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Habitat factors influencing the distribution of the hazel dormouse (*Muscardinus avellanarius*) in the Ore Mountains, Saxony, Germany

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Abstract

In Saxony (eastern Germany) the hazel dormouse inhabits a large variety of different habitats and is even known from spruce-dominated forests and small isolated woodlands. We searched for evidence of hazel dormice in 100 study plots in Saxony and analysed what habitat factors affect the presence or absence of hazel dormice. As survey methods we used checking of bird nest boxes and nest tubes and also searches for gnawed hazelnuts and summer nests. We found hazel dormice in large coniferous forests as well as in small isolated deciduous woodlands. They preferred forests and smaller woodlands over hedgerows. Distance to the next site occupied by hazel dormice, the number of woody plant species (especially food plants) and the altitude were statistically very important factors explaining the occurrence of hazel dormice.

Keywords: common dormouse, habitat selection, isolation, species diversity, presence/absence

1. Introduction

As an arboreal species the hazel dormouse (*Muscardinus avellanarius*) is strictly bound to woodlands (Bright & Morris 1996, Juškaitis & Büchner 2010). The hazel dormouse is usually associated with deciduous trees and shrubs. Typical habitats described in British literature include ancient semi-natural forests and forest-edges with a dense understorey and high plant diversity (Bright & Morris 2005, Bright et al. 2006). In contrast, hazel dormice occur in pure spruce forests in the southern mountainous parts of Saxony in eastern Germany, whereas they avoid coniferous forests in the lowlands of Saxony (Möckel 1996, Büchner et al. 2009).

We aimed to find out what habitat factors determine the presence or absence of hazel dormice in one region of Saxony – the Eastern Ore Mountains.

2. Material and methods

The study was carried out from March to November 2010 in the Eastern Ore Mountains (Osterzgebirge, longitude 13°27’E, 13°39’E; latitude 50°49’N, 50°59’N). It is a hilly landscape at the foot of a mountainous region. The area is dominated by large agricultural fields, forests, and smaller villages. Between the fields are some hedgerows and small woodlands, most of them windbreaks. Both, windbreaks and hedgerows, are characterised by high plant diversity, especially among the shrub species, and a dense structure. Unlike hedgerows, windbreaks are longer and wider and also contain old deciduous trees, e.g. sycamore (*Acer pseudoplatanus*) and ash (*Fraxinus excelsior*).

The study area consisted of 100 study sites, including 38 forests, 33 small isolated woodlands (< 3 ha) and 29 hedgerows. As a separation between two sites we defined a distance of more than five metres or borders like rivers, streets or railway lines without overhanging trees. We have chosen the distance of five metres with regard to Bright (1998), who found out that gaps of six or more metres were not crossed by hazel dormice, whilst smaller gaps were easily crossed.

We searched for evidence of hazel dormice by checking more than 400 bird nest boxes and over 1000 nest tubes. Additionally we looked for summer nests in hedgerows and smaller woodlands and for gnawed hazelnuts where hazel was present. The nest boxes have already been in the study area for 25 years. Therefore the numbers of nest boxes varied in different sites. Nest tubes were set out in groups of 50 (25 in smaller woodlands) every 20 m, as proposed by Chanin & Woods (2003). Nest boxes and nest tubes were checked once a month between spring and autumn. Summer nests were searched for in late autumn. To search for summer nests we walked along both sides of a hedgerow or small woodland. According to Juskaitis & Büchner (2010) we concentrated on typical structures like dense bramble or branches of young trees. The method of searching for gnawed hazel nuts was adopted from Bright et al. (1994, 2006). We only analysed presence/absence of hazel dormice. If evidence of hazel dormice was found with one method no other method was used.

In forests we recorded different structural habitat factors, using up to five sample plots of 20 m × 20 m. The number of plots depended on the size and variety of the forest. In small and homogeneous forests only one plot was analysed, whilst in large and heterogeneous forests more plots were necessary to represent the various structures of the site. Hedgerows and small woodlands were analysed as single entities.

The habitat factors that were recorded were:

- Type of habitat (forest, small woodland, hedgerow)
- Size of study sites (ha)
- Degree of isolation (distance to the next forest, distance to the next hazel dormouse site, distance to the next hazel dormouse site with a size of more than 20 ha, number of hedgerows next to the site)
- Tree covering (per cent at each sample plot)
- Density of understorey (per cent at each sample plot)
- Plant species diversity (number of woody plant species, number of potential food plants, number of tree species and number of shrub species)
- Number of soft mast species
- Hazel availability (per cent at each sample plot)
- Quality of forest edges, measured in classes between 0 (no forest edge) and 3 (marvellous structure, high number of plant species)
- Altitude
- Soil types

