Martin Ludwig, Laura Sutcliffe and Sven Büchner (Eds.)

Monitoring of the hazel dormouse under the EU Habitats Directive in member states around the Baltic Sea

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Monitoring of the hazel dormouse under the EU Habitats Directive in member states around the Baltic Sea

Proceedings of the Workshop held on the island of Vilm on 29th and 30th of October 2018

Editors
Martin Ludwig
Laura Sutcliffe
Sven Büchner

Federal Agency for Nature Conservation

Cover picture: top: hazel dormouse (*Muscardinus avellanarius*) (B. Schultz); bottom left: discussion during the workshop (V. Pilāts); bottom right: hazel dormouse nest with droppings found during the field trips (V. Pilāts)

Editors' addresses:

Dr. Martin Ludwig
Federal Agency for Nature Conservation
Division II 1.3 "Terrestrial Monitoring"
Konstantinstr. 110, 53179 Bonn
E-Mail: martin.ludwig@bfn.de

Dr. Laura Sutcliffe
E-Mail: lsutcli@gwdg.de

Sven Büchner
E-Mail: muscardinus@gmx.net

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2 Introduction

Sven Büchner & Martin Ludwig

The hazel dormouse (*Muscardinus avellanarius*) was a little-studied small mammal for a long period. Public awareness about it has changed since its inclusion in Annex IV of the Habitats Directive by the European Union (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora). Our knowledge about the hazel dormouse is therefore now much better than 30 years ago (Juškaitis & Büchner 2013).

The listing in Annex IV requires a regular monitoring of the species (§ 11) and regular reports to the European Commission (EU-COM) every six years (§ 17). Four parameters need to be reported to the EU-COM: range, population, habitat of the species and future prospects. The aim of the monitoring is to recognize a declining or bad conservation status. This shall enable member states to take measures in time to keep or restore a favourable conservation status.

However, monitoring of the hazel dormouse is challenging. The species is small, nocturnal, has low population densities compared to many other rodents, is climbing and therefore partly living in heights that are difficult for humans to reach. According to experts on hazel dormouse monitoring, there is a great need for knowledge exchange about monitoring methods for the hazel dormouse especially in the circum-Baltic states. Sweden, Denmark and Latvia are in the process of developing a monitoring system and in Germany, where a system is already established, monitoring is difficult especially in the northern part where the species is particularly rare.

The Federal Agency for Nature Conservation in Germany therefore funded a workshop on monitoring of the hazel dormouse under the EU Habitats Directive in the circum-Baltic states. The workshop was held from 28th to 30th of October 2018 at the International Academy for Nature Conservation on the island of Vilm, Germany. During this workshop, international experts discussed open questions on monitoring range, population and habitat of the hazel dormouse under the specific conditions in the Baltic region.

The landscapes around the Baltic Sea encompass part of three biogeographic regions. The assessment of hazel dormouse range in the Atlantic Region is “unfavourable - bad”, but for the Continental Region and the Boreal Region it is “favourable” (2019 report of EU-COM). However, in contrast to the assessment for whole biogeographic regions, experts had the impression that the situation in the north of the hazel dormouse range in the Continental Region differs from other parts. For example, the Danish part of the Continental Region already lost core populations, and consequently core parts of the range in the last 20 years. Therefore experts discussed the following questions:

- What is the most feasible method to gather range data?
- How to keep range data up to date?
- How do the experts assess the status of the range in different parts of the Baltic Region?
- Which factors influence the local distribution?

Trends in population size should also be reported. A population decline of 12% in two reporting periods (12 years) should be detectable in population trends. This is equivalent to a loss of 1% per year. Species suffering of such a decline are assessed to have an unfavourable conservation status according to the so called “DocHab” (DG Environment 2016). Low population sizes and densities are a challenge for a precise monitoring. In hazel dormouse habitats around the Baltic Sea, usually lower population densities are recorded in comparison to habitats further south. Experts discussed the following questions on monitoring of populations:

- Which methods allow a sensitive detection of population trends to achieve data precise enough for the required assessment?
- How should data on population and trends be evaluated?
- Detailed questions on this topic were:
- How to select sample sites?
- How often do these sites need to be checked?
- How large should sample sites be to avoid edge effects?
- What is the influence of small-scale shifts within the populations?
- What are the drivers of changes / fluctuations in populations (trophic interactions, e.g. yellow necked mice [*Apodemus flavicollis*] or edible dormice [*Glis glis*]; natural cycles; …)?

Regarding the parameter quality of the habitat of the species, some monitoring sites show high hazel dormouse densities but the habitat quality is assessed as only medium. Other habitats show only low population densities but seem to have a good quality. Therefore experts discussed the questions:

- How to assess habitat quality?
- How high is a possible influence of forestry (standards in forest management)?

The aims of the workshop were to discuss answers for these questions, share experience concerning monitoring programmes and methods and to exchange ideas for possible joint projects.

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3 Summary

On 29 and 30 October 2018, experts from countries around the Baltic Sea met for a hazel dormouse monitoring workshop with the aim of sharing experiences with different survey methods and improving data collection, especially for Habitats Directive reports.

The hazel dormouse is difficult to survey because it is small, nocturnal, occurs in low population densities compared to other small mammals, and climbs, which means that some of its habitat is at heights that are difficult for humans to reach. Sweden, Denmark and Latvia are developing monitoring programmes for the hazel dormouse. In Germany, there is already a monitoring programme, but it is difficult to record the dormouse, especially in northern Germany, where it occurs in low densities and lives in habitats that are mainly formed by hedges.

At the workshop, the methods used and being tested in the countries around the Baltic Sea to determine the range and population density in the different countries were presented and discussed. Important characteristics determining habitat quality were also discussed.

During the workshop and afterwards, participants compared established and developing methods for determining range and population size and compiled advantages and disadvantages (chapters 5.8 and 6.8). This compilation can be used to find a uniform methodological standard.

4 Zusammenfassung

Am 29. und 30. Oktober 2018 trafen sich Experten aus den Ländern rund um die Ostsee zu einem Workshop zur Erfassung der Haselmaus mit dem Ziel Erfahrungen mit verschiedenen Erfassungsmethoden auszutauschen und die Erfassung von Daten insbesondere für Berichte nach Fauna-Flora-Habitat-Richtlinie (FFH-Richtlinie) zu verbessern.

Die Erfassung der Haselmaus ist schwierig, da sie klein und nachtaktiv ist, im Vergleich mit anderen Kleinsäugern in geringen Populationsdichten auftritt und klettert, wodurch ihr Lebensraum sich teilweise in einer für Menschen schwer erreichbaren Höhe befindet. Schweden, Dänemark und Lettland entwickeln Monitoringprogramme zu Erfassung der Haselmaus. In Deutschland gibt es bereits ein Monitoring allerdings ist die Erfassung insbesondre im Norden Deutschlands schwierig, da die Haselmaus hier in geringen Dichten vorkommt und in Habitaten lebt die zu einem hohen Anteil durch Hecken gebildet werden.

Auf dem Workshop wurden die in den Ländern rund um die Ostsee genutzten und in Erprobung befindlichen Methoden zu Bestimmung der Verbreitung und der Populationsdichte in den verschiedenen Ländern vorgestellt und diskutiert. Auch wichtige die Habitatqualität bestimmende die Merkmale wurden diskutiert.

Während des Workshops und im Nachgang haben die Teilnehmer etablierte und in der Entwicklung befindliche Methoden zu Bestimmung des Verbreitungsgebietes und der Populationsgröße verglichen und Vor- und Nachteile zusammengestellt (Kapitel 5.8 und 6.8). Diese Zusammenstellung kann der Findung eines einheitlichen Methodenstandard dienen.

5 Parameter range

5.1 Long-term survival of hazel dormouse (*Muscardinus avellanarius*) in fragmented landscapes

Björn Schulz & Sven Büchner

(shortened version of DOI: 10.2478/lynx-2018-0008)

The hazel dormouse is described as arboreal woodland species (e.g. Airapetyants 1983, Bright & Morris 1996, Rossolimo et al. 2001, Juškaitis 2008). It is known that hazel dormice also live in hedges (Hurrell & McIntosh 1984, Eden & Eden 1999, Bright & MacPherson 2002, Bright et al. 2006, Wolton 2009, Ehlers 2012). However, a model by Mortelliti et al. (2011) clearly showed the importance of forests for the species. This model predicts that even high densities of hedgerows (>30 km per km² = 30 m / ha) are unlikely to increase the probability of occurrence of hazel dormouse in landscapes where there are low levels of forest cover (<5%–10%) and in such low forested landscapes hazel dormice cannot survive in the longrun, no matter how well the remaining habitat patches are connected (Mortelliti et al. 2011).

In parts of north-western European lowlands, the forest coverage fluctuated widely during historical and recent times due to intensive human impacts on landscapes and is low today (Table 1). For example, in the northern German federal state of Schleswig-Holstein, the minimum of forest cover of ca. 4 % was reached around 1780 (Hase 1983).

Today, the hazel dormouse is present in 10 x 10 km grids in Schleswig-Holstein (Fig. 2) with a forest cover lower than the average forest cover of the whole federal state (Table 1). This leads to the assumption that hazel dormice do not necessarily prefer grids with high current forest cover. There must be more that determines the dormouse presence.

Table 1: Forest coverage per country and number of raster cells with hazel dormouse presence

country	forest cover of the total country	number of 10x10 km cells with hazel dormouse presence
Belgium	23 %	71
Britain	12 %	710
Denmark	14 %	48
France	31 %	466
Germany	33 %	137
Schleswig-Holstein in 1800	4 %	Unknown (but hazel dormice must have been present in several populations)
Schleswig-Holstein in 2000	11 %	69
Sweden	69 %	20

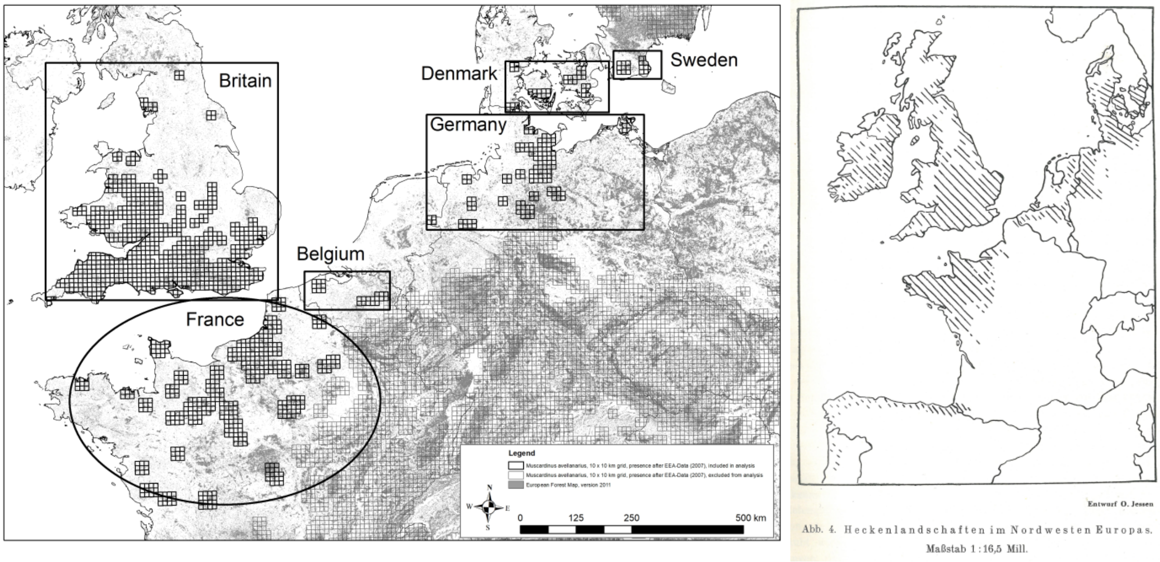

Fig. 1: Left: Study site with hazel dormouse distribution in the NW-European lowland, data source: EEA-European Topic Centre on Biological Diversity (ETC/BD). Right: The hedge-dominated landscapes according to Jesse (1937)

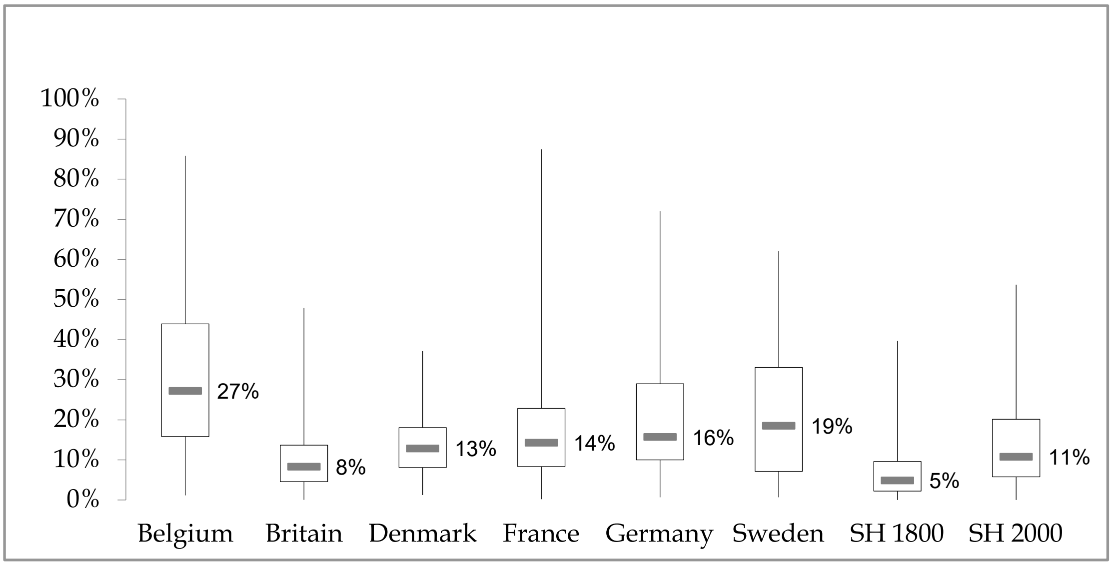

Fig. 2: Forest cover in grid cells with hazel dormouse presence (only grids in fragmented lowland ranges) of the different European countries and in detail of Schleswig-Holstein at the years 1800 (SH 1800) and 2000 (SH 2000) (boxplot showing maximum, upper quartile, median, lower quartile, minimum) (Source: B. Schulz & S. Büchner)

The history of a site influences the present status of hazel dormice as well. Where no ancient woodlands remain, there is only a small chance of hazel dormice being present today. But if even small patches of ancient forest are left, the likelihood of surviving hazel dormouse populations can be high. The difference is highly significant. When looking at younger forests, the difference is smaller but still significant. Where the hazel dormouse is present today, in median 3.5 % of the landscape is re-afforested since 1800, in places where it’s absent, nearly no afforestation took place (0.7 %).

Fig. 3: Historical landscape maps (top: Wiebeking 1786, middle: Schmettau 1788) in comparison to a recent map (bottom: OSM 2018). Dots represent the position of hazel dormouse summer nests detected in November 2016. Size of the map areas is approx. 5 x 7 km.

Knowledge about ancient woodland and historical hedgerow systems can help to find places with unknown hazel dormouse presence. According to Jessen (1937), hedgerow (Fig. 3) important factors for habitat suitability for the hazel dormouse. The data from Schleswig-Holstein follow the same pattern as the data of Bright et al. (1994), who found hazel dormice more frequently in ancient woodland than in recent woodland in the UK. It can be assumed that this pattern is typical at least for north-western Europe and highlights the importance of ancient woodland as reserves for biodiversity.

However, ancient woodland was reduced to small copses in most parts of the study site. And even though, the hazel dormouse is nowadays scattered but relatively widespread throughout NW-Europe. For Schleswig-Holstein we can state that there are only few regions in the federal state, where the habitat suitability today is high (Dietz et al. 2018) and recent evidence of hazel dormice is lacking. Hazel dormice have survived in spite of the lack of forests (4 %) due to a high density of hedges (according to Müller 2013 on average 115 m / ha) as a highly suitable secondary habitat. Genetic studies (Mouton et al. 2016) provide proof that dormice did not recently immigrate here but survived during the past.

Studies from England and eastern Germany emphasize a minimum woodland size of 20 ha for a long-term survival of a local population (Bright et al. 1994, Keckel et al. 2012). There is a high risk of extinction in small and isolated sites (Bright & Morris 1996). According to Bright & Morris (1996), hedgerows work as corridors between woodlands ensuring the linkage between metapopulations and with that the long-term survival of the species.

In the general scale of a landscape, Mortelliti et al. (2011) found that probability of hazel dormouse presence was related to habitat amount. In their model, the probability of hazel dormouse presence increased with the amount of forest cover and increasing structural connectivity (hedgerows) in the landscape. The main conclusions of this model can be confirmed with the data from this study. However, for the hazel dormouse, the lack of forest habitats in north-western Europe was successfully compensated by the creation of a hedgerow network. We are sure that hedgerows function as a habitat by themselves, not only as a connecting structure.

The hedgerow network in Schleswig-Holstein and adjacent regions had to be developed after different land use acts from the early 18th century onwards (Jessen 1937), but was basically already present in the decades or even centuries before (Müller 2013). In the late 18th century at the time of the heaviest loss of forests, the hedgerow network reached its maximum density of > 110 m per ha in certain regions of northern Germany. It is now reduced to a little more than 50 m per ha. Our hypothesis is that the dormouse can survive in almost completely deforested landscapes as long as the density and quality of the hedge-system is sufficient. A density of 50 m hedgerows in high quality per ha seems to be a minimum for the survival of hazel dormice in north-west European landscapes.

How can this knowledge contribute to species conservation strategies? Understanding the historical dynamics of habitats may be crucial for the interpretation of the historical and recent distribution of not only the hazel dormouse. The analysis of maps of historical and recent habitat distribution can facilitate monitoring and conservation of species. It helps to identify a) possible key factors for the species' long-term survival, b) potentially undiscovered populations and c) strategies for the regeneration of a favourable conservation status. Furthermore, it is apparent that the historical development of landscapes and thus population and range dynamics must be considered in modern "species occurrence models", where usually only recent distribution of species and habitat factors are taken into account. Recent distribution of species is not only dependent on recent habitat suitability, but also from historical habitat suitability.

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5.2 Range of the hazel dormouse in northern Germany

Sven Büchner, Björn Schulz, Kristin Zscheile, Nina Klar, Melina Heinrich, Birte Müller & Martin Ludwig

In Germany, the federal states are responsible for the monitoring of Annex IV species. The Federal Agency for Nature Conservation (BfN) compiles the German report and provides the data to the European Commission. We therefore have four different sub-projects on mapping the range of the hazel dormouse in the north of Germany.

For **Schleswig-Holstein (SH)**, the data base was rather poor in 2006. At that point, a citizen science project was started - the “great nut hunt”. The chosen method was the search for gnawed hazel nuts with the typical tooth marks of hazel dormice. The volunteers in this project contributed to the knowledge of 26 grid squares with hazel dormouse records. The project also considerably increased the public awareness of the hazel dormouse. Subsequently different projects focussing also on the hazel dormouse were conducted. Here repeatedly mapping of hazel dormice on a federal state level was carried out by staff of a nature conservation agency, a road agency and a compensation agency, as well as volunteers and researchers. One of the main methods was the search for vacated summer nests in late autumn and winter by skilled persons.

