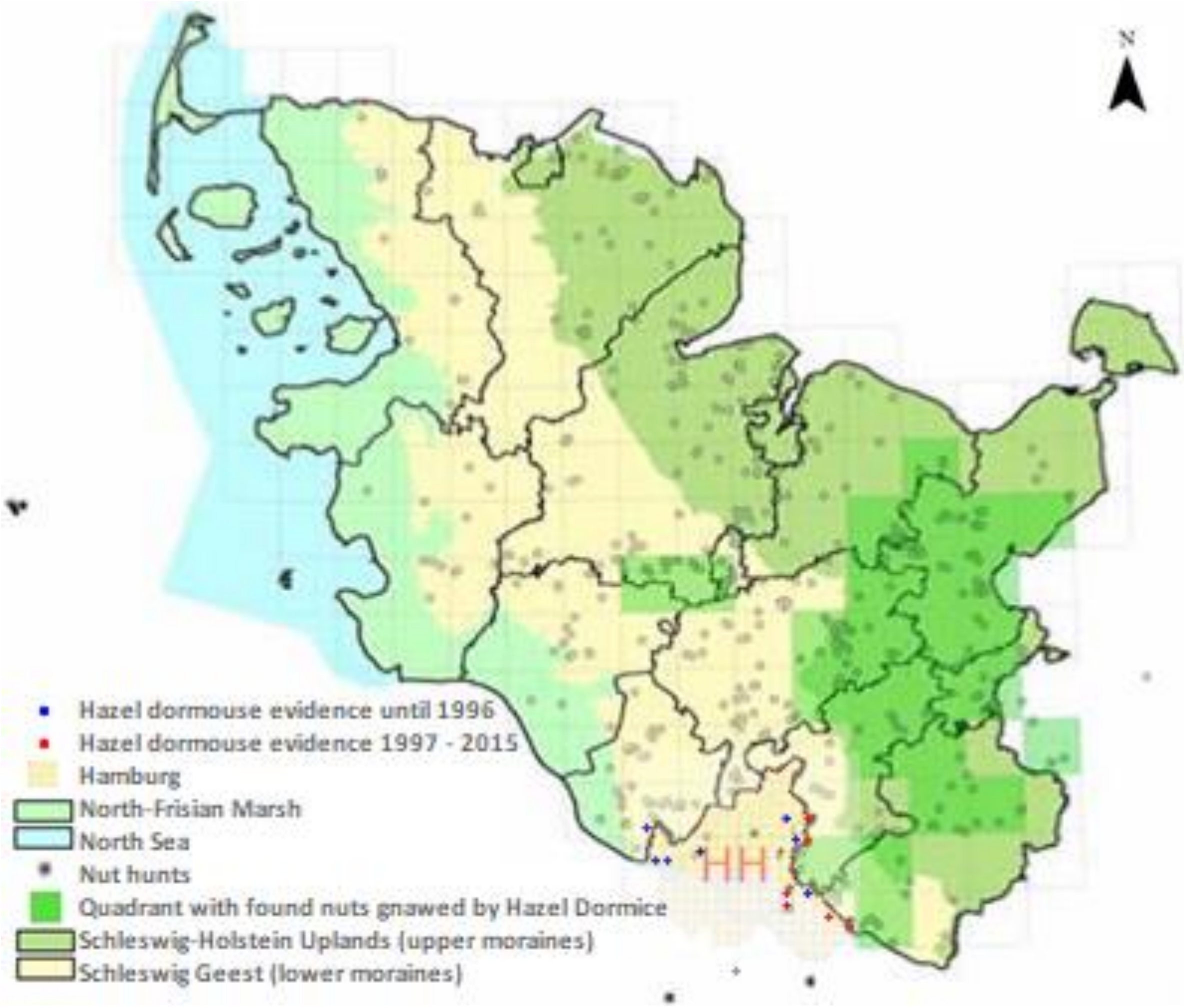

Figure 5: Distribution of nut-hunts (grey dots) in Schleswig-Holstein combined with the 26 TK-25 quadrants (each ca. 11 x 11 km) in which hazel dormouse occurrences were proven through the nut hunt (green squares) (Schulz et al., 2008) and hazel dormouse evidence in Hamburg (Schäfers et al., 2016)

Additionally, investigations along several motorways and Federal roads (such as the A7, A24, B404 and B207; see figure 6, page 17) and several traffic islands along the motorway A21 in 2008 until 2011 resulted in findings of dormouse nests and other evidence (Schulz *et al*., 2012; see Appendix II).

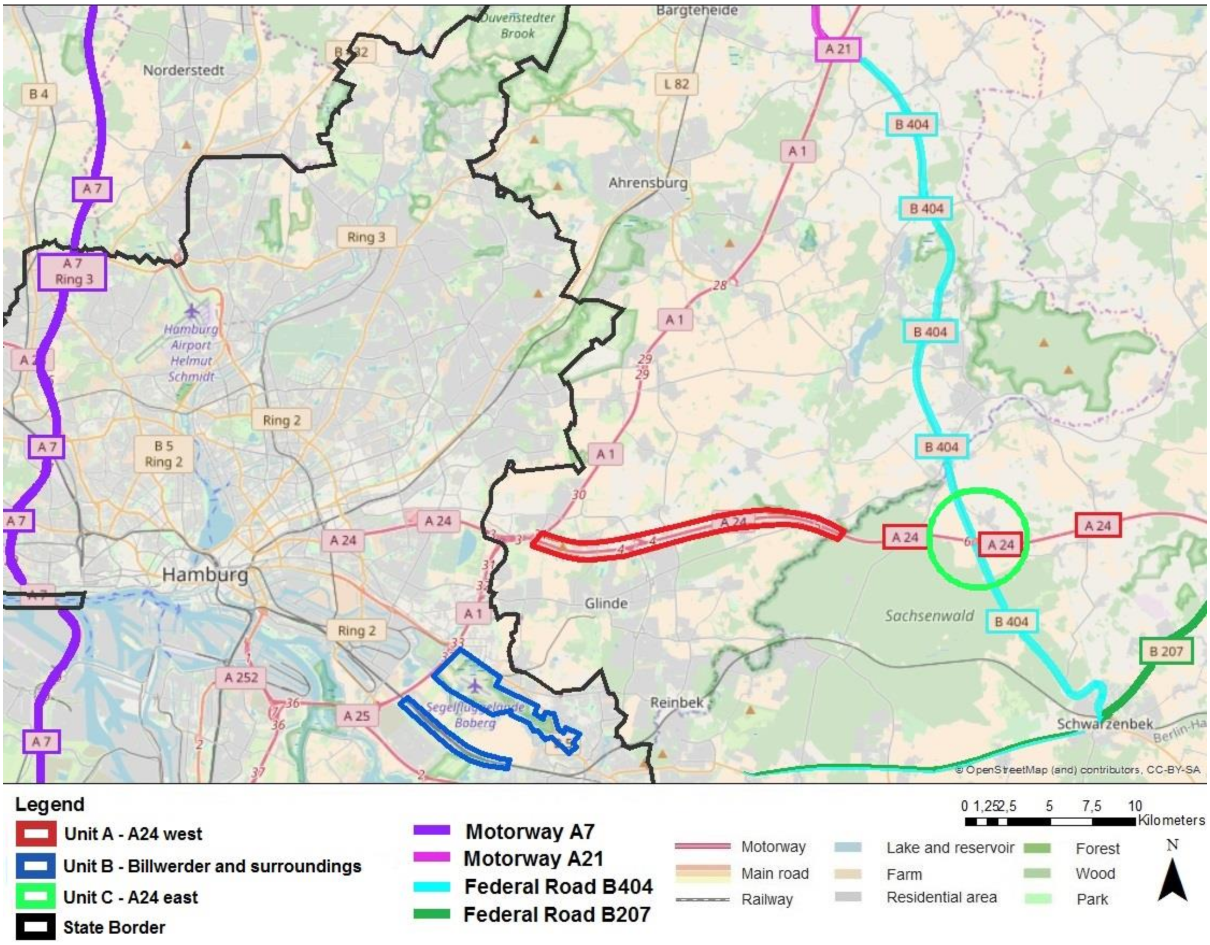

Figure 6: Positioning of the chosen research unit's A and B (and C) relative to relevant roads across Hamburg and Schleswig-Holstein

This evidence supports previous theories that hazel dormice utilise roadside shrubbery and can be found in isolated habitats with a size of less than 1 ha (Chanin and Gubert, 2012). An additional study in the area also proved that road-crossing can be a relatively frequent behaviour in dormice (Kelm, Lange, Schulz, Göttsche, Steffens and Reck, 2015). Due to the results of the 2012 study of Schulz *et al.* as well as additional reports of sightings of hazel dormouse nests along the A24 (Schulz, pers. Comm, July 2017), the forest patches along this motorway were the focus for unit A and C of the current study.

1.3. Data Collection

After determination of the general locations of interest within the two states, the selection of possible camera sites was narrowed down further by identifying, dividing and eliminating forest patches along within the chosen units. For this, their necessary characteristics and suitability were appraised via maps, before going into the field and choosing the definitive camera sites due to a habitat score system.

1.3.1. Area Choice

The investigated areas within the units were chosen based on three basic characteristics: size, separation from other habitats and vegetation. To figure out the most promising spot regarding hazel dormouse occurrence for camera placement within the areas, a score-system was used.

First, sites with shrub and/or forest characteristics and an effective habitat size of more than 0.5 ha were determined based on satellite maps. While hazel dormice were previously found to be present in 4 out of 8 traffic islands of an effective size under 0.2 ha, they were consistently present in 17 areas with a size above 0.2 ha (Schulz *et al*., 2012) and a 2012 study in the UK found them to be breeding only in areas of 0.5 ha or lager (Chanin and Gubert, 2012). Therefore, the minimum effective size chosen for an area to be considered for camera placement was set at 0.5 ha. It was important that the chosen locations are easily accessible (*i.e.* no isolated circles of forest entirely surrounded by motorway exits/entries) to be able to safely carry out the investigations without trespassing or violating traffic regulations.

While it has also been determined that hazel dormice cross roads like federal highways quite frequently (18 % of mark-recaptured and 60 % of radio marked animals) to access new suitable areas (Kelm *et al*., 2015), landscape characteristics known to rarely be crossed were used as the borders of a study location. This includes cemented roadways accessible for the public by car, rivers and streams of more than 1 m in diameter and open/agricultural fields and strips of more than 50 m. The borders of forests and other suitable areas were traced along such features on street- and satellite-maps in ArcGIS until a location was isolated (see figure 7).

Figure 7: Area 15 (108,71 ha) of unit A in street view, worldview (with a former military compound visible to the upper right) and on the hazel dormouse suitability map

To remotely assess overall eligibility of the area and find the best possible spots for camera placement before entering the field, a habitat suitability map created by the LLUR (Landesamt für Landwirtschaft, Umwelt und ländliche Räume) was used for all areas within Schleswig-Holstein (the majority of unit A and all of unit C, see figure 6, page 17). For all areas within Hamburg, all habitat areas marked as “H = Gebüsche und Kleingehölze” (coppice) and “W = Wälder” (forests) within the Biotopkatasterkarte (habitat register) of Hamburg (see figure 8, page 19) provided a rough estimate of where suitable areas can be found.

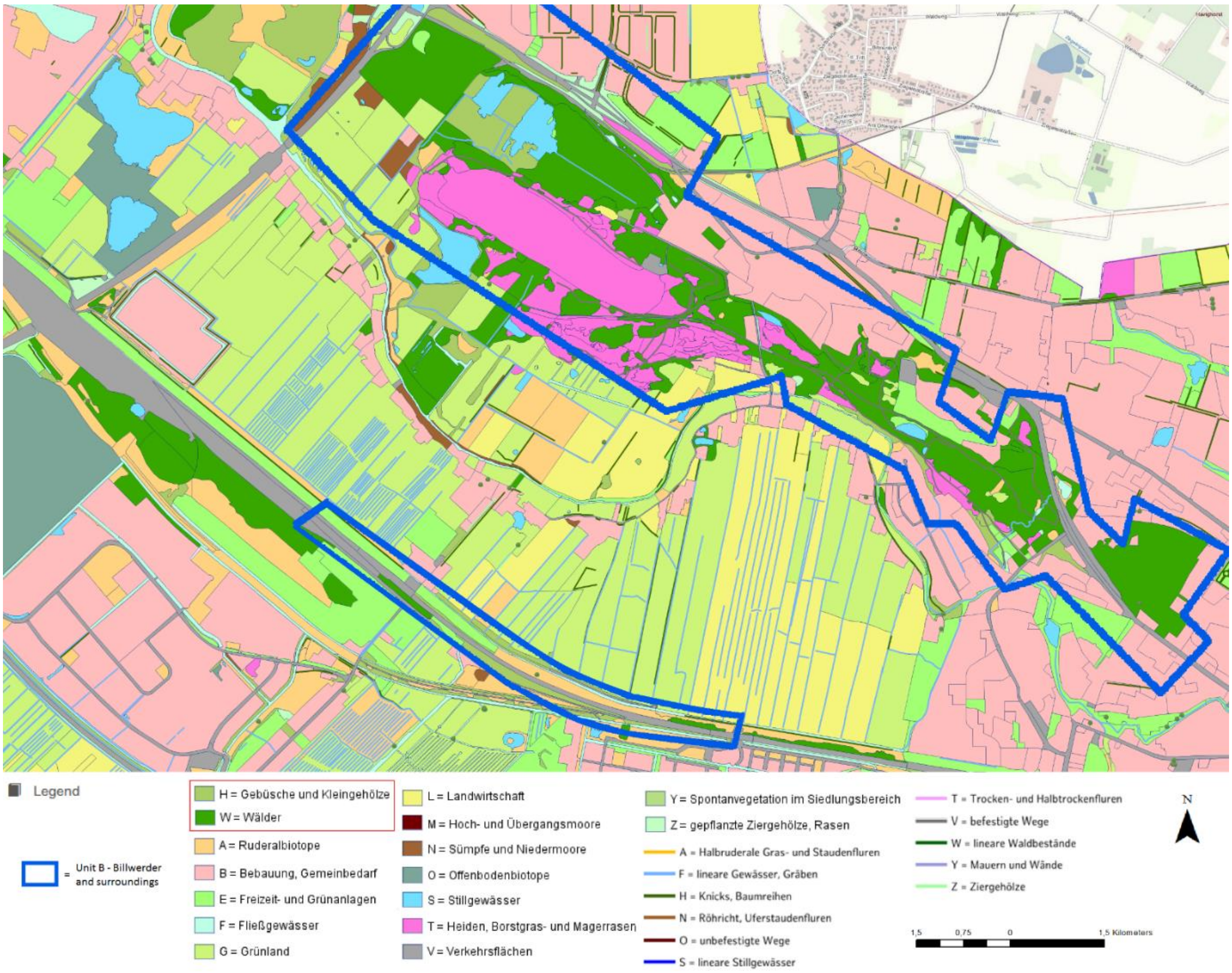

Figure 8: Excerpt of the Biotopkataster Hamburg, with Billwerder and surrounding areas of interest framed blue on the map and the important habitats on top of the legend

After determining the desired areas within the units on screen, the situation was evaluated by physical visits, during which the actual suitability of the areas was reassessed. No area turned out to be unsuitable for the study upon assessment, so none were dismissed. If, upon initial visual examination, an area fulfilled the initial criteria of sufficient size, separation from other habitats and appropriate vegetation, two spots for the camera trap setup (camera sites) were determined via habitat scores consisting of 11 more in-depth criteria (see chapter 1.4), to maximise the chance of hazel dormouse encounter. The final choice of camera sites in the field was sometimes found to be quite contradicting to the provided maps that were used as guidelines, as can be seen in figure 9.

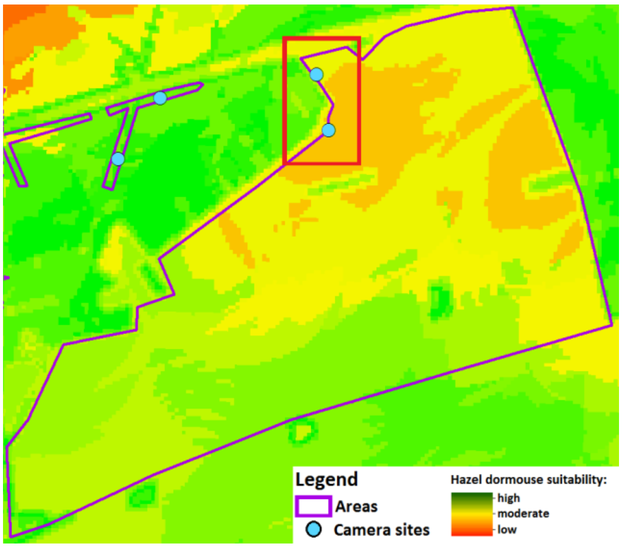

Figure 9: Placement of camera sites (framed red) of area 15 of unit A (both detected dormice)

The smallest and greatest area chosen for sampling were 0.74 ha and 108.71 ha respectively, the mean being 10.53 ha (± 18.89 ha, n = 43).

1.3.2. Camera Site Choice and Habitat Score System

Within each area two camera sites were chosen by estimating the value of the local habitat for the focal species. During physical visits in the previously chosen areas, promising spots regarding vegetation and cover were assessed in a 20 m radius, through a numerical scoring system of 11 criteria, as seen in table 1. The criteria are presumed to increase or decrease the habitat suitability for hazel dormice. Scores were devised from the factors named in the Dormouse Conservation Handbook (Bright *et al*., 2006) and weighted relative to their perceived contribution to the habitat suitability value.

A vegetation species richness of at least 5 different tree and shrub species of value to the hazel dormouse was for example chosen to make sure the investigated habitat offers sufficient food and suitable living environment throughout the active period, including the possibility to obtain enough energy for reproduction and fattening up prior to hibernation. Since actual flowering, budding and fruiting of the species is of great importance as a source of food, these parameters added extra points, depending on how many different fitting species were found. If only one species with the respective parameter was present, one point was added to the score, if there were two different species, two points were added. Three points were added if there were three or more species that fit the parameter. Presence of fruiting or budding common hazel (*Corylus avellana*), added two points to the score, as it offers the principal source of food (nuts as well as many insect species) when available. Especially for fattening up before hibernation, hazel nuts play an important role, as they contain a lot of energy. Furthermore, the understory formed by hazel sprawling poles allows easy arboreal activity. If an area was within a wood of a size of 2 – 20 ha, at least 20 ha or over 50 ha, it raised the likelihood of dormouse presence within the area, therefore this factor added 1, 2 or 3 points respectively. All further positive criteria were allotted one score point each as they all add to the overall habitat suitability, but by themselves only marginally increase the attractiveness of the immediate surroundings in comparison with for example an abundance of active food sources.

Scores for each criterion were determined, with a minimum of 12 score points accumulated for a spot to be considered as camera site. The lowest possible score was -3 and the highest 20 (see table 1, page 21).