The correlation of habitat features with the presence or absence of hazel dormice was analysed statistically using Mann-Whitney-U-Test, discriminant analysis and logistic regression (PASW Statistics 18.0 for Windows). The Mann-Whitney-U-Test was used to analyse the correlation between the single habitat factors and the presence/absence of hazel dormice. The discriminant analysis was used to group sites with and without hazel dormice. Before we used the logistic regression we checked for correlation with predictor variables. Some habitat factors contain parts of other factors (e. g. number of plant species contains number of tree species and number of shrub species). We only used those which do not contain other factors. With the stepwise logistic regression we started analysing many habitat factors and step by step deleted the factors that turned out to be of no importance. With this method we found out what habitat factors have the highest influence on the presence/absence of hazel dormice.

3. Results

Hazel dormice were detected with all the survey methods used (nest boxes, nest tubes, hazel nuts, summer nests). Evidence of hazel dormice was found in 30 of the 100 sites (14 forests, 14 small woodlands and 2 hedgerows). Among the small woodlands were a lot of windbreaks. In 2010 evidence of hazel dormice was found in 10 of 12 windbreaks and in 2011 all windbreaks were inhabited by hazel dormice (Bellmann personal communication). Table 1 shows median and mean with standard deviation of sites with and without hazel dormice.

Tab. 1 Median and mean with standard deviation of 16 factors of sites with hazel dormouse occurrence in contrast to sites without hazel dormice.

	Hazel dormouse sites			**Sites without hazel dormice**		
	median	**mean**	**standard deviation**	**median**	**mean**	**standard deviation**
site area [ha]	2	41.69	61.866	1	49.98	132.148
distance to next woodland [m]	10	26.50	56.724	10	40.10	87.539
distance to next forest [m]	14	181.23	268.991	28	123.16	180.905
distance to next forest > 20 ha [m]	116	197.07	265.792	45	157.51	228.097
distance to next hazel dormouse site [m]	10	176.53	582.742	788	1471.38	1725.478
distance to next hazel dormouse site > 20 ha [m]	135	324.67	642.403	1365	2027.96	2303.617
tree covering [%]	70	72.83	12.906	75	66.84	26.913
density of understorey [%]	64	59.13	29.230	75	67.03	25.626
altitude [m]	514	511.47	92.483	409	401.56	65.611
number of tree species	6	5.77	2.063	5	5.34	2.691
number of shrub species	10	9.93	4.638	9	8.90	4.060
number of woody plant species	17	18.13	4.493	14	15.12	6.775
number of food plant species	14	14.20	3.336	12	12.21	5.199
number of hedgerows next	1	0.97	0.765	0	0.66	0.840
number of soft mast species	8	8.00	2.304	7	7.47	3.098
hazel extent [%]	1	5.60	10.763	1	6.76	12.784

With the help of the discriminant analysis, sites with and without hazel dormice could be distinguished. Function 1 shows that altitude, distance to the next hazel dormouse site, the number of woody plant species and the number of soft mast plants are the most important factors explaining the presence or absence of hazel dormice (Tab. 2).

Tab. 2 Statistical results of discriminant analysis and Mann-Whitney-U-Test (* significant, $p < 0.05$, ** high significant, $p < 0.01$).

Habitat features	Function 1 Discriminant analysis	Mann-Whitney-U p
altitude	0.82	****< 0.001**
distance to next dormouse site	-0.688	****< 0.001**
number of woody plant species	0.642	****0.002**
number of soft mast species	-0.635	0.166
number of feeding plants	0.442	*** 0.011**
distance to next dormouse site > 20 ha	0.309	****< 0.001**
number of shrub species	0.253	0.152
density of understorey	-0.247	0.204
site area	-0.222	0.192
number of tree species	-0.22	0.257
distance to next forest	-0.149	0.774
number of hedgerows next	0.146	***0.037**
distance to next forest > 20 ha	-0.129	0.852
distance to next woodland	0.111	0.888
hazel extent	-0.068	0.821
tree covering	-0.047	0.928

The binary logistic regression showed that altitude, number of plant species and the distance to the next dormouse site of more than 20 ha are influencing factors on the distribution of hazel dormice, whereas the other factors do not have a high influence (Tab. 3).

Tab. 3 Results of logistic regression. Three variables turned out to have a significant influence on the presence or absence of hazel dormice.

Habitat features (variables in the model)	b	Wald	df	sig	exp(B)
altitude	0,013	10,127	1	0,001	1,013
distance to next dormouse site > 20 ha	0,176	9,487	1	0,002	1,192
number of plant species	-0,001	6,537	1	0,011	0,999
constant	-8,564	15,004	1	0,000	0,000

The size of the sites was not correlated with the presence of hazel dormice. Hazel dormice were found in large forests as well as in very small woodlands. More than half of the hazel dormouse sites were smaller than 15 ha.