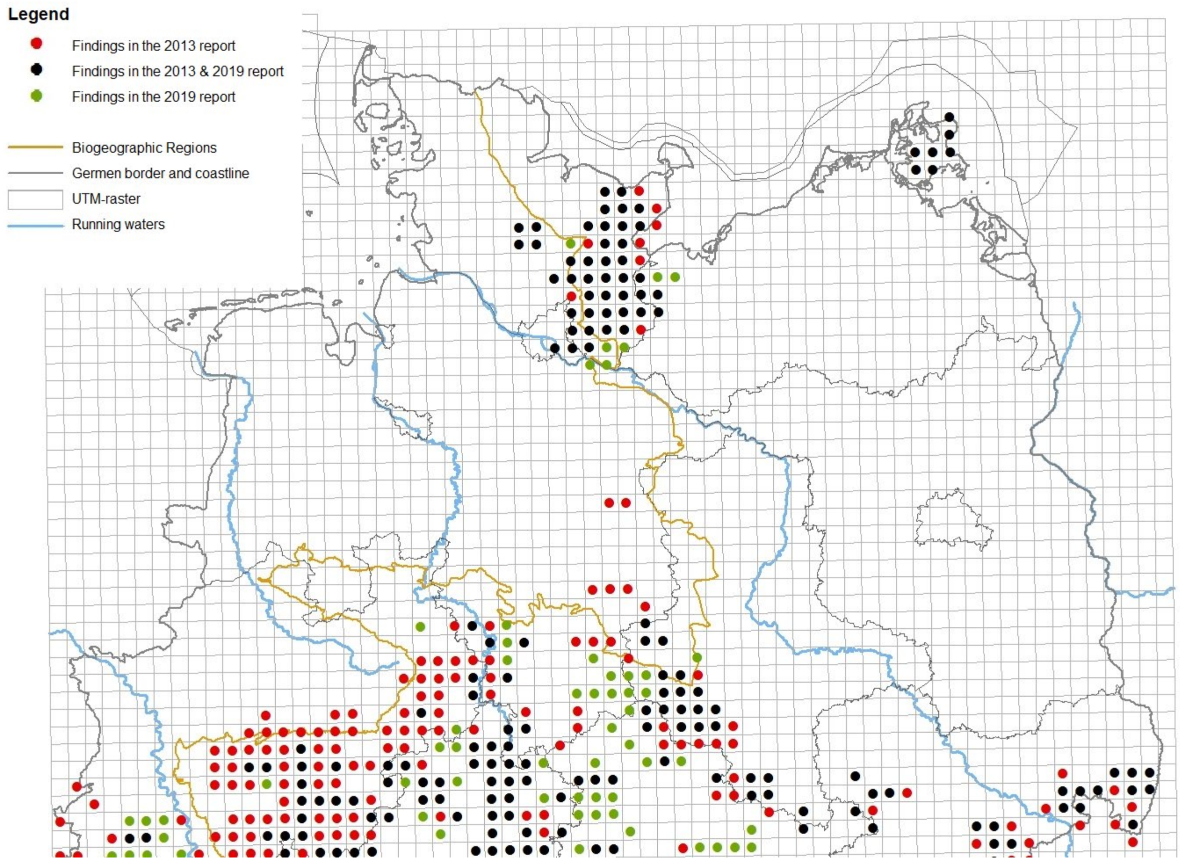

Fig. 4: Range data of the hazel dormouse in Northern Germany and the fluctuations in range from Habitats Directive reports 2013 to 2019. Changed map based on data from the German Länder created by the Federal agency for Nature Conservation (Two misleadingly positive reported cells been corrected).

Up to now there is no specific monitoring scheme for the parameter range. A trial during winter 2018/2019 showed that it is possible to confirm presence in 37 10x10 km grids within several working days only, with a daily maximum of six 10x10 km grids. The results of this trial in Schleswig-Holstein show that the search for vacatedempty summer nests under certain circumstances (suitable season and habitats, experienced staff) can function as a highly effective and efficient method to at least confirm the known distribution range, but also to find formerly unknown populations.

Current knowledge about the species distribution is comparably good, as there are around 2,000 records in the federal state data set, which allows an assessment for this species. There is a clear and ongoing decline in number of positive grids in national reports from 2006 (n = 63) to 2012 (n = 48) and 2018 (n = 45). Some older records cannot be verified today (mainly scattered in northern SH). Smaller populations far from the core population seem to be lost. In total, the hazel dormouse range has receded to half its size within the last 50 years. This heavy decline confirms the assessment as endangered species.

When looking at biogeographic regions, it is most probable that there was a heavy decline of species range in the Atlantic Biogeographic Region (ATL) during history. But during the last decade populations in the ATL seem to be as stable as those inside the Continental Biogeographic Region (CON).

The city of **Hamburg (HH)** has only small areas of potential habitat, mainly in connection to the neighbouring states of Schleswig-Holstein and Lower Saxony. The few forests are mostly located in the surroundings of the city. The hazel dormouse was recorded in some of these places just by chance between 1959 and 2008. A first recent check was done with nest searches in 2012 which resulted in 5 records. However, a repetition in 2016 was not able to confirm the occurrence of the hazel dormouse at those sites. In December 2017, a team of skilled researchers spent 275 hours to search for hazel dormouse signs (nests and gnawed nuts) in HH. It resulted in one record at the edge of the city. This could hint to a real decline of the hazel dormouse.

For **Mecklenburg-Vorpommern (MV)** hazel dormouse occurrence was known for two parts of the state within historical times. The last records on the island of Rügen dated from 1960 and in north-west Mecklenburg (at the border to Schleswig-Holstein) the species was recorded in 1906 for the last time (summary in Büchner 2012). An active search was conducted on the island of Rügen from the year 2000 on and in north-west Mecklenburg from 2007 onwards. The hazel dormouse was confirmed in both regions, in total for 13 10X10 km grid cells (2018 report). There are nearly no records by chance and no volunteers are involved in the search. The mapping is done by consultants hired by the state conservation agency and by staff of the biosphere reserves. The chosen methods are searches for gnawed hazel nuts and left summer nests in late autumn. Single sites in the two involved biosphere reserves are equipped with nest boxes that were also used as monitoring sites for the parameter population.

In **Lower Saxony**, to determine the current distribution of the hazel dormouse, extensive research has been carried out in the ATL from 2015 on. This included interviews with nature conservation agencies, forestry authorities and wildlife experts as well as an analysis of survey reports and wildlife databases. In a follow-up survey, a hazel dormouse expert installed nest boxes and tubes in areas where the occurrence of the species was considered to be likely based on the review of previous records. Survey areas comprised five sites. None of these field surveys found any evidence of hazel dormouse. The database of Lower Saxony held only five entries of the species recorded during the last 20 years, none of which turned out to be reliable when critically checked. Further, no hazel dormice have been found in other surveys in the ATL of Lower Saxony, e.g. during environmental impact assessments prior to construction projects. In summary, to our current knowledge there is no recent and firm evidence of the present occurrence of the species in the ATL region of Lower Saxony; hence the status of the species is classified as unknown. Old data, however, suggest two main areas of (former) distribution. The northern one follows the river Elbe close to the city of Hamburg. The southern one is adjacent to the CON. Only further south in the hills and mountains in the CON the species is present. Although detectability of this species is rather difficult, the complete lack of reliable occurrence data over such a long time suggests that only small and isolated populations might remain. However, a big unknown is the historic distribution of this species in the ATL of Lower Saxony in terms of whether the apparent distribution gaps are the result of disappearing local populations, or a reflection of the natural distribution of this species.

In summary, we can state that searching for vacated empty summer nests along the inner and outer edges of forests and hedgerows, in shrubs under power lines, railways and comparable linear habitats has a high potential to reconfirm known populations or to fill gaps in the distribution map rather quickly. The best time for mapping nests and nuts is late autumn, but nests can be found even until the end of winter. However, this method cannot be proposed as standard method for consultants! Only well-trained people have chances to spot the nests. But the search for nests and nuts can be a reliable, quick and cheap method on the large scale of 10x10 km grids for range. It does not work in all habitats and is therefore not applicable for small scaled distribution data and it is not possible to get absence data!

Putting together the data for the northern parts of Germany, large gaps in distribution between the small regions are obvious (Fig. 4:). The recent range is also only a part of a former much wider distribution. However, the reasons for this decline still need to be further examined. Habitat fragmentation and loss seem to be the major threats for the hazel dormouse.

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5.3 Range data from Poland

Martin Ludwig & Mirosław Jurczyszyn

Only few occurrences of hazel dormice are known from northern Poland. Forest distribution maps show that around 1900 large parts of northern Poland were deforested. Reforestation began after World War II. A distribution map by Pucek & Raczyński (1983) shows few records along the Baltic coast (on the island of Wolin close to the border to Germany, close to the cities of Koszalin and Elbląg and at the border to the Kaliningrad region). In a current atlas of Polish mammals there are no records on Wolin and close to Koszalin (Atlas Ssaków Polski, http://www.iop.krakow.pl/Ssaki/gatunek/85). The record close to the city of Elbląg has been confirmed in recent years, but we do not know much about the size and range of the population. Two older records at the border to Kaliningrad Region from the 1960s and 1970s have not been confirmed in recent years, but there are new records on the eastern part of the border to Kaliningrad.

All localities were found by chance, as there are no mapping programmes or citizen science projects (nut hunt, online platform) in Poland. Sometimes foresters have knowledge about occurrences of the hazel dormice but they are afraid to reveal this because of possible restrictions on forest management. However, generally detection of hazel dormice does not lead to protection or minimize the risk of extinction.

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5.4 Methods and results of range mapping of the hazel dormouse (*Muscardinus avellanarius*) in Lithuania

Rimvydas Juškaitis

The hazel dormouse (*Muscardinus avellanarius*) is the most thoroughly investigated dormouse species in Lithuania. The number of localities of this species is continually increasing. While only 34 localities of *M. avellanarius* were presented in the book "Fauna of Lithuania. Mammals" (1988), these dormice were known from 161 10 x 10 km squares in 2018 (Fig. 5). The number of separate localities is even larger, exceeding 250. *M. avellanarius* are widely distributed across almost all of Lithuania. They live in mixed coniferous-deciduous forests, but not in pure coniferous forests. For this reason, localities for this species are lacking in south and south-east Lithuania, where Scots pine (*Pinus sylvestris*) forests prevail. The largest number of localities occurs in central Lithuania, where mixed forests grow, and dormice should be found here in every forest. Many blank areas occurring in Fig. 5 are only the consequence of lack of data. *M. avellanarius* should be found in about 500 out of 710 squares covering area of Lithuania.

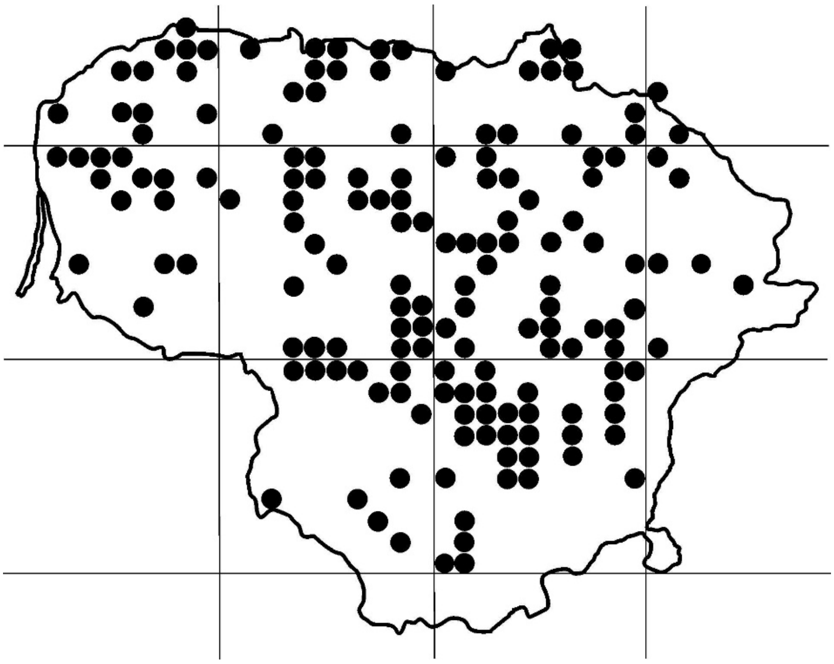

Fig. 5: Localities of *M. avellanarius* in Lithuania mapped on 10 x 10 km squares (n = 161) (Source: R. Juškaitis).

No special actions like the "Great nut hunt" were organised for search of *M. avellanarius* in Lithuania. Personal communications by both professional and amateur naturalists as well as by normal citizens provided the largest number of new localities of *M. avellanarius* (Fig. 6). More than quarter of all localities were found by the author of this chapter during field studies in different protected areas and ordinary forests. Some information on localities of *M. avellanarius* was found in publications including the internet (Fig. 6).

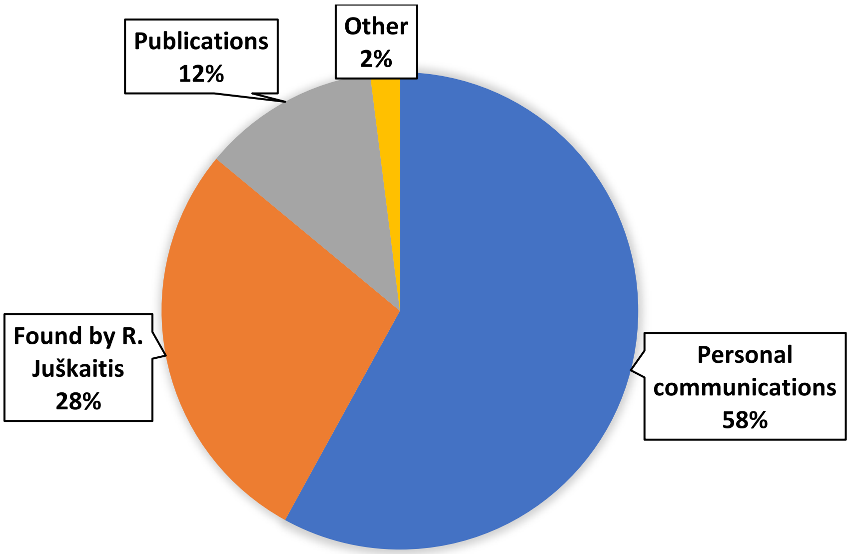

Fig. 6: Information sources on localities of *M. avellanarius* in Lithuania (n = 257) (Source: R. Juškaitis).

M. avellanarius willingly occupy nest boxes for birds. For this reason, the majority of localities of this species were detected during inspections of nest boxes by ornithologists, foresters and young naturalists (Fig.). Nest boxes were used for search of rare dormouse species in Lithuania, and *M. avellanarius* were also found in such cases. Many cases of observation of dormice in the wild (sometimes in buildings situated near forests) are rather surprising. Nests of *M. avellanarius* or hazelnuts gnawed by these rodents comprise a small proportion of all detections because use of these methods needs some special experience or confirmation by professionals. Nest tubes were not used for search of *M. avellanarius* in Lithuania until now. Remains of *M. avellanarius* were also found in Tawny owl (*Strix aluco*) pellets, but in already known localities, and for this reason they are not included in Fig. 7.

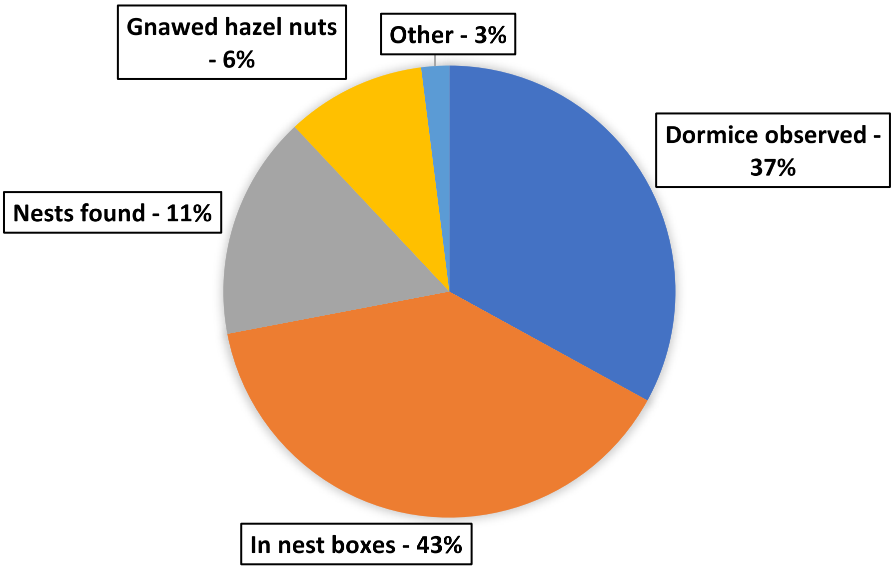

Fig. 7: Frequency of methods of *M. avellanarius* detection in Lithuania (n = 255). If dormice were found using different methods in the same locality, only the method of the first detection is included (Source: R. Juškaitis).

Searching for nests of *M. avellanarius* in regenerating clearings outside of the growing season would be the cheapest and most effective method for special mapping of *M. avellanarius* in Lithuania. This method could be combined with searching for hazelnuts gnawed by *M. avellanarius*, but hazel does not fruit every year in Lithuania.

5.5 Methods and results of hazel dormouse range mapping in Latvia with short remark about Estonia

Valdis Pilāts, Digna Pilāte & Uudo Timm

The first review of the distribution of mammal species including the hazel dormouse (*Muscardinus avellanarius*) within the area of present states Latvia and Estonia was made in 1909 (Grevé 1909). The author of this review was able to identify only 9 records of the hazel dormouse (Fig. 8). Knowledge about species distribution didn't improve significantly during the whole 20th century despite the attempts to collect data for national mammal atlases (unpublished) and for the European Mammal Atlas (Mitchell-Jones et al. 1999). In Latvia, data collection covered the period of 1990s, in Estonia 1980-1999. It involved mainly checking publications as well as inquiry, including personal communications, addressed both to professional zoologists and the general public. As the hazel dormouse is an elusive and nocturnal species, only a small number of accidental observations were collected in both countries (Fig. 8).

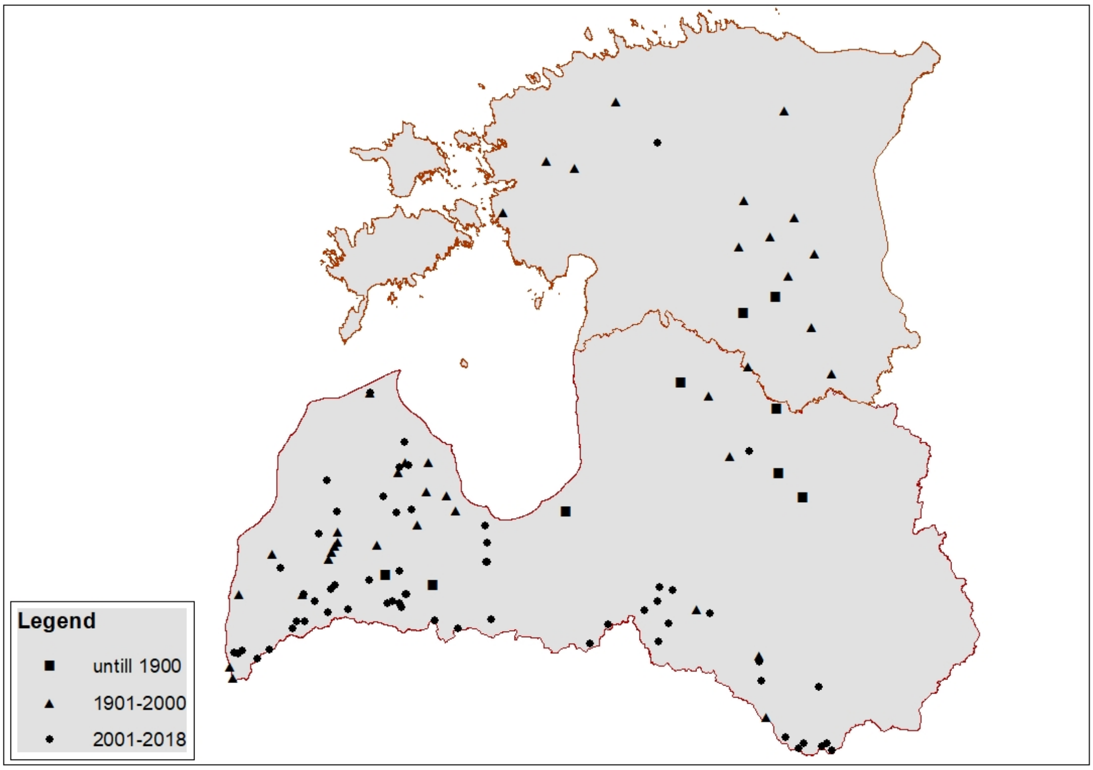

Fig. 8: Records of hazel dormouse in Estonia and Latvia (Source: V. Pilāts and U. Timm)

In Latvia, small scale dormice surveys were started in 2002 as part of mammal species inventories prior to the elaboration of management plans for protected areas (nowadays - Natura 2000 sites). Setting up nest-boxes was chosen as the main method to determine the species presence in a study area. During the surveys, nest-boxes are set out in small groups in habitats presumably suitable for dormice. Usually 5-10 nest-boxes are placed 10 to 30 metres apart in such a group. Until 2015, the nest-box method was applied in 20 protected areas and the hazel dormouse was recorded in 12 of them. A similar approach but on a wider scale was continued when the monitoring of hazel dormouse as part of the national biodiversity monitoring program was started in 2016. During the last 3-year period nest-box groups were arranged in 39 sites all over the country, mainly within the assumed range of hazel dormouse.

