SZENT ISTVÁN UNIVERSITY

Ph.D. THESIS

ANALYSIS OF THE DISTRIBUTIONAL ECOLOGY OF DORMOUSE SPECIES' (GLIRIDAE) POPULATIONS IN HUNGARY IN TWO SITES, BASED ON THE NATIONAL BIODIVERSITY MONITORING PROGRAMME

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2013

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INTRODUCTION AND AIMS

Dormice are, despite their special features and physiological and ecological attributes, in scientific terms rather unknown and poorly researched. However, in the last decades, because of their poor distribution in nature compared to other rodents, they have been receiving more and more attention, especially with regard to species and habitat conservation.

Three dormouse species occur in Hungary: fat dormouse (*Glis glis*), forest dormouse (*Dryomys nitedula*) and hazel dormouse (*Muscardinus avellanarius*). All three species are under legal protection in Hungary since 1974; in 2012 the forest dormouse was categorised as "increased protection".

The importance of dormice in Hungary is shown also by the fact that all three species have become, within the National Biodiversity Monitoring System (NBMS) started in 1997, so-called objects right from the establishment of the system.

The first research, aimed especially at the ecology and population biology of the Gliridae-species in Hungary, started 20 years after this animal group received the legal protection. As part of the research for my diploma, following the NBMS guidelines, with several years of data collection, I updated the Hungarian distribution maps of the dormouse species.

The international scientific reviews of the Gliridae group show different habitat requirements for the different species; firstly in terms of vegetation structure, though several researchers have elaborated on the co-existence of multiple species. In the Eastern-European region there is an overlap in distribution of the three dormouse species which occur in Hungary, nevertheless real co-existence is rather rare. Based on the Hungarian distribution data of dormouse species, from all UTM-squares, where the occurrence of dormice was evident, it was only in 7% of squares that all three dormouse species were found.

My prediction is that specific differences can be detected in habitat requirements or other ecological parameters by examining the parameters of their co-existence within the same habitat. The main hypothesis of this study is that if no division is detecteble in space use, then presumably there are seasonal differences, meaning that one specific species occupies different areas at different times of the year, or uses other niches within the same habitat.

The goals of my PhD research were the following:

1. Methodological goals:
    - establish a nest box colony by minimalising nest site competition; regular controls thereof (nest box checks once a month, noting all occupancy and other signs of activity), in order to find out, to what extent nest boxes are useful for dormouse monitoring in Hungary
    - test the plastic nest tubes made and used successfully on hazel dormouse in the United Kingdom, compairing their practicality and effectivity towards wooden nest boxes in Hungary.
2. Goals at population level:
    - analyse the seasonal dynamics of different dormouse species; detecting their breeding season as accurately as possible

- estimate yearly changes in population size of the three dormouse species, or (if possible) recognise the reasons for these changes; long-term monitoring of trends in population size.

3. Goals at habitat level:
   - analyse the differences in the habitat requirements of each dormouse species based on the results
   - find out the environmental factors allowing the co-existence of the three dormouse species, or with which parameters the niche segregation is possible
   - provide habitat-based conservation and monitoring proposals.

MATERIAL AND METHODS

The suitable area was chosen based on the distribution maps of the three dormouse species, showing the habitats, where the co-existence of all three species can be predicted, and where previous research revealed co-existence. My research showed the most cases of co-existence in the Northern-hills (North-Eastern part of Hungary). The highest distribution of the rarest forest dormouse can be found in the Cserhát-Börzsöny hills, so it seemed pertinent to point out the research site in this region. The Naszály-hill near Vác is an area rich in plant species but also in forest types, where the occurence of all three species was proven. The other area chosen was near Gödöllő, Domony-valley, a forest patch dominated by locust and poplar, where we had distribution data on hazel- and forest dormouse from previous field research.

The setting-up of the wooden and plastic nest boxes at the Naszály site was done in several steps, in eight habitat types, differing in structure and species constitution (**Table 1**). In Domony-valley, in total 60 nest tubes were set up in four different vegetation patches. The boxes were placed at a height of 1.5 – 2 m, at a distance of 5 m from each other. There was one site, which was used to compare the two different nest box types, where the wooden box was put on a stronger tree trunk, whereas the plastic tube was fixed on a nearby shrub.