***Table 1** – Criteria and scores used to assess habitat value in a radius of 20 m (a minimum of 12 points is needed for a spot to be considered as a camera site) (derived from Bright et al., 2006)*

<table>
<tr><th>No.</th><th colspan="2">Habitat parameter</th><th>Effect/use</th><th>Point score</th></tr>
<tr><td>1.</td><td colspan="2">Vegetation species richness (>5 species of oak, honeysuckle, bramble, sycamore, ash, wayfaring tree, yew, hornbeam, broom, sallow, birch, sweet chestnut, blackthorn, hawthorn)</td><td>Necessary to maintain a sequence of foods through the seasons</td><td>+3</td></tr>
<tr><td>2.</td><td colspan="2">Fruiting or budding hazel (Corylus avellana) present</td><td>Favoured food source</td><td>+2</td></tr>
<tr><td rowspan="4">3.</td><td colspan="2" rowspan="4">None, 1, 2 or 3 and more different flowering or budding species (see first criterion) present</td><td rowspan="4">Available food source</td><td>+0</td></tr>
<tr><td>+1</td></tr>
<tr><td>+2</td></tr>
<tr><td>+3</td></tr>
<tr><td rowspan="4">4.</td><td colspan="2" rowspan="4">None, 1, 2 or 3 and more different fruiting species (see first criterion) present</td><td rowspan="4">Available food source</td><td>+0</td></tr>
<tr><td>+1</td></tr>
<tr><td>+2</td></tr>
<tr><td>+3</td></tr>
<tr><td>5.</td><td colspan="2">Continuous shrub layer/dense understory thickets</td><td>Offers possibility to move around easily without coming to the ground</td><td>+2</td></tr>
<tr><td rowspan="4">6.</td><td rowspan="4">Within or adjacent to a wooded area of</td><td>over 50 ha</td><td rowspan="4">Increases likelihood of dormouse presence</td><td>+3</td></tr>
<tr><td>at least 20 ha</td><td>+2</td></tr>
<tr><td>2-20 ha</td><td>+1</td></tr>
<tr><td>under 2 ha</td><td>+0</td></tr>
<tr><td>7.</td><td colspan="2">Older trees and shrubs with hollows and rotten branches</td><td>Possible resting places</td><td>+1</td></tr>
<tr><td>8.</td><td colspan="2">Vegetation bridges between understory and canopy</td><td>Offers possibility to move around easily without coming to the ground</td><td>+1</td></tr>
<tr><td rowspan="2">9.</td><td>Species present:</td><td>Conifers</td><td rowspan="2">Possible alternative food source (e.g. insects)</td><td>+1</td></tr>
<tr><td></td><td>Hip, cherry, crab apple,
holly, ivy and similar</td><td>+1</td></tr>
<tr><td>10.</td><td colspan="2">Tree canopy casts too much shade (>50 % of understory layer not reached by sun)</td><td>Understory will fail to fruit enough, reducing or removing key sources of food</td><td>-1</td></tr>
<tr><td>11.</td><td colspan="2">Visibility in high summer at eye level is > 20 m</td><td>Deteriorating species habitat as the shrub layer is thinning out</td><td>-2</td></tr>
<tr><td></td><td colspan="2">Max total</td><td></td><td>20</td></tr>
</table>

The distance between camera trap and board was chosen based on the individual fixed distance settings of the camera traps and on the preconditions given be the local flora. A distance that allowed the whole board to be on camera was preferred, but not always possible.

Regardless of size, each area was equipped with 2 camera traps, except for one occasion where equipment failure resulted in an area of 2.14 ha being surveyed by a single camera.

The distance between the camera trap sites within an area was ensured to be a minimum of approximately 50 m. Due to variation in habitat suitability the distances were not exactly the same between camera sites. If there were no two suitable spots with a minimum of 12 points detectable within 1 hour, the area would have been considered unsuitable and abandoned, but that was never the case. The coordinates of the chosen sites were documented with a GPS device.

1.3.3. Material

To determine hazel dormouse presence, camera traps (the models Moultrie MCG-12634, Cuddeback 1255, Cuddeback C, Spypoint Force-11D2, Maginon WK3HD and Medion S47119 (MD 87396)), modified for documentation of small animals over a short distance (20 – 70 cm) and equipped with infrared flash, were used. The camera traps have been set to only take photos with a burst of 3 photos per detection and a delay of 30 seconds. If possible (for example with the Cuddeback model) the cameras operated with a FAP (Fast As Possible) delay and a burst of 3 pictures per detection during the night and take single shots with a 60 second delay during the day. Due to the large number of photos expected, the image size was set to 5 MP, if possible, to avoid loss of data due to full SD cards. The used SD cards ranged from 2 GB to 16 GB. During the second round of the the camera traps were chosen to only take photos during the night, (from dusk until dawn) so as to avoid the large amounts of surplus pictures of birds and squirrels collected during the daytime hours.

Image 2: Basic setup of board and camera trap, without roof

Image 3: Apodemus sp. easily passing through the wire cage

The camera traps faced the long sides of ca. 40 x 17 x 2 cm wooden boards with peanut butter and strawberry marmalade applied as bait. To keep birds and larger mammals, such as rats and squirrels, from eating the bait, a cage with wire mesh large enough for mice to go through was attached to the board. The mesh size was 1.7 x 1.7 cm with every second mesh widened to make sure larger mouse species or pregnant mice can safely pass (see images 2 and 3). The mesh construction has been devised and utilised by Goedele Verbeylen in her technical report in the form of a movie (Verbeylen and Buelens, 2014). To facilitate the application of bait, the wire cage was stapled to one side of the board and only fixed with wire on the opposite side. By detaching the fixing wire, the cage could be tilted up to allow access to the board.

The boards were strapped to trees and/or bushes with wire, zip ties and/or string, depending on the given preconditions (see images 2 and 3).

To keep rain from washing away the bait, roofs either made of roofing felts or thin pressboard were installed above the boards. Since heavy rain sometimes compromised the camera traps, by leaving drops on the lenses, they were equipped with roofs as well.

For unit C, another type of board was employed additionally, namely a hanging type, as devised by G. Verbeylen. The same board as used in the basic design was adapted by attaching strings to the corners of the plank, fixing a roof above it and then hanging from a branch (see image 4). Because the occasionally strong wind kept blowing the board off the camera trap range, a thin string was attached to the bottom of the board to anchor it in the ground with a tent peg. This type of board was specifically constructed to keep other species, primarily mouse species, from reaching the board, but allows hazel dormice to access it, due to their superior climbing abilities.

Image 4: Hanging board utilized in unit C

1.3.4. Time Schedule

During the pilot study of 2016 first occurrence of hazel dormouse presence was documented after 2 - 5 days. However, a UK survey conducted in 2010 by Mills, Godley and Hodgson (2016), using sunflower seeds, peanuts, apple pieces as well as two to three drops of honeysuckle oil as bait, found a median of 13 trapping nights to first detection of dormice (interquartile range 6 - 15) and 8 (interquartile range 4 - 13) for wood mice. As a result of these studies, each camera site was surveyed for 14 days, after which the camera traps and bait were taken down and installed in a new area.

On day one in the respective site, the camera traps and the wooden boards with bait were installed. The bait was renewed on the third, fifth, eighth, tenth and twelfth day. On the 14th day the camera traps were taken down and relocated within the next set of areas. Before reinstalling a camera at a new location, the SD card was replaced with an empty card and the batteries with recharged ones. To check positioning of the cameras and since there was not always a sufficient number of SD cards available, a laptop was sometimes taken into the field and utilized to check and copy the pictures in order to reuse the respective card immediately.

To cover the regions to be surveyed in Hamburg and in Schleswig-Holstein, the respectively chosen sectors were roughly defined on a map, resulting in 3 different units, two in Schleswig-Holstein and one in Hamburg. Within these units, the aforementioned areas were chosen.

Originally the cameras were split up into two units, with 10 cameras for unit A and 10 cameras for unit B respectively, to be able to change location and bait in a consistent manner. The left-over cameras were kept aside, in case a camera needed to be replaced, i.e. due to malfunction, which happened several times. Since two camera traps were installed per area, 5 areas could be surveyed per fortnight per unit.

Since the first areas were unsuccessfully surveyed, some doubt arose concerning the suitability of the method. Consequently, a third unit was chosen (unit C), where hazel dormouse occurrence was considered certain due to records from previous years, to test if the method works. Furthermore, a second type of board was utilised, as developed by Goedele Verbeylen, to make sure it is not the type of board or the other species using it, that kept the focal species from showing up.

Another concern was the suitability of the time of the year, as the first hazel dormouse detection occurred on the 1st of September, but camera traps were installed starting at the end of July. During the test phase, a camera trap near the camera site that, during the official sampling period, would be numbered as 059, documented a hazel dormouse in the end of July with only 2 pictures, while passing the board without showing interest in the bait. At that time the hazel dormouse did not return to the board, whereas multiple hazel dormice were documented there in September, regularly returning to the board. That fact led to the concern that hazel dormouse detection might be more successful at a bit later time of the year. Consequently, most of the early surveyed areas were surveyed a second time.

In total 3 units, consisting of 43 areas and 85 camera sites (excluding the test phase) were surveyed from the 7th of August until the last camera traps were taken down on the 23rd of October. Within the 85 camera sites, of which 36 sites were successfully sampled twice, 121 trapping sessions were carried out, with 14 nights each trapping session, resulting in a total of 1,694 trapping nights.

Due to equipment failure during sampling of unit A and B, the final amount of camera sites fell short. Instead of the planned 40 sites within 20 areas in both units, only 39 sites in 20 areas (camera site 21 being the only case of only one site being sampled in an area) were surveyed in unit A and only 38 sites in 19 areas were surveyed in unit B (see table 2).

The total sampling period from the start of the first round on until the retrieval of the last cameras from the second round comprised 84 nights.

Table 2 *– Summary of survey effort*

Round	Start Date	Unit	Areas	Amount of camera sites	No. of camera sites	Number of trapping nights
1	07.08.17	A	20	39	001-010, 021-029, 058-067, 076-085	546
1	08.08.17	B	19	38	011-020, 030-039, 048-057, 068-075	532
1	04.09.17	C	4	8	040-047	112
2	18.09.17	A	9	16	001-006, 009-010, 021-028	224
2	19.09.17	B	10	20	011-020, 030-039	280

One camera (029) was stolen and one became defective during sampling of the second round, resulting in the data taken during the session not being able to be recovered.

Image 5: *Completely obscured picture due to malfunction at camera site 029*

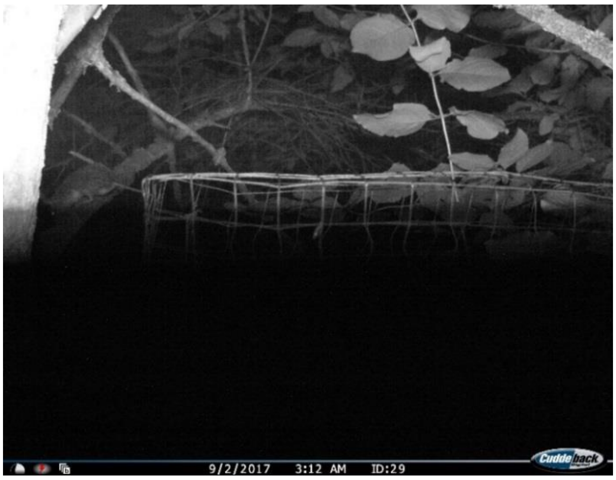

Image 6: Partly obscured picture due to malfunction at camera site 029

Malfunctions resulting in black or partly black photographs affected 8 cameras (4 within unit A, 1 within unit B and 3 within unit C), causing a total of 14,969 obscured pictures during round 1 in which no animal could be identified (see images 5 and 6; table 3, page 24).

Table 3 – *The 8 camera sites were malfunctions resulting in black pictures were discovered, the original amount of pictures, black pictures taken and the estimated hours and nights lost*

Camera site	Hazel dormouse	Original	Black	Lost hours*	Lost nights*
029	No	7488	2188	19	2
041	No	6504	4926	100	10 ½
042	Yes	1331	89	8	1
046	Yes	1809	1541	47 ½	6
055	No	845	396	8	1
060	Yes	9902	5067	62 ½	7
067	Yes	10719	684	< 1 ½	< ½
078	Yes	101	78	< 30 min	6
Total		**38699**	**14969**	**ca. 247**	**ca. 34**

malfunctions were not always continuous across pictures series (3 photos per trigger) or throughout one night, resulting in a higher estimated loss of time for cameras that were triggered more often

Pictures counted towards the totals per camera that can be seen in table 3 if the malfunction obscured the board to such a degree that its occupants were not at all visible or could not be identified reliably. If any species were still clearly recognizable, as is the case in image 7, the pictures were still included in the sampling effort and, where applicable, processed further.

Image 7: Partly obscured picture due to malfunction at camera site 060, with Apodemus sp. still recognizable

1.4. Data Preparation

The collected photos were saved in separate folders for each camera site. If a site was surveyed twice, the photos were saved in separate folders within the main folder. The photos were then assessed, all present mammal species were documented in an excel table, and photos without any animals visible and therefore of no use for the study were deleted, to save some memory capacity. The remaining photos were renamed with camera ID and serial number, providing each photo a unique designation. If a camera documented hazel dormouse presence, the respective folder of photos was processed with Speedymouse 2.2, a program used to reduce the time needed to process a large volume of images. The output from each folder was then converted to excel tables, that were ultimately combined into one table. The information from the Speedymouse 2.2 output consisted of photo designation, camera ID, shoot date and time, species present and number of individuals on the respective photo. Another excel table was created, containing information about each camera site, including camera ID, unit and area code, the individual site name, that made distinguishing camera sites during the whole process of data collection, preparation and analysis easier. Furthermore, the geographic coordinates, start and end date of the installation and if necessary some annotations concerning the camera or camera site were included. Possible annotations included malfunction of the camera trap and factors apparently compromising the effectiveness of the set-up, like presence of a large number of aggressive ants feeding off the board (see Appendix III).

1.5. Data Analysis

General

All decimals and percentages were rounded to either the nearest full number or the second decimal where applicable.

Areas

ArcMap 10.5 was used to calculate the chosen area sizes in ha, their mean and Standard deviation.

Temporal activity

Diagrams of hazel dormouse pictures taken per nightly half hour and across sample dates were constructed from the extracted Speedymouse data with Excel 2016.

Testing influence of presence of other mammal species

The program PRESENCE was used to examine the influence of the most often encountered mammal species on hazel dormouse presence of Unit A and C. In a single-season occupancy model hazel dormouse presence was entered for each day at each camera site while other species' presence was included as covariates. The first model included all four species present at the camera sites where hazel dormice had been detected (*Apodemus sp., Apodemus agrarius, Myodes glareolus, Rattus norvegicus*). After gradually removing the species with the lowest reported influence and testing different combinations of species with the most influence in different models against each other, the model with the lowest AIC (Akaike information criterion) was selected for its superior relative quality.

Habitat scores

The habitat parameters taken during camera site selection were entered into Excel and transferred to SPSS24 as seen in table 4.

Table 4 *– Scheme of variables entered in Excel and SPSS24 for habitat criteria analysis*

Variable	Description	Values
HM_pres	Hazel dormouse presence detected or not	0 or 1
Species_rich	Vegetation species richness (>5 species of the listed shrubs and broadleaved trees present)	0 or 1
Hazel_20m	Fruiting or budding hazel (*Corylus avellana*) present	0 or 1
Board_in_Hazel	Baited board mounted in hazel (*Corylus avellana*)	0 or 1
Alt_food_1	Conifers present	0 or 1
Alt_food_2	Hip, cherry, crab apple, holly, ivy and similar present	0 or 1
Flower	1, 2 or more different flowering species (see possible food source) present	0 - 3
Fruit	1, 2 or more different fruiting species (see possible food source) present	0 - 3
Access_high	Vegetation bridges between understory and canopy	0 or 1
Access_low	Continuous shrub layer/dense understory thickets	0 or 2
Rest_places	Older trees and shrubs with hollows and rotten branches	0 or 1
Area_cat	Size of forested area in 4 categories: within a large wood of less than 2 ha, 2-20 ha, 20-50 ha or over 50 ha	0 - 3
Too_shady	Tree canopy casts too much shade (>50% of understory layer not reached by sun)	0 or 1
Visibility	Visibility in high summer at eye level is > 20 m	0 or 1
Total	Total score	12 - 18

Excel 2016 was used to calculate the mean and Standard deviation of the total habitat score. Statistical significance was determined via chi-square in SPSS 24, and the Cramer's V was assessed first of each criteria and hazel dormouse presence and then between the criteria that were not eliminated by either low association (Cramer's V < 0,25) or failed significance (p > 0,05).

2. Results

To preface the results of the analyses that were carried out and figures that were constructed, the general information regarding the collected data will be reviewed. The subsequent presentation of the results will be divided into chapters dealing with the respective research questions. At the end a conceptual model incorporating the results of the statistical analyses will be displayed to visualize the assessed influences on hazel dormouse presence.

2.1. General Results

Hazel dormice were recorded on 27 of the 77 nights sampling was carried out during survey. The first hazel dormouse was recorded on the 1st of September, the last on the 8th of October.

In total 349,920 photos were taken across all units and 53,654 were processed with Speedymouse 2.2, of which 5,312 (1.5 % of the original total and 9.9 % of the pictures processed, see table 5) captured hazel dormice. Black pictures due to malfunction were excluded from processing with Speedymouse 2.2.

Table 5 *– The amount of total pictures taken, deleted, processed and showing the focal species across all 17 successful camera sites*

Camera site	Original amount	Processed with Speedymouse	% deleted**	Dormouse pictures taken	% dormouse pictures of Speedy
042*	1,331	1,089	18	2	0.18
044	8,064	7,812	3	6	0.08
045	195	126	35	111	88.1
046*	3,359	1,488	56	2	0.13
047	5,322	4,783	10	6	0.13
058	11,645	11,005	5	4,113	37.37
059	1,470	1,388	6	971	69.96
060*	9,902	4,627	53	3	0.06
062	938	736	22	2	0.27
064	3,543	2,911	18	12	0.41
065	1,751	1,353	23	4	0.3
066	1,145	913	20	4	0.44
067	10,719	9,212	14	3	0.03
077	106	42	60	29	69.05
078*	102	16	84	2	12.5
079	39	11	72	11	100
081	6,844	6,142	10	31	0.5
Total	**66,475**	**53,654**	**19**	**5,312**	**9.9**

**obvious malfunction (see also table 4, page 27)*

*** both due to malfunction and false triggers/no visible trigger*

Of the 5,312 hazel dormouse pictures taken, 95 % of said pictures came from two camera sites, 058 and 059, leaving most of the other camera sites to produce less than 1 % of the total each, and even the second and third highest amount sitting at 18 % and 2 % respectively, as can be seen in figure 10 (page 29).