In Estonia two different survey methods: setting up nest-boxes (10 to 25 boxes in every place) and searching for summer nests were used to check the presence of dormice in localities where they were recorded previously (mainly in 1970-1980s). No results were obtained. Similarly, surveys with the nest-box method in all localities where hazel dormouse has been recorded accidentally, even recently, in north-eastern part of Latvia, i.e. outside the assumed range of hazel dormouse, did not produce any results.

The species range within Latvia was mapped for the first time in 2013 as part of reporting under Article 17 of the Habitats Directive for the period 2007-2012 (Fig. 9). The range was calculated based on the map of the species distribution using a standardised algorithm: the Range tool available on the Reference portal for reporting under Article 17 of the Habitats Directive (European Environment Agency). In general, the range of the hazel dormouse covers the western and southern part of Latvia up to rather large Daugava River in the north. The hazel dormice inhabiting SW Latvia most probably are part of metapopulation located to the south, including Lithuania where the species is rather common (Juškaitis 2008).

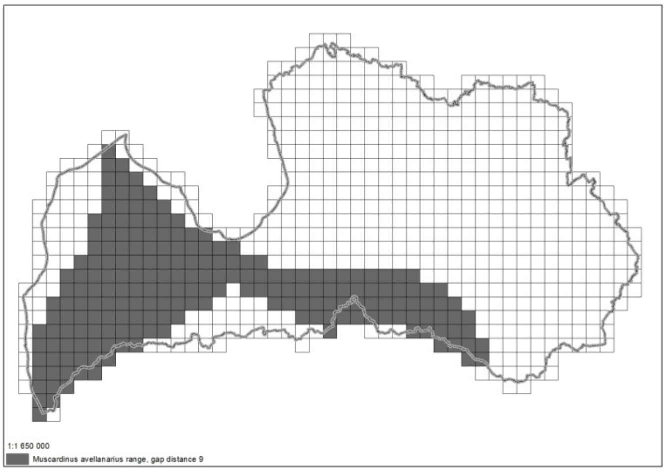

Fig. 9: Range of hazel dormouse in Latvia (Source: V. Pilāts (Range tool of European Environment Agency used))

The status of localities with hazel dormouse records in north-eastern Latvia as well as in Estonia is unclear. As such records altogether are rather numerous, it is hard to explain them by any kind of animal translocation. Most probably they are or were part of joint population inhabiting both a large part of Estonia and the adjoining region in NE Latvia (Fig. 8). We may speculate that this theoretical population was probably disjunct from the southern metapopulation for already a longer period. The negative results of surveys carried out might indicate that it is a vanishing or already vanished population.

The distribution of the hazel dormouse within its known range in SW Latvia also might be discontinuous. The wider gaps between known localities with hazel dormouse might be either due to lack of data or lack of suitable habitats, as the forests with a rich understory also are distributed unevenly. The existence of areas without hazel dormice is proved by unoccupied nest-box groups.

It is also uncertain if there are any trends in the species distribution/range in SW Latvia. If we would simply compare the species distribution maps between different time periods, we easily might come to the wrong conclusion. For example, both comparisons - the period 2001-2018 versus 1901-2000 (Fig. 8) and the period 2007-2018 versus 1994-2006 (Fig. 10 left side versus right side) indicate a general increase in the distribution area. Especially marked are difference between the last two periods which are indicated (DG Environment 2017) as such for evaluation of long-term trends for reporting under Article 17 of the Habitats Directive. However, the changes seen in the maps are misleading regarding the distribution of the hazel dormouse. They in fact reflect the distribution of survey activities, i.e. their results during the period 2001-2018. There are only a few localities or areas with recurrent records of the hazel dormouse. In consequence we cannot state for certain that the species has vanished in some localities where it was once recorded, nor that it has inhabited new areas.

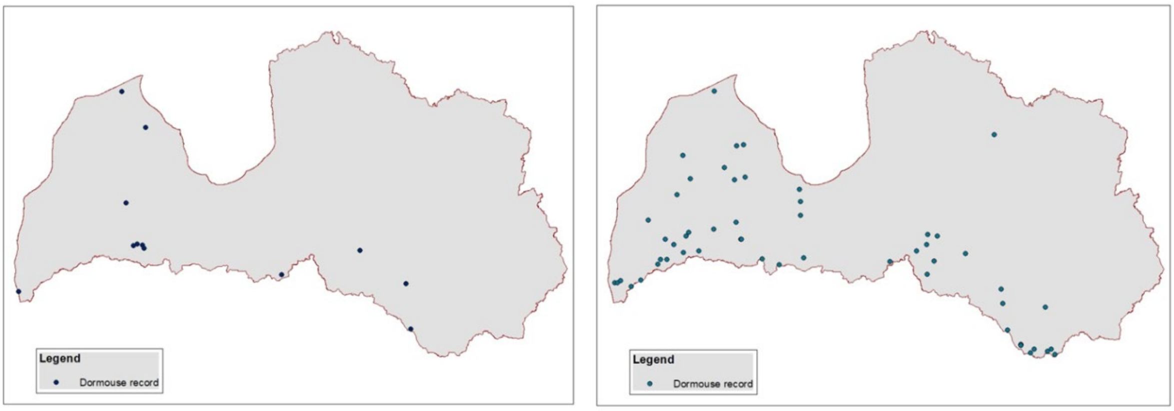

Fig. 10: Records of hazel dormouse in Latvia during different time periods: left – 1994-2006; right – 2007-2018 (Source: V. Pilāts).

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5.6 Methods and results of range mapping in Sweden

Pavel Bína, Julie Dahl Møller & Jeroen van der Kooij

In total, the range of the hazel dormouse in Sweden is estimated to be 63,200 km^2 (Fig. 11), of which 56,800 km^2 in the boreal and 6,400 km^2 in the continental region. The area of suitable habitat is estimated to be at least 20,000 km^2, of which 17,000 km^2 in the boreal and 3,000 km^2 in the continental region. According to the Swedish Forest Agency's statistics, there are about 55,000 km^2 of forest and shrub land in Götaland and Örebro county in the boreal region, and 80% of the land are areas larger than 50 ha.

Fig. 11.: Range of hazel dormouse in Sweden (10 x 10 km squares). Source: Artportalen (Species Observation System) https://www.artportalen.se.

The aim of this ongoing research is to test and compare different methods of investigating presence and abundance of the hazel dormouse. The field work has so far been carried out in three different areas of occurrence: in the north of Sweden (Örebro 2016), in the middle (Västra Götaland 2017) and in the southeast (Blekinge 2018). The following methods have been tested: search for nests in autumn, nut hunt, nest tubes, nest boxes (since 2017), camera traps and ink traps (2018). The 2018 results have not yet been fully analysed.

The camera traps consist of a camera and a food dish which are attached to a metal frame in order to keep the right distance and angle between them. The camera traps were baited with hazelnuts and sunflower seeds (2016 & 2018) or with a hemp seed mixture (2017). A sponge with hemp oil was also attached to each dish.

25 nest tubes, six wooden boxes, two camera traps and 12 ink traps were placed alternately in one transect. Searches for dormouse nests in the transect were conducted before and after the installation of tubes, boxes and cameras. Gnawed hazelnuts were searched for

under hazel bushes within the same locality. Both search methods were standardized and registered. Nest tubes, nest boxes, ink traps and camera traps have been checked with slightly different intervals each year, varying from once a month to once every other month.

There was no positive correlation between the number of nests found and search effort.

Camera traps were most consistently successful in detecting the occurrence of hazel dormouse, followed by nest tubes and nest boxes. Nest search was not conducted or not successful in about half of the localities due to the lack of bushes or a dense understorey in forests. The hazelnut search was the least successful of all methods due to poor hazelnut production and lack of mature hazelnut bushes at many localities.

Camera traps revealed the occurrence of hazel dormice within a few days in good localities and within one to three weeks on poor localities. Food competition from *Apodemus*-species and *Myodes glareolus* was severe. A comparison between traps with and without bait (but both with a hemp seed oil sponge) revealed that camera traps without bait produced more pictures, more events, earlier occurrence and an earlier dish entrance of the hazel dormouse while the opposite was the case for the other rodents. Furthermore, the reduction of non-target activity resulted in fewer pictures to analyse.

The data of this study will be statistically analysed when the field work has been completed.

5.7 Range mapping of hazel dormice in Denmark

Lene Bech Sanderhoff

The extensive monitoring of hazel dormouse in Denmark is part of the Nationwide Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments 'NOVANA, 2004' and is carried out by the Danish Environmental Protection Agency. The aim of the programme is to monitor the status and trend for selected plant and animal species encompassed by Annexes II and IV of the Habitats Directive, including hazel dormouse. Monitoring has been carried out every 6 years in 2004, 2012-2013 and 2018-2019. The methods are search for summer nests (2004) and using nest tubes (2012-2013 and 2018-2019). One occurrence of hazel dormouse equals one positive square in the Danish grid net of 10x10 km squares and the search stops.

In 2012-2013, the hazel dormouse did not occur in southern Jutland, and its range also decreased on Funen (Fig. 12.:). In this period, there was a slight increase in range on Zealand, but it is unclear whether this can be contributed to better monitoring methods.

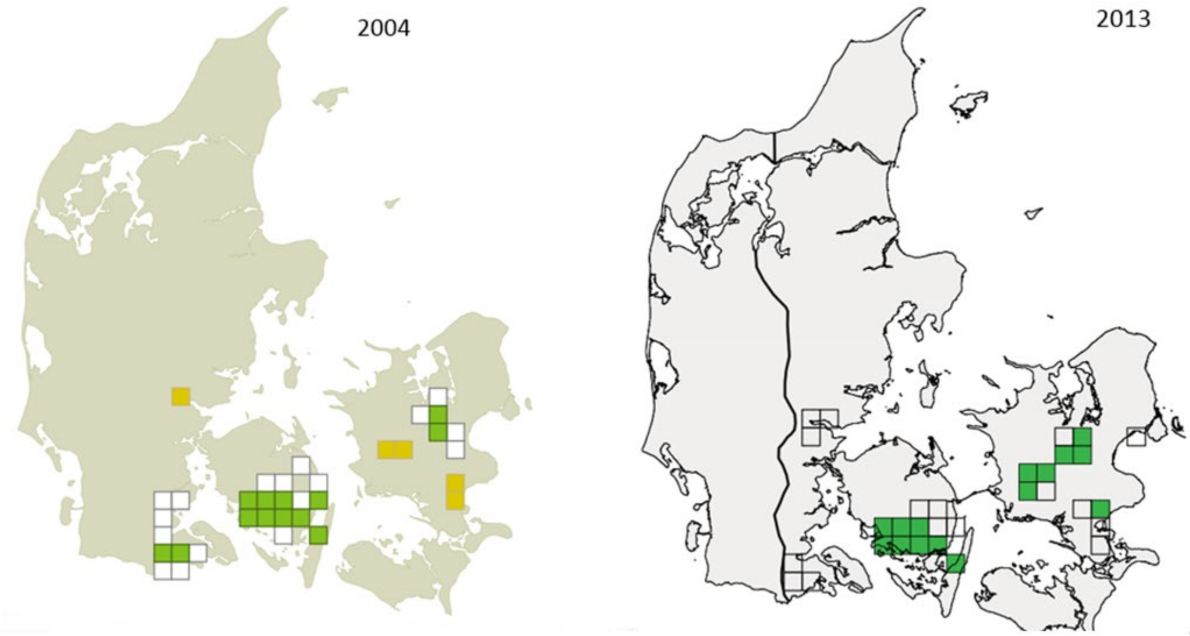

Fig. 12.: Results of range mapping in Denmark in 2004 and 2013. Empty squares indicate searches square without proof. Yellow squares indicate proof for the hazel dormouse between 2000 and 2003. Green squares on the left indicate proof for the hazel dormouse in 2004. Green squares on the right indicate proof for the hazel dormouse in 2012-2013. (Source: Søgaard el al. 2006, 2015)

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5.8 Outcome of the workshop sessions about assessing the range

Martin Ludwig, Pavel Bína, Melina Heinrich, Mirosław Jurczyszyn, Rimvydas Juškaitis, Nina Klar, Jeroen van der Kooij, Julie Dahl Møller, Birte Müller, Valdis Pilāts & Sven Büchner

The range status of a species assessed for reporting under the Habitats Directive can only be favourable if it is "stable (loss and expansion in balance) or increasing AND not smaller than the 'favourable reference range' "(DG Environment 2016). The favourable reference range is defined as the "range within which all significant ecological variations of the […] species are included for a given biogeographical region and which is sufficiently large to allow the long-term survival of the […] species; favourable reference value must be at least the range (in size and configuration) when the Directive came into force; if the range was insufficient to support a favourable status the reference for favourable range should take account of that and should be larger (in such a case information on historic distribution may be found useful when defining the favourable reference range); 'best expert judgement' may be used to define it in absence of other data.' " (DG Environment 2017)

Historic / potential range

The historic and / or potential range of a species are often used as reference parameters for conservation goals and claims. For example, the historic range (in 1992, when the Habitats Directive came into force) is part of the definition of the 'favourable reference range' used to assess the conservation status of the range reported under the Habitats Directive (see above).

However, for concealed species such as the hazel dormouse historic range data mostly come from rare by chance observations. Thus, at this workshop experts assumed that the actual range in 1992 was much larger than data from that time suggest. The interest of conservation authorities and the public in the hazel dormouse increased with the listing of the species in Annex IV of the Habitats Directive. Consequently, also the number of records and the knowledge on the range of the species increased.

The determination of the potential range of the species is especially difficult as the habitat requirements of the species are not yet understood in detail (see chapter 7.1).

Current range

Several methods to detect hazel dormouse presence are available. They differ e.g. in required expertise, labour, material costs and suitability for sampling in different habitats. The authors created a synoptic table comparing methods suitable for the detection of hazel dormice and the determination of its range (Table 2). These methods are described in detail in the literature listed in the last row of Table 2.

Even though several different methods are available, there is only little information on how a systematic range mapping for the hazel dormouse could be organised and how intensively a raster cell (e.g. the 10 km UTM Raster used for the Habitats Directive) needs to be searched until it can be treated as probably not occupied (but see chapter 5.1 and Schulz & Büchner 2018).

Table 2: Comparison of methods most suitable for detection of hazel dormice in order to determine the range of the species. The listed characteristics, remarks, and recommendations can vary e.g. between states (legal restrictions) and local circumstances (e.g. season).

	Nest boxes	Nest tubes	Nest search	Live traps	Nut hunt	Camera traps	Foot print tunnels
Time/labour expense	2 visits	≥ 2 visits	1 visit	≥ 2 visits	1 visit	2 visits	≥ 2 visits
Time between visits	3 months	2 months	Not relevant	In maximum 12 hours	Not relevant	5-10 days (good habitats) 10-45 days (poor habitats)	2 weeks
Season	Whole active season, with highest detectability in autumn	Whole active season, with higher detectability from August on	Whole year, but higher detectability in leafless state (autumn/winter)	Whole active season, with higher detectability from August on	Whole year (unless snow cover); best late summer and autumn	Whole active season	Whole active season, with higher detectability from August on
Distance between sampling units in a site	50 m	10 m	Not relevant	10-15 m	Not relevant	100 m	20 m
No. of sampling units per site	10-20	30	Not relevant	25	5 sample units	2	20
Acquisition costs per sampling unit	10-15 €	2 €	No costs	10 - 50 €	No costs	500 €[1]	2.50 €
Running costs (time / sampling unit)			30 min per site		5 x 20 min/site		
Adaptation	30 min	5 min		2 min		None	5 min
Installation	7 min	5 min		5 min		15 min	7 min
Checking	10 min	5 min		5 min		5 min	5 min
Post processing	5 min	5 min		5 min		60 min	8 min
Detection probability/site	High in most habitats	Intermediate; a thin shrub layer may lower detection probability regionally	Intermediate, depends on the site	Intermediate	Depends on the site and crop of hazel	High	High

[1] Cheaper camera traps are less reliable and often use white flash, which is not recommended for a nocturnal animal.

	Nest boxes	Nest tubes	Nest search	Live traps	Nut hunt	Camera traps	Foot print tunnels
Habitat types method is suitable for	All habitat types with stems that can carry nest boxes	All habitat types with enough understory to fix nest tubes	Habitats types with a dense shrub layer (forest edges hedgerows, regenerating clearings, …)	All habitat types with enough understory to fix traps; limited in crowded areas (disturbance and stealing of traps)	Habitats with hazel; most suitable in years with masting hazel	All habitat types, but limited in crowded areas	All habitat types with enough understory (with horizontal branches) to fix tunnels
Legal restrictions	Permit for checking	Permit for checking	No permit	Trapping permit	No permit	In situation where photos of humans may be produced a permit may be needed	No permit
Experience level	Intermediate	Intermediate	High	High	Low for collection of gnawed nuts; high for identification of gnawing traces	Intermediate	Low for trap handling; high for identification of foot prints
Usable for citizen science	No	No	No	No	Yes	Yes	Yes
Pro	Once installed, boxes can detect presence / absence for many years.	Low costs	No equipment costs; low effort; quick results	Quick results	No equipment costs; low effort	High detection rate, good data quality; quick results	Low equipment costs; quick results
Con	High effort for presence / absence; short suitable time in bushy habitats with regular coppicing		High level of experience needed	High level of experience needed; labour intensive	Only in habitats with hazel and in masting years of hazel	High acquisition cost; limitations in crowded areas	
References	Morris et al. 1990	Bright et al 2006	Berglund & Persson 2011, 2012	Berg & Berg 1999, Vogel et al. 2012, Verbeylen et al. 2017	Bright et al. 2006	Mills et al. 2016, van der Kooij & Møller. 2017, 2018, Stille et al. 2018	Mills et al. 2016, Bullion et al. 2018 ; Melcore et al. 2020.

There is no comparative range survey in the countries around the Baltic Sea yet. Therefore, expert assessments of the development and status of the range in countries around the Baltic Sea was collected at the workshop (Table 3). In summary, the expert assessment shows that the range is stable at the northern edge of the range, i.e. in the Boreal Region, with the exception of Estonia where the population may be extinct (see also Juškaitis 2018). In the Continental Region around the Baltic Sea as well as in the bordering Atlantic Region of Denmark and parts of northern Germany the range is shrinking or probably shrinking.