Table 1. The steps and numbers of nest boxes set-up

Year of set-up	Areas	Number
1999	hedge, abandoned orchard, forest edge	150 wooden boxes
2002	shrub, young pine stand, oak forest (old pine stand)	150 plastic tubes (and moving of 20 wooden boxes)
2005	Naszály: downy oak patch – *comparison of the two nest box types in one site* (old pine stand, forest edge) Domony: hawthorn-blackthorn, bromus-locust, poplar-juniper and the edge between the first two	35 wooden boxes and plastic tubes (and an additional 35 wooden boxes at given sites) 15 plastic tubes each

The nest boxes were usually checked every month during the vegetation period (between March and November), but for various reasons the nest box site was not checked on a monthly basis every year. In order to avoid distortion of the results caused by the differences in sample numbers in the different seasons, I proportionated the data to the number of nest boxes actually examined.

The data were then grouped by nest box type, area and different vegetation parameters (type of tree or shrub species in the direct vicinity of the nest box, the density of the vegetation or whether the nest box was put on a living or dead tree or shrub). Depending on the number of the different categories I did homogenity or independence analysis (χ^2-trial) on these data sets.

At the start we used tattooing to mark the animals. The recapture results, however, showed that the colour could not be seen, but also the numbers could not be recognised clearly. In the latter years tattooing of the toes was used. In Domony-valley, I had positive results with aluminium bird rings on hazel dormouse.

RESULTS

Total occupancy

On the Naszály-hill during the 13 years of research I made **16,921** nest box checks, of which **9,163** were on wooden nest boxes, **7,758** on plastic tubes. In total **4,778 (28.2%)** occupancies were noted, of these **3,508 (20.7%)** were in wooden boxes and **1,270 (7.5%)** were obtained from plastic tubes. The homogenity test of the data grouped by nest box type showed significant difference in the division between the two groups (critcal χ^2-value: 26.3; calculated χ^2-value: 805.78; $P<0.05$). The proportion of confirmed dormouse-related nest box occupancies on the Naszály-hill was 33%. This means that roughly 9% of the total number of nest boxes can be related to the activity of dormice (**Table 2**).

Table 2. Nest box occupancy of dormouse species on Naszály-hill

Nest box type	Occupancy	*Muscardinus*	*Dryomys*	*Glis*	**Total**
Wooden	Animal	110	53	364	**527**
	Nest	220	63	280	**563**
Plastic	Animal	121	3	4	**128**
	Nest	342	5	14	**361**
Total		**793**	**124**	**662**	**1579**

In the Domony-valley, where the reserch was conducted using only plastic tubes, there were **1,916** nest box checks during the 8 year period. **360** occupancies (**18.8%**) were noted (**Table 3**). **183** data from Domony were definitely from dormice (9.6% of all gained data).

Table 3. Nest box occupancy of dormouse species in Domony-valley

	Animal	Nest	**Total**
Muscardinus	50	120	**170**
Dryomys	6	7	**13**
Total	**56**	**127**	**183**

At Naszály, all three species were found every year. Both nest box types were used by all three dormouse species for nesting, however, the total occupancy was higher in wooden nest boxes. Nevertheless, hazel dormouse had a significant occupancy rate in plastic tubes, as well. For this reason, the effect of the nest box type was analysed for this species.

Comparing the hazel dormouse occurence data based on nest box type, I found a significant difference (critical χ^2-value: 18.31; calculated χ^2-value: 107.88; $P<0.05$). In the year after the set-up, the yearly occupancy rate of the plastic tubes was higher for almost the whole period.

Dormice or their nests were also permanently found in plastic tubes in Domony-valley. However, there were two years (2006 and 2010), in which no sign of the forest dormouse could be found.

Other vertebrates occupying nest boxes regularly were woodmouse and tit species. The invertebrates were mostly butterflies and wasps.

Spatial division

If the occupancy data were divided by the different habitat patches, the independence analysis showed that the data groups are related to each other (critical χ^2-value: 26.3; calculated χ^2-value: 679.6; $P<0.05$).

At Naszály, hazel dormice were found predominantly in the shrub patch and the young pine stand, with the two other dormouse species scarcely occuring here. In the remaining patches all three species were found regularly during the whole research period. Also, in the downy oak patch all three species were detected with both nest box types.