The distance to the next hazel dormouse habitat and the next large hazel dormouse habitat (> 20 ha) was correlated with the presence of hazel dormice with high significance ($p < 0.001$). More than 80 % of the sites were closer than 500 m. For 60 % of the hazel dormouse sites the distance to the next inhabited site was less than 20 m and half of the hazel dormouse habitats were closer than 10 m to the next site (Fig. 1). But hazel dormice were also found in small isolated woodlands.

Tree cover and density of understorey were not correlated with the presence of hazel dormice. Places with a dense understorey seemed to be preferred, but hazel dormice were also found in places with hardly any shrubs at all.

The presence of hazel dormice depended on the number of woody plant species ($p = 0.002$). For hedgerows and small woodlands it was highly significant ($p < 0.001$). The number of potential food plants was also related to the presence of hazel dormice, especially in hedgerows and small woodlands ($p < 0.001$, Fig. 2). In all hazel dormouse sites at least 12 woody plant species and 9 potential food plant species were essential.

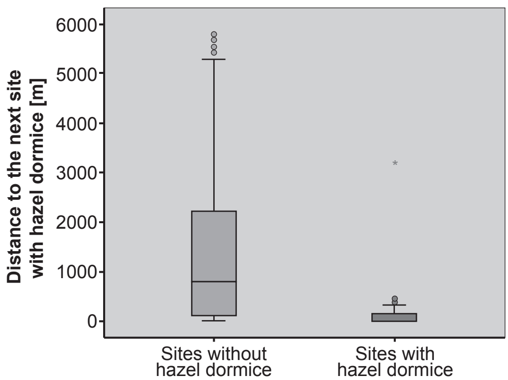

Fig. 1 Distance to next site with hazel dormice in places with and without hazel dormice.

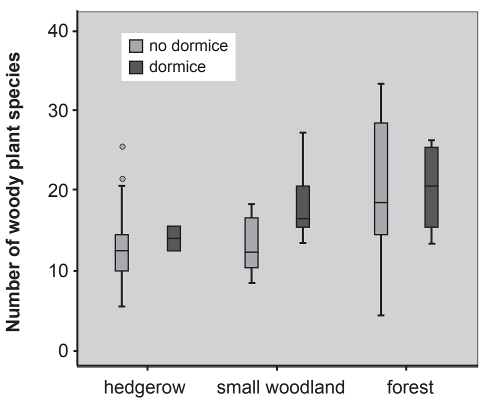

Fig. 2 Number of woody plant species in sites with and without hazel dormice.

Hazel dormice lived in coniferous and mixed forests as well as in deciduous small woodlands and hedgerows. Deciduous woodlands dominated by sycamore and ash formed 43 % of hazel dormouse sites (Tab. 4). However, almost all hazel dormouse sites in forests were dominated by spruce (*Picea abies*). Spruce forests with several deciduous tree species present were the second favoured biotope type (40 % of sites with hazel dormice). Thus, important tree species were spruce, ash and sycamore.

Tab. 4 Types of biotopes in sites with and without hazel dormice.

Type of biotope	Hazel dormouse sites [%]	Sites without hazel dormice [%]
pure spruce forest	7	4
spruce-dominated forest mixed with deciduous trees	40	22
beech forest	0	3
oak forest	0	1
maple forest	0	4
deciduous woodlands dominated by sycamore and ash	43	7
wetland scrub	3	16
small coniferous woodland	0	3
hedgerow (deciduous)	7	38

In hedgerows and small woodlands the number of soft mast species was positively correlated with the presence of hazel dormice ($p = 0.038$). Important shrub species were bramble (*Rubus fruticosus agg.*), black elder (*Sambucus nigra*), raspberry (*Rubus idaeus*) and glossy buckthorn (*Frangula alnus*). Hazel (*Corylus avellana*) was growing in many hazel dormouse sites, but was not obligate for the presence of hazel dormice.

About 60 % of hazel dormouse sites were characterised by a well-structured forest edge. In forests without a good forest edge no hazel dormice could be found.

The altitude was highly correlated with the presence of hazel dormice ($p < 0.001$). Hazel dormice were found in places between 360 m and 632 m.

The favoured soil type was brown earth (69 %), whereas wet soils, such as gley soils and planosols seemed to be avoided as none or only very few hazel dormice were detected on those soil types (Tab. 5).

4. Discussion

Within its range the hazel dormouse lives in forests as well as in small wood copses (Juškaitis & Büchner 2010). In the northwest of the range they also use hedgerows (Bright & MacPherson 2002, Ehlers 2009). In the study area hazel dormice live in forests, small woodlands (including windbreaks) and hedgerows. Windbreaks that combine the features of woodlands and hedgerows are especially favoured. With a dense and diverse understorey and old deciduous trees, windbreaks offer optimal hazel dormouse habitats with safe nest sites and good feeding conditions.