Table 3: Expert assessment on range development and status in countries around the Baltic Sea, Abbreviation for federal states of Germany: NI = Lower Saxony, SH = Schleswig-Holstein, HH = City of Hamburg, MV = Mecklenburg-Vorpommern

State	Range development and status
Sweden	In the Boreal Region the short-term trend is stable. In the Continental Region the short-term trend is declining. The long-term trend is unknown. Generally, the distribution in Sweden is well known, but there have been no surveys along the east coast around Stockholm. The large gap between the population in Skåne and the northern population leads to a high extinction risk for the population in Skåne.
Denmark	The range is probably shrinking. At the coast the situation is worse than in more continental regions. The southern Jutland population disappeared.
Germany **(only Schleswig-Holstein, Lower Saxony, Hamburg, Mecklenburg-Vorpommern)**	Generally, the range is shrinking or unknown in the northern part of Germany. (In SH the range is declining in the Continental and Atlantic Region. Several populations are isolated from the core population indicating a heavy decline from a once larger connected range. In NI the situation is largely unknown. It is assumed the population is declining in the Continental as well as in the Atlantic Region of NI. In HH the range is declining. In MV the situation is largely unknown. Recently populations in the north-west and on the Island of Rügen have been rediscovered.
Poland	Hazel dormice disappeared since World War II in the costal and western parts. On the central and eastern part the species is still present but no exact data are available.
Kaliningrad	No information is available.
Lithuania	The range is stable and the species is widespread.
Latvia	The range is stable. The distribution is unknown or mosaic type.
Estonia	Probably extinct

The experts agreed that the main reason for the shrinking range in the southern part of the Circum-Baltic States is habitat loss. This habitat loss is caused by historic deforestation and more recent removal of hedgerows in agricultural landscape. Additionally, climate change (mild winters, humidity, low snow cover, weather extremes) and fragmentation might affect the range of the species.

In general, the participants recommend that a comprehensive, systematic and internationally harmonized survey of the range of the hazel dormouse is advisable to receive more accurate data for range assessment in frame of the Habitats Directive. Also, for the protection of the species current and high-quality range data are needed (e.g. protection by restrictions for the use of certain rodenticides in the range of the species1). A joint project evaluating, comparing, and further developing methods of range mapping on a wide geographic scale might contribute to improve the knowledge on the range of the hazel dormouse in regions

[1] https://www.isip.de/isip/servlet/isip-de/regionales/llg-sachsen-anhalt/pflanzenschutz/pflanzenschutzmittel/konkretisierung-der-anwendungsbestimmungen-fuer-rodentizide-288712

with up to date poor knowledge on the range.

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6 Parameter population & trends

6.1 The German Habitats Directive monitoring and the evaluation scheme for the hazel dormouse

Martin Ludwig

Germany has to report the conservation status of 93 habitat types and 281 species spread over three biogeographical regions for its Habitats Directive report. The responsibility to conserve and evaluate the conservation status falls to the 16 German Länder (federal states). The national government has to provide one national report based on the assessments of the Länder. Therefore, the national government and the Länder developed a national harmonised monitoring plan (Sachteleben & Behrens 2010) and assessment matrix which describe how the degree of conservation of the habitats and species shall be evaluated on sample sites.

The monitoring plan schedules that for relatively widespread species and habitats data from 63 sample sites are collected per biogeographical region. For rare species with less than 63 known places of occurrence, all of these occurrences need to be sampled (total census). The assessment matrices define how the sampling at the sampling sites shall be performed. Box 1 shows an English translation of the assessment matrix for the hazel dormouse (BfN & BLAK FFH-Monitoring und Berichtspflicht 2017).

The first part of assessment matrix declares that in the Atlantic region all known occurrences shall be sampled (total census), while in the Continental region the species is relatively widespread and a sample of 63 sample sites is evaluated. In the alpine region, the species conservation status is assessed based on expert opinion considering all available data. Further below the assessment matrix describes details of the field methods.

The main part of assessment matrix is a table with listed attributes for each of three criteria “Status of the population”, “Habitat quality” and “Pressures”. For each attribute, value levels (A = Excellent, B = Good, C = Medium to poor) are defined, either by the definition of a numerical threshold value or by a text describing the value level.

For example, for the hazel dormouse for the criterion “Status of the population” only the attribute “Population size/Abundance” needs to be rated. Population size is rated by the “number of individuals per 50 boxes (evidence of individuals, food remains and nests)”. Population size is rated as “excellent” when evidence of ten or more individuals is found, it is rated as “good” when evidence of four to nine individuals is found and as “medium to poor” if evidence of less than four individuals is found. The relation of evidence of individuals per 50 boxes to population size and the thresholds were part of the discussion in the workshop (see Chapter 6.8).

In contrast to the criterion “Status of the population”, which is rated on one attribute only, the criterion “Habitat quality” is rated based on four attributes: “Size of uncut forest areas and adjacent woodland structures”, “Degree of coverage of fruiting trees”, “Degree of cover-age of fruiting shrubs” and “Average number of hollow trees or trees with nesting potential/100 m-transect length”. However, the attribute “Size of uncut forest areas and adjacent woodland structures” is not applicable to the situation of hazel dormouse populations in hedgerow landscapes, which can persist even without forests. The importance of fruiting shrubs and trees was also part of the discussion (see Chapter 7.1).

Box 1: Translated version of the Habitats Directive assessment matrix for the hazel dormouse: The German original is published in BfN & BLAK FFH-Monitoring und Berichtspflicht 2017

Hazel dormouse – *Muscardinus avellanarius*

Habitats Directive: Annex IV

Reference area: sample areas as "reference areas" with 50 boxes each on 10 ha in occurrence areas.

Habitats Directive-monitoring at federal level:

- Atlantic Region: total census
- Continental Region: sample
- Alpine Region: expert assessment at federal state level based on all available data

Period of survey:

- Population: at least two examination years per reporting period; two checks per examination year
- Habitat and degradation: once per reporting period

Method population size: The data are collected by nesting box controls (and alternatively by nest tubes, preferably in edge and hedge structures, for a method comparison see CHANIN & GUBERT 2011), which are attached individually to suitable structures at a height of 1-3 m protected from the prevailing wind. The evidence of individuals as well as food remains and nests will be evaluated as evidence. The locations should be chosen in such a way that the distance between the boxes is about 50 metres. Inspection twice per examination year in June and September. If possible, the same examination period (within 1-2 weeks) should be chosen for each examination year in relation to the respective sample area. As a basis for the determination of the relative abundance (number of hazel dormouse individuals in 50 nesting boxes), the control visit with the most hazel dormice encountered is chosen. If the results of the other control allow clear statements (based on sex and age of the animals) about the occurrence of other individuals, this is considered by appropriate addition. If the presence of other individuals is only probable (hazel dormice in areas further away), these are not added up.

Method habitat quality: Quantitative estimation of relevant habitat attribute on approx. 10 % of the sample area. To estimate the tree hollow density, a representative transect of 500 m is laid through the sample area and all visible tree hollows or structures suitable as nesting sites (e.g. protruding bark, ivy vines etc.) are recorded along this transect. The average number of trees with nesting potential on 100 m transect length is calculated from this.

Hazel dormouse – *Muscardinus avellanarius*			
Criteria/Value Level	**A**	**B**	**C**
Status of the population	**Excellent**	**Good**	**Medium to poor**
Population size/Abundance: Number of individuals per 50 boxes (evidence of individuals, food remains and nests)	≥ 10 individuals	≥ 4 to < 10 individuals	< 4 individuals

Box 1 continued

Hazel dormouse – *Muscardinus avellanarius*			
Criteria/Value Level	A	B	C
Habitat quality	Excellent	Good	Medium to poor
Size of uncut forest areas and adjacent woodland structures [1)]	≥ 40 ha	≥ 20 to < 40 ha	< 20 ha
Degree of coverage of fruiting trees	≥ 50 %	≥ 25 to < 50 %	< 25 %
Degree of coverage of fruiting shrubs	≥ 50 %	≥ 25 to < 50 %	< 25 %
Average number of hollow trees or trees with nesting potential/100 m transect length	≥ 5 trees	≥ 3 to < 5 trees	< 3 trees
Pressures	Excellent	Good	Medium to poor
Destruction of structurally rich forest edges, hedges and shrub layer (describe type and extent; evaluation as expert opinion with justification)	No impairments	Minor impairment (on < 5 % of the area)	Substantial impairment (on ≥ 5 % of the area)
Urban sprawl / fragmentation of habitats (e.g. by expanding settlement areas, roads and forest paths (describe type and extent; expert opinion with justification)	No impairments	Minor impairment (only marginal)	Substantial impairment (not only in peripheral areas)
Further pressures for *Muscardinus avellanarius* (expert opinion with justification)	None	Medium to low	Strong

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6.2 Descriptive, inductive, and power statistics as means for the optimization of hazel dormouse trend detection

Sabine Stab & Sven Büchner

Introduction

In Germany, monitoring and assessing the conservation status of the hazel dormouse in the framework of EU Habitats Directive is based on the regular count of animals in 50 nest boxes per site. The Federal States agreed to check nest boxes in at least two years per reporting period; with two checks per year (see chapter 6.1).

The Federal State of Hessen is located in the centre of Germany and hosting an important part of the hazel dormouse population. The sampling scheme in Hessen is more intensive than the minimum standard published in Bundesamt für Naturschutz (BfN) and Bund-Länder-Arbeitskreis BLAK (2017). Hessen monitors all 11 biogeographical subtypes in the state (all in the Continental Biogeographic Region).

Since 2006, the monitoring scheme in Hessen consists of a minimum of 24 and up to 40 sites originally selected because of reported hazel dormouse occurrence by volunteers or foresters. Most sites are revisited every year, others scarcer depending on the availability of volunteer support. It became clear in the first years of monitoring that there are no (more) hazel dormice occurring at some pre-selected sites. This resulted in a reduction in the number of monitored sites, so called zero-sites were excluded from the set. At the same time new sites were established, when a hazel dormouse occurrence was detected and skilled volunteers were willing to check the site. All sites were checked yearly in June and September.

At new sites, 60 nest boxes were put up, to have at least 50 nest boxes at each nest box check even if some boxes were damaged. Existing study sites established by volunteers with more nest boxes (some even more than 200) were also included. The abundance index for one year is then calculated as: Maximum detected number of hazel dormice on the plot / number of controlled boxes * 50.

The Explanatory Notes & Guidelines to the European Habitats Directive include a matrix for the general evaluation of parameters that need to be monitored and reported. Thus, a population monitoring programme should be sensitive enough to indicate a decline of 1% per year, respectively 6% per reporting period in the biogeographic region.

In this article, we briefly assess the output for long-term trend detection using the Hessen 12-yr-data set as an example, and outline a simplified optimization procedure based on the requirements of statistical data analysis and the Habitats directive alike. This is a straightforward approach suitable if resources for more sophisticated statistical analysis and modelling are lacking.

Table 4: Assessing the conservation status of the parameter "population" per biogeographic region within a member state (MS)

favourable ('green')	unfavourable - inadequate ('amber')	unfavourable - bad ('red')	unknown
Population(s) above 'favourable reference population' AND reproduction, mortality and age structure not deviating from normal (if data available)	Any other combination	Large decline: Equivalent to a loss of more than 1% per year (indicative value MS may deviate from if duly justified) within period specified by MS AND below 'favourable reference population' OR More than 25% below favourable reference population OR reproduction, mortality and age structure strongly deviating from normal (if data available)	No or insufficient reliable information available

Descriptive statistics as means for first data evaluation

The Hessen data set was first characterised by descriptive statistics calculating means, standard deviations, and a coefficient of variation (CV) for temporal and spatial variation separately (Table 5). The chosen dimensionless CV can be used as key indicator for comparison with other studies of the same or similar species, and as criterion in order to discriminate extraordinary, doubtful, or fragmentary data.

This first comparison reveals a much higher temporal variation (CV 0,8) of the counts in contrast to a mean spatial variation of 0,47 - clearly indicating that there are "good" and "bad" hazel dormouse years. The same holds true repeating the procedure for the September count data: mean temporal variation is 0,42, mean spatial variation 0,33.

When contrasted to other small mammal monitoring schemes, the calculated CV for temporal variation in the June count of adult hazel dormice appears to be comparatively high (see Table 6). As the CV´s for the complete count data (adults, juveniles, and offspring) are much lower, a first conclusion can be drawn: for long-term and time series evaluation of hazel dormouse data, counts of the full number of detected animals should be used. Because of the comparatively short life span of hazel dormice and their often segregated spatial distribution, every individual detected is important.

Table 5: Hazel dormouse abundance index (adults, June count) from Hessen/Germany, complemented by general statistical parameters for the comparison of inherent spatial and temporal variation (n = sample size, m = mean, sd = standard deviation, cv = coefficient of variation; bold: n, means of the parameters).

Year	plot 1	plot 2	plot 3	plot 4	plot 5	plot 6	plot 7	plot 8	plot 9	plot 10	plot 11	plot 12	plot 13		*spatial variation* n per year	m per year	sd per year	CV per year
2007	28.33	1.67				0.00				0.00			0.00		5	6.00	12.51	2.08
2008	2.24	0.00	4.17		1.64	3.57	4.92				1.61		0.23		8	2.30	1.79	0.78
2009	2.42	1.67	1.67		0.89	2.68	4.10	1.64	2.50		2.50		0.00		10	2.01	1.11	0.55
2010	2.38	0.85	12.71	3.53	0.00	3.57	2.46	3.45	1.69			9.62	0.00		11	3.66	3.99	1.09
2011	2.54	1.67	4.69		1.75	0.00	0.81	1.69	1.75			1.67	0.00		10	1.66	1.34	0.81
2012	16.38	8.33	4.84		2.63		2.42	0.00	3.57		2.17	4.17	0.92		10	4.54	4.75	1.05
2013	1.72	0.00	6.35		0.00	0.00	0.82	0.00	1.79	0.17		5.47	1.15		11	1.59	2.25	1.42
2014	6.45	0.83	6.67	4.12	0.00		4.10	2.50	3.45			4.69	0.00		10	3.28	2.43	0.74
2015	5.83	5.83	0.83	2.94	0.00	0.00	0.00	1.67	0.00	0.33	0.98	5.47	0.75		13	1.90	2.33	1.23
2016	4.10	1.67	2.63		0.78	0.00	1.64	2.54	7.02	0.00	2.00	8.33	0.00		12	2.56	2.70	1.06
2017	13.56	0.85	2.50		0.00	1.89	0.82	3.73	4.17	0.83	0.00	1.56	0.00		12	2.49	3.75	1.51
															11	**2.91**	**1.37**	**0.47**
n per plot	11	11	10	3	10	9	10	9	9	5	6	8	11	**13**				
m per plot	7.81	2.12	4.71	3.53	0.77	1.30	2.21	1.91	2.88	0.27	1.54	5.12	0.28	**2.65**				
sd per plot	8.38	2.59	3.41	0.59	0.95	1.62	1.69	1.32	2.00	0.35	0.92	2.84	0.44	**2.12**				
CV per plot	1.07	1.22	0.72	0.17	1.24	1.25	0.76	0.69	0.69	1.30	0.60	0.55	1.59	**0.80**				
												temporal variation						

Table 6: Average coefficients of variation (CV) of several systematic groups of animals monitored; N gives the number of studies involved (Gibbs et al. 1998, Gibbs 2000).

Group	N	Temporal variation (average C.V.)
Mammals, Large	17	0.142
Grasses and Sedges	16	0.209
Herbs,Compositae	9	0.213
Herbs, Non-Compositae	32	0.225
Turtles	7	0.333
Terrestrial Salamanders	8	0.354
Large-bodied Birds	25	0.363
Lizards	11	0.420
Fishes, Salmonids	42	0.473
Caddisflies	15	0.497
Snakes	9	0.541
Dragonflies	8	0.566
Small-bodied Birds	73	0.569
Beetles	20	0.580
Small Mammals	14	0.597
Spiders	10	0.643
Medium-sized Mammals	22	0.647
Fishes, Non-Salmonids	30	0.709
Pond-breeding Salamanders	10	0.859
Moths	63	0.903
Frogs and Toads	21	0.932
Bats	24	0.932
Butterflies	13	1.106
Flies, Drosophilids	13	1.314

As in many other wildlife species, variability of the data is high in hazel dormouse counts and field work is expensive, even when supported by volunteers. Two ways of controlling variability will be discussed: opting for the less variable of the two annual data sets, and optimize overall sampling effort during each reporting period in order to detect and test for trends if they are present.

Survey methods of rare and/or elusive species tend to be difficult or expensive (for a summary on this topic see Thompson 2004), and resulting count data might contain variation of different origin and show even contrary trends. This is the case also for the current data set from Hessen, as a first visualization of the field data for 6 of plots easily reveals (Fig. 13). The different plots do not show uniform changes over time, whereas for example the year 2011 obviously represents a “good” hazel dormouse year in nearly all the plots. This point often marks the limit of descriptive statistics: it is obviously not possible to state if there is an extinction process under way or not.

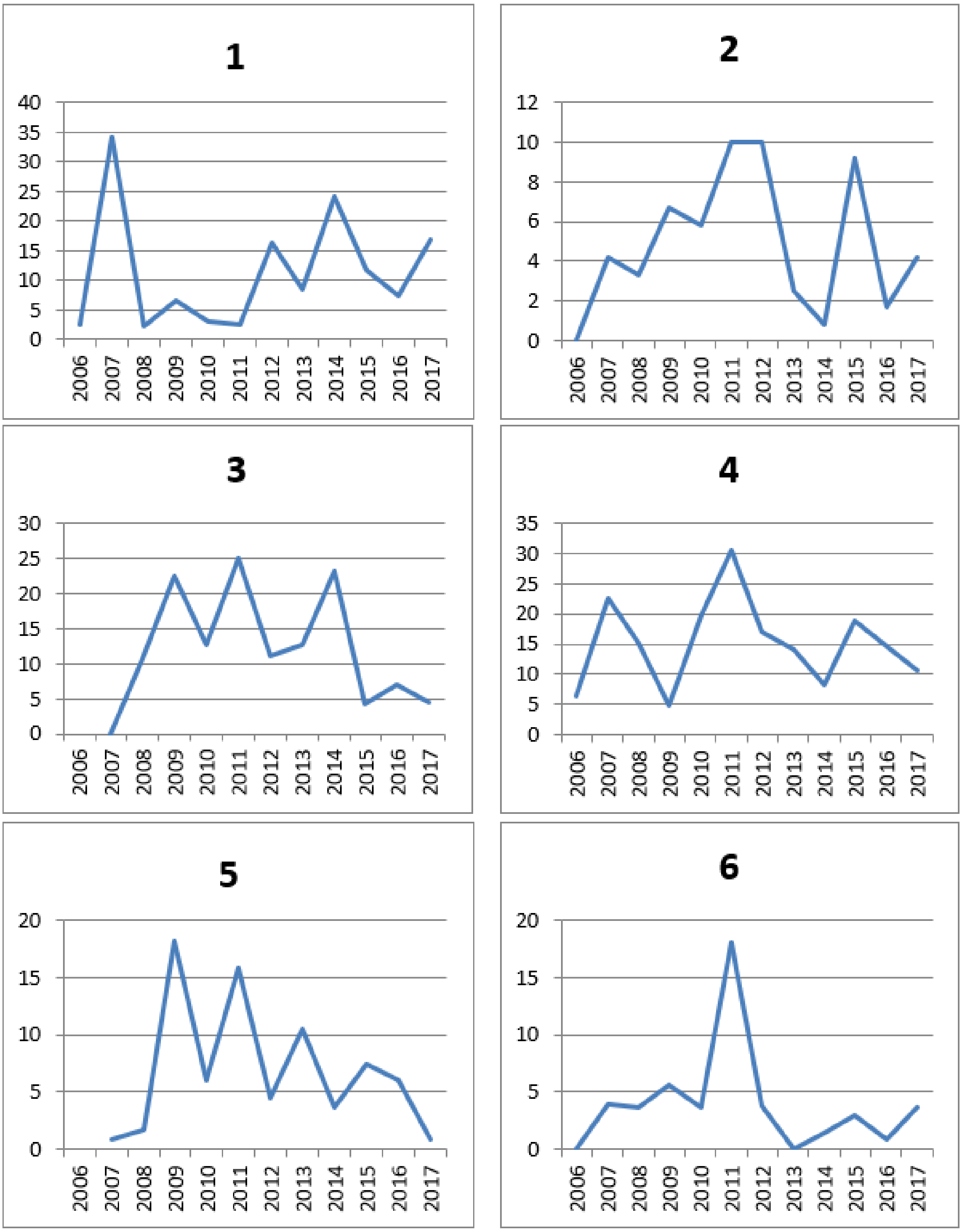

Fig. 13.: Example of 6 different plots showing partly opposing effects of time on the abundance index. (Source: S. Stab & S. Büchner).