The homogenity test was also done for the Domony vegetation patches. The result showed a siginificantly different division between the four sites (critical χ^2-value: 7.82; calculated χ^2-value: 14.97; $P<0.05$). However, when testing for solely those patches where only hazel dormouse was present, the data sets showed high homogenity (critical χ^2-value: 5.99; calculated χ^2-value: 0.97; $P<0.05$).

In Domony, the proportion of hazel dormouse found in all four distinct patches was similar. Forest dormice also regularly nested in the plastic tubes, but almost only in the hawthorn-blackthorn patch with a low canopy level. Fat dormouse was not found in the Domony site, but no data was ever recorded for the species in the area.

Analysing the data sets of Naszály and Domony, the individual sites, vegetation patches differed significantly from each other. However, it was assumed that there was some kind of relation between the two research sites. For this, those areas were selected which showed similarities in vegetation structure and occupancy data based on the field observations. A homogenity test of these sites was performed using the occupancy data of the hazel and the forest dormouse: the hawthorn-blackthorn in Domony, the abandoned orchard, the hedge, the old pine stand and the forest edge patches in Naszály.

The calculation revealed that these five habitat patches show no significant difference based on the data obtained for hazel- and forest dormouse occupancy, although with regard to the occurence of these two species these vegetation patches can be considered as homogenic (critical χ^2-value: 9.49; calculated χ^2-value: 5.27; $P<0.05$).

From the comparison of the areas it is evident that in Naszály, six out of eight, and in Domony only one out of four vegetation patches was suitable for several dormouse species, but the hazel dormouse was regularly found in all analysed sites. The comparison between Naszály and Domony showed that forests with different species constitution but similar vegetation structure have similar value for dormice.

Abundance

As previously shown, the two sites in Naszály differ from the others in dormouse species composition, as it was mostly hazel dormouse which occurred there. If we take out the shrub and young pine stand site from the list of vegetation patches of Naszály, there are still 6 types of vegetation patches, where all three dormouse species co-exist. The spatial units are mostly in direct contact with the neighbouring – sometimes surrounding – forest, so the artificial nesting wholes which were placed here probably attracted individuals from areas further afield.

The occurence of the fat dormouse in Naszály usually happened in wooden nest boxes, whereas hazel dormice were found more often in plastic tubes. The latter species seemed to be the most abundant in both sites. The forest dormouse was rarely found in either nest box types.

Since the start of the research, the fat dormouse, though showing low abundance in total figures, occured at a higher rate compared to the two other species in the summer-autumn period. The first peak year was 2005, where the number of fat dormice was very high, including large litter sizes. In the following year the juvenile fat dormice appeared rather early in the nest boxes, but the total occupancy stayed rather low and very few adult individuals were found.

Comparing the data sets of the hazel- and the fat dormice, it could be established that during the activity period of the bigger sized species there are more nestings detected for the smaller one in plastic tubes than in wooden boxes. The same was found when out in the field: during the spring checks a larger number of hazel dormice were found in wooden boxes, and during summer checks almost none were found. In autumn, the numbers of hazel dormouse in wooden boxes increased again, though it did not decrease further in the plastic tubes, probably because of the nestings of the juveniles of the year.

The yearly fluctuations are similar between the hazel- and the fat dormice. It is probably the years rich in food that affects the abundance of both species. For the forest dormouse, the data set is rather homogenic, no fluctuations could be detected. Breeding was also scarcely seen for this species in the nest boxes.

If we analyse the relative abundance in Naszály, the result is as follows: besides the fluctuations within and between the years, there was an incresing tendency for the hazel- and the fat dormice, whereas the index for the forest dormouse seems to remain static. For the hazel dormouse, stable increase can be seen for plastic tubes. The variation is much higher for fat dormouse, but the trend is also increasing. The first increase in numbers was detected in 2005 both for hazel- and the fat dormouse populations. It must be emphasized that in the year 2009, where we did not find any forest dormice in wooden boxes, we found them mostly in plastic tubes.

The analysis of abundance changes brought slightly different results in Domony. There was a decrease until 2007, then a peak in 2008, after which a constant increase started from a higher value than the 2007 figure, which ended finally with a decrease in 2012. However, no visible trend could be detected. From field experience it could be noted that there were less and less animals, but more and more nests found only in the plastic tubes in Domony.