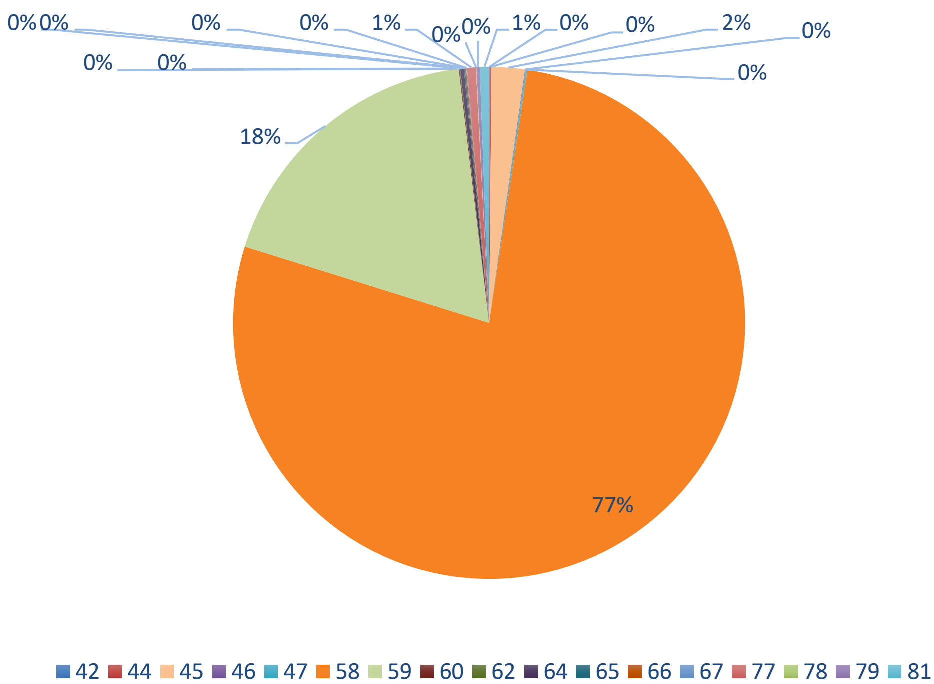

Figure 10: Percentages distribution of hazel dormouse pictures taken at each of the 17 successful camera sites 042, 044 - 047, 058 - 060, 062, 064 - 067, 077 - 079 and 081

Both of these out of the ordinary camera sites were situated within the same 22.3 ha area (see figure 11) that had also previously been used during the test phase and were the only locations where two individuals at a time were photographed.

Figure 11: Placement of camera sites 058 and 059 (orange circle) within unit A

2.2. Hazel Dormouse Presence

Hazel dormice were detected at 17 of the total 85 camera sites, with all of the successful ones having been situated along the A24 (Route A and C, see figure 12, page 30).

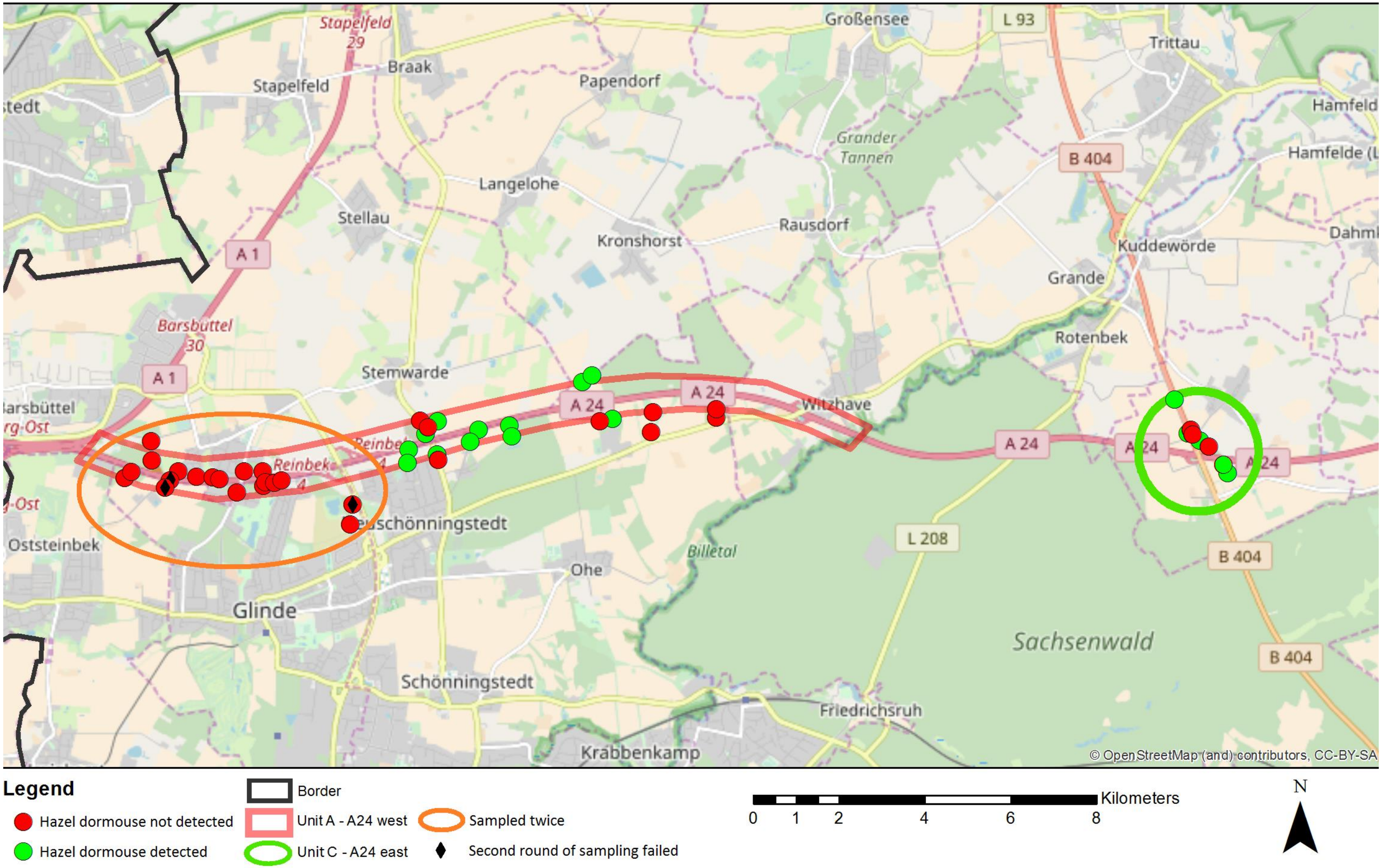

Figure 12: All 47 camera sites of units A (A24 west, 39 camera sites) and C (A24 east, 8 camera sites) displaying successful and failed detection of hazel dormouse presence, with the repeat camera sites (16 successful) of the second round circled orange

The second round of sampling incorporated camera sites 001 – 039 of unit A and B, minus camera sites 007, 008 and 029 (all within unit A, see figure 12, page 30), as the first was not accessible anymore and the latter two had its camera stolen and become defective respectively before the end of the session. No additional hazel dormouse presence was detected at any of the 36 repeat camera sites (see table 8, page 37). No dormouse presence was detected at any of the 38 camera sites of unit B, neither during the first or second round of sampling (see Appendix IV).

2.3. Hazel Dormouse Activity Patterns

Apart from the amount of trapping nights until first detection of the focal species, possible temporal patterns throughout its nightly activity as well as across the 14 sampling days and amount of (re-) occurrences were of interest.

2.3.1. First Detection

The mean number of trapping nights to first detection was 5.88 with a standard deviation of ± 4.55 (n = 17). The shortest time to first detection was right during the first night of installation (before 00:00 on camera sites 042 and 059) and the longest it took for hazel dormice to appear was 13 days (camera sites 060 and 064). The first hazel dormouse appearance on the other extraordinary successful camera site 058 was in the second night. After a peak in the first night the distribution of first appearances was relatively even, with no clear trend (see figure 13).

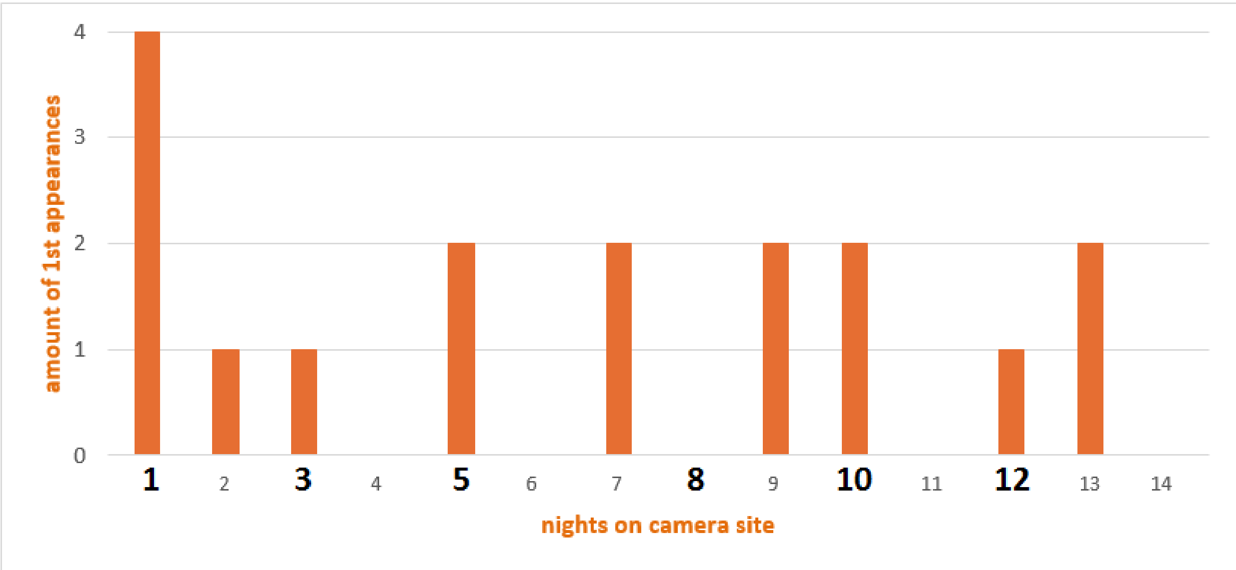

Figure 13: First appearances of the hazel dormouse related to the nights of the camera trap on site (nights after reapplication of bait in bold)

2.3.2. Nightly Activity

Hazel dormice were documented between 19:27 as the earliest moment for this nocturnal animal and 06:34 as the latest active moment of the night. Hazel dormouse activity visibly peaked 3 times. Twice to above 350 pictures per hour during 21:00 to 21:30, as well as at around 0:30 and once to above 450 pictures at 4:00 (see figure 14). At the beginning of the study, the sun was rising at around 05:50 and setting at 21:00 (August), with progressively shortening days until sunrise at 08:00 and sunset at 18:00 when the last camera was retrieved in October. From the first to the last day hazel dormice were detected (01.09.2017 – 08.10.2017) sunrise shifted from 06:46 – 07:50 and sundown 20:25 – 18:56.

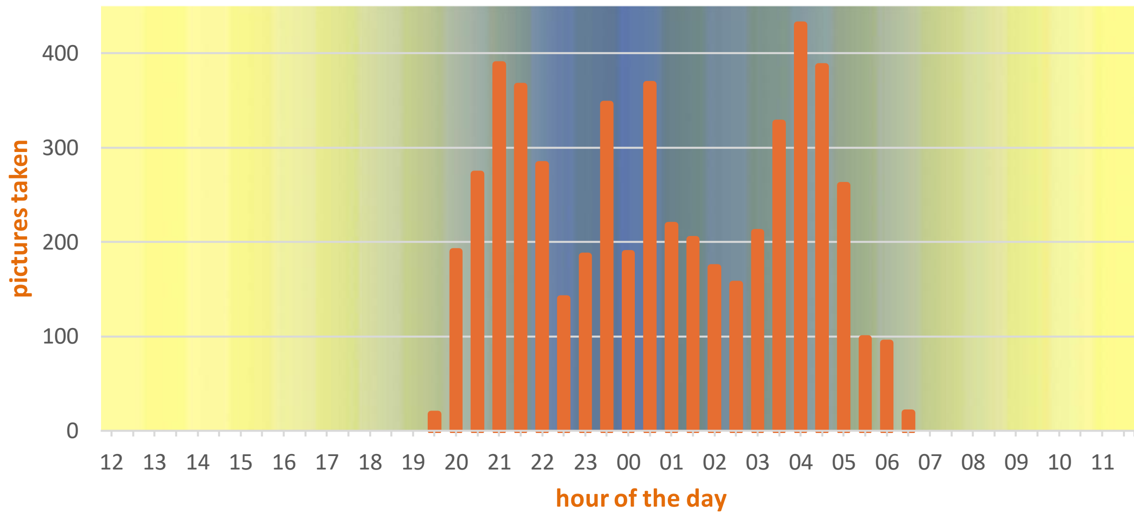

Figure 14: Temporal presence of hazel dormice on the boards at all 17 camera sites, shown as amount of pictures taken during each 30-minute interval

Even when adjusting for the large amount of pictures coming from camera sites 058 and 059 by viewing those two sites as well as all others combined separately, the three peaks in activity are still visible (see figures 15 – 17, pages 32 – 33).

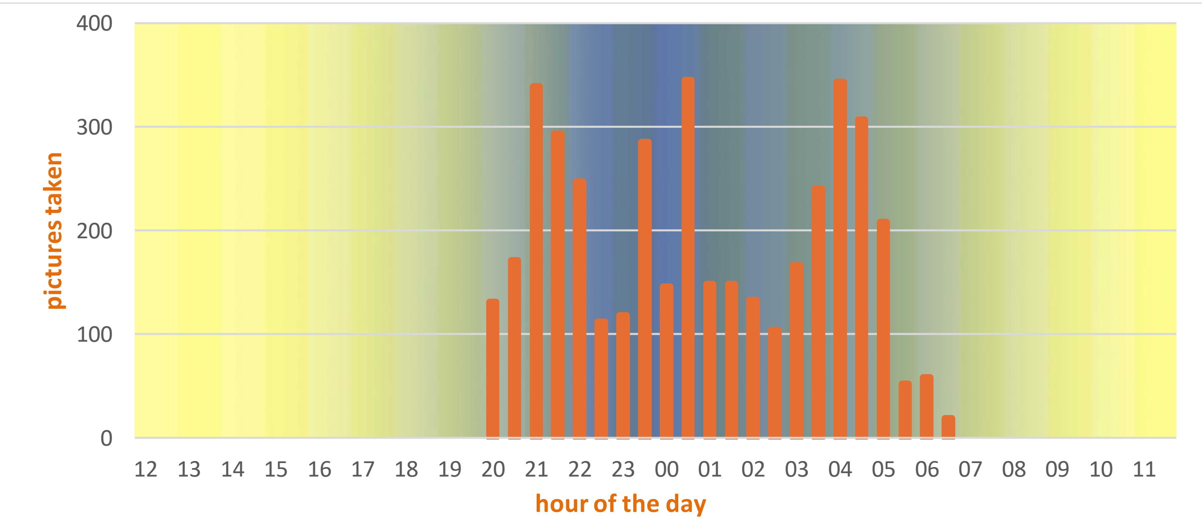

Figure 15: Temporal presence of hazel dormice on the boards at camera site 058, shown as amount of pictures taken during each 30-minute interval

However, they are not as neatly arranged and distinct as for 058 (n = 4,113) alone (see figure 15, page 32), showing the strong influence of the data from this site. Of the 5,312 hazel dormouse photos, 4,113 (77.4%) were from site 058, 971 (18.3%) from site 059 and the remaining 228 (4.3%) from the other fifteen sites combined, making the influence of the activity on site 058 quite significant.

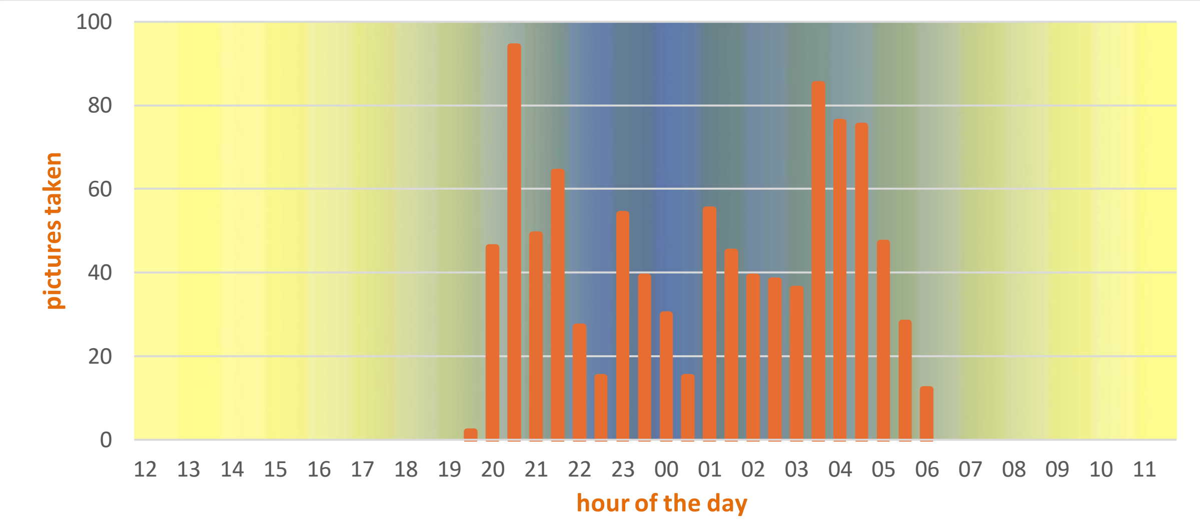

Figure 16: Temporal presence of hazel dormice on the boards at camera site 059, shown as amount of pictures taken during each 30-minute interval

Figure 16 shows the temporal activity at site 059 (n = 971). The peaks show similar temporal activity to site 058, which is in the same area. The peak around midnight is not as distinct as in figure 14 and 15. The three peaks are still visible, if all sites except 058 and 059 are combined (n = 228) (see figure 17), only slightly deviating from the peaks seen in figure 15 and figure 16. A clear peak is visible at around 20:00 and another one at around 23:30 and the third at 05:30 until 06:00 in the morning.