Inductive statistics: Is there a trend in my data?

Although inductive statistics have long since become state-of-the-art in ecology (Low-Décarie 2014), application and reporting of hypothesis testing, in this case statistical trend tests against the null hypothesis of a stable population, in reporting for the Habitats-Directive in

Germany is still scarce. This is due to different sampling schemes in the different Federal States, the prevalence of abundance indices in field data, high sampling and evaluation costs, generally small or very scattered data amounts for most animal species included in the directive, and a generally lacking tradition of incorporating statistics in the sampling design planning of complex wildlife monitoring schemes. For general issues regarding the use of abundance indices, see Conn et al. (2004).

In order to come up with a simple and objective method of data evaluation available to every agency or consultancy, simple linear regression is further on applied to calculate and visualize population trends. The method is easy to use and ostensive, and there are many examples for a broad array of organisms to compare the results with. For a more detailed analysis of different approaches to detect population trends, see Bart & Beyer (2012).

The Hessen data were used to derive short (6 years) and long term (12 years) linear trends from a set of 14 plots, visualized in Fig. 14 including the central regression parameters. Both data sets fail to reject the null hypothesis of a stable population (t-Test of r, alpha = 0.05), although the decline taking place in the last 6 years is visually detectable. This is a common problem in wildlife biology: the “signal”, a declining population trend, is hidden behind too much “noise”, i.e. data variability, often combined with small sample sizes.

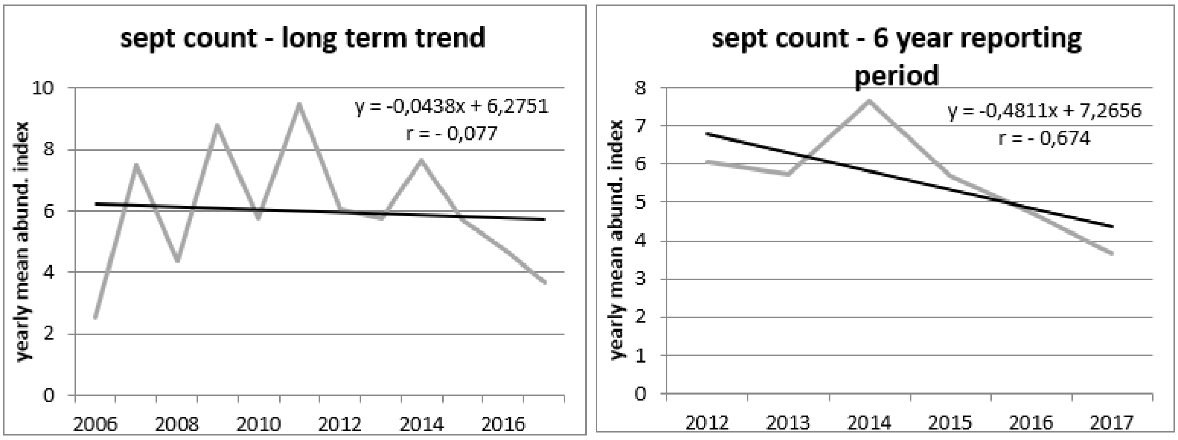

Fig. 14.: Long term vs. reporting period trend. (Source: S.Stab & S. Büchner).

Additionally, Fig. 15 reveals that two examinations per 6-year reporting period provide anecdotic results for hazel dormice, at least on the Federal States level: would the years marked with the bright blue points have been chosen, a rising population would have been deducted for Hessen, the blue marked years a declining population, and the black ones a constant one. Taking the fact of occurrence of “good” and “bad” hazel dormouse years into account, it becomes instantly clear that this finding will be aggravated by the fact that the reporting years differ between the Federal States in Germany.

In this context it is important to remember that despite the chosen statistical test for trend detection, there are general relationships between the quality of field data and the ability to detect trends:

1. data with higher variation will lower chances to detect trends,
2. the higher the variation, the more plots and/or years of observation are required,
3. only very precise data or huge data sets with many plots and long-time series will enable

the detection of small rates of change (i.e. 2 % per year).

Especially the third point is essential for Habitats Directive monitoring and nature conservation: one reporting every 6 years revealing e.g. a 10% yearly decline might be too late to sound the alarm: far over 50% of the population is already lost at the time when the report is published in year 7. Legitimately, the aimed precision of the hazel dormouse monitoring is therefore required to be 1% per year.

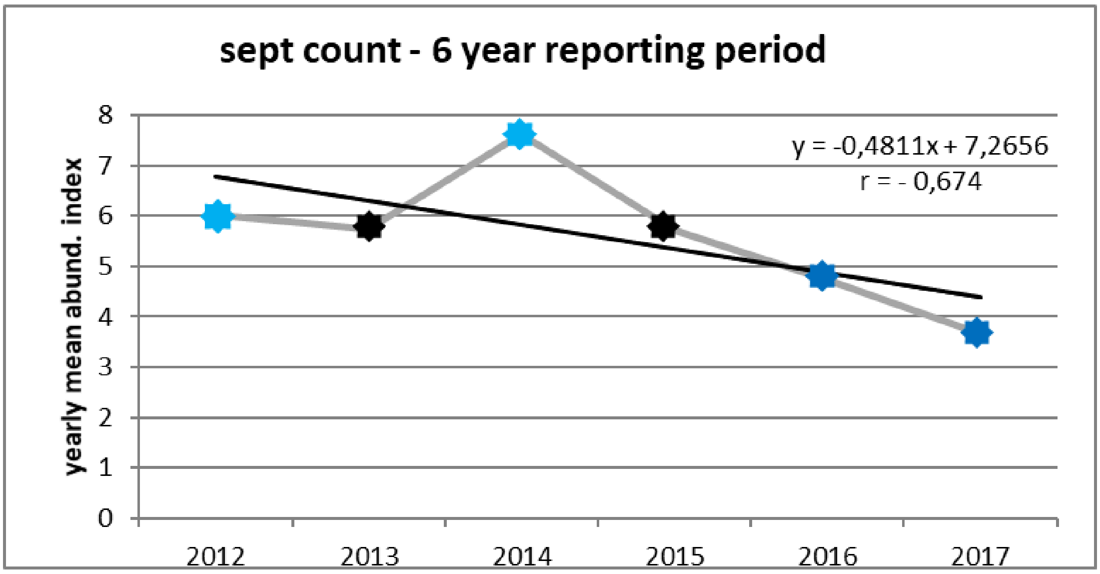

Fig. 15.: Effects of single year selection on result (bright blue: 2012 & 2014 chosen, blue: 2016 & 2017 chosen, black: 2013 & 2015 chosen, explanation: see text). (Source: S.Stab & S. Büchner).

Power statistics – post-hoc or retrospective: Why did the trend test fail to detect the visible trend?

Wildlife data are highly variable, and the high cost of field work inhibits high sample sizes: the two main reasons behind weak data for detecting population trends. The statistical quality of a time series can be tested and adjusted by power analysis, thus levelling the ratio between the alpha and beta errors (see Cohen 1988 for a detailed description of the method, and Taylor & Gerrodette 1993, Lewis 2006, and Flesch & Steidl 2006 for typical applications in wildlife monitoring). A power level of 80%, equalling a beta error of 0.2 whilst allowing for a standard alpha error of 0.05, is currently accepted as standard (di Stefano 2003, Christensen & Ringvall 2013) and therefore applied in the present study as acceptable quality level.

Several statistical software packages offer power analyses based on simulation procedures, e.g. G*Power, Pass, or GenStat. The freewares MONITOR (Gibbs & Ene, 2010) and TRENDS (Gerrodette 1987, 1991) are especially adapted for wildlife biology data sets and are a quick and easy alternative, if financial or human resources are missing to conduct more detailed research including maximum likelihood analysis of variability patterns and trend assessment using Generalised Linear or Additive Models. Current state of the art are routines written and shared in the R environment (www.r-project.org), their broad application in nature conservation being still hindered by a level of required statistical and programming knowledge which is hardly available at public administrations or agencies.

Retrospective power analysis of all Hessen plots counted in June (adult animals) revealed that only 7 out of the 13 plot time series had a power to detect trends of or above 80 %, even when the time span was reduced to the less variable period 2010-2017. In Fig: 16 typical examples of single plots are shown in contrast to the pooled data (black graph). The data of plot 11 are too scarce to detect a decline of even 10% per year, only an increase in the population of 8.5% or more per year could be detected. On plot 1 much better power is achieved: 6% per year in declining, 5.5% per year in increasing populations. Clearly, the value of long-term time series without missing values is illustrated: although this plot has a high temporal variation and reaches extreme values in single years (abundance index ranges between 1,7 and 16,4, resulting in a CV of 1), it can be used for statistical trend detection.

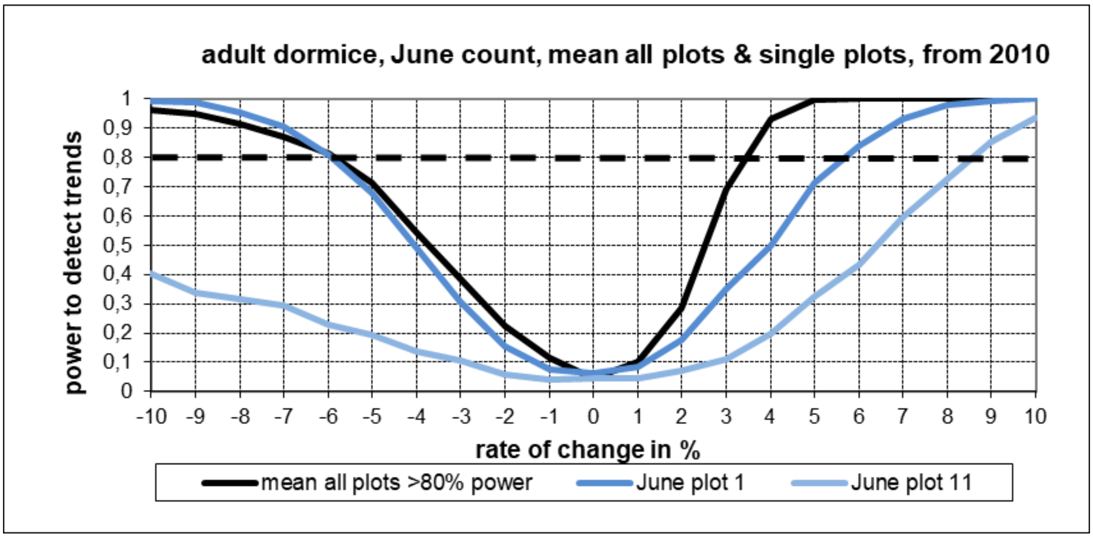

Fig: 16.: Power of single plots as compared to all plots over 80% power. The dashed line marks the 80% power level, its intercepts with the coloured graphs the detectable rate of change per year. (Source: S.Stab & S. Büchner).

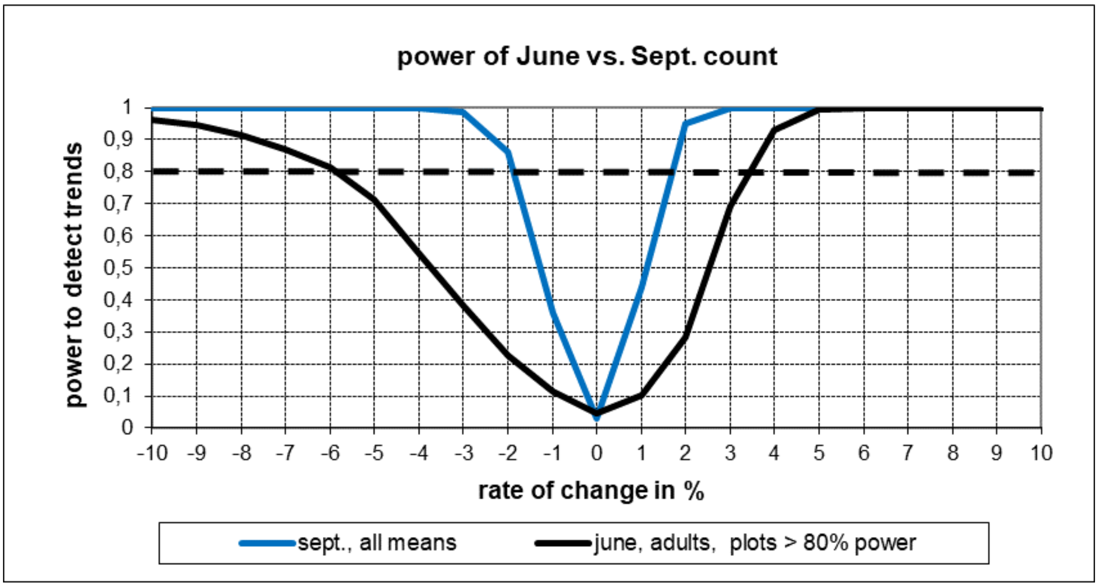

Fig. 17.: Retrospective power analysis: the September counts have the power to detect population trends of + / - 2 % rate of change per year. (Source: S.Stab & S. Büchner).

Contrasting the power level of the June counts to the September data (Fig. 17), the lower variability of the autumn data result in remarkably better performance towards trend detection: on the same plots changes as detailed as +/- 2 % per year could be detected. Variability can be controlled and trend detection facilitated by opting for the less variable data set, in this case the September count.

Power statistics – a priori or prospective: How can sampling design be optimized to enhance trend detection?

For enhanced planning and optimization another capability of power analysis is valuable: the prospective calculation of the needed sample size to reach a given level of precision, correlation, or power. As example for such an optimization process, we used the same data set to improve the ability of the sampling scheme to distinguish between "signal" and "noise".

Taking into account that in Germany the responsibility for nature conservation rests with the Federal States, we applied the prospective power analysis to the Hessen data. By eliminating the highly variable June counts, some additional sampling effort could be directed into the September surveys. How many plots would be necessary to sample in September in order to detect a 1% per year change of the Hessen hazel dormouse population within the reporting period of 6 years?

A simulation procedure is needed at this point, it was conducted using the freeware G*Power. Fig. 18 and Fig. 19 visualize the effects of the correlation coefficient r (strength of the correlation) and regression line slope (size of the effect over time) on the required sample size. The simulation process results in a needed sample size of 23 plots for Hessen to achieve the target value of 1%/year.

Further details need to be integrated, but as example for an optimization process it can be stated, that the overall sampling effort of the Federal State of Hessen could decrease from 26 plots per year (13 in June, 13 in September) to 23 in September, while the ability to detect a population decline would improve from 2% per year to 1 % per year.

For many other settings, tables showing the general relationship of power level and correlation coefficient r can be used to estimate the minimum required sample size (i.e. in Gatsonis & Sampson 1989).

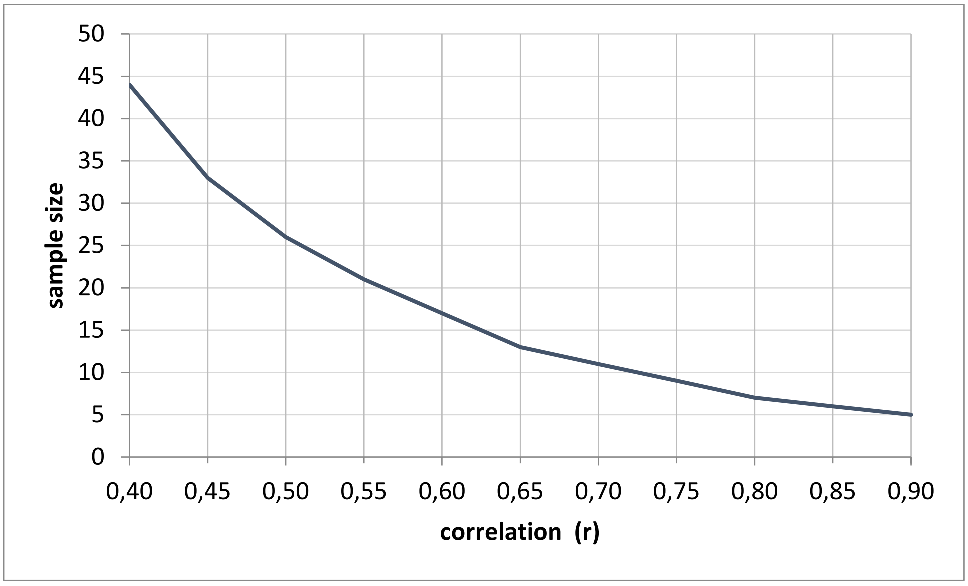

Fig. 18.: Effect of correlation coefficient r on the required sample size. (Source: S.Stab & S. Büchner).

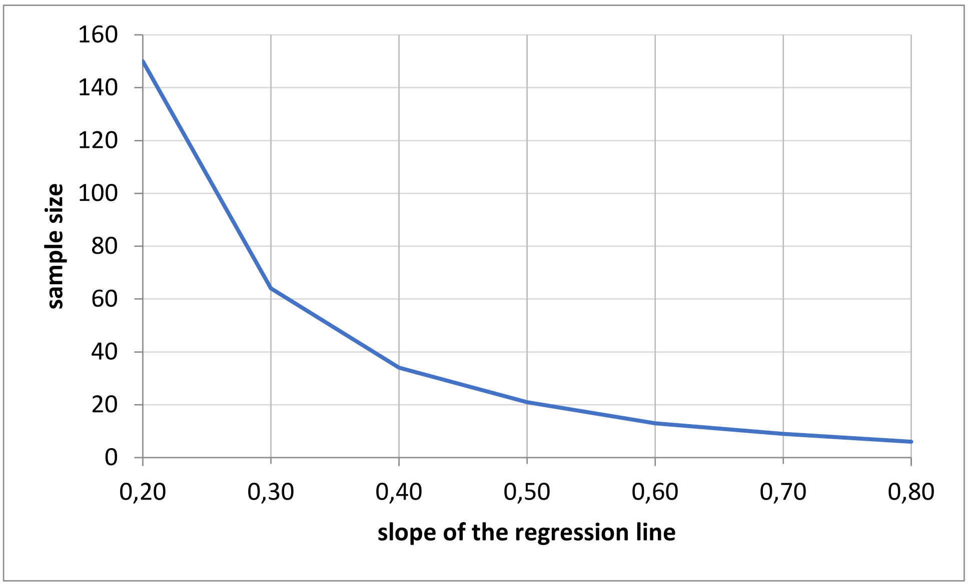

Fig. 19.: Effect of slope of the regression line (effect size) on the required sample size. (Source: S.Stab & S. Büchner).

Recommendations for a hazel dormouse monitoring

The monitoring method using regular nest box checks for hazel dormice has been broadly evaluated by Goodwin et al. (2017, 2018) in the framework of the UK National Dormouse Monitoring Programme (NDMP) (see also Sanderson 2004). As for today, the method of checking at least 50 nest boxes per site can be recommended. Important recommendations out of the statistical analyses are to check the nest boxes at least once a year in an optimal period of the season, to count all individuals and to include in the analyses only plots with a minimum of one adult hazel dormouse present and surveyed for at least 2 years.

The preliminary analyses in our study show comparatively high data variability and “reappearing” hazel dormice after several years with zero counts. As single juvenile hazel dormice may migrate further than 1 km from their place of birth (Juškaitis & Büchner 2013), sub-optimal habitats could be inhabited from time to time when individuals immigrated from source sites. Sites depending on immigration are not suitable for monitoring. Additionally, edge effects have to be considered, too. Juškaitis (2008a) found in a 50 m nest box grid that adult female hazel dormice travelled to nest boxes in distances up to 250 m and adult males up to 500 m. Shifts in the nesting sites depend on population densities and habitat changes (e.g. because of forest management or succession) (Juškaitis 2008a & 2008b). Thus, monitoring sites should be as large as possible, also in order to reduce variability. Juškaitis (2008a) emphasized the influence of a high nest box density on a hazel dormouse population. If nest boxes where put up in a 25 m grid, hazel dormouse population parameters were influenced with an increased hazel dormouse abundance while a nest box grid of 50 m distance between boxes gave more accurate characteristics of the hazel dormouse population (Juškaitis 2006). Thus, 50 nest boxes in a 50 m grid seem to be a minimum for monitoring sites. However, we suggest a thorough analysis regarding the size of the plot, number and allocation of the boxes (like 4 sites with 25 boxes in comparison to one site with 100 boxes). Subsequently, it would be helpful for comparing the data around the Baltic Sea if the setup guidelines for the plots could be standardized in order to facilitate trend detection on the European level.