Breeding

Pregnant, lactating females were not disturbed, however, the data related to breeding compared to the whole dormouse occupancy, and its spatial distribution could provide some further answers. To analyse this, the occupancy data derived from juveniles was added, as the young, recently unmated individuals also represent signs of successful breeding. Though exact data on litter size could not be gained, the number of youngsters was between 3 and 7 for all three species.

Three categories were analysed for each species: pregnant-, lactating female and juvenile. 12.4% of the total occupancy can be related to breeding (all dormouse related occupancy was 1579, the rate differs by species). Most data in all three categories were found for fat dormouse. These data show that, though in total there were not so many occupancies, the breeding related indeces are much higher (67.3%!).

In Domony, only hazel dormouse breeding could be detected. Interestingly, the captured forest dormice were all adult specimen.

The low number of data (only 1.2% of the whole data set), and the spatial and temporal spread did not allow statistical analysis. However, when the spatial distribution of breeding related data of Naszály was checked, breeding signs were found for all species in all areas, where they regularly occurred, except for the forest dormouse, where in the forest edge no signs of breeding were found in any years. Both for hazel- and forest dormouse, the most data from wooden boxes came from the old pine stand and the abandoned orchard. The breeding of the fat dormouse was greater in all sites with wooden boxes than it was for the other two species, though the most data recorded was from the forest edge and the downy oak sites. In plastic tubes, only the hazel dormouse showed breeding activity. Even in the downy oak patch with the two nest box types, hazel dormice were only breeding in plastic tubes. Interestingly, the most breeding related data in plastic tubes were detected in the young pine stand, considered as least ideal habitat.

Impact of vegetation

Grouping the data by vegetation density around the nest box, I did not find any detectable difference. The independency test on these density related data, however, showed some kind of relation between the three categories, without visible differences (critical χ^2-value: 46.19; calculated χ^2-value: 111.08; $P<0.05$).

A distinct result was found when the data based on the condition of the plant where the nest box was put: living or dead. The homogenity test for this case gave a significant difference, thus these two data sets were different (critical χ^2-value: 26.3; calculated χ^2-value: 119.66; $P<0.05$). The dormouse data came predominantly from the living trees and shrubs.

The plant type was also used as a grouping parameter, and the independency test was run on these groups. The calculation revealed that the plant type categories are not independent; the distribution of data is significantly different (critical χ^2-value: 101.88; calculated χ^2-value: 670.22; $P<0.05$). The occurence of hazel dormouse was much greater in fruity shrubs, and also in the conifer category, whilst for deciduous trees and the category oak; it was the fat dormouse which was far more abundant.

Impact of nest box type

In order to analyse the differences between the two nest box types, a special test was set up where all three species could be detected in both nest box types. However, it was clear that the hazel dormouse used plastic tubes much more often. With regard to total occupancy, including invertebrates and feeding signs, plastic tubes were used far less than wooden boxes.

From a statistical point of view, the distribution within the two different nest box types was significantly different (critical χ^2-value: 9.49; calculated χ^2-value: 244.12; $P<0.05$). Peak value was achieved for the hazel dormouse, meaning that this species used the plastic tubes much more often than any other small mammal, including woodmice. However, during the three year period of analysis, the tits never used the plastic tubes for nesting, despite the fact that this artificial hole was suitable for them in those sites, where there was no other type. In the oak forest and the young pine stand in Naszály or in Domony, tit nests were regularly found, even successful broods, in plastic tubes.

A similar trend was also detected when comparing the other areas, where all three species occured. The higher abundance or higher nest box occupancy of fat dormice lead to a reduction in the occupancy of the much smaller hazel dormouse. This process was most visible in the neighbouring hedge and shrub patches. Over time, as the hedge and the orchard turned to forest, the density of the vegetation also grew. At the same time, more and more fat dormice moved to the more densely vegetated area, resulting in a reduction in hazel dormouse numbers. As a result of this decrease, the nesting of the hazel dormouse in the nearby shrub patch increased. It was detected, and later confirmed by data, that hazel dormice used the wooden boxes in the hedges in spring, whilst the fat dormice were still in hibernation. Thus, hazel dormice were flexible in their “commuting” between the two patches, which depended upon the strength of nest site competition.