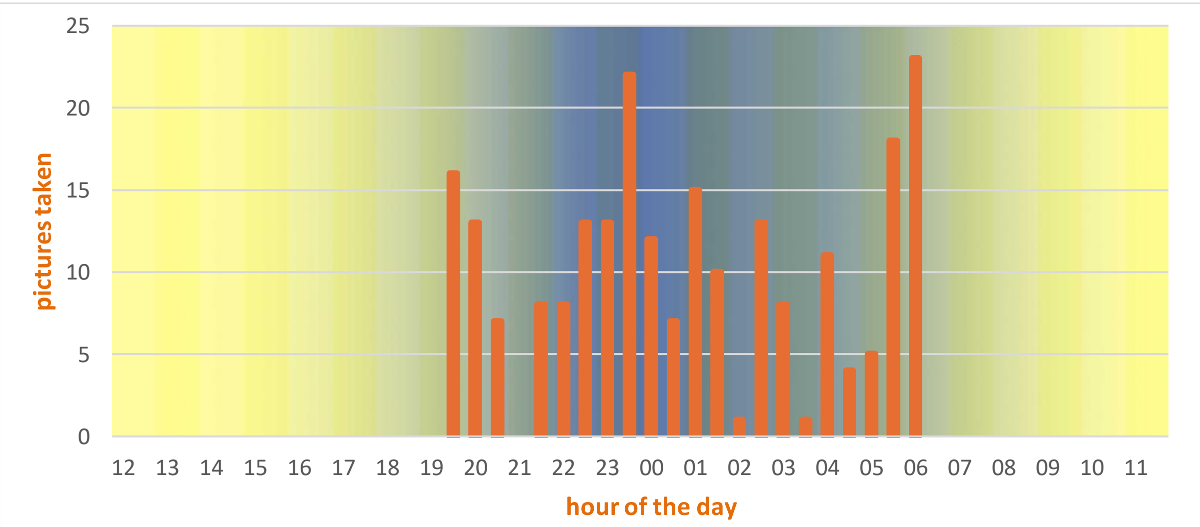

Figure 17: Temporal presence of hazel dormice on the boards at camera sites 042, 044 - 047, 060, 062, 064 - 067, 077 - 079 and 081, shown as amount of pictures taken during each 30-minute interval

2.3.3. Amount of Nights and Occurrences

At 11 of the 17 camera sites that successfully detected dormice, the focal species was only photographed during one of the 14 sampling nights (see figure 18).

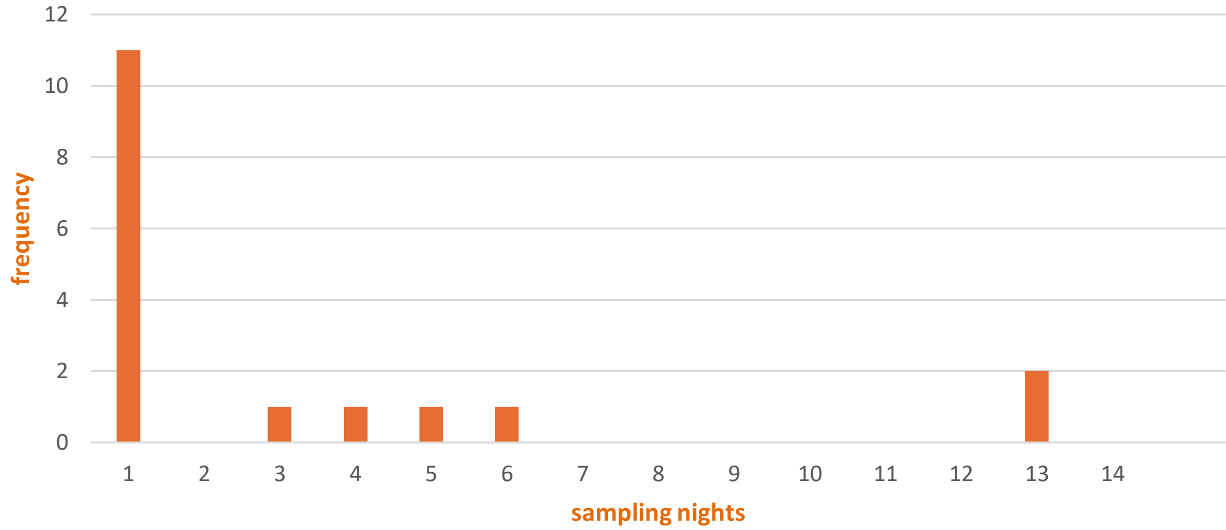

Figure 18: Amount of successful sampling nights (read: during which the focal species was recorded) at all camera sites at which hazel dormice were recorded (n = 17)

Camera sites 058 and 059 stand out, having not only recorded dormice returning for every night but one during the respective sampling session.

As shown in table 4 (page 27), cameras with malfunctions took an increased number of pictures that were not identifiable, possibly missing additional dormouse occurrences in the process. However, while any amount of black pictures due to malfunction could signify a missed dormouse occurrence, 6 of the 12 camera sites free of malfunctions still only recorded very few occurrences, with 5 sites recording only a single one, 1 recording two and 2 recording 5 (see table 6, page 35). Even if it is assumed that an unknown amount of occurrences were missed across any of the camera sites that experienced malfunctions, there seems to be a trend of dormice not returning often or even at all to the board after discovery.

Table 6 *– The amounts of nights, pictures and corresponding occurrences on which the focal species was recorded across all 17 successful camera sites, plus black pictures taken due to malfunction*

Camera site	Nights HM recorded	Amount of HM pics	Occurrences*	Black pictures
042	1	2	1	89
044	1	6	1	0
045	4	111	24	0
046	1	2	1	1541
047	1	6	1	0
058	13	4113	numerous	0
059	13	971	numerous	0
060	1	3	2	5067
062	1	2	1	0
064	1	12	2	0
065	1	4	1	0
066	1	4	1	0
067	1	3	1	684
077	6	29	13	0
078	1	2	2	78
079	5	11	5	0
081	3	31	5	0

* any amount of pictures in series with less than 5 minutes of absence in-between, numerous > 300

2.4. Other Mammal Species

A total of 18 mammal species were recorded, with the majority belonging to one of the two from photographs indistinguishable *Apodemus* species *A. flavicollis* or *A. sylvaticus* (see Appendix V for complete species name key), which were present at 76 of the 85 camera sites (see table 7).

2.4.1. General

The main species encountered after the two *Apodemus* species were the red squirrel (*Sciurus vulgaris*), bank vole (*Myodes glareolus*) and brown rat (*Rattus norvegicus*, see table 7).

***Table 7** – Amount of camera sites that recorded each species per unit during round 1*

Species	Route A (n=39)	Route B (n=38)	Route C (n=8)	Total (n=85)
Muscardinus avellanarius	12	0	5	17
Apodemus* sp.	33	38	5	76
Apodemus agrarius	2	0	0	2
Myodes glareolus	14	15	1	30
Sciurus vulgaris	17	16	0	33
Rattus norvegicus	10	17	1	28
***Soricidae* sp.**	0	1	0	1
Oryctolagus cuniculus	0	1	0	1
Lepus europaeus	0	1	0	1
Martes martes	0	2	0	2
Mustela putorius	1	0	0	1
Mustela ermine	0	1	0	1
Felis catus	1	2	0	3
Procyon lotor	1	0	0	1
Capreolus capreolus	2	0	1	3
Capra sp.	0	1	0	1
Ovis sp.	0	1	0	1
Human	1	1	0	2

While no change in recorded presence for the focal species was achieved, the second round saw a decrease in many other mammals' occurrences (*Apodemus* sp.*, Myodes glareolus, Rattus norvegicus, Sciurus vulgaris*), while some rarer ones remained completely undetected (*Soricidae sp., Oryctolagus cuniculus*) and two new species were recorded (*Martes foina, Micromys minutus*, see table 8, page 37). The decrease in red squirrel presence was likely a product of changed camera settings (night only).

__Table 8__ – Comparison of mammal species at the 36 repeat camera sites between round 1 and 2

Species	Round 1 (07.08.2017 – 09.10.2017)	Round 2 (03.10.2017 – 23.10.2017)
Muscardinus avellanarius	0	0
Apodemus* sp.	36	34
Myodes glareolus	15	13
Micromys minutus	0	2
Sciurus vulgaris	23	15
Rattus norvegicus	10	6
***Soricidae* sp.**	1	0
Oryctolagus cuniculus	1	0
Lepus europaeus	0	1
Martes martes	1	2
Martes foina	0	1
Felis catus	1	1
Capreolus capreolus	1	2
Capra sp.	1	0
Ovis sp.	1	0
human	2	3

Most of the taken pictures on all sites with hazel dormouse presence were of *Apodemus flavicollis* and *Apodemus sylvaticus.* These two species are not distinguishable on photos and therefore collectively recorded as "*Apodemus sp.*". In total 41,758 (77.8 %) of the 53,654 pictures were taken of *Apodemus sp.,* resulting in graphs dominated by this species as seen in figure 19, which shows the amount of pictures taken per species per day from day 1 to 14 on site. Only the 5 most relevant species were visualised, while all birds and the single occurrence of a European polecat (*Mustela putorius*) at camera site 066 were excluded.

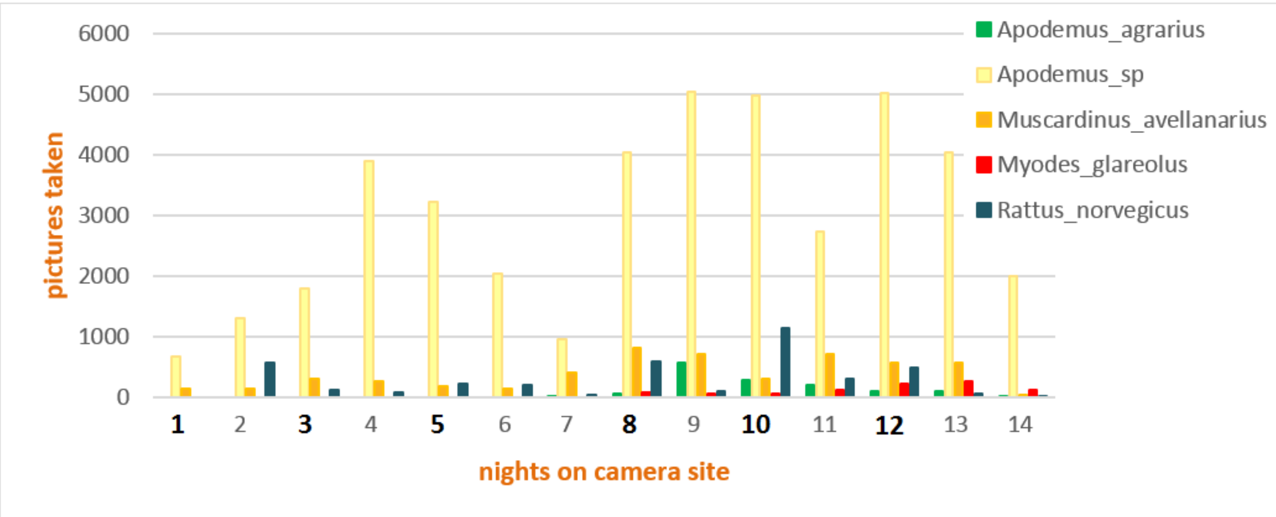

Figure 19: The amount of pictures taken per species per each of the 14 sampling nights across the camera sites that detected hazel dormice (N=17), including the two indistinguishable species Apodemus flavicollis and A. sylvaticus as "Apodemus sp." (nights after reapplication of bait in bold)

Figure 20 shows the other rodent species that were present at the 17 sites that also recorded hazel dormice, excluding the overwhelming two main *Apodemus* species, in order to make the species with lower amounts of pictures more easily visible. A clear increase in species occurrences overall can be seen in week 2 on site, two species only started visiting the board in week 2 and were never recorded in the first week.

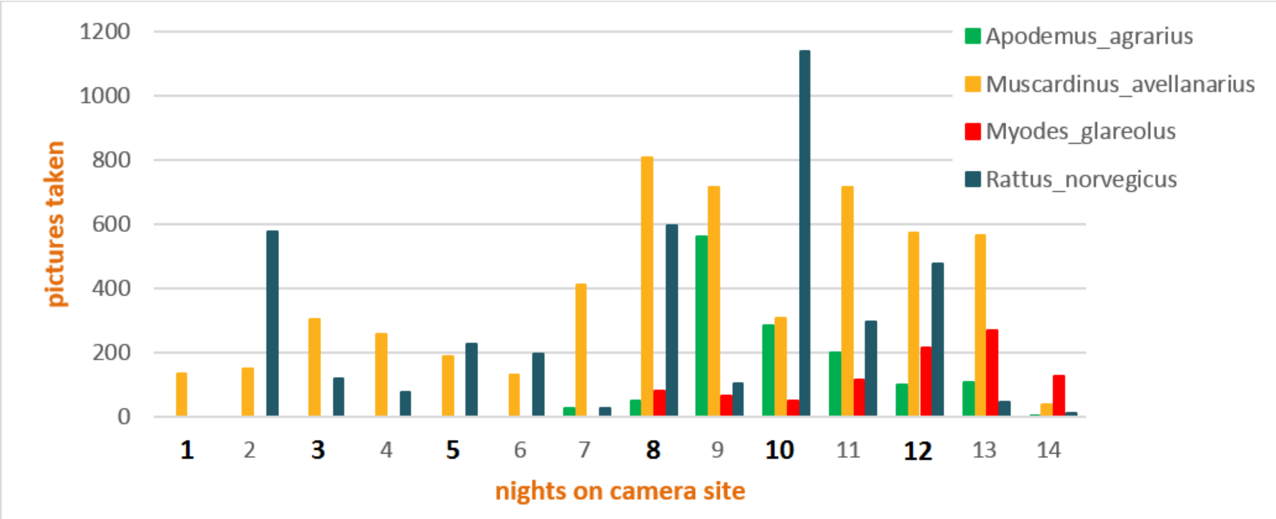

Figure 20: The amount of pictures taken per species per each of the 14 sampling nights across the camera sites that detected hazel dormice (N=17), not including the two indistinguishable Apodemus species A. flavicollis and A. sylvaticus (nights after reapplication of bait in bold)

The striped field mouse (*Apodemus agrarius*) was recorded at only two sites (site 058 = 1,323 pictures; site 66 = 18 pictures) and first appeared on night 7 (site 058) and day 9 (site 66), with an increasing number of records until day 11, and none on day 14. The bank vole *Myodes glareolus)*, recorded at 7 of the 17 sites, was exclusively recorded in week 2. Brown rats (*Rattus norvegicus*) were recorded at only 3 of the 17 sites with hazel dormice. The first brown rat appeared on day 1, most brown rat records were taken on day 9, none appeared on day 6 and day 14.

The numbers of pictures of *Apodemus sp.* and brown rats as well as, to a degree, hazel dormice, increased a few times in relation to the nights during which a freshly baited board was available. While they did not seem to respond in any particular pattern to the schedule during the first week, the highest amount of photos taken in all three cases is after rebaiting the board following the weekend – the only time when the board had been left without fresh peanut butter and marmalade for more than one night. After that, *Apodemus sp.* pictures on the consecutive (not freshly baited) night as well as the next two freshly baited nights stayed close to 5000 per night, to then decrease across the next weekend. Brown rat presence on the board increased most after the fifth time the board was freshly baited. As described, striped field mice and bank voles mostly appeared on the board after the first week and no clear pattern in response to the baiting schedule can be seen.

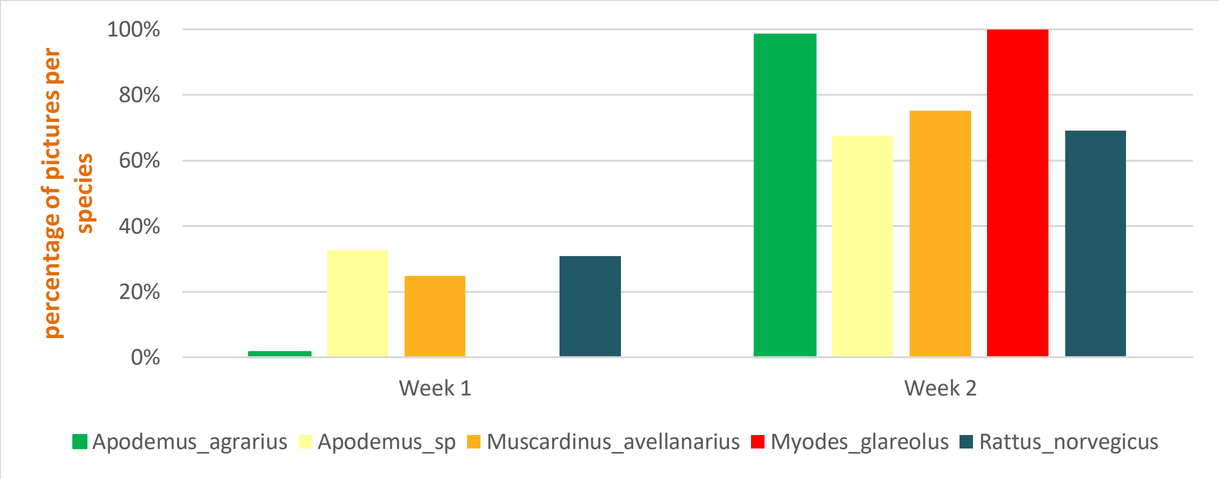

Figure 21: Percentage of pictures taken of each species across the camera sites (N=17) that successfully detected hazel dormice, with the 14 sampling days divided into weeks

As already slightly visible in figures 19 and 20 (see page 37 and 38), most pictures were taken in the second sampling week, with most of *Apodemus agrarius* and all of *Myodes glareolus* having been recorded exclusively after the first seven days (see figure 21).

Presence of *Apodemus* sp. on the board mostly concentrated between 19:00 and 06:00 and the amount of pictures taken is generally several times higher than that of all other species combined (see figure 22). Two peaks can clearly be seen, one at around 20:00 and a second at 05:00, during dusk and dawn, before and after the two species' barely .

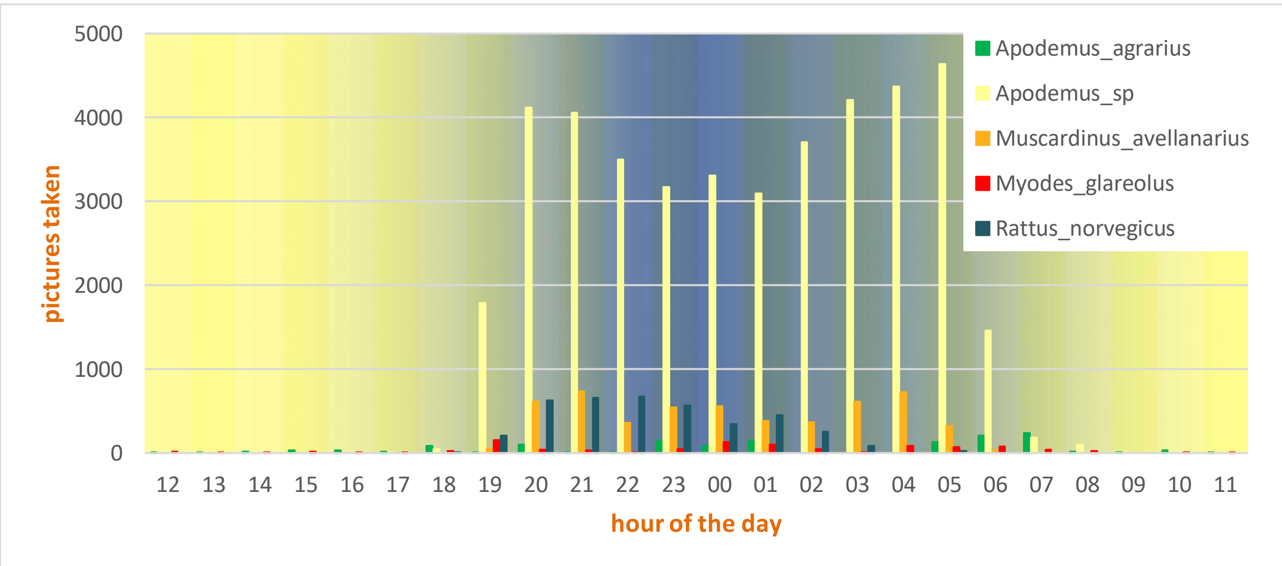

Figure 22: The amount of pictures taken per species per hour across the camera sites that detected hazel dormice (N=17), including the two indistinguishable species <u>Apodemus flavicollis</u> and <u>A. sylvaticus</u> as "<u>Apodemus sp</u>."