Further research is also needed to evaluate if the 50-box-abundance index reflect changes in populations properly, detailed studies investigating the type and strength of correlation between population size and the nest box abundance index out of2 or 1 check per year are still missing. For a general monitoring scheme, we therefore suggest that further investigation into that point, ideally including different typical hazel dormouse habitats and densities, be carried out including a doublecheck of population size through mark-recapture or similar methods.

A statistical framework for data evaluation, testing for linear trend, and optimization of trend detection is outlined, taking into account the aims and standards of the Habitat directive as well as the difficulties of monitoring rare or elusive species.

In the Habitats Directive monitoring framework, the required precision of reporting, and thereby sampling effort, is inevitably high. This is due to the fact that most species included are endangered - with constantly lower detection rates in case of decline, and/or elusive. At the same time, monitoring effort is financially depending on restricted public funding, and in Germany is led under responsibility of 16 different Federal States. Under these conditions, quick and easily applicable methods for field data evaluation and sampling design optimization are required, taking the main sources of variability into account. A stepwise and thorough continuous process of method evaluation and optimization in close cooperation to species experts needs to be applied.

In recent years, occupancy modelling in the R environment has gained significant meaning in the ecological monitoring literature (Bailey et al. 2013). The combination of range and population size parameters in occupancy modelling is highly interesting for the time when the Habitats Directive monitoring will be methodologically evaluated and eventually updated.

Acknowledgements

This work benefited from the manifold expertise and fruitful discussions throughout the workshop. We are grateful towards Hessian Agency for Nature Conservation, Environment and Geology and the field data collectors to allow the use of a 13-year-data set as indispensable prerequisite for the outlined optimization process of sampling design and trend detection at the interface between field data survey and assessment.

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6.3 Long-term data on abundance dynamics of the hazel dormouse (*Muscardinus avellanarius*) population in Lithuania

Rimvydas Juškaitis

Long-term studies of the hazel dormouse (*Muscardinus avellanarius*) population were carried out at 'study site A' in Lithuania from 1984–1990 and from 1999–2018. In the area of 60 ha, 272 wooden nest boxes intended for small hole-nesting birds were spaced in a grid system at 50 meter intervals between boxes. Nest boxes were checked twice a month from April until October. All dormice caught were marked with aluminium rings, they were weighed, and their sex and age determined. Over the entire study period, 4,440 individuals were marked, and dormice were handled 13,344 times.

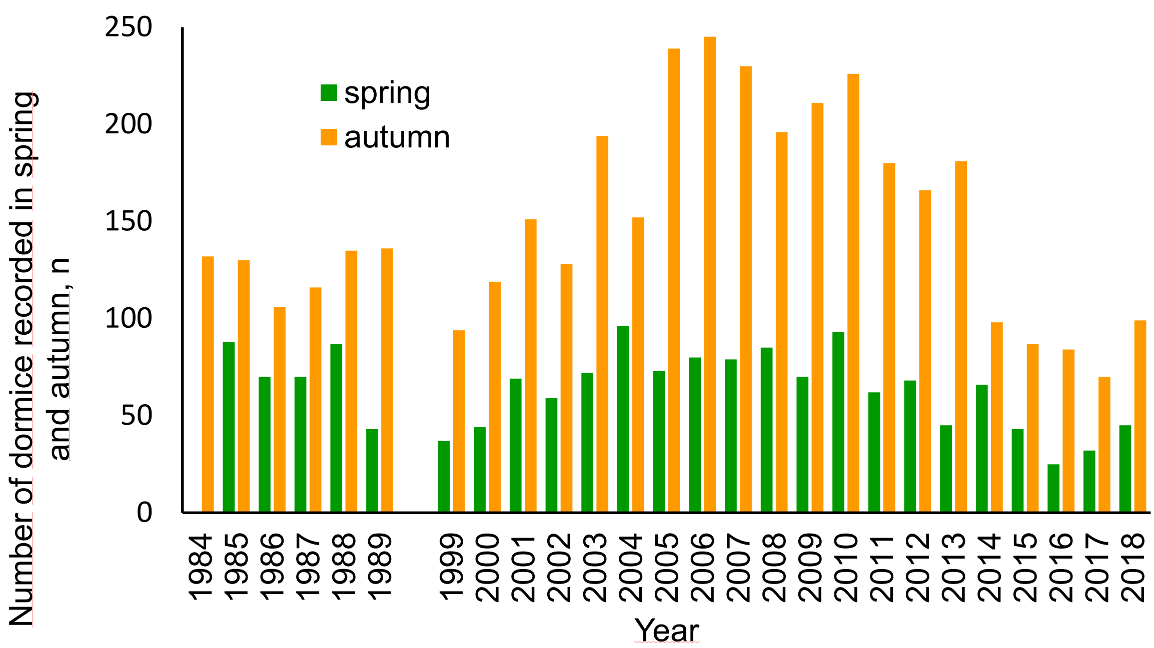

Fig. 20.: Dynamics of numbers of marked *M. avellanarius* recorded at 'study site A' in spring and autumn from 1984–1989 and from 1999–2018 (Source: R. Juškaitis).

The abundance dynamics of the investigated *M. avellanarius* populations was comparatively smooth, i.e. the numbers of dormice recorded usually differed no more than two-fold in two successive years. The average population density was about 1 ind./ha in spring and about 3 ind./ha in autumn over the entire study period. Population abundance was moderate and rather stable from 1984–1989 and from 1999–2002, increased from 2003–2013, and decreased from 2014–2018.

Various forest management operations, including clear-felling, were carried out by foresters in the area of the study site. Most of these operations have some short-term negative effect on dormouse habitats and dormouse abundance, but the affected plots became even more suitable for *M. avellanarius* after few years. Clear-felling destroys dormouse habitat completely, but regenerating clearings situated on fertile soils are very attractive for *M. avellanarius*, and dormouse density can be much higher there than in surrounding forest areas. In general, forest management practice, particularly small-scale clear-felling, is favourable for this species in Lithuania.

Increased winter and summer mortality, an unfavourable sex ratio, unbalanced population age structure and low reproduction success are factors that can cause a decrease in dormouse population size. When abundance decreases below a critical threshold, it is difficult to restore it. It may take many years for a depleted population to reach its former size. This happened for the *M. avellanarius* population investigated in 2014, and period of decreased abundance continues until now (Fig. 20). In small dormouse populations, such decreased population density together with an unfavourable sex ratio can cause the extinction of these populations.

6.4 Counting hazel dormice on sample sites in Mecklenburg-Vorpommern – results and challenges

Sven Büchner & Kristin Zscheile

The German federal states have agreed to carry out population monitoring within a monitoring program on 63 sample sites in the continental biogeographic region of Germany (BfN & BLAK 2017). Because of the lack of records at the start of this this program, none of the 63 sample sites were located in the federal state of Mecklenburg-Vorpommern. After the first observation of hazel dormice were recorded there, a monitoring for Mecklenburg-Vorpommern was developed and three sites (two in north west and one on the island of Rügen) were established in 2011. Recent records were the precondition for these sites. On each site, 55 wooden nest boxes were put up with a 25 mm diameter entrance facing the tree trunk. The boxes are spaced in a grid of 50 meters and are inspected by the staff of the biosphere reserves yearly in June and September for the presence of hazel dormice.

The number of hazel dormouse individuals recorded on the sites were low (Table 7). In several years, only nests were found in the nest boxes.

Table 7: Index of hazel dormice per 50 nest boxes at monitoring sites in Mecklenburg-Vorpommern between 2011 and 2018.

Site (region)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Schanzenberg (island of Rügen)	0*	7	3	0*	0*	4	1,7	0,8
Horster Holz (northwest Mecklenburg)	0,9	3,6	1,7	3,7	0,8	0*	1,7	0*
Bahrenkrogsrieth (northwest Mecklenburg)	-	-	-	0	0	0	0*	0*

*no individual was found, presence was determined by nests only

At one site (Bahrenkrogsrieth), the species was documented by vacated summer nests in 2013. Subsequently, a monitoring site was established in the following winter. The first use of the nest boxes by the hazel dormouse was only detected after four years, when a few nests were found in the boxes. No individual was recorded during the two checks per year so far.

These data are difficult to interpret. All three sites in Mecklenburg-Vorpommern represent ancient woodland with deciduous trees. The habitat features (woody plant species composition, age of woodland and age classes of trees, number of trees with natural hollows at these sites) are comparable to sites in central and southern Germany. However, in the south there are frequently much higher numbers, in some sites more than 20 ind./50 boxes although the same method is used (see e.g. Büchner et al. 2010).

The dataset of only three sites is too small to analyze properly. However, the differences are obvious. The very low numbers in individuals at the sites near the Baltic Sea may result from a more Atlantic climate as was shown in the UK (Goodwin et al. 2018). Small populations as well as populations with very low abundances at in high(er) risk of extinction (unpubl. data by Juškaitis presented in this workshop).

Further research is urgently needed on the correlation of hazel dormouse abundance with climatic conditions (e.g. data on snow cover, on days above 0°C in winter) interspecific competition for nest boxes and higher influence of anthropogenic pressures in small or lower density populations.

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6.5 Monitoring of the hazel dormouse in Latvia: concept, options and limitations

Valdis Pilāts & Digna Pilāte

The hazel dormouse (*Muscardinus avellanarius*) is a Red Listed and protected species in Latvia. It is also listed in the Annex IV of Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora. Therefore, special attention is required to the conservation status of hazel dormouse in the country.

The hazel dormouse is the most widespread of four dormouse species recorded in Latvia (Pilats 1995). At the same time, it is one of the less-studied mammal species in Latvia. The first assessment for the hazel dormouse was done in 2007 as part of reporting under Article 17 of the Habitats Directive for the period 2001-2006. It was based on sporadic data of mainly accidental records collected for the first Atlas of European Mammals (Mitchell-Jones et al. 1999) as well as for the unpublished National Mammal Atlas during 1990s. The monitoring of hazel dormice was started as part of the national biodiversity monitoring program in 2016. It follows guidelines given in the hazel dormouse monitoring program developed the same year (Pilāts 2016). An analysis of available information on hazel dormouse monitoring in other countries was an essential step in the design of our monitoring program.

Our hazel dormouse monitoring program can be considered as a scheme for data collection on species distribution, population demographics, species habitat status as well as on pressures and threats that might affect the future prospects of the species. The main focus is on dormouse distribution within the country. First, the changes in distribution on local scale might reflect changes in the species' 'global' range. Secondly, shifts in distribution might gave the first notable signal of changes in the environment. Moreover, the exact distribution of hazel dormice within the country is still not known, as is the case for other dormouse species. There are "white spots" in the map of hazel dormouse distribution where species presence is quite possible.

As hazel dormice are arboreal, nocturnal and elusive animals, specific survey methods are needed to detect their presence. Searching for gnawed hazel nuts, use of nest-tubes or nest-boxes, use of hair tubes, summer nest searches and trapping are named as possible, but not always recommended, methods (Bright et al. 2006). Recently, camera traps and footprint tracking at bait stations are proposed as rapid-assessment, non-invasive methods to detect the presence of dormice (Mills at al. 2016). In Latvia, the use of nest-boxes has been proved as useful method for the survey of all dormice species (Pilāts et al. 2009). Therefore, the nest-box method is also recommended in the hazel dormouse monitoring programme as the main survey method. It is also probably a less labour- and time-consuming method for local conditions. The method involves the establishment of temporary small study plots with 5-15 nest-boxes in each in suitable habitats. Wooden nest-boxes intended for small hole-nesting birds with internal dimensions of 110 x 110 x 200 mm might be used for this purpose. Most appropriate is to put up nest-boxes in the spring and to check them in autumn to record any signs of dormouse activity. If the animal itself or it's nest is found, the nest-boxes might be removed for use in another area. It is recommended to leave nest-boxes in place for 3-5 years if there are no signs of dormice presence.

According to our monitoring scheme, areas with suitable habitat within the species' range but without positive records should be checked first. Natura 2000 sites within the species' range are also regarded as top priority areas for survey. The second level of priority is given to localities where the species was recorded before 2000. After this, all records or all 10 x 10 km squares with records must be inspected at least once every 12 years. This last level of data collection should allow the assessment of long term trends in species distribution, however, it is difficult to implement with limited financial resources.

The principal population parameters for species assessment are abundance of individuals, (estimated) population size, population structure (demographic and genetic) and population dynamics. Whilst the work plan for further hazel dormouse surveys is quite easy to develop, there is greater uncertainty regarding the monitoring of its population parameters. An open question is how many and how large study plots are necessary to give a representative sample size for the evaluation of population parameters. In the hazel dormouse monitoring program, it is also recommended to use nest-boxes to collect data on population parameters. In this case, a network of permanent study plots should be developed. Each study plot should consist of at least 50 nest-boxes placed in a grid system at 50 meter intervals between boxes. The checking of nest-boxes should be performed once a month from April to October or at least twice a season (in May and September). In this way, data on nest-box occupation can be obtained and used for the trend indices. The capture-mark-recapture method is recommended to determine the number of animals in a study plot.

It is expected that most effort will be needed to assess the area and quality of hazel dormouse habitat. No studies on habitat requirements of the hazel dormouse have been carried out in Latvia. It is generally assumed that the species mainly inhabits forests with a richly structured understory, especially of hazel shrubs. It can furthermore be found in dynamic habitats such as overgrown clearings if the density of fruiting shrubs is sufficient to provide appropriate living conditions for dormice. Unfortunately, the State Forest Register does not provide data about the understory nor on shrub species diversity in overgrown clearings. Baseline data on habitat quality might be obtained either from the state programme "Monitoring of forest resources" or by surveys based on remote sensing. The hazel dormouse monitoring program recommends first the research on habitat requirements of hazel dormouse and then the mapping of suitable habitats in study plots within the species range.

Finally, the hazel dormouse monitoring programme takes into account that resources allocated to monitoring activities are variable, and usually inadequate. It therefore distinguishes three possible levels of monitoring: minimum (covering almost only distribution aspects), basic (data obtained both for distribution and population) and maximum (additional mapping of habitats is carried out).

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6.6 Monitoring concept in Sweden

Pavel Bína, Julie Dahl Møller & Jeroen van der Kooij

The population density in the hazel dormouse in Sweden is estimated at 1 individual/ha in the boreal and up to 20-30 individuals/ha in the continental region. The numbers are mainly based on expert opinion (Boris Berglund and Christer Persson). The observation data are mainly coming from Artportalen (Species Observation System, www.artportalen.se, Fig 21), the website for observations of plants, animals and fungi in Sweden, with over 67 million observations (January 2019).

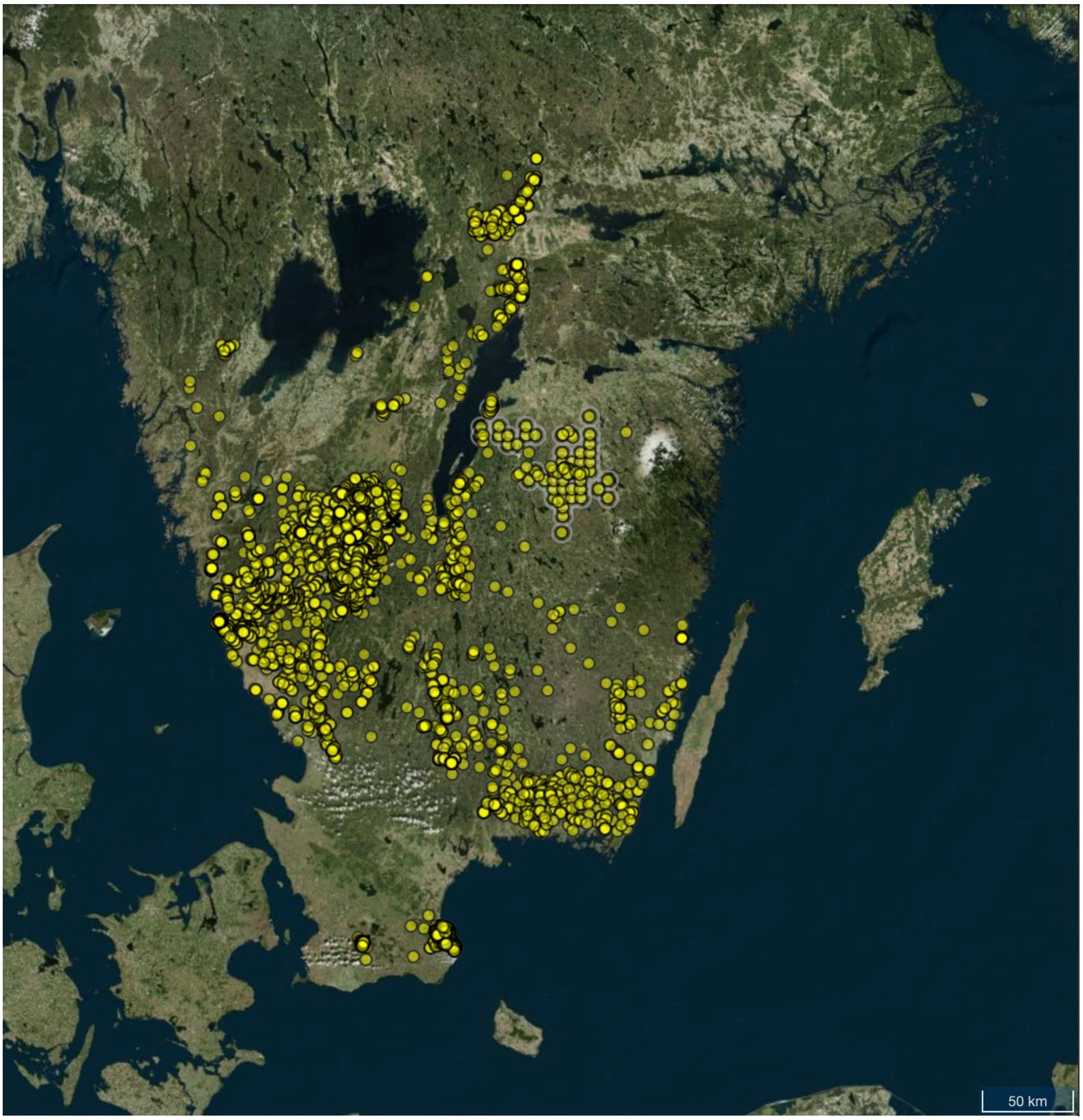

Fig 21.: Records of hazel dormouse in Sweden. Source: Artportalen (Species Observation System) https://www.artportalen.se.

Over 87% of observations in Artportalen are based on nest searches. This method has been used as the standard method for mapping and monitoring of hazel dormice in Sweden. 6% of observations in Artportalen are spontaneous reporting of animals. Nest searches should be compared with other methods to develop a standard methodology for the monitoring of hazel dormice in Sweden. With that, Sweden is preparing a monitoring scheme, and currently different methods are being compared.

Sometime it is possible to identify individuals from pictures of camera traps. From this, we know that some individuals move up to 100 m per night. Also up to 4 individuals could be identified on one camera. However, the possibilities to identify individuals are not good enough to estimate population size.

We investigate if any of the following methods are correlated and can be used to assess habitat quality and to follow population trends: nest search in autumn, hazelnut hunts, nest tubes, nest boxes, camera traps and foot print tunnels. A preliminary analysis of 2017 data indicates that there is a correlation between the number of nests found during nest searches and the number of camera trap nights with hazel dormouse. The number of camera trap nights with hazel dormouse activity is lower in poorer quality habitats.