Seasonality

The previous analysis shows that the co-existence of the three species is based more on the avoidance of one another – the smaller species avoiding the larger one. However, it is also evident that the avoidance is temporal. The data show that the earliest active species occupying the nest boxes is the hazel dormouse (from mid March, depending on snow conditions), followed by the forest dormouse in April. However, the nest box related abundance of both species decreases when the fat dormouse appears. At the same time, as the fat dormouse is the first to start hibernation, the empty nest boxes begin to host hazel dormice again and sometimes even forest dormice from September-October. The latter species is rather rare, and the autumn occurence rate is much lower than the spring activity of the forest dormouse. Again, the following spring they moved into the boxes in large numbers and even raised young.

If we look at the seasonal dynamics of breeding, the forest dormouse was first present in April and breeding was detected until May-June. Though the hazel dormouse is the first after hibernation, the first sign of breeding appeared in May. Based on the data it was possible to distinguish two mating seasons: May-June and August-October. There is some difference in plastic tubes as breeding activity was found to be less during the period between the two main seasons. The main breeding period of the fat dormouse, based on the results, seems to be August-September. The latest data related to breedingwere from November for hazel- and fat dormouse.

The monthly distribution data in Domony show that the plastic tubes were used by the hazel dormouse during the whole activ season. The forest dormouse here, however, appears later than in Naszály, with the first individuals being detected in June. Here, the summer or even autumn occurance of forest dormice can be seen as typical.

Body parameters

During the 13 years of research in Naszály, 308 individuals were measured from all three species, but in most cases there are only body weight data available. The biggest difference in the values for all three species was in the body weight. The species, but also the different age groups, can be differentiated based on body weight. The highest value was measured for a female fat dormouse in autumn, 172 g, and the lowest value was for a juvenile hazel dormouse living with its mother, 7 g.

In Domony-valley, all body parameters were only measured for one adult hazel and one forest dormouse. However, the body weight data for the forest dormice in Domony were higher than in Naszály.

Capture-mark-recapture

In Naszály, data were gathered from 95 marked individuals in the years 2006-2007. Regarding the 26 recaptures, most occured in the same year, one-two months after marking, or a maximum of one year later (for 7 individuals), in close vicinity (20-30 m) to the first capture, sometimes even in the same nest box. Interestingly, these marked individuals did not appear in later years.

Migration was observed for three fat dormice. The longest distance travelled was done by a male, which was recaptured one year after marking, and was travelling from the marking position (the forest edge) to the old pine stand, which in a straight line is a 5-600 m. A much closer recapture happened with a female fat dormouse, which travelled from the old pine stand to the downy oak patch. The distance travelled was around 300 m, and the time between the two captures was one month. The third individual worth mentioning moved from the old pine stand to the neighbouring orchard, which is a distance of approximately 100 m or less. With the individuals recaptured several times, migrations were not observed.

In Domony capture-mark-recapture data were gained also from 2006-2007. Here, only hazel dormice were marked with aluminium rings. One juvenile female and an adult male were recaptured in close vicinity of the marking. Both animals appeared a year after marking, but in latter years the marked individuals were not found.

New scientific results

Methodological results:

1. Confirmation that dormouse species can be well monitored with nest boxes, also in Hungary; and that in the case of co-existence between the three species, the best suitable box for long-term monitoring is the wooden nest box. However, for the hazel dormouse the plastic nest tube is a good alternative.
2. The data showed that the nest box type affects the dynamics of nest box occupancy: hazel dormice use the plastic tubes more often if fat dormice are in the same area. On the other hand, it was observed that after fat dormice have left the habitat, hazel dormice again nested in wooden boxes, showing that they swap between the two nest box types based on the intensity of nest-site concurrence.

Results on population level:

1. The exact abundance of the three species was not determined in the research sites, but increasing trends could be shown in the numbers of hazel- and fat dormouse, whereas no changes could be observed for forest dormouse.
2. The cause of the observed strong fluctuation in yearly fat dormouse numbers depends supposedly on the acorn mast of the oak trees.
3. Furthermore, the data showed that hazel dormice breed in the research sites in May-June and in August-September, which is a longer time period than described in the literature. Such a precise delimitation was not found for the two other species but in Naszály, the forest dormouse breeding period was April-May, whereas fat dormice bred in August-September.