The striped field mouse and the bank vole are almost exclusively the only ones also active on the board during the day (see figure 23, page 40). The most records of striped field mice, which were only present at two camera sites (058 and 066), were taken in the early morning hours (05:00 to 07:00). Between 23:00 to 01:00 and at 18:00 and 20:00 increased presence can be seen as well.

The bank vole shows a similar pattern, with the highest peak at 19:00, and is only absent at 09:00. The amount of records during the night is generally higher than during the day, with the highest peak around dawn, one at around 00:00 to 01:00 and one at dusk, between 04:00 and 06:00.

The majority of pictures (99%) of brown rats were from camera site 058. Therefore, this site has a heavy influence on the results again. The records show a clear increase in presence on the board starting at 18:00, rising up to 673 pictures at 22:00 and then decreasing again until the last appearances at around 5:00.

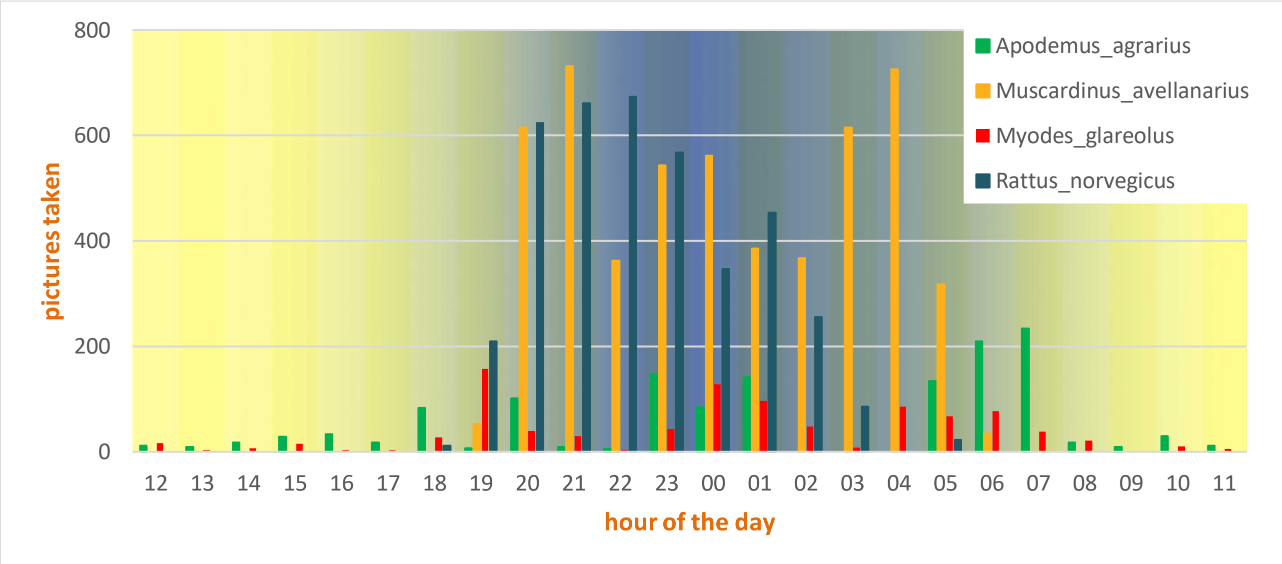

Figure 23: The amount of pictures taken per species per hour across the camera sites that detected hazel dormice (N=17), not including the two indistinguishable species Apodemus flavicollis and A. sylvaticus as "Apodemus sp."

Only twice was a hazel dormouse documented in close proximity with and on the board while another species was present, the other species in question in both cases being an *Apodemus* species (see images 8 and 9). This occurred on consecutive nights at camera site 059, one of the two sites with and anomalously large amount of hazel dormouse pictures and sampling nights with hazel dormouse occurrences.

Images 8 and 9: Hazel dormouse climbing on the baited board while an Apodemus sp. is feeding on the bait

The wire cage proved to be sufficient at keeping out unwelcome larger species that would otherwise quickly deplenish the applied bait (see images 10 – 12). Brown rats were not able to fit through the cage, keeping them from accessing the bait. Subadult rats could stick their head though the mesh, but still only managed to access a part of the bait.

Image 10: Red squirrel (Sciurus vulgaris) searching for access to the bait

Image 11: Brown rat (Rattus norvegicus) after an attempt to push past the wire cage

Image 12: European pine marten (Martes martes) lifting the board while trying to reach the middle

Against all expectations, only a single occurrence of a raccoon (*Procyon lotor*) was recorded during the whole sampling period, namely late during round 1 at camera site 82 on unit A.

2.4.2. Influence of Other Mammal Species on Dormouse Presence

The initial model including all four species present at camera sites where hazel dormice were detected produced an AIC of 344.55. Given that the AIC is an estimator of statistical models belonging to the same dataset, the lowest AIC identifies the model with the highest relative quality. The lower the AIC, the fewer non-relevant parameters are included in the model.

After removing the species with the lowest deemed influence (in order: *Apodemus agrarius, Myodes glareolus, Rattus norvegicus*) the final model with an AIC of 338.91 only included the combined *Apodemus* species *flavicollis* and *sylvaticus.*

The PRESENCE output showed that probability of hazel dormouse occupancy was slightly higher if none of the two *Apodemus* species were present, in other words: *Apodemus* sp. presence had a slight negative effect on hazel dormouse occupancy (A2 = -0.45, SE = 44.33), while absence had a slight positive effect (A3 = 0,25, SE = 44,34; see Appendix VI). The odds ratio, calculated as the inverse-logarithm of the beta parameter A3, suggests that the chance of hazel dormouse occupancy at a site where *Apodemus* sp. are not present is 1.28 times larger than at a site where they are present.

2.5. Habitat Parameters

The relationship between hazel dormouse presence and select habitat parameters was examined for correlation. Of interest were the final number of points between camera sites with and without recorded hazel dormouse presence, the relationship between hazel dormouse presence and all single criteria as well as the association between criteria that were deemed relevant.

2.5.1. Total Habitat Score

The average habitat score of all camera sites was 13.85 points (s = 1.75, n = 85), with the average of the camera sites that detected hazel dormice being 14 points (s = 1.74, n = 17). The maximum score taken was 18.

2.5.2. Correlation of Habitat Criteria with Dormouse Presence

The criteria eliminated before analysis were species richness, as not a single camera site was chosen were the criterion was not fulfilled, and visibility, as only one camera site was chosen were the criterion was fulfilled. Only the camera sites from unit A and C were included in the correlation analysis (n = 47).

While only the presence of hazel (*Corylus avellana*) within 20 m was included in the list of desirable habitat traits for camera sites, every instance of the baited board being placed directly within the tree (which was not always possible) was also recorded and considered for its possible influence.

The criteria eliminated from further analysis because of low association were alternative food sources in the form of conifers (Cramer’s V = 0.035) and hip, cherry, crab apple, holly, ivy, etc. (Cramer’s V = 0.105), flowering plants (Cramer’s V = 0.163), continuous shrub layer/dense understory thickets (Cramer’s V = 0.159), vegetation bridges between understory and canopy (Cramer’s V = 0.246), resting places (Cramer’s V = 0.187) and the surroundings being too shaded (Cramer’s V = 0.191). The criteria of fruiting plants (0, 1, 2, or ≥ 3 different fruiting species) was deemed as having a strong level of association but failed the bar set for significance (Cramer’s V = 0.355; p = 0.052).

Hazel within 20m (Cramer’s V = 0.366; p = 0.012), placing the board in hazel (Cramer’s V = 0.587; p < 0.001) and size of forested area (Cramer’s V = 0.562; p = 0.002) were assessed as having a strong or higher level of association with hazel dormouse presence and were included in a further round of tests of correlation against each other, to explore possible association see Appendix VII).

Hazel being present within 20 m and placing the board in hazel were of course assessed to be extremely correlated (Cramer's V = 0.688; p < 0.001), and the correlation between hazel within 20 m and forest size was deemed to be moderately strong but not significant (Cramer's V = 0.254; p = 0.387). The association between forest size and placing the board in hazel, on the other hand, was not only considerably strong, but also significant (Cramer's V = 0.447; p = 0.024; see Appendix VIII).

From the 47 camera sites analyzed, hazel was present within 20 m at 34 and only once was hazel dormouse presence detected at a site were no hazel was found within 20 m (see figure 24). The board was mounted directly within hazel at 26 sites and, again, hazel dormouse presence was only once detected at a site were no hazel was around for the board to be fixed (both cases being camera site 067, see figure 25).

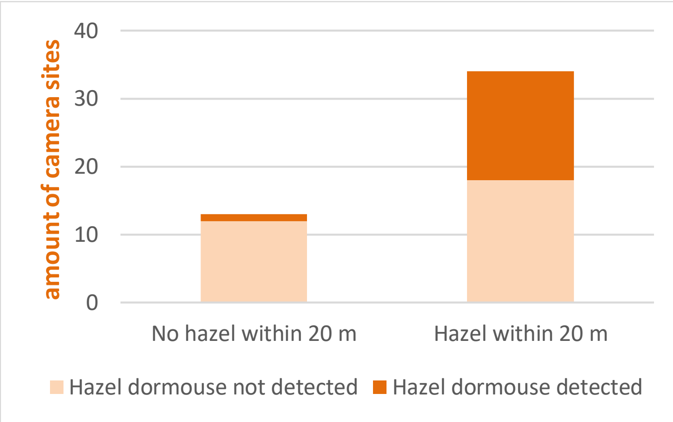

Figure 24: Distribution of sites with hazel within 20 m hazel in relation to hazel dormouse presence across the camera sites of units A and C (n = 47)

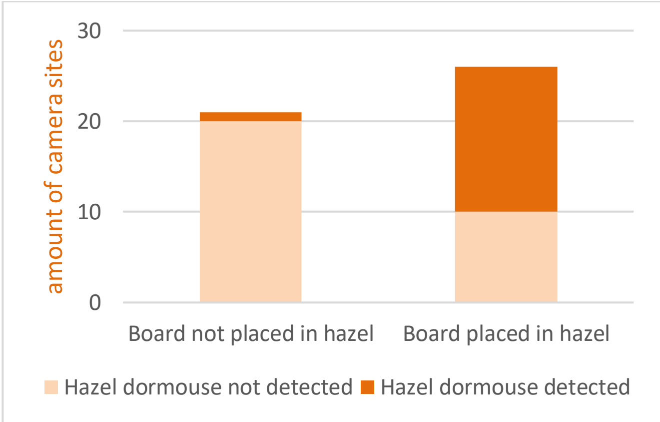

Figure 25: Distribution of sites where the board was placed in hazel in relation to hazel dormouse presence across the camera sites of units A and C (n = 47)

In regards to area size categories, 13 camera sites were chosen within a wooded area of less than 2 ha (category 0), 22 within a wooded area of 2-20 ha (category 1), 2 within a wooded area of at least 20 ha (category 2) and 10 within a wooded area of at least 50 ha (category 3). Hazel dormice were detected at camera sites of these categories respectively 6, 3, 0 and 8 times (see figure 26, Appendix IX).

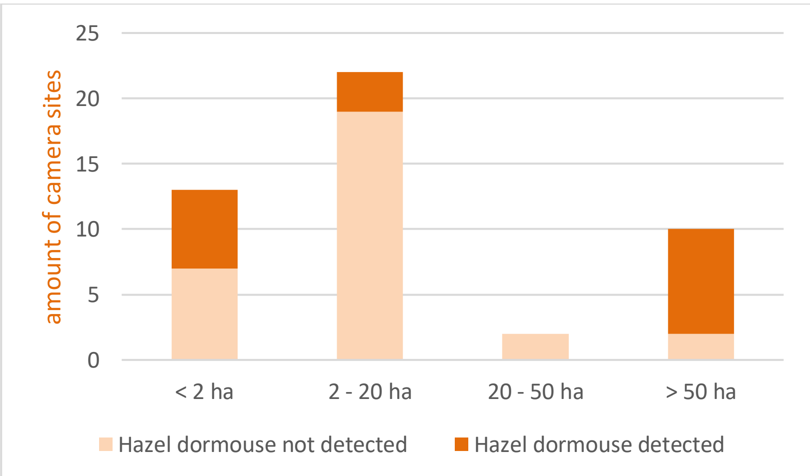

Figure 26: Distribution of forest size (divided into 4 categories) across the camera sites of units A and C (n = 47) in relation to hazel dormouse presence

3. Discussion

By confirming its presence at several sites along both sides of the A24 motorway and through surveying those sites with camera traps, new information about the temporal habits and possible influences on the presence of the hazel dormouse was gained that can be utilized for future hazel dormouse research and conservation.

To summarize: hazel dormice were most active just after dusk, at midnight and just before dawn, the time until their first appearances lasted from just a few hours to almost a fortnight after installation of the bait, and they often only explored the board once without returning. Absence of *Apodemus sp*. was found to have a slight positive effect and presence of hazel is as much a preference as the nomenclature suggests. Forest size also seems to be favoured by this species (see figure 27).

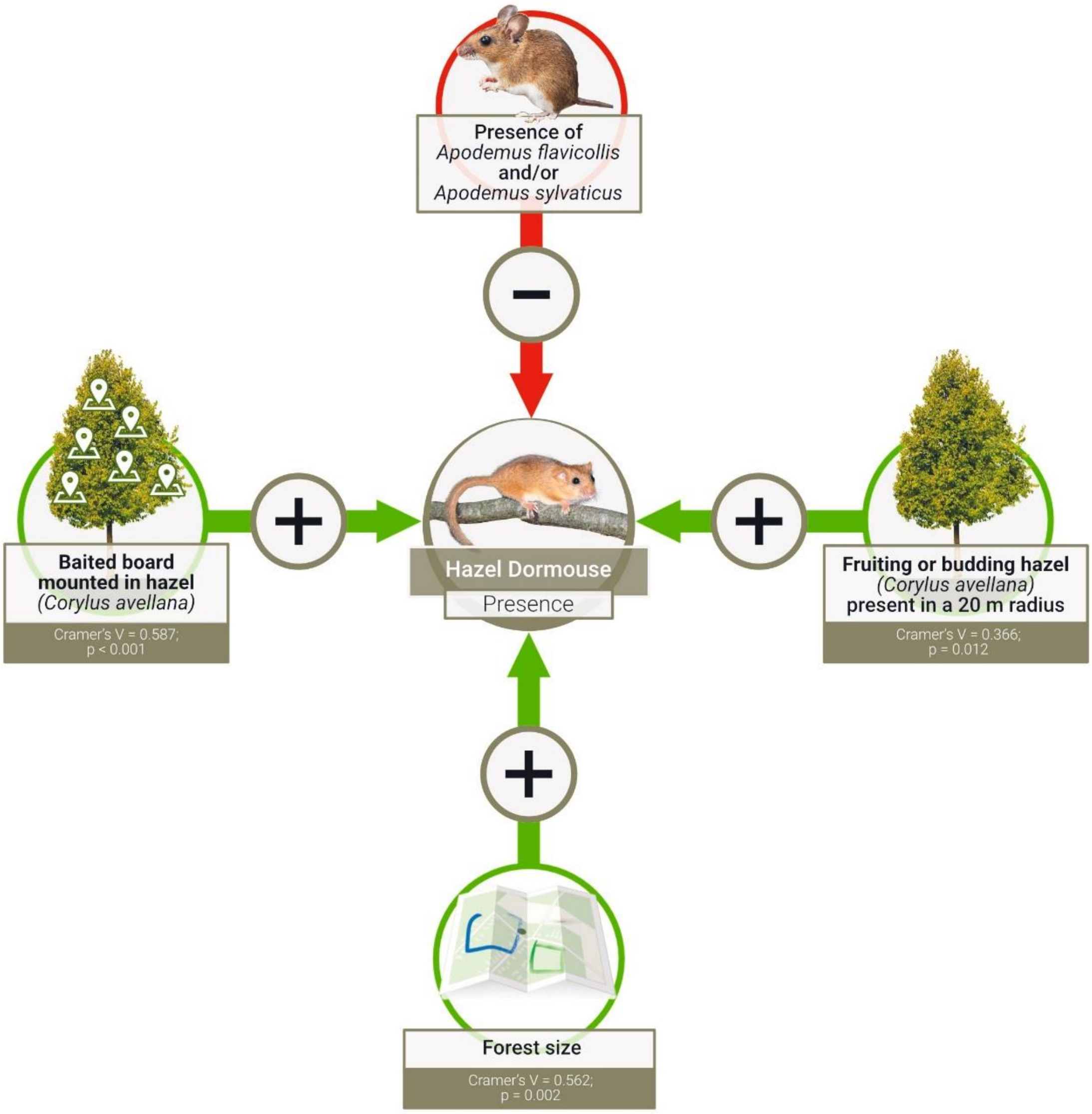

Figure 27: Final model of determined influences of habitat parameters and two indistinguishable rodent species of the genus Apodemus on hazel dormouse presence

In this chapter these results are interpreted and put into relevant context in order to be able to translate them to expedient conclusions.

General Results

The high amount of cameras with malfunctions makes it difficult to exclude hazel dormouse presence on many camera sites with certainty, especially on sites near confirmed presence and within the same areas such as 061 and 060 and 080 and 081 and others (see Appendix X).

The presence of hazel dormice can therefore be assumed at all of the 4 areas in unit C, as they are closely connected and hazel dormouse presence was confirmed at 5 out of 8 sites (see figure 28). No occurrence was documented west of the K80 (see figure 29, page 46), even though almost all of the sites there were sampled twice, suggesting that there are either truly no hazel dormice present, or that the camera sites were not suitable enough. The same applies for the whole of unit B in Hamburg, where not a single hazel dormouse was detected.

Besides several malfunctions, the success of camera sites 078 to 085 (circled orange in figure 27) was presumably compromised due to the heavy storm "Xavier" in October 2017.