To estimate an absolute population size, it would be necessary to differentiate between individuals photographed by the camera traps. However, a clear identification of all individuals is not possible. Nevertheless, one can differentiate between juveniles and adults. In addition, some animals show individual traits like tail reduction or scars on the ears. Ticks on the face are also clearly visible but can only be used within a small time frame.

6.7 Monitoring concepts in Denmark

Thomas B. Berg & Lene B. Sanderhoff

Besides the official monitoring scheme within the national NOVANA program, Naturama (the Natural History Museum in Svendborg) is conducting yearly surveys on a local hazel dormouse population on the island of Funen. The survey frequency as designed by the NOVANA programme offers very poor possibilities for detecting population trends. As short-lived species may fluctuate greatly in density within a relatively short time frame, a survey frequency of six years must at best be regarded as insufficient to detect reliable trends. Fig. 22 uses one dataset to show how the sample frequency of surveys can lead to highly different conclusions of trends in population density.

The southern part of the island of Funen in the centre of Denmark is considered one of the core areas of the hazel dormouse distribution in Denmark. Data from within a highly diverse forest area of approx. 470 hectares is collected from 23 small study sites ranging in size from 0.4 – 2.5 ha (Fig. 23). Here approx. 600 dormouse boxes are placed with a 25-meter distance between nest boxes. The first 300 nest boxes were placed in 2012 in areas that were expected to be highly suitable for dormouse and subjected to one yearly check for nest occurrence. The nests were divided into the following categories of species use: hazel dormouse, yellow necked mouse, bird, wasp, shrew and no-use. As of 2017, approx. 300 additional nest boxes were established, now also including areas with lower likelihood of dormouse presence. Areas covered by the 23 sites includes mature beech and oak forest (150 years old), young beech and oak stands (15-40 years old), mixed forests (50-80 years old) and within these areas grazed and un-grazed areas (by cattle), coniferous forest (20-70 years old) and Christmas tree plantations.

Small pilot projects using capture-mark-recapture (CMR) were conducted in 2015-2017 in selected sites. From autumn 2018, CMR studies were conducted in all sites and will continue as two survey campaigns each year in August and October. These two campaigns will provide data on reproduction, summer survival and density estimates, and will over the years be correlated with climate variables and nut availability. A planned Ph.D. study will add an additional survey in June in order to quantify the winter survival.

As the hazel dormouse is known to travel over relative long distances (100 m in radius per night) and up to one kilometre between years, the 23 study sites may most likely be considered as connected, as there are no significant barriers in between. Hence, variation in habitat between sites (and between years) is of minor importance as the various sites may act as source and sink sites. An example of year-to-year changes in nest occupancy among three neighbouring sites is shown in Fig. 24. Birds seems to slowly increase their use of nest boxes over the years, while the use by the hazel dormouse and the yellow-necked mouse varies more between years. One interpretation of Fig. 24 would be that both hazel dormice and yellow-necked mice benefited without delay from the establishment of the nest boxes, while it took some time for the birds to adapt, probably due to the position of the entrance hole at the back of the nest box oriented towards the tree trunk. After three years, the hazel dormouse occurrence in the nest boxes dropped, maybe due to the continuing increase of nest box use by the yellow-necked mouse, as yellow-necked mice are more dominant than hazel dormice. In 2017, nest box use by the yellow-necked mouse dropped, maybe due to density dependent effects giving the hazel dormouse a possibility to increase their use of nest boxes.

We all know that the hazel dormouse is affected by a number of variables, i.e. season-specific climate, season-specific food abundance, summer nest sites, winter nest sites, predators, forest management and human disturbance. All these variables may vary between years and many of them are intercorrelated (Fig. 25).

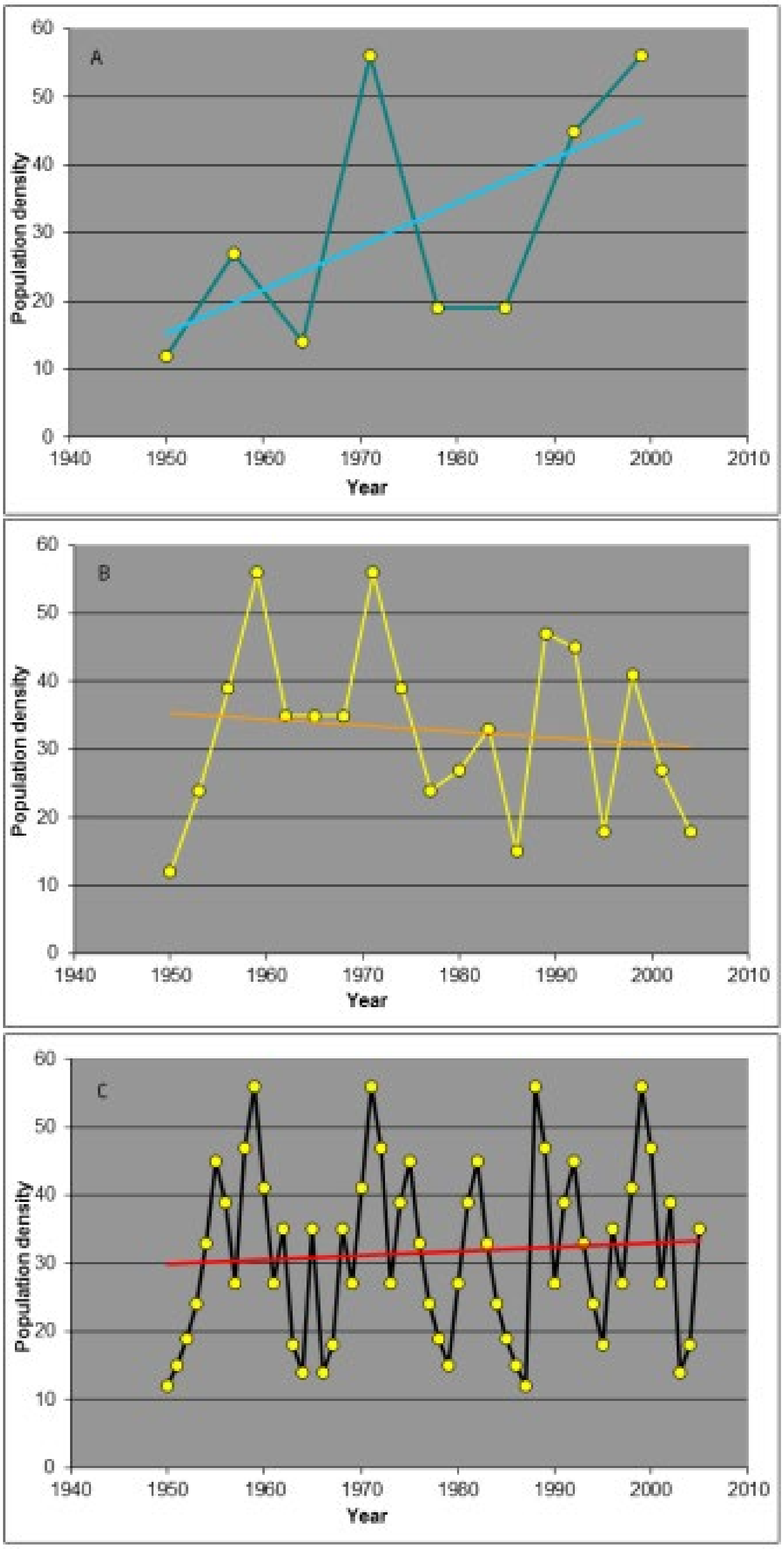

Fig. 22.: Three different outcome of population trends based on three different survey frequencies on the same data set. A: one survey every seven year. B: one survey every third year and C:one survey every year. (Source: T.B. Berg & L.B. Sanderhoff).

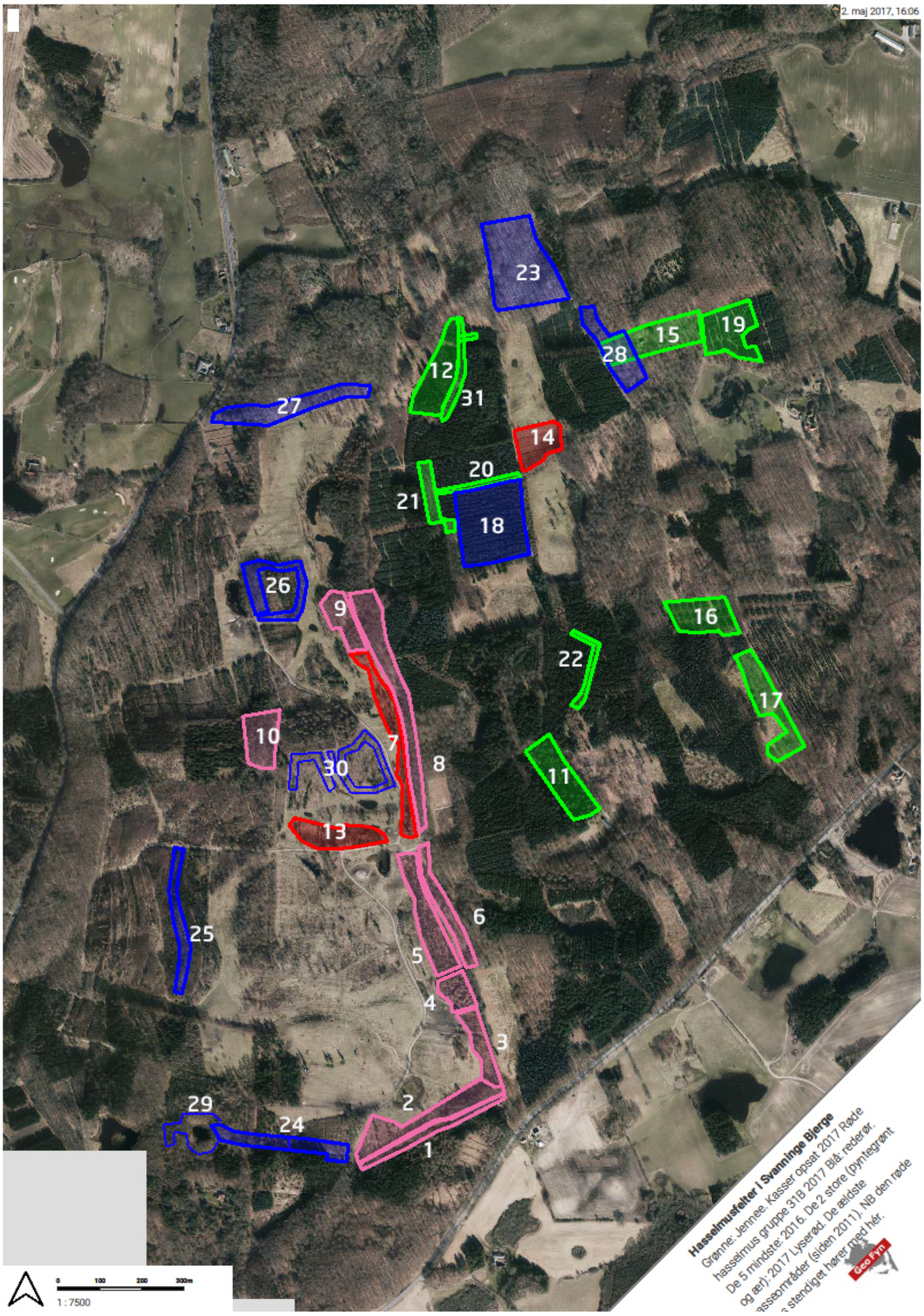

Fig. 23.: Study sites. Blue coloured sites (no. 18, 23-30) has only been surveyed by nest tubes one year each. All sites except no 18, 19 and 23 have provided positive data on dormouse occurrence. Sites 1-10 were established in spring 2012 and sites 11-17, 19-22 and 31 were established in spring 2017.

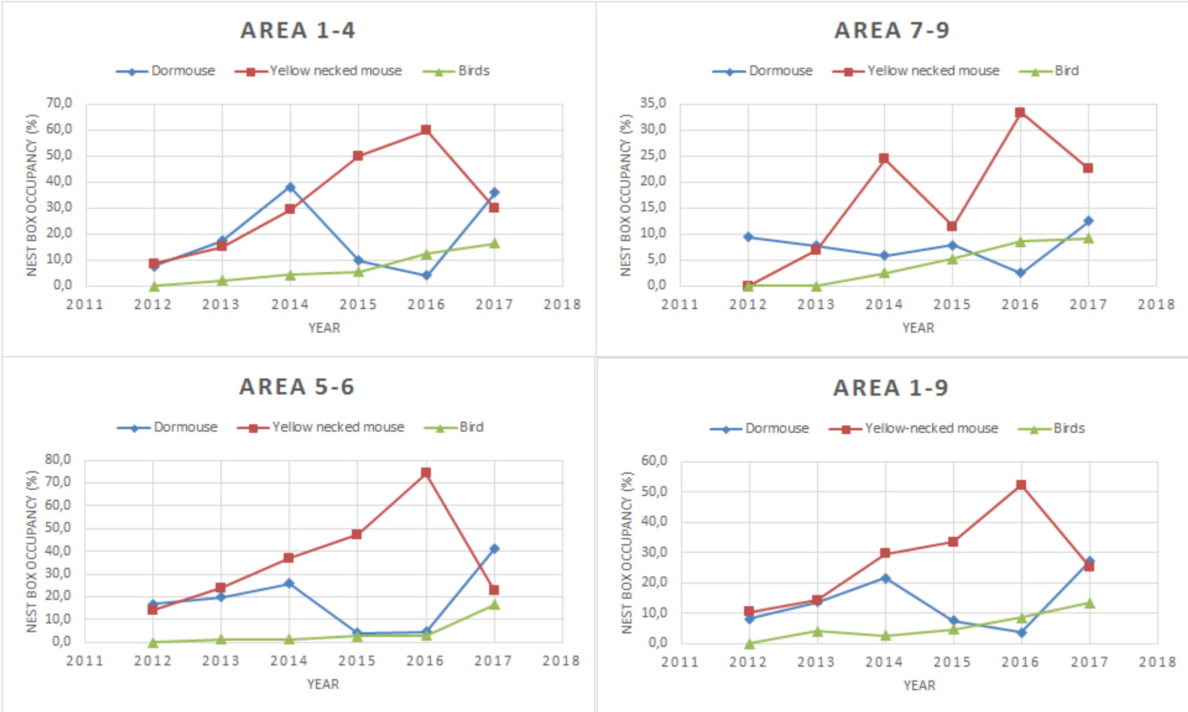

Fig. 24.: Three study sites showing nest box occupancy in percent by species group. Areas 1-4 are placed in the southern part of the forest. Areas 5-6 just north of 1-4, and areas 7-9 just north of 5-6. See **Fehler! Verweisquelle konnte nicht gefunden werden.**0. (Source: T.B. Berg & L.B. Sanderhoff).

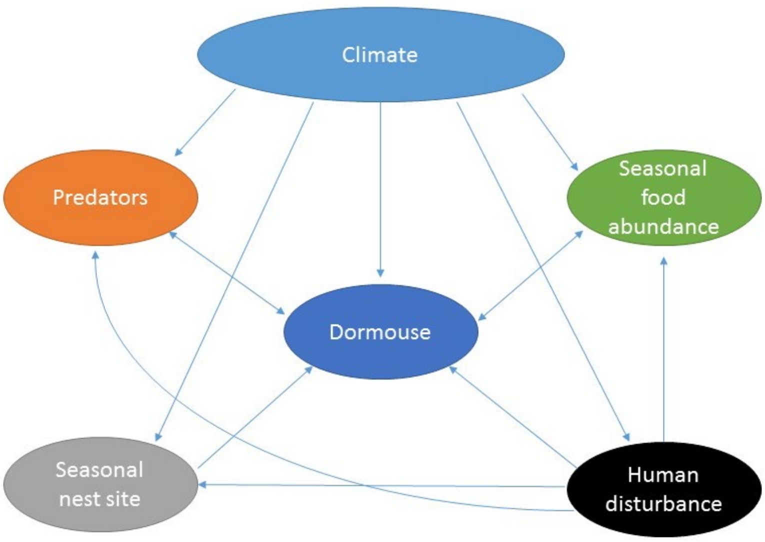

Fig. 25.: Factors affecting the hazel dormouse population both directly and indirectly (Source: T.B. Berg & L.B. Sanderhoff).

6.8 Outcome of the workshop sessions on assessing populations

Martin Ludwig, Melina Heinrich, Rimvydas Juškaitis, Jeroen van der Kooij, Julie Dahl Møller, Thomas B. Berg, Sabine Stab & Sven Büchner

Methods to estimate population size are different to those of range determination. To determine the range of a species, its presence or absence must be checked in a large number of raster cells (see chapter 5.8). Surveys for estimating the size and assessing the trends in the population need to be carried out on a lower number of sample sites. However, the measured variables need to be closely correlated to the population size (preferably linearly). In Table 4, methods that are suitable for measuring the population size are compared. The methods are not described in this text but in the references listed in the last row of Table . In comparison to Table , which lists methods for the determination of the range (chapter 5.8), the methods “nut hunt”, “camera trap” and “footprint tunnel” are not considered as suitable. In surveys with these methods, it is usually not possible to identify individuals. Therefore, records with e.g. camera traps or footprint tunnels are highly affected by activity.

The apparent abundance as result of using nest boxes, nest tubes, nest searches or live traps is considered to mainly depend on the real population size. However, the counts of these methods might be affected by additional factors. For example, counts from nest boxes, nest tubes and nest searches may be affected by the availability of natural nesting sites in tree hollows, seasons and weather conditions (which may affect the preference for free or hollow nests), competition with other small mammals for nesting sites (Lang et al. 2018) and the horizontal structure of the habitat (which may affect the time hazel dormice spend in the canopy or the shrub layer). Live trapping may also be affected by activity, competition with other small mammals, the availability of other food sources (than the bait) and the vertical structure of the habitat.

Live traps, nest boxes and nest tubes in combination with capture-mark-recapture methods (CMR) may result in high quality data, because individual marking allows the estimation of the percentage of the population that was not captured/detected. However, those calculations need high recapturing rates. Therefore, high quality results in CMR surveys need very intensive sampling and are usually too laborious for a widespread monitoring programme. However, CMR can be used in studies to better understand how counts from other methods (nest boxes, nest tubes, nest search or live traps) are linked to population size and other factors. Suitable methods for individual marking dormice are: ear tattoos, bird-rings and microchips (Juškaitis & Büchner 2013, Trout et al. 2018).

In general, none of these methods (nest boxes, nest tubes, nest search or live traps) are supported by solid evidence that the counts correlate closely to population size (but see Juškaitis 2008). Hence, a better understanding of the links between data obtained with the methods listed in Table and population size and other factors is needed. Studies investigating the effect of population size, availability of tree hollows, season and weather conditions, competition with other small mammals, habitat structure and food availability on measurements with the methods listed in Table are therefore needed.

Population genetic methods used for monitoring other cryptic mammals such as the wildcat (Ludwig et al. 2021), are not listed in Table , even though some studies on population genetics in the hazel dormouse exist, the authors are not aware of any experiences in monitoring hazel dormice using population genetic methods.

Table 8: Comparison of methods for monitoring the population of the hazel dormouse. The listed characteristics, remarks, and recommendations can vary e.g. between states (e.g. legal restrictions) and local circumstances (e.g. season).