Results on habitat level:

1. Confirmation of a difference between the habitat requirements of the three species was found. The hazel dormouse can be seen as the most euryoecious species in Hungary. The comparison of the two research sites (Naszály and Domony) shows that habitats of similar vegetation structure have the same importance for dormice even where there are differences in species composition.
2. The data also showed that the vegetation type affets the species composition of the dormouse community. Whereas the coniferous and shrub cover enabled the collection of more data for hazel dormice, there was a higher presence of the fat dormouse in the deciduous cover and the habitats dominated by oak trees.
3. Confirmation of the hypothesis of the national and international literature – that dormouse species can on a long-term co-exist in one habitat, even in the same vegetation patch - was found.
4. It was proven that the segregation between the dormouse species occurs through the seasonal avoidance of one another, namely that hazel- and forest dormice avoid the use of the nest boxes for nesting purposes during the active period of the fat dormouse in order to minimise competition. This is highlighted also in the data from Domony, where forest dormouse specimens were found in nest boxes, mostly in the summer months, when their Naszály “relatives” were looking for nesting sites elsewhere.
5. This strategy explains how three dormouse species can co-exist in a rather small space.

CONCLUSIONS AND PROPOSALS

Based on the results it can be stated, with certainty, that good monitoring of dormouse species is possible by setting up and regularly checking nest boxes. The use of nest boxes is also important for species conservation, as it replaces natural holes, providing hides and safe breeding sites, whilst also providing the opportunity for other hole-nesting animals to use them. However, it must be noted that setting up of nest boxes does not significantly influence the carrying capacity of the area.

The rate of nest box utilization by dormice was independent of its type and showed similar values: 9-10% utilization of all boxes was found for dormice at both sites. Based on this, the plastic tubes can be considered a good alternative for long-term monitoring.

If we analyse those areas where only plastic tubes were put out, we can state, based on the results, that it is almost soley the hazel dormouse that used this nest box type. This phenomenon, however, cannot be explained only by the probable selective effect of the plastic tubes. The character and vegetation structure of the young pine stand and shrub patch in Naszály can also contribute to this selectivity. In the shrub patch, the movement of the heavier-bodied forest- and fat dormice is rather difficult, and in the young pine stand even the hazel dormice occured in the edges, where there is rich undergrowth, showing that the latter area was also not ideal for them. This observation is underlined by the fact that in the oak forest, where only plastic tubes were placed, forest- and fat dormice were found several times. Moreover, in the downy oak patch, where the dormice could chose from two different nest box types, both larger species were found in plastic tubes.

However, if the aim is to investigate the co-existence of the three species, the nesting rates show that supposedly the wooden nest boxes provide reliable distribution data. If we look at the results of the breeding-related analysis, the difference is even more obvious, with only the wooden nest boxes seen as suitable for breeding for all three species. But, if by the utilization of nest boxes we aim at only providing evidence on the occurence of dormice in an area, plastic tubes can be advantageous because of the lower purchasing costs and relative ease in setting-up.

The aggregation of several specimens outside the breeding season was mostly found for fat dormouse immediately after the awakening from hibernation, and in one case for hazel dormouse where two adult females were raising their offspring together. From this, it can be concluded that, given the number of and distance between nest boxes, the quantity of nesting sites was not a limiting factor, namely adult specimens were not forced to regularly share nest boxes.

Whether, both in Naszály and in Domony, the nest box colony had any effect on the population size, the data could neither prove nor disprove this. However, there was a trend in Naszály for of increasing hazel- and fat dormouse numbers, but this could also be explained by immigration from other areas. In the absence of natural holes, artificial nest boxes are surely an important factor in colonising a vegetation patch, which is otherwise rich in food plants. At the same time, the observed breeding peakes, especially for fat dormouse, are the result of the rich acorn mast in that particular year rather than the large amount of nesting holes, as the total occupancy, with little fluctuations, remained stable throughout the years.