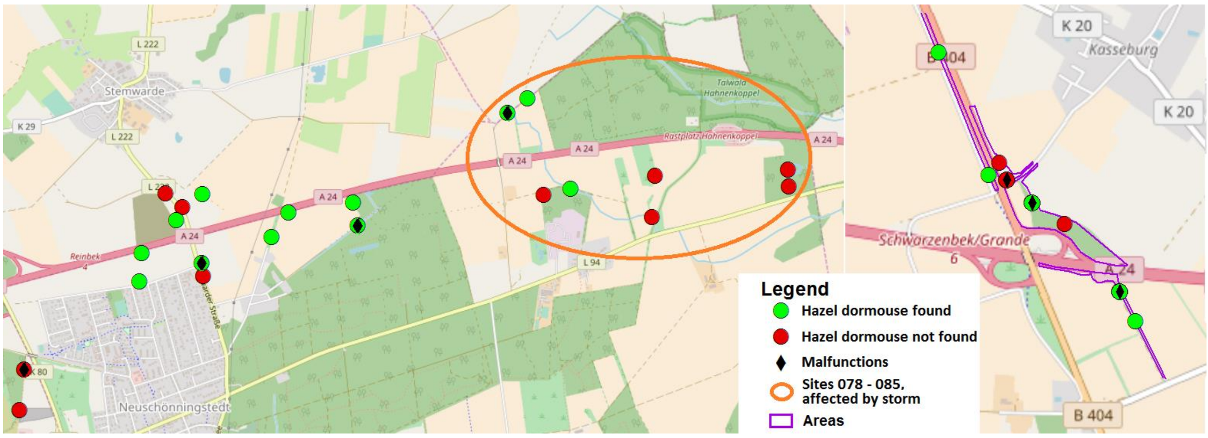

Figure 28: Camera malfunctions in relation to where hazel dormice were detected (unit A and C)

The high number of the main species recorded was no surprise, since they are common in the study area their presence was expected. Grazers like roe deer and hare are not suspected to have any influence on hazel dormouse presence, since the chosen sites offered very good to ideal habitat that is not compromised by excessive foraging activity. Predators like martens and cats accessing the board and leaving their smell, however, may function as deterrence and result in respectively more vigilant abidance in the background, undetected by the camera. This behaviour of hazel dormice sitting in the surrounding vegetation, observing *Apodemus sp.* on the board and not accessing it at all could be seen frequently on site 16_03 of the pilot study, which monitored a larger section of the site, not only the board. Only focussing the camera trap on the board, not the surrounding vegetation, might also have caused the lack of hazel dormouse confirmation at some sites.

Hazel Dormouse Presence

The purpose of the second round of sampling was to test the hypothesis of the lack of Dormouse detection during the initial round being partly due to the time of the year. Therefore, no new camera sites with higher scores or other differences were sought out, possibly resulting in an overall decrease in chance to encounter previously missed individuals in new, more suitable spots within the same area.

Hazel Dormouse Activity Patterns

While the high amount of pictures taken at cameras 058 and 059 may initially seem like just a result of the increased amount of nights the focal species was present at these sites, this alone is insufficient as explanation for a total of 5,804 hazel dormouse pictures taken. Even accounting for the malfunctions at 4 of the other 15 sites, 6 of the continuously functional ones still collected fewer than 7 pictures during the same amount of time, with none of those photos more than 10 seconds apart (presumably meaning they resulted from the single visit of one individual). The only explanation that can be offered for the high numbers of pictures and consistent presence of hazel dormice at sites 058 and 059 is that they were situated within the same area that was used for testing the method in July 2017. Site 058 in particular was closer (90 m) to the test site, making a possible familiarization with the board and bait by some individuals a plausibility (see figure 28).

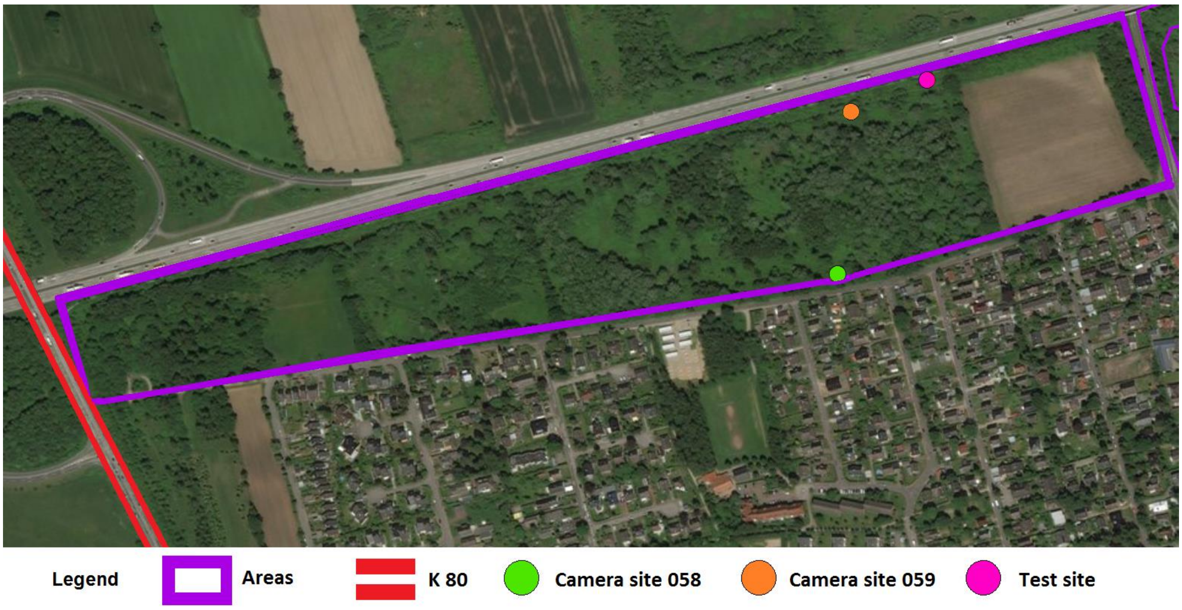

Figure 28: Positions of test phase camera site and K80 to camera sites 058 and 059

However, not only did the test phase merely result in a very covert and fleeting visit of a single individual (few seconds, only the tail visible, no return, no accessing the board), the distance between site 058/the test site and camera site 059 was 0.19 km (almost 200 m) and both active sites were often visited during the same time. Due to the limited home range of the species (60 – 70 m) as well as temporal constraints, it is therefore not only impossible that the same mice consistently visited both sites, but also highly unlikely that all the recorded mice had a chance to familiarize themselves with the method during the test phase. Additionally to being the only two camera sites were a pair of dormice was recorded (each), a third individual on camera 059 was clearly distinguishable by its shortened tail. This suggests a difference for the overall area, such as a larger population of dormice being present and, for unknown reasons, individuals being more willing to approach the bait overall, instead of a lingering effect due to previous sampling.

The three activity spikes across nightly hours suggest a possible feeding rhythm, which has been assessed for other rodent species, such as for example the 2-hour rhythm for the common vole, *Microtus arvalis* (Hoogenboom, Daan, Dallinga and Schoenmakers, 1984).

In comparison to the results of the study at hand, during the pilot study in the National Park Hainich, Thuringia, in 2016, hazel dormice were recorded at 6 out of the 16 sampled sites. The research in the

National Park showed two activity peaked, with increased hazel dormouse activity at around 23:00 and again between 02:00 and 04:00 (see figure 29). The camera traps recorded day and night. The pilot study took place from the 06.07.2016 – 31.08.2016, with sundown between 21:29 and 20:01 and the sun rising between 05:11 and 06:29, resulting in a narrower time frame for the hazel dormouse to be active than during the days they recorded during the current study (01.09.2017 – 08.10.2017, putting sundown at 20:25 – 18:56 and sunrise at 06:46 – 07:50). The shortened night during the sampling period of the pilot study is likely the explanation for the reduction from three activity peaks to two.

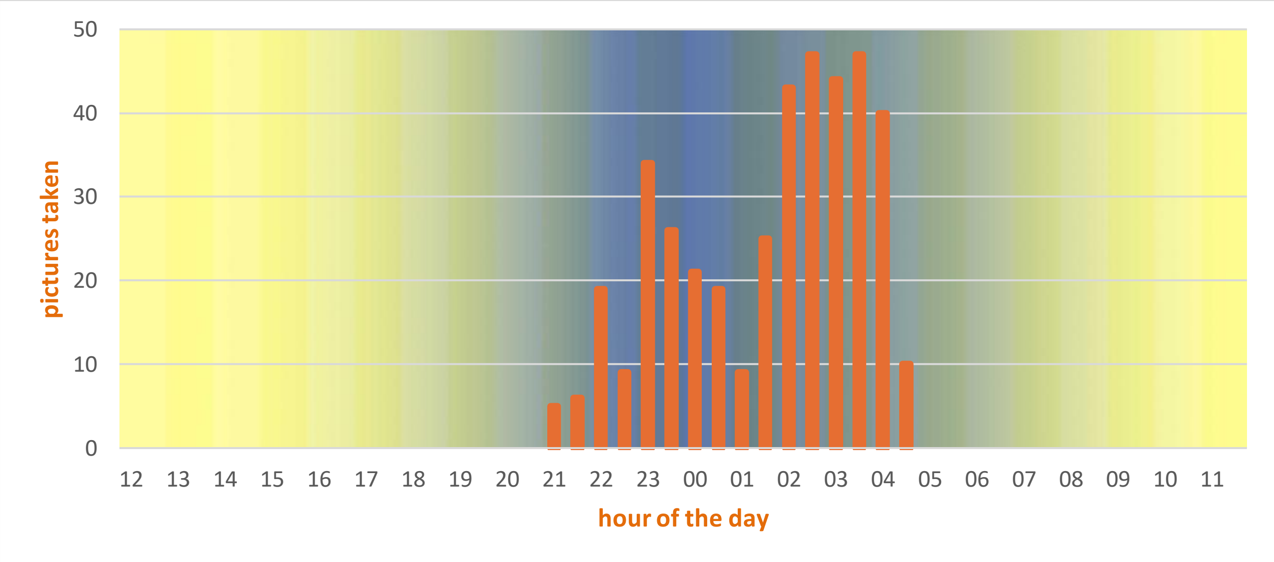

Figure 29: Temporal activity of the hazel dormouse in the National Park Hainich, Thuringia, based on 404 records taken on 6 different locations (L.Horst, 2016)

And just as seen in the current study with sites 058/059, one of the sites during the pilot study, no. 16_03, had a considerably high number of recorded pictures of hazel dormice (n = 375), compared to the other sites and therefore dominates the distribution of temporal activity (see figure 30).

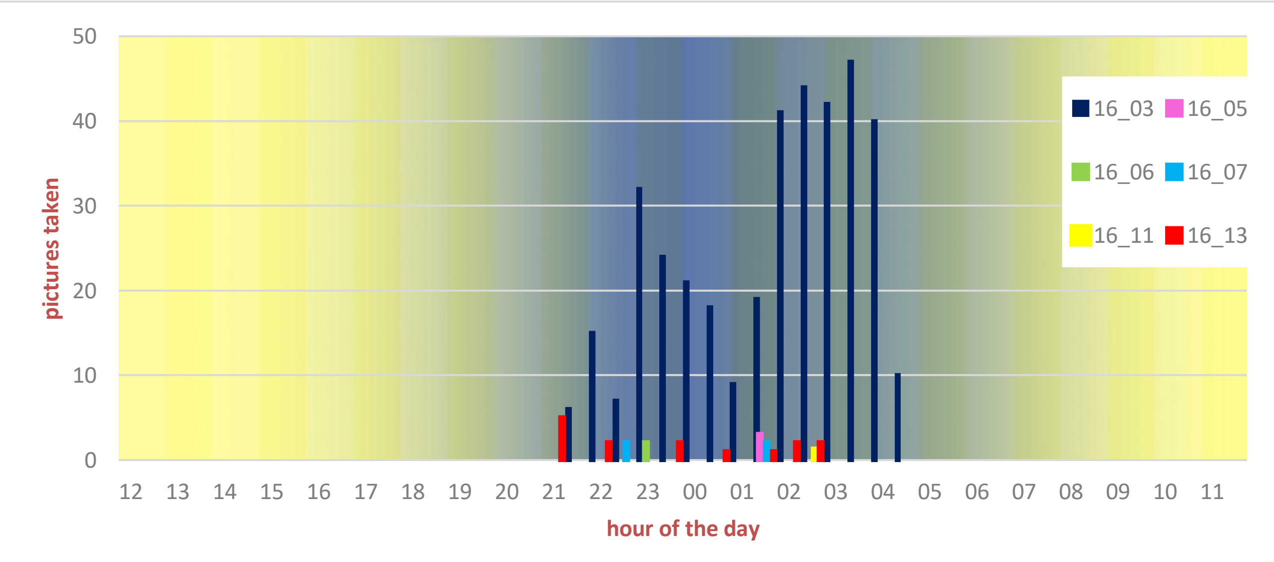

Figure 30: Temporal activity of the hazel dormouse in the National Park Hainich, Thuringia, per camera site (L.Horst, 2016)

Amount of Occurrences

It is unclear why the majority of camera sites saw only a single or very few occurrence of hazel dormice after being discovered, but it does imply that a single picture series of malfunction could have missed the only visit at other sites.

Other Mammal Species

The only species recorded together with a hazel dormouse on site was an *Apodemus sp.*, although the analysis showed that probability of dormouse occupancy was higher if no *Apodemus sp.* were present on a camera site. It is likely that the absence of *Apodemus sp.* favors hazel dormouse occurrence because there is less competition for the bait. Since the density of *Apodemus sp.* is likely to be significantly higher in the study areas than the density of hazel dormice, the sheer number of *Apodemus sp.* Individuals might have had a negative effect. The board is occupied a lot, sometimes by 4 *Apodemus sp.* individuals at once, leaving only a short time frame for the hazel dormouse to visit the board undisturbed. Furthermore, the bait is consumed quickly when many *Apodemus sp.* occupy the board, leaving it less attractive for the hazel dormouse. The one time the species were recorded together, the *Apodemus sp.* was the one occupying the board, while the hazel dormouse was watching and leaving before the *Apodemus sp.*, in both the current and the pilot study. Additionally, the only location where this occurred during the current study was at camera site 059. Given that this was one of the two sites where hazel dormouse activity was abnormally high a possible connection between the two phenomena could exist. This corroborates the theory of a lower level of fear or increased level of curiosity and willingness to approach the board, at least in the case of this one individual in particular.

Apodemus sp. and brown rats were the main consumers of the bait (the former in particular and in high numbers, the latter if they could stick their head through the wire). As such ,and due to the high amount of pictures taken up by these species, their response towards the baiting schedule is the most pronounced, but their immediate feeding after rebaiting may also be the cause that the other species' nightly records did not show a similar reaction.

Hazel dormice and *Apodemus* sp. show similarities in activity peaks and are both only recorded during the night, but despite the increased presence there are no visible influences or reaction when comparing the two temporal patterns. The high standard errors (> 44.3) of the PRESENCE analysis are likely a result of the small sample size.

Total Habitat Score

The minimal difference in average habitat scores between camera sites that saw hazel dormouse presence and those that did not could be an indicator that the chosen habitat criteria were possibly weighted wrong or are not overall as important for hazel dormice than suggested. The two anomalous camera sites 058 and 059 both accumulated a score of 15 points and were not exceptional in terms of any of the criteria, thereby excluding an improved habitat as possible explanation for increased hazel dormouse activity, at least in regard to the habitat parameters sampled.

Ultimately, this study was not conducted with the testing of the scores in mind, but used this instrument as a preliminary instrument to narrow down the best spots for board and camera placement. To make a definitive statement about the usefulness and applicability of the devised scores, they should be tested across a wide range of its scale within areas that are known to be occupied by hazel dormice.

Correlation of Habitat Criteria and Hazel Dormouse Presence

All but one successful camera were situated within a hazel tree and the level of association was stronger between boards placed directly within the plant and hazel dormouse presence than just with 20 m proximity. This supports the high importance for and implicit connection with hazel from which this dormouse derives its name. A suggestion for future repetition of this method, or any other study involving (camera) traps and hazel dormice, would be to place the instruments exclusively within hazel to increase chances of detection.

The correlation between the two criteria of hazel being present within 20 m and the board being mounted within hazel itself is no surprise, as they were almost measuring the same concept and there could not have been any hazel to mount the board in if there was none within 20 m in the first place. The levels of association between forest size and the criteria based on presence of hazel can be easily explained by the fact that the two camera sites within an area were rarely more than a few 100 m apart (with a minimum of 50 m between sites). Additionally, if there was no hazel (or only trees too young to be used to install the board) to be found in one part, it was quite likely to be the same case for the whole area.

Ultimately, the potential of camera traps as sampling method for hazel dormouse presence was reaffirmed and the data provided by this instrument gives valuable insight into activity patterns, possible species interactions and favoured habitat characteristics. However, the application of cameras is far more expensive, work intensive and prone to malfunctions than conventional methods. Therefore, nest searches and deployment of nest boxes and tubes will likely stay the preferred methods for confirmation of hazel dormouse presence.

4. Conclusion

Hazel dormouse presence was detected at select camera sites to the north and south along the A24 motorway, starting to the east of the district road K80, north of Neuschönningstedt and continuing intermittently for approximately 2.86 km. Data from previous years were also reconfirmed further to the east along the A24, to the northeast, northwest and southeast of the crossing of the federal highway B404 and the A24. No hazel dormouse presence was confirmed around the Billwerder railroad embankment or nature reserves to the north.

Hazel dormice were at the earliest detected on the very first night after camera installation and the latest after 13 days, reaffirming the selection for a minimum sampling period of 14 days to detect this species. A temporal pattern of three activity peaks during the night – one after dusk, one around midnight and one before dawn – was recorded, suggesting a rhythm such as is known to be present in other mouse species. A high amount of camera sites saw hazel dormice either returning very few times or even not at all after their first visit. Both pilot and present study showed anomalies in hazel dormouse activity at select camera sites compared to the average.

The two on photos indistinguishable *Apodemus* species *Apodemus flavicollis* and *Apodemus sylvaticus* combined were found to have a slight negative effect on the presence of hazel dormice, while the striped field mouse (*Apodemus agrarius),* bank vole *(Myodes glareolus)* and brown rat *(Rattus norvegicus*), were not deemed influential enough.

The importance of presence of hazel (*Corylus avellana*) and large forested areas for habitat preference was reaffirmed. A possible link of camera-/bait-placement within the hazel tree itself in order to increase detection rates was discovered.