Tab. 5 Soil types in sites with and without hazel dormice.

Soil types	**evidence of hazel dormice [%]**
brown earth	69
alluvial gley soil	7
colluvisols	6
brown earth podzol	5
slope soil brown earth	3
gley planosols	3
planosols	2
gley-vega	2
slope planosols	1
brown earth planosols	0
regosol	0
low moor	0
para brown earth	0
stagnogley	0
planosol brown earth	0

Bright et al. (1994) assume that 20 ha is the minimum size to support a viable hazel dormouse population in isolated woods. In our study region lots of small isolated woodlands (< 3 ha) are inhabited by hazel dormice and half of all hazel dormouse sites in the study area are smaller than 25 ha. Hence the size of a site does not seem to correlate with the presence of hazel dormice. However, statistical analyses show that the distance to the next hazel dormouse site is a very important factor explaining the distribution of the hazel dormouse in the study area. With help of logistic regression we found out that the distance to hazel dormouse sites of more than 20 ha is one of the most important factors. The majority of hazel dormouse sites are situated closer than 20 m from the next wood or hedgerow with hazel dormice and all hazel dormouse sites are close to large forests with a size of more than 20 ha. Therefore, the viability of hazel dormouse populations in small woodlands and hedges seems to be related to the existence of large forests in the surroundings. However, a few hazel dormouse sites in the study area are isolated by about 400 m from the next forest. This proves that hazel dormice are able to travel comparatively large distances over open ground (Büchner 2008, Keckel 2010).

Many authors underline the importance of a dense understorey for hazel dormice (Görner & Henkel 1988, Vilhelmsen 1996, Juškaitis 1997, Berg & Berg 1998, Bright et al. 2006). Although many hazel dormice were found in dense scrub, the statistical results of this study could not prove a significant relation between understorey density and the presence of hazel dormice. Hazel dormice were likely to be found in places with dense scrub, but also in places without a dense understorey. The density of tree cover does not seem to play any role at all.

The number of woody plant species and those which potentially offer food are very important factors explaining the presence of hazel dormice in the area investigated. This corresponds with data from elsewhere (Bright & Morris 1990, 1996, Berg & Berg 1998) and is similar to the results of Ehlers (2009) who found 12 or more woody plant species in hedges where hazel dormice live. At least 12 woody plant species were a prerequisite for the presence of hazel dormice in all sites of our study area. Among them the number of potential food plants plays an important role because hazel dormice are specialised feeders needing a diverse food supply during the active season (Bright & Morris 1996). In contrast, Eden (2009) suggests that the hazel dormouse can adapt to different food situations and insect food is as important as plant food.

Although hazel dormice are usually associated with deciduous trees, they sometimes occur in conifer-dominated forests (Bright 1995, Juškaitis 2007) and in the study area they appeared to thrive in coniferous forests dominated by spruce. All of the inhabited small woodlands in the study area are deciduous woodlands, dominated by sycamore or ash with a high diversity of shrub species. This indicates that some microstructures may occur within spruce-dominated larger woodlands ensuring the survival of the hazel dormice, although it is hard to imagine what they eat during the whole season in pure spruce stands.

Hazel dormice are likely to be found in species-rich and well-structured forest edges and overgrown clearings (Görner & Henkel 1988, Bright & Morris 2005, Foppen et al. 2007, Juškaitis & Büchner 2010) and this is also supported by the current study.

According to discriminant analysis and logistic regression, the altitude was one of the best factors explaining the presence of hazel dormice in the study area. As the hazel dormouse appears within its range from low to high altitudes (Juškaitis & Büchner 2010), the altitude is probably correlated with other factors such as tree species diversity. Soil types may also influence habitat choice by the hazel dormouse as van Laar (1984) showed in the Netherlands. In the study area hazel dormice preferred sites on brown earth. Wet soils seemed to be avoided probably because of problems with safe hibernation sites on the ground. According to Bright & Morris (1996) hazel dormice usually occur on calcium-rich and neutral soils but avoid acid and sandy soils. They suppose that soil types may influence habitat selection of the hazel dormouse, because of their effect on food quality and quantity. Also Juškaitis (2007) assumes that the presence of the hazel dormouse indirectly depends on soil fertility, because fertile soils are responsible for high plant diversity. Maybe further investigations could find out more about the importance of soil types to the hazel dormouse.

We are aware that there may be a spatial autocorrelation, but it was not possible to check this in the current study. Further analyses are planned to check for spatial autocorrelation.

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