Concerning the segregation between the different vegetation patches, if we disgard the selective effect of the plastic tubes based on the reasons given above, two of the eight sites at Naszály can be considered as different, namely those where hazel dormice was the main occuring species. In theory, given the vegetation structure of the shrub patch, it is not suitable for the two bigger-bodied species, whereas in the planted young pine stand, the absence of food plants might be the excluding factor. The hazel dormouse, at least as far as the vegetation structure and the species composition of the habitat is concerned, is the most euryoecious of the three dormouse species occuring in Hungary. This is also shown by the larger distribution area.

Hazel dormouse was found in Domony in all analysed vegetation patches. However, the forest dormouse was mostly found in the hawthorn-blackthorn patch. This part, with its lower canopy level, dense wooded vegetation – at lease in terms of its structure – very much resembles the abandoned orchard or the hedge patch in Naszály. This can be highlighted through statistical analysis. Moreover, these areas also showed similarities to the Naszály forest edge and old pine stand.

In years when the fat dormouse appeared in higher numbers, hazel dormouse occurence in wooden boxes was rarer. In the area dominated by downy oak, where the two nest box types where put next to each other, in years with high fat dormouse numbers, it was rarer to find hazel dormouse even in plastic tubes. It can be assumed, however, that there has not been a decrease in the abundance of the population. For the hazel dormouse, the nest box occupancy data do not provide a fully reliable source for accurately estimating the population size, the reason being that if nest boxes are not suitable for nesting – such as due to strong nest site competition – they simply build free-standing nests in the shrubs.

If we look at the breeding data, the fat dormouse seems to be benefiting the most from the artificial nest boxes: the breeding rate of this species was much higher than for the other two. It must be emphasized that even if hazel dormice are the first to move in during the spring, they still start breeding later than the forest dormouse, which appears one month later on average. For the fat dormouse, the breeding period was determined as August-September. The observed breedings in November were probably the result of trying to compensate earlier unsuccessful broods, but the offspring born so late in the year have very low survival rates during long winters. However, in cases where there is favourable late-autumn weather they might get enough food to prepare themselves for a successful hibernation.

Concerning the quality of the adjacent vegetation around the nest boxes, or the type of the tree or shrub, the higher rate of occurance of hazel dormouse in the shrub patch and the young pine stand is supposedly actually the result of the vegetation structure. On the other hand, the high numbers of the fat dormouse in oak trees underline their strong reliance on this food source.

Based on the data, no statistical difference could be determined between any of the three species concerning the density of surrounding vegetation around the nest boxes. It seems that this feature is not an important factor in the choice of nesting site, as the nest box provided enough safety. However, dividing the data into two groups based on the variable ‘living tree or shrub’; living, meaning growing leaves, or dead, meaning completely bare. In this case, there was a clearly visible avoidance of the dead woody plants. It may be that because of their nocturnal activity, the amount of branches which are close to the nest box, and which provide a corridor for quick movement, is more important than the dense shelter.

The analysis of seasonal occupancy data revealed that in parallel to the apearance of fat dormice in the boxes, the numbers of the other main hole-breeding species decreases. On the other hand, later, when the fat dormice leave for hibernation, the other species occur again in higher numbers in the nest boxes. Only the forest dormouse did not show this trend. *Apodemus* species occur all year long in the nest boxes, but in larger numbers when all dormouse species – including the hazel dormouse – are absent from the nest boxes. This shows that woodmice supposedly avoided using nest boxes for the rest of the year because of dormouse presence.

Analysing the yearly activity, the difference found for the forest dormouse in the two research sites must be highlighted. Whereas in Naszály we found the species right after hibernation in spring, and their numbers were decreasing throughout the year, in Domony, specimens were found mostly in autumn. This phenomenon can be explained by the nest box type, or rather the size of the box. As no breeding for the forest dormouse was detected in either site, one can conclude that the Domony plastic tubes were used after the breeding season, when a smaller hole was enough for nesting. In Naszály, however, the presence of the fat dormouse could have been the reason for the avoidance of nest boxes. Another possible reason for this phenomenon could be the food availability of the patch, particularly if hawthorn and blackthorn provide sufficient quality and quantity of food at the end of summer and into autumn.

Because of the high fluctuations in sample numbers for body measurements, one cannot draw precise conclusions. This is even more the case if comparing the two research sites. However, one could point out the differences found in body weight values amongst the forest dormouse. The data in Domony were taken in autumn, meaning that the difference could have been the result of the preparations and fattening for hibernation.