5. Recommendations

Recommendations for future hazel dormouse research would be to:

- sample the devised habitat score or similar instruments only across areas where hazel dormouse presence has already been confirmed;
- place any camera traps exclusively within hazel to increase the possibility of detection;
- increase the distance from the camera trap to the baited board such as to observe more of surrounding area and therefor the approach and possible hesitation of the focal species when other species are present;
- test the adapted board used in this study against Goedele Verbeylen's hanging platform on a larger scale within areas where hazel dormouse presence has been confirmed to more reliably detect influence of other species on hazel dormouse detection;
- examine the area/camera sites with increased hazel dormouse activity to discover what causes the anomalous presence/behaviour

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Figure sources

Figures 3, 6, 7, 9, 11, 12, 28 and 29: ArcGIS Online basemaps used on ArcGIS Online content

Figure 4: Schäfers, G., Ebersbach, H., Reimers, H., Körber, P., Janke, K., Borggräfe, K., and Landwehr, F. (2016). Atlas der Säugetiere Hamburgs. Artenbestand, Verbreitung, Rote Liste, Gefährdung und Schutz. – Behörde für Umwelt und Energie, Amt f. Naturschutz, Grünplanung und Energie, Abteilung Naturschutz. Hamburg. pp. 32-33

Figure 5: Schulz B. Fervers-Marten B., Heigelmann, W., and Brockmüller N. (2008). Pressespiegel der „Nussjagd in Schleswig-Holstein“. Found on www.stiftungsland.de

Figure 8: Hamburg, Landesbetrieb Geoinformation und Vermessung, found on 30th of June on www.geoportal-hamburg.de

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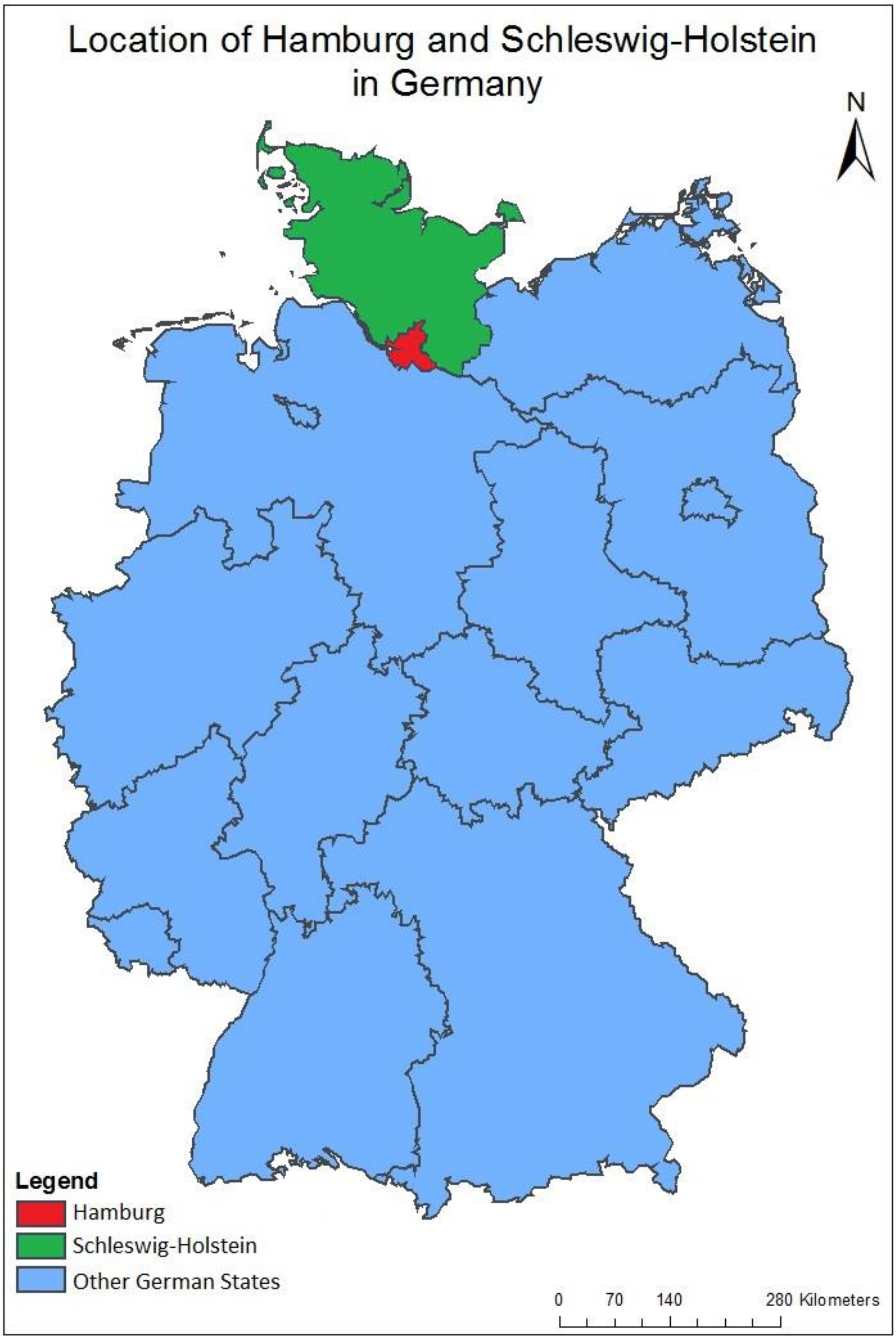
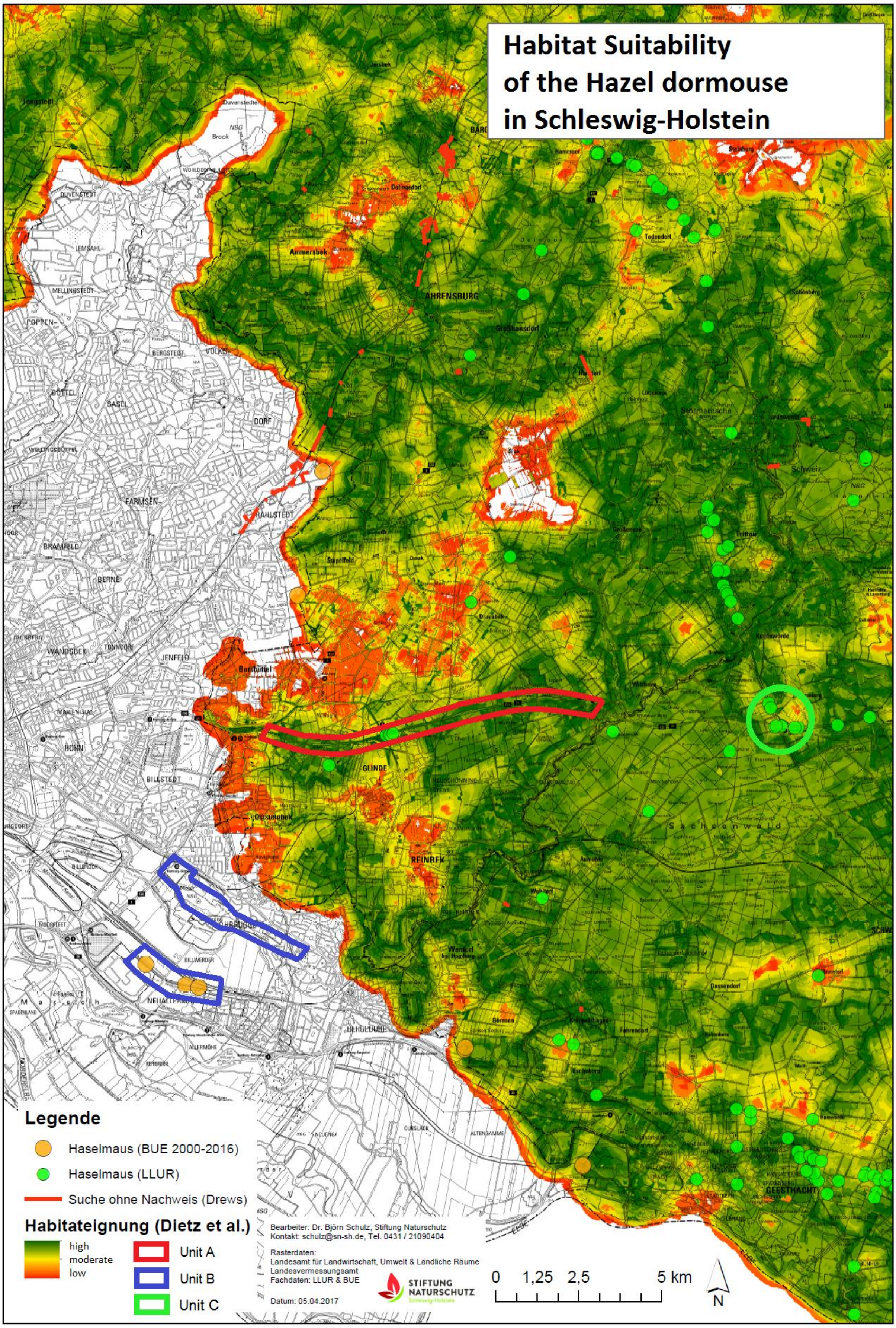
Appendices I, IV and X: ArcGIS Online basemaps used on ArcGIS Online content

Appendix I – Hamburg and Schleswig Holstein in Germany



Appendix II – Hazel Dormouse Habitat Suitability



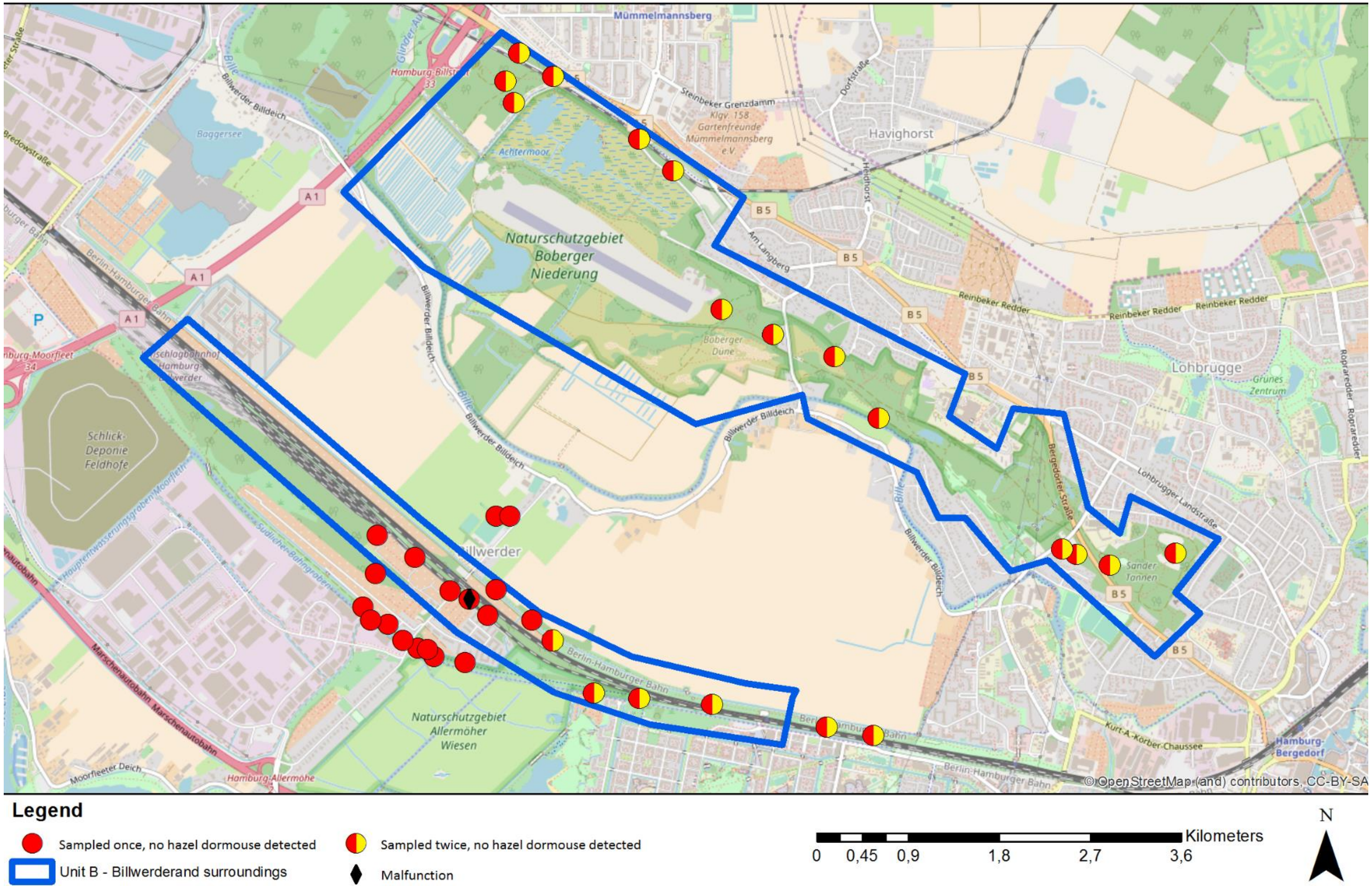
Appendix III – Data Documentation

Locations		*Documentation of the camera trap locations*
Serial_number	15	Consecutive number of the location
Location_ID	A15	Exclusive ID for each location (A15 = camera location 15 on unit A, B67 = camera location 67 on unit B)
Location_Name	A24_Tannenallee	Descriptive name of the location (next crossing street, town etc.)
Easting	53.561.615	Easting value taken with GPS device
Northing	10.246.301	Northing value taken with GPS device
Setup	03.07.2017	Exact date of camera trap setup
Dismount	10.07.2017	Exact date of camera trap dismount
Remarks		Relevant information regarding camera trap settings, placement of bait, defects
No. of total photos	578	Total amount of photos taken from setup until dismount

Species detections		*Documentation of species presence*
Location_ID	A15	Exclusive ID for each location (A15 = camera location 15 on unit A, B67 = camera location 67 on unit B)
Setup	06.07.2017	Date of taken record (1 or more directly connected photos)
Species	Hazel Dormouse	Species name, if different species are present, each gets its own record
Number of individuals	1	Maximum number of individuals present simultaneously in a photo, further description in "remarks"
Remarks	malfunction	Further remarks or descriptions regarding taken photo

Species detections		*Documentation of photos from successful (dormouse) camera sites*
Location_ID	A15	Exclusive ID for each location (A15 = camera location 15 on unit A, B67 = camera location 67 on unit B)
Setup	06.07.2017	Date of taken record (1 or more directly connected photos)
Photo_ID	Cam_023_2032	Exclusive ID for each photo taken
Species 1	Hazel Dormouse	Species name, if different species are present, each gets its own record
Number of individuals	1	Number of individuals in the photo, further description in "remarks"
Shootdate	8.07.2017	Date of photo taken
Shoottime	22:25	Time of photo taken
Remarks	overexposed	Further remarks or descriptions regarding taken photo
Processor	N. Villing	Person responsible for processing the respective record

Appendix IV – Camera Sites of Unit B



Appendix V – Encountered Mammal Species

Latin Name	English Name	German Name	Dutch Name
Muscardinus avellanarius	Hazel dormouse	Haselmaus	Hazelmuis
Apodemus sp. (flavicollis or sylvaticus)	Yellow-necked mouse or Wood mouse	Gelbhalsmaus oder Waldmaus	Grote bosmuis of bosmuis
Apodemus agrarius	Striped field mouse	Brandmaus	Brandmuis
Myodes glareolus	Bank vole	Rötelmaus	Rosse woelmuis
Micromys minutus	Eurasian harvest mouse	Zwergmaus	Dwergmuis
Sciurus vulgaris	Red squirrel	Eichhörnchen	Eekhoorn
Rattus norvegicus	Brown rat	Wanderratte	Bruine rat
Soricidae sp.	Shrew	Spitzmaus	Spitsmuis
Oryctolagus cuniculus	European rabbit	Wildkaninchen	Konijn
Lepus europaeus	European hare	Feldhase	Haas
Martes martes	European pine marten	Baummarder	Boommarter
Martes foina	Beech marten	Steinmarder	Steenmarter
Mustela putorius	European polecat	Europäischer Iltis	Bunzing
Mustela ermine	Stoat	Hermelin	Hermelijn
Felis catus	Cat	Katze	Kat
Procyon lotor	Raccoon	Waschbär	Gewone wasbeer
Capreolus capreolus	Roe deer	Reh	Ree
Capra sp.	Goat	Ziege	Geit
Ovis sp.	Sheep	Schaf	Schaap

Appendix VI – PRESENCE Output

AIC model comparison:

Model	AIC	deltaAIC	AIC wgt	Model Lil	no.Par.	-2*LogLil
psi(Apo),p(.)	338.91	0.00	0.6265	1.0000	4	330.91
psi(Apo+Myo),p(.)	341.38	2.47	0.1822	0.2908	6	329.38
psi(Apo+Rat),p(.)	342.35	3.44	0.1122	0.1791	6	330.35
psi(Apo+Myo+Rat),p(.)	344.33	5.42	0.0417	0.0665	8	328.33
psi(Apo+Agr+Myo*Rat),p(.)	344.55	5.64	0.0373	0.0596	10	324.55

Min. AIC model output:

```
Number of parameters          = 4
Number of function calls          = 87
-2log(likelihood)             = 330.9056
AIC                           = 338.9056

Untransformed Estimates of coefficients for covariates (Beta's)
======================================================================
                                          estimate    std.error
A1    psi.a1                       :  -0.201150    44.332288
A2    psi.Apodemus_sp              :  -0.453710    44.332574
A3    psi.No_Apodemus_sp           :   0.252532    44.336963
B1    P[15].b1                     :  -1.277760     0.158527

============================================================
```

Appendix VII – SPSS Outputs I, Correlation with Dormouse Presence

Parameter	Cramer's V for correlation with Dormouse presence: Symmetric Measures		Value	Approximate Significance	Strength
Hazel 20m	Nominal by Nominal	Phi	,366	,012	
		Cramer's V	,366	,012	
	N of Valid Cases		47		
Board in Hazel	Nominal by Nominal	Phi	,587	,000	
		Cramer's V	,587	,000	
	N of Valid Cases		47		
Area cat	Nominal by Nominal	Phi	,562	,002	
		Cramer's V	,562	,002	
	N of Valid Cases		47		
Alt food 1	Nominal by Nominal	Phi	-,035	,813	
		Cramer's V	,035	,813	
	N of Valid Cases		47		
Alt food 2	Nominal by Nominal	Phi	,105	,470	
		Cramer's V	,105	,470	
	N of Valid Cases		47		
Flower	Nominal by Nominal	Phi	,163	,742	
		Cramer's V	,163	,742	
	N of Valid Cases		47		

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<tr><td>Nominal by Nominal</td><td>Phi</td><td>-,187</td><td>,199</td></tr>
<tr><td></td><td>Cramer's V</td><td>,187</td><td>,199</td></tr>
<tr><td>N of Valid Cases</td><td></td><td>47</td><td></td></tr>
</table>
</td>
<td></td>
</tr>
<tr>
<td>Too shady</td>
<td>
Symmetric Measures
<table>
<tr><th></th><th></th><th>Value</th><th>Approximate Significance</th></tr>
<tr><td>Nominal by Nominal</td><td>Phi</td><td>-,191</td><td>,191</td></tr>
<tr><td></td><td>Cramer's V</td><td>,191</td><td>,191</td></tr>
<tr><td>N of Valid Cases</td><td></td><td>47</td><td></td></tr>
</table>
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<td></td>
</tr>
</table>