	Nest boxes	Nest tubes	Nest search	Live traps also in combination with capture-mark-recapture
Time/labour expense	≥ 2 visits per year	≥ 2 visits per year	1 visit per year	≥ 5 visits per year
Time between visits	3 months	2 months	Not relevant	Max. 12 hours
Season	Spring & Autumn	Whole active season, higher detectability from August on	Whole year, higher detectability in leafless state (autumn/winter)	Whole active season, higher detectability from August on
No. of sampling units / site	50	50	Not relevant	25
Distance between sampling units in a site	50 m	10 m	Not relevant	10-15 m
Acquisition costs per sampling unit	10-15 €	2 €	No costs	10 - 50 €
Running costs (time/sampling unit)	- -	- -	30 min per site -	- -
Adaptation	30 min	5 min	-	2 min
Installation	7 min	5 min	-	5 min
Checking	10 min	5 min	-	5 min
Post processing	5 min	5 min	5 min	5 min
Data quality	Good	Intermediate, a thin shrub layer may lower data quality regionally	Correlation to population data is uncertain	Good, especially in combination with CMR
Habitat types method is suitable for -	All habitat types, with stems that can carry nest boxes	All habitat types with enough understory to fix nest tubes; a thin shrub layer may lower data quality regionally	Habitats types with a dense shrub layer (forest edges, hedgerows, regenerating clearings, …)	All habitat types with enough understory to fix traps; limited in crowded areas (theft and disturbance of traps)
Pro	Possibility to handle animals and sample various parameters	Low costs; possibility to handle animals and sample various parameters	No equipment costs; low effort	Possibility to handle animals and sample various parameters

	Nest boxes	Nest tubes	Nest search	Live traps also in combination with capture-mark-recapture
Con	Short suitable time in bushy habitats with regular coppicing		High level of experience needed Only suitable for habitats with bushes or young spruce trees; as trees mature the method becomes unsuitable	Intense time investment each year
Legal restrictions	Permit for checking	Permit for checking	No permit	Trapping and marking permit
Experience level	Intermediate	Intermediate	High	High
Usable for citizen science	No	No	No	No
Other remarks		Needs more analyses / comparison with other techniques, but see Chanin & Gubert 2011	Needs more analyses / comparison with other techniques	
References	Juškaitis 2014, Büchner & Lang 2014, Wembridge et al. 2017; Vogel et al 2012	Søgaard et al. 2013, Bright et al. 2006	Berg, 1996, Bright et al. 2006, Foppen et al. 2007, Søgaard et al. 2013, 2015, La Haye et al. 2016, Ledegen & Verbeylen 2017	Berg & Berg 1999, Verbeylen et al. 2017

A problem linked to the selection of the method for monitoring the population is the selection of sampling sites. A minimum distance of 1.5 km between independent sampling sites was considered as sufficient, as adult hazel dormice usually do not move more than 500 m while young non-settled individuals move up to 3 km. To produce optimal data quality to assess the population status (size and trend), monitoring should include all habitat types (e.g. hedges, different types of forests, regenerating clear-cuts) that sustain relevant parts of the (national) population. The sampling sites can be pre-stratified to cover all important habitats but should be randomly selected.

In practice however, financial restrictions limit the inclusion of all habitat types that sustain relevant parts of the population. Thus, monitoring needs to focus on the most important habitat types. Furthermore, several necessities limit a random site selection. For example, the sampling sites need to be easily accessible but not in crowded places where nest boxes, nest tubes or live traps might frequently be disturbed or stolen. A monitoring system using nest boxes fixed with a nail to a tree might be faced with the objection of landowners to attaching nest boxes to their property. This may result in bias to habitats that are not managed for wood production but for conservation purposes.

The hazel dormouse inhabits different types of habitats. Therefore, habitats vary not only throughout the species range but also between sampling sites. In general, habitats can be divided into:

- tree dominated areas (forest)
- shrub type dominated areas (e.g. young forest)
- linear tree dominated habitats (e.g. very old uncut hedge)
- linear shrub dominated habitats (e.g. hedgerow, shrub vegetation under powerlines)

The participants suggested creating an internet-based habitat handbook, to get a clearer picture about different hazel dormouse habitats in different parts of its range. The handbook may include photos, aerial photos and a verbal description of habitats.

The different methods are differently suited for different habitat types (see Table 8). For example, nest boxes are not suitable for habitats that mainly consist of young shrubs, as they do not have stems that nest boxes can be attached to. In contrast, a nest search does not work in habitats that mainly consist of trees, but only have few shrubs. Consequently, results gained with different methods are not comparable. More studies are needed that analyse how counts resulting from different methods for sampling the population size are related to the true population size in different habitats.

The participants also discussed possible reasons for changes in population size. They named inter-specific competition, predation, natural cycles, diseases, climate change and habitat conversion as possible reasons for changes in population size. However, the importance of these reasons in comparison to each other as well as in different parts of the range is largely unknown.

Conclusions:

For high-quality monitoring on the size and trends of populations of hazel dormice, the following topics need to be further examined:

To measure population size in a more precise way, a better understanding is needed of how the number of individuals recorded using different methods relates to true population size (see Table 8). Furthermore, it has to be considered how these numbers in general depend on other factors as listed above. Consequently, further studies are needed on how data gathered with different methods can be combined, converted, and translated into true abundances. To distinguish between real trends in population size and natural population fluctuation, a monitoring system that provides a sufficiently high resolution in space and time but is still affordable is needed (chapter 6.2 & 6.7). To interpret results on monitoring of population size and to be able to implement effective conservation measures, a better understanding of what drives changes in population size is vital.

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7 Assessing habitats of the hazel dormouse

7.1 Outcome of the workshop sessions on assessing habitat quality

Martin Ludwig & Sven Büchner

The reporting format of the Habitats Directive requires the member states to assess the "sufficiency of area and quality of occupied habitat" on their territory (DG Environment 2016). A realistic assessment of habitat quality is important to interpret changes in population size and to be able to respond to decreasing population sizes, for example with improvements in habitat quality. The basis for a realistic assessment of habitat quality is a solid understanding of the habitat requirements of a species.

One of the most obvious habitat requisites is food. Hazel dormice are less well equipped to digest cellulose compared to other small mammals. Therefore, they need constant availability of flowers, berries, fruits, fatty seeds and insects throughout the period of activity. Thus, a high diversity of shrubs and trees providing these is generally seen as important for a high habitat quality (Bright & Morris 1996, but see Büchner et al 2018).

A well-connected shrub layer allowing easy movement between shrubs is often seen as important for the hazel dormouse. Surprisingly, sometimes relatively large numbers of hazel dormice can be found in beech and upland spruce forests with low numbers of other trees and with a sparse shrub layer, thus in unsuitable habitat according to current knowledge. It is so far unknown how hazel dormice can build up a fat reserve in these habitats where vegetative plant material makes up a large part of their diet (Büchner et al 2018).

Hazel dormice can build free bowl-shaped nests in shrub vegetation, but tree hollows and other protected nesting sites are seen as a key resource. Juškaitis (2006; 2008) showed that in forests in Lithuania, the hazel dormouse densities increased when the number of nest boxes was increased.

Very little is known about the hibernation sites of the hazel dormouse. Reported hibernation sites were on the ground covered by leaf litter. In this situation, they seem to be extremely vulnerable to disturbance and predation. Lying deadwood may provide some shelter to hibernating hazel dormice (Büchner und Lang 2014)

Another factor affecting habitat quality might be competition for nesting sites and food with other rodents and birds. Further, altitude may affect habitat quality: in Germany the species seems to avoid lowland spruce forests but is present in spruce forests in the low mountain range (Büchner et al 2018). Habitat size and habitat connectivity may also play an important role as the species avoids open land and has a relatively limited dispersal ability.

The participants furthermore discussed the role of forest management. Forests with a well-developed shrub layer are seen as most suitable habitat, but also forests with single-aged trees can be suitable habitat. Thus, forest management leading to a multi-level forest stand are advantageous for the hazel dormouse. While fresh clear cuts are unsuitable habitat, young regenerating forest stands are highly suitable. Therefore, if forests are managed with clear-cuts, these should not be too large, to allow recolonization.

Large transport infrastructure such as motorways and railways are often bordered by wide and species-rich shrub vegetation that is potentially a good habitat for hazel dormice. Although large (linear) transport infrastructure is surely a barrier in the crossing direction, at the same time it might play a role as habitat and corridor in a parallel direction.

In summary, although there is some knowledge on factors affecting habitat quality; there are still important open questions regarding the assessment of habitat quality.

- What makes beech or spruce forest with sparse shrub layers and low amounts of other trees a suitable habitat?

- What makes spruce forests in low mountain ranges suitable habitats compared to lowland spruce forests?

- How does the habitat affect winter survival?

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8 Field trips on the island of Rügen

Hilmar H. Schnick

As part of the workshop, two field trips took place to present three hazel dormouse (*Muscardinus avellanarius*) monitoring sites on Rügen. The aim of the field trips was the discussion of monitoring methods and results in relation to habitat quality.

Hazel Dormice on Rügen – an overview in the context of landscape history

The occurrence of *M. avellanarius* on Rügen raises the question about the origin of this long isolated population. The spread of hazel dormice from their Pleistocene refugia in southern Europe to the north was facilitated by the rapid spread of hazel during the Boreal after 10,800 calibrated years before the present (cal. yr. BP) and subsequently hazel dominated woodlands in central Europe. The immigration of the hazel dormouse from central Germany to Rügen is not supported by the fossil record and seems to be unlikely due to habitat fragmentation on the north-eastern German mainland. In contrast, and supported by DNA data, immigration via Denmark is more likely considering the post-glacial development of the south-western Baltic Sea region. Especially the Darss Sill could have been used as a land bridge between south-eastern Denmark and north-eastern Germany about 9,800 to 8,800 cal. yr. BP (Schnick & Büchner 2015). According to palynological studies, *M. avellanarius* inhabited pristine deciduous natural woodland on Rügen in the Mesolithic about 10,000 to 6,100 cal. year BP (Endtmann 2004). A low-intensity but differentiated use of woodland in the surroundings of human settlements began in the Early Neolithic about 6,100 cal. yr. BP (Endtmann 2004). In mediaeval times, the demand for timber grew considerably caused by brick, ceramic and mortar production, metallurgy, building of churches, fortifications, houses, ships, boats and fishing equipment. That was the reason for both the necessity to import timber from the Pomeranian mainland and to introduce a more sustainable forestry regime on the island. For example, there is a management system of small-scale, mosaic-like rotating clearcuttings known on Rügen since the 16th century (Wichert 2016). Thus, *M. avellanarius* permanently had the opportunity to choose habitats in optimal succession stages. There is detailed information about Rügen's landscape history available since the end of the 17th century. Maps of the Swedish land survey, the Prussian ordnance survey maps, modern aerial images as well as a huge amount of literature enable detailed analysis to identify former migration routes and undiscovered habitats.

Hazel dormice on Ruegen – recent status

After a research hiatus of several decades, *M. avellanarius* was rediscovered on Rügen about twenty years ago (Siefke 1998). This was the start of professional mapping, management and monitoring to fulfil the requirements of the EU Habitats Directive. Some additional data also arose from accidental observations and nut hunt actions of children and volunteers. Today, about 30 *M. avellanarius* occurrences are known but probably there is still a number left undiscovered.

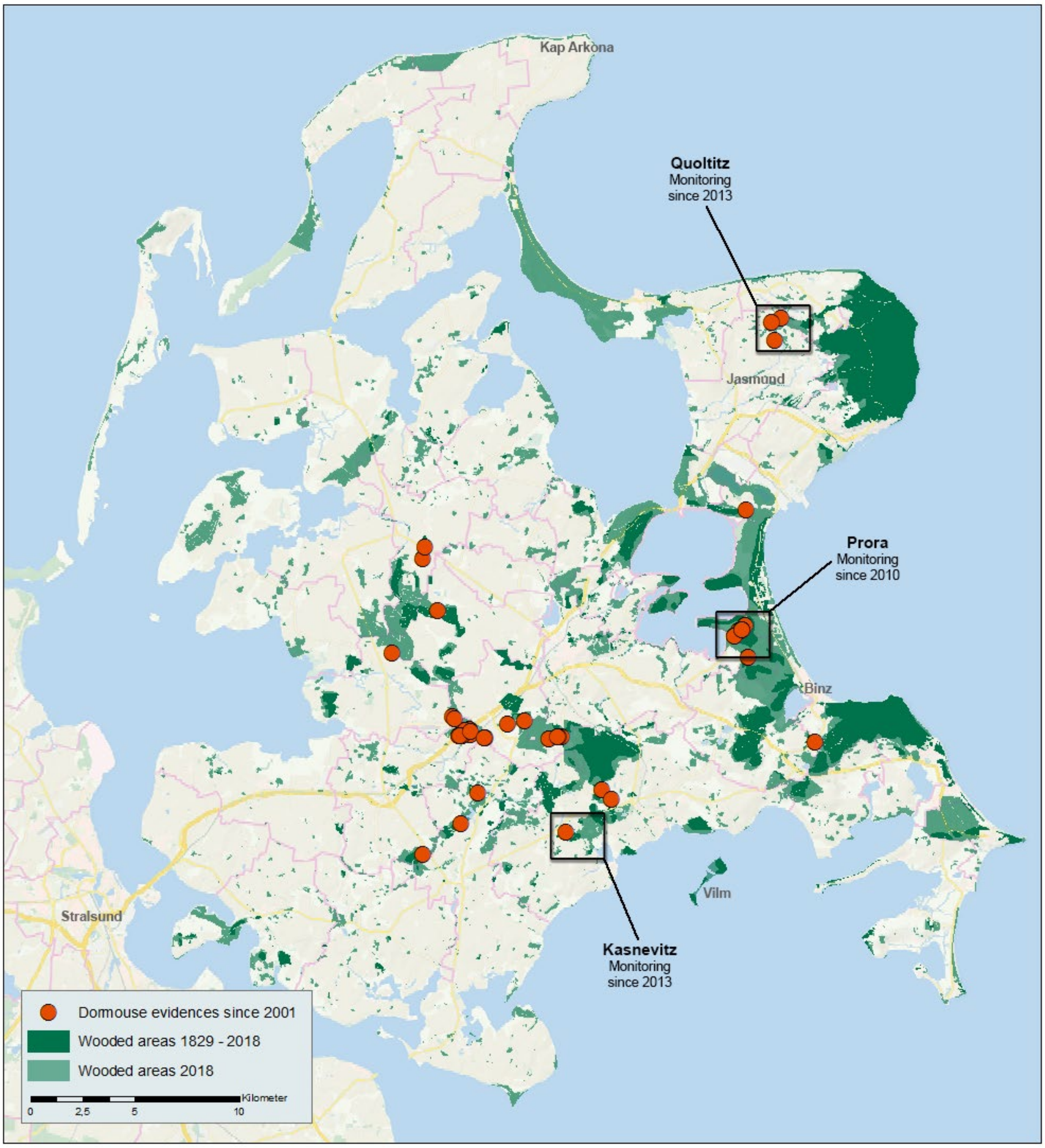

Fig. 26.: Distribution of hazel dormouse occurrences on Rügen – present knowledge in comparison with wooded areas 1829 and 2018 (Sources: GeoBasis-DE/MV 2018 and Hagenow's map 1829, modified).

With respect to geological development and to landscape history, two main areas with *M. avellanarius* occurrence can be distinguished on Rügen. The first one is the Jasmund peninsula that originally was a separate island at the end of the Littorina transgression about 7,000 cal. years BP. The recent connections to other parts of Rügen consist of marine sands without any biotopes suitable as dormice habitats or migration routes. Therefore, it is reasonable to assume that the Jasmund population has been isolated for several millennia.

The other *M. avellanarius* habitat area is located on central Rügen in or close to forests older than 300 years. There is one concentration of habitats in the central part and a second in the eastern part of central Rügen. Waterbodies and large fields have separated these for centuries. Obviously, there are no known habitats in the immediate coastal zone, despite the presence of appropriate vegetation and structures in many coastal woodlands. Probably this is due to the delayed phenological development in this zone.

Monitoring sites exist at three locations: near Prora in the eastern part of central Rügen, near Kasnevitz in southern central Rügen and near Quoltitz on the Jasmund peninsula (Fig. 26). The first two sites are situated in or close to woodland complexes that are both older than 300 years. The Prora site is surrounded by a former military training area that is now in natural succession. Presumably this habitat could be enlarged in the future.

The Jasmund site is located in the centre of the peninsula. The landscape has a mosaic-like pattern of different biotopes and succession stages. Beside the woodland area of the Jasmund National Park in the east, there are several valleys with diverse scrub and woody vegetation linked with hedges, coppices and former chalk mines with appropriate habitat quality today. The Quoltitz chalk mining area is such an example. After closing down mining in the 1960s, natural succession has resulted in new dormouse habitats. The rediscovery of the Rügen dormouse occurred in this area (Siefke 1998).

The results of the monitoring program are given in the contribution of S. Büchner & K. Zscheile (Chapter 6.4).

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9 List of participants and authors

Name	Institution	Adresse	E-mail	Workshop participant
Ph.D. Thomas Björneboe G. Berg	Naturama	Dronningemaen 30 DK-5700 Svendborg	thomas@naturama.dk	Yes
Pavel Bína	ArtDatabanken (Swedish Species Information Centre), Swedish University of Agricultural Sciences	Almas allé 8E S-75007 Uppsala	pavel.bina@slu.se	Yes
Sven Büchner	Büro für Ökologische Studien	Ortsstr. 174 D-02829 Markersdorf	muscardinus@gmx.net	Yes
Dr. Ralf Grunewald	Bundesamt für Naturschutz INA	Insel Vilm D-18581 Putbus	ralf.grunewald@bfn.de	Yes
Dr. Melina Heinrich	NLWKN (Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz)	Göttinger Chaussee 76 a D-30453 Hannover	melina.heinrich@nlwkn-h.niedersachsen.de	Yes
Dr. Mirosław Jurczyszyn	Adam Mickiewicz University in Poznan, Institute of Environmental Biology, Department of Systematic Zoology	Umultowska 89, PL-61-614 Poznan	mj_otis@poczta.onet.pl	Yes
Dr. Rimvydas Juškaitis	Nature Research Centre	Akademijos 2 LT-08142 Vilnius	rjuskaitis@gmail.com	Yes
Dr. Nina Klar	Behörde für Umwelt und Energie	Neuenfelder Str. 19 D-21109 Hamburg	nina.klar@bue.hamburg.de	Yes
Jeroen van der Kooij	Naturformidling,	Rudsteinveien 67 NO-14 Slattum	jevader@online.no	Yes
Dr. Martin Ludwig	BfN (German Federal Agency for Nature Conservation)	Konstantinstr. 110 D-53179 Bonn	martin.ludwig@bfn.de	Yes
Julie Dahl Møller	Julie Dahl Møller Consult	Kærupvej 21 DK-7741 Frøstrup	julie@birkemusen.dk	Yes
Birte Müller	Behörde für Umwelt und Energie	Neuenfelder Straße 19 D-21109 Hamburg	birte.mueller@bue.hamburg.de	Yes
Dr. Digna Pilāte	Latvian State Forest Research Institute	Rigas iela 111 LV-216 Salaspils	digna.pilate@silava.lv	Yes
Valdis Pilāts	Nature Conservation Agency	Baznicas iela 7 LV-21 Sigulda	valdis.pilats@daba.gov.lv	Yes
Lene Bech Sanderhof	Naturama	Dronningemaen 30 DK-5700 Svendborg	lene@naturama.dk	Yes
Anna-Lena Sander	Biosphärenreservatsamt Südost-Rügen	Circus 1 D-18581 Putbus	anna-lena.sander@stud.hs-owl.de	Yes
Hilmar Henning Schnick	Biosphärenreservatsamt Südost-Rügen	Circus 1 D-18581 Putbus	h.schnick@suedostruegen.mvnet.de	Yes
Dr. Björn Schulz	Stiftung Naturschutz Schleswig-Holstein	Eschenbrook 4 D-24113 Molfsee	bjoern.schulz@stiftungsland.de	Yes
Dr. Sabine Stab	NationalparkZentrum Sächsische Schweiz	Steinruecken 24 D-0182 Stadt Wehlen	sabine.stab@gmx.net	Yes
Uudo Timm	Estonian Environment Agency	Mustamäe tee 33, Tallinn, 10616, Estonia	uudo.timm@envir.ee	No
Kristin Zscheile	Landesamt für Umwelt, Naturschutz und Geologie	Goldberger Str. 12 D-18273 Güstrow	kristin.zscheile@lung.mv-regierung.de	Yes