Appendix VIII – SPSS Outputs II, Correlation between Parameters

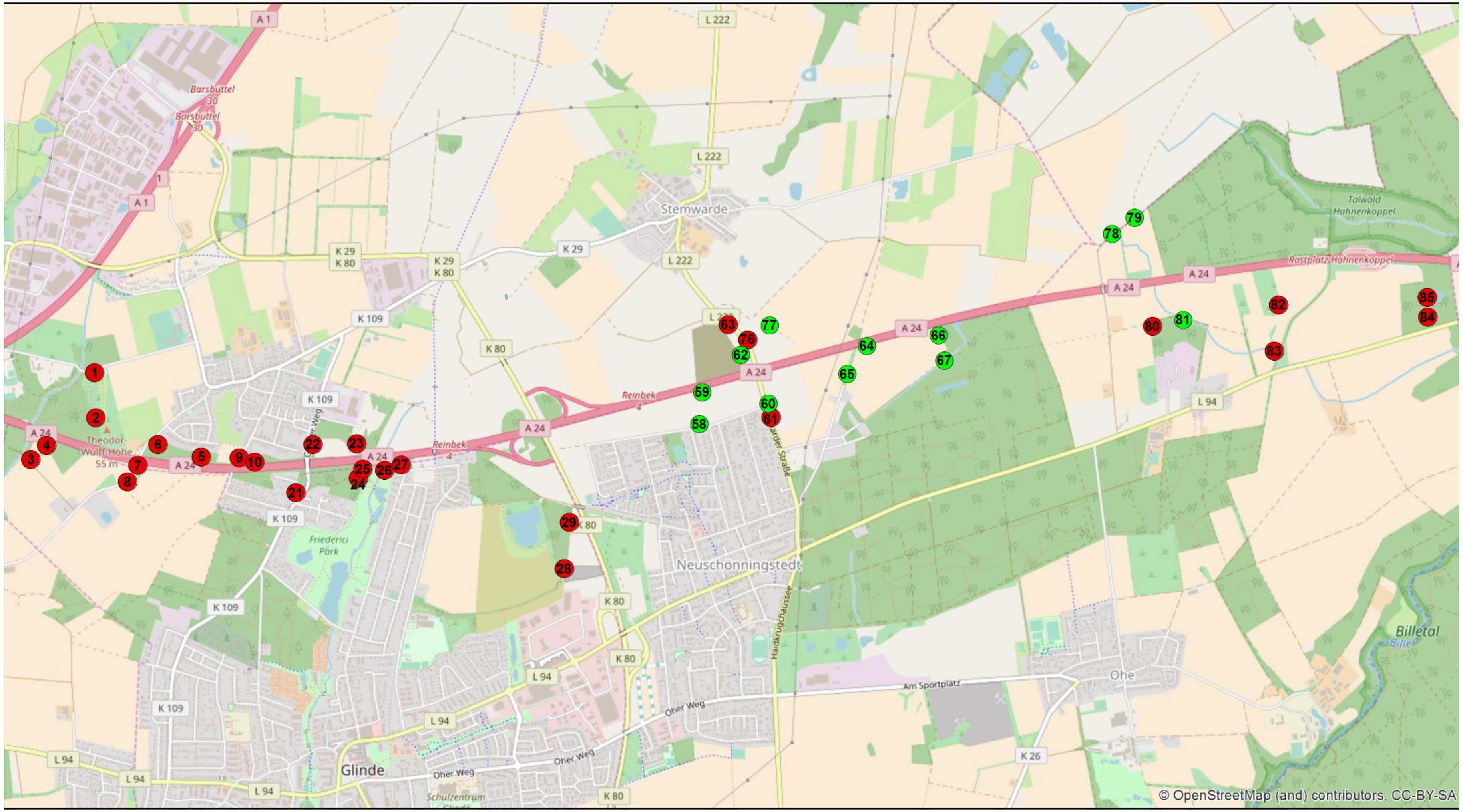
<table>
<tr><th>Parameters</th><th>Cramer’s V for correlation between parameters</th><th></th></tr>
<tr><td>Hazel 20m
x
Board in
Hazel</td><td>
Symmetric Measures
<table>
<tr><th></th><th></th><th>Value</th><th>Approximate Significance</th></tr>
<tr><td>Nominal by Nominal</td><td>Phi</td><td>,688</td><td>,000</td></tr>
<tr><td></td><td>Cramer's V</td><td>,688</td><td>,000</td></tr>
<tr><td>N of Valid Cases</td><td></td><td>47</td><td></td></tr>
</table>
</td><td></td></tr>
<tr><td>Hazel 20m
x
Area</td><td>
Symmetric Measures
<table>
<tr><th></th><th></th><th>Value</th><th>Approximate Significance</th></tr>
<tr><td>Nominal by Nominal</td><td>Phi</td><td>,254</td><td>,387</td></tr>
<tr><td></td><td>Cramer's V</td><td>,254</td><td>,387</td></tr>
<tr><td>N of Valid Cases</td><td></td><td>47</td><td></td></tr>
</table>
</td><td>not significant</td></tr>
<tr><td>Hazel board
x
Area</td><td>
Symmetric Measures
<table>
<tr><th></th><th></th><th>Value</th><th>Approximate Significance</th></tr>
<tr><td>Nominal by Nominal</td><td>Phi</td><td>,447</td><td>,024</td></tr>
<tr><td></td><td>Cramer's V</td><td>,447</td><td>,024</td></tr>
<tr><td>N of Valid Cases</td><td></td><td>47</td><td></td></tr>
</table>
</td><td></td></tr>
</table>

Appendix IX – SPSS Outputs III, Crosstabulation of Parameters

<table>
<tr><th>Parameters</th><th>Crosstabulation counts with Hazel dormouse presence</th></tr>
<tr><td>Hazel 20m
x
Dormouse presence</td><td>
HM_pres * Hazel_20m Crosstabulation
<table>
<tr><td></td><td></td><td colspan="2">Hazel_20m</td><td></td></tr>
<tr><td></td><td></td><td>0</td><td>1</td><td>Total</td></tr>
<tr><td>HM_pres</td><td>0</td><td>12</td><td>18</td><td>30</td></tr>
<tr><td></td><td>1</td><td>1</td><td>16</td><td>17</td></tr>
<tr><td>Total</td><td></td><td>13</td><td>34</td><td>47</td></tr>
</table>
</td></tr>
<tr><td>Hazel in board
x
Dormouse presence</td><td>
HM_pres * board_Hazel Crosstabulation
<table>
<tr><td></td><td></td><td colspan="2">board_Hazel</td><td></td></tr>
<tr><td></td><td></td><td>0</td><td>1</td><td>Total</td></tr>
<tr><td>HM_pres</td><td>0</td><td>20</td><td>10</td><td>30</td></tr>
<tr><td></td><td>1</td><td>1</td><td>16</td><td>17</td></tr>
<tr><td>Total</td><td></td><td>21</td><td>26</td><td>47</td></tr>
</table>
</td></tr>
<tr><td>Area_cat
x
Dormouse presence</td><td>
HM_pres * Area_categories Crosstabulation
<table>
<tr><td></td><td></td><td colspan="4">Area_categories</td><td></td></tr>
<tr><td></td><td></td><td>0</td><td>1</td><td>2</td><td>3</td><td>Total</td></tr>
<tr><td>HM_pres</td><td>0</td><td>7</td><td>19</td><td>2</td><td>2</td><td>30</td></tr>
<tr><td></td><td>1</td><td>6</td><td>3</td><td>0</td><td>8</td><td>17</td></tr>
<tr><td>Total</td><td></td><td>13</td><td>22</td><td>2</td><td>10</td><td>47</td></tr>
</table>
</td></tr>
<tr><td>Hazel 20m
x
Board in Hazel</td><td>
board_Hazel * Hazel_20m Crosstabulation
<table>
<tr><td></td><td></td><td colspan="2">Hazel_20m</td><td></td></tr>
<tr><td></td><td></td><td>0</td><td>1</td><td>Total</td></tr>
<tr><td>board_Hazel</td><td>0</td><td>13</td><td>8</td><td>21</td></tr>
<tr><td></td><td>1</td><td>0</td><td>26</td><td>26</td></tr>
<tr><td>Total</td><td></td><td>13</td><td>34</td><td>47</td></tr>
</table>
</td></tr>
<tr><td>Hazel 20m
x
Area cat</td><td>
Hazel_20m * Area_categories Crosstabulation
<table>
<tr><td></td><td></td><td colspan="4">Area_categories</td><td></td></tr>
<tr><td></td><td></td><td>0</td><td>1</td><td>2</td><td>3</td><td>Total</td></tr>
<tr><td>Hazel_20m</td><td>0</td><td>3</td><td>8</td><td>1</td><td>1</td><td>13</td></tr>
<tr><td></td><td>1</td><td>10</td><td>14</td><td>1</td><td>9</td><td>34</td></tr>
<tr><td>Total</td><td></td><td>13</td><td>22</td><td>2</td><td>10</td><td>47</td></tr>
</table>
</td></tr>
<tr><td>Hazel board
x
Area</td><td>
board_Hazel * Area_categories Crosstabulation
<table>
<tr><td></td><td></td><td colspan="4">Area_categories</td><td></td></tr>
<tr><td></td><td></td><td>0</td><td>1</td><td>2</td><td>3</td><td>Total</td></tr>
<tr><td>board_Hazel</td><td>0</td><td>5</td><td>13</td><td>2</td><td>1</td><td>21</td></tr>
<tr><td></td><td>1</td><td>8</td><td>9</td><td>0</td><td>9</td><td>26</td></tr>
<tr><td>Total</td><td></td><td>13</td><td>22</td><td>2</td><td>10</td><td>47</td></tr>
</table>
</td></tr>
</table>

Appendix X – Maps of all Units with Camera Site IDs

Hazel Dormouse Presence within Unit A - A24 west



Legend

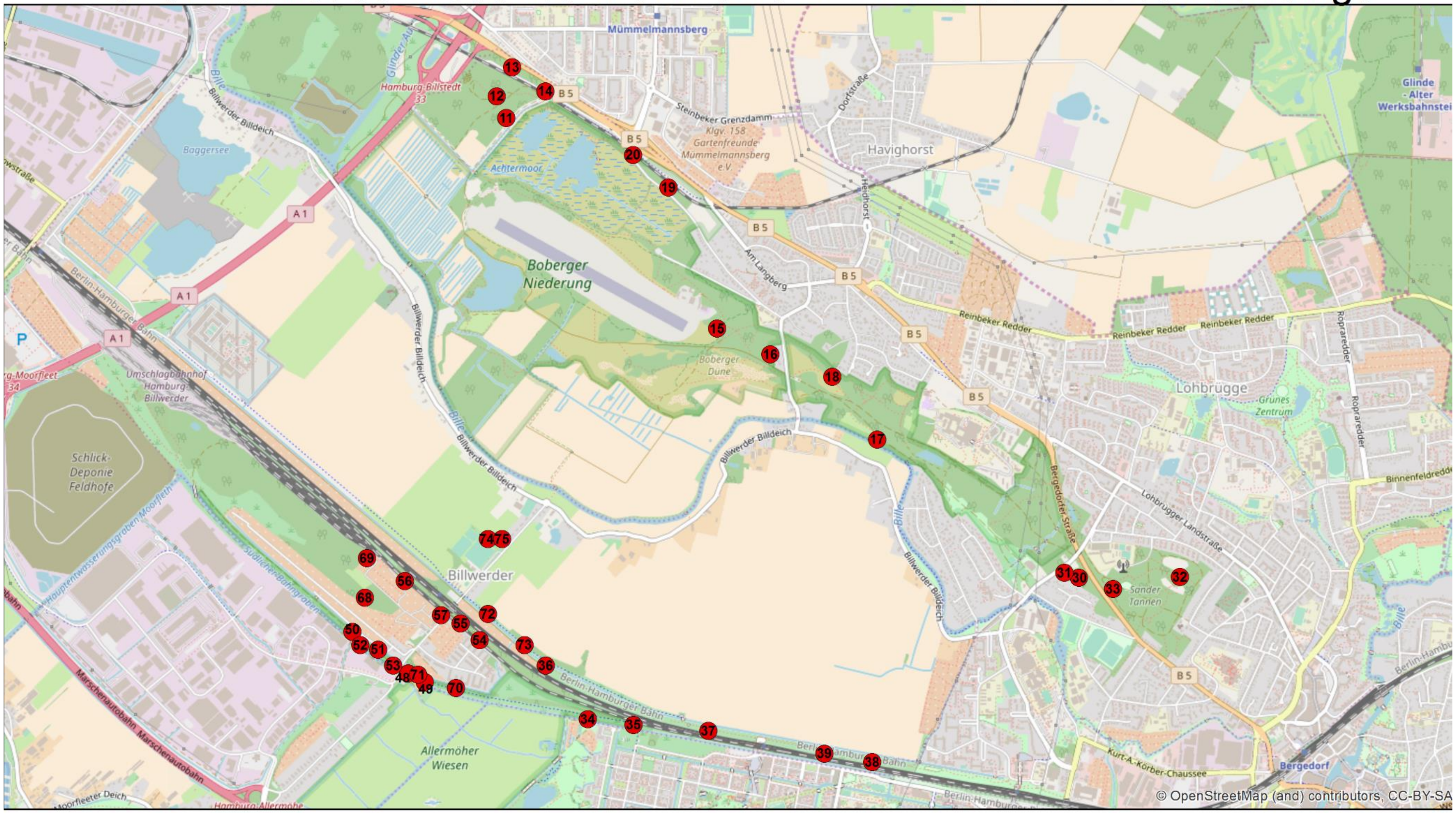
Dormouse found

Dormouse not found

0 0,5 1 2 3 4 Kilometers

N

Hazel Dormouse Presence within Unit B - Billwerder and surroundings



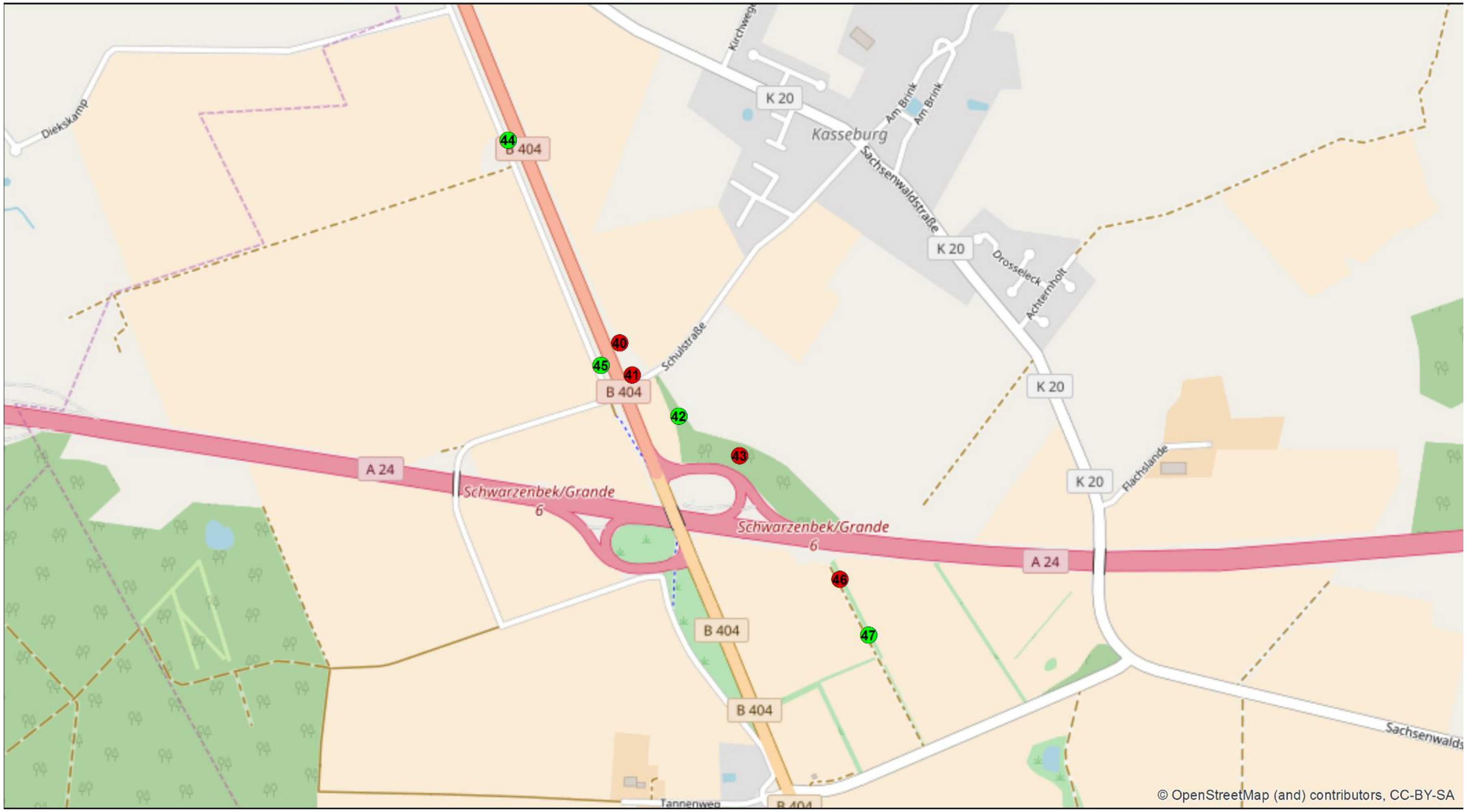
Legend

- Dormouse found
- Dormouse not found

0 0,475 0,95 1,9 2,85 3,8 Kilometers

N

Hazel Dormouse Presence within Unit C - A24 east



Legend

- Dormouse found
- Dormouse not found

0 0,15 0,3 0,6 0,9 1,2 Kilometers

N

Glossary

AIC - estimator of the relative quality of statistical models relative to each other for a given set of data, thereby providing a means for model selection

Area – plot of potentially suitable habitat for the hazel dormouse, segregated from similar plots by landscape characteristics known to rarely be crossed by hazel dormice, including cemented roadways accessible for the public by car, rivers and streams of more than 1m in diameter and open/agricultural fields and strips of more than 50m

Burst mode – camera trap setting that takes a series of continuous images following a trigger event

Cramer's V – measure of association between two variables, resulting in a value between 0 (no association between the variables) to +1 (complete association/equal variables)

DGK5 – abbreviation for Deutsche Grundkarte (German Basemap), ordnance survey map with quadrants of 2 x 2 km at a scale of 1: 5000

Effective habitat size – habitat of an area suitable for the focal species

FAP – abbreviation of **F**ast **A**s **P**ossible (usually 1 second delay)

Focal species – species desired to be detected

Hair tubes – narrow plastic tubes with adhesive tape stretched across each opening, causing hairs to be left on the sticky surface when an animal squeezes through

LAU – abbreviation for Landesamt für Umweltschutz Sachsen-Anhalt, german: State Office for Environmental Protection

LLUR – abbreviation for Landesamt für Landwirtschaft, Umwelt und ländliche Räume, german: Ministery for Agriculture, Environment and Rural Areas

Occurrence – visit at a camera site by an individual (in case of the same or visually indistinguishable individuals, photos taken more than 5 minute intervals apart were viewed as independent occurrences)

(Roadside) shrubbery – strip of vegetation often found running alongside roads, highways and motorways

Trapping session – 14 nights of camera trapping as they were carried out at each camera site

Unit – cluster of areas that is systematically surveyed; "unit" also refers to the respective cluster of cameras used there

SD card – acronym for Secure Digital cards; removable digital storage medium

TK-25 – abbreviation for Topographische Karte (topographic map), ordnance survey map with quadrants of ca. 11 x 11 km at a scale of 1 : 25000