Mark-capture-recapture studies were only performed in 2006-2007. The results provide only some insights into the movement patterns of the fat dormouse. The majority of the 26 recapture incidents occured in the immediate vicinity of the marking, which shows a strong site-fidelity. A possible reason for the relatively few migrations which were noted, is resource scarcity, meaning that the particular specimen moved further away to avoid competition for food or nesting sites. The recapture distances (< 600 m), however, are quite normal, as fat dormice can cover more than 500 m-s in one night.

Conservation proposals

It would be interesting to study the effects of the two different nest box types on the study results. For this, both wooden and plastic nest boxes of different sizes would need to be used to figure out whether it really is the material of the box or the inner volume which is the limiting factor. But, if I were to make an assumption based on the current results, I would say that the wooden nest box seems to be the best option for monitoring all three species. This is especially the case if we want to encourage breeding for conservation purposes. However, if the aim is only to prove the presence of the species, the plastic tube is also a good alternative. The lower cost and relative ease of seeting-up provides further advantages for the practical conservation in Hungary. It can also be noted that this type could also be considered for setting up bird nest box colonies as tit species were found nesting in plastic tubes.

The results show that dormouse species can co-exist on a long-term within one area, even in the same vegetation patch if the habitat provides enough resources for nesting and feeding. It is only diverse habitats which are suitable and can support three species which have similar diets and home range, even within the same hedge or forest edge. This is even more important for the hazel dormouse, which has the smallest home range of the three species, as they need food rich in energy and protein throughout the whole vegetation period.

From the habitat patterns, it must be highlighted that, from what could also be seen in Domony, even rows of trees between agricultural fields, provided they consist of native tree and shrub species, can be important habitats for the rarest dormouse species in Hungary: the forest dormouse. Such woody strips can have particular value in connecting larger forest areas, as eco-corridors, which are suitable for the species, but otherwise not connected.

The number of nesting opportunities is another important aspect of the suitability of a habitat for dormice. The hazel dormouse can also build free-standing nests, but the two other species are more in need of natural holes for nesting. Some habitats, where they go only for feeding, or which are the above mentioned eco-corridors, where there are no or not enough natural holes, can be made more attractive for dormice by putting out artificial nest boxes. Such areas can be considered as important for conservation purposes.

One of the key elements leading to a better understanding of population dynamics of dormouse species in Hungary is the development of individual marking methods. Besides making use of further tattooing possibilities – depending on funding – microchips could be used. Given that catching and handling of dormice needs practice, targeted courses could be used for training.

The conservation of protected species on the long-term is only possible through the preservation of their habitats. There are severeal more suitable dormouse habitats in Hungary, and these should be sought for in order to preserve our natural heritage. It is important to emphasize that human influence is also crucial for preserving the diversity of habitats, considering the co-existence of the three species. The extensive, species-rich orchards close to forests, with hedges planted between them provide the necessary conditions within a rather small area. Furthermore, the occurance of dormice in such cultivated orchards shows the high conservation value of this habitat, and in turn provides suitable areas for many other protected plant and animal species, which can be observed in them.

Raising awareness on dormouse species is also an important conservation tool. Fat dormice often appear in houses, summer lodges close to forests, where the owners often meet these animals. Many people simply are not aware of what kind of animal they encounter and have an unfounded fear and hatred against this small mammal, which is legally protected. Public relations and stakeholder involvement is crucial for all conservation measures.

Besides the obligatory dormouse monitoring in the national parks of Hungary, it would be practical to establish further nest box colonies. This would be especially justified in those areas where – based on the country-wide distribution of dormice – the co-existence of the three species can be predicted. For this, the leaders of national parks and the local groups of BirdLife Hungary (MME) can be contacted, in order to achieve regular nest box checks and their maintenance if necessary. Furthermore, the area where the nest boxes are put out might need conservation measures to keep the vegetation structure favourable for dormice in the long-term. An old, but well-maintained forest is the most favourable dormouse habitat, as clearings allow sunlight to pass through, so shrubs and young trees grow better, more flowers and insects appear, which increases the food base for dormice. On the other hand, the closed canopy, with its shading effect, reduces the survival rate of dormice, with animals moving into the forest edges. The habitat requirements of dormice should be taken into consideration by forest managers in Hungary, including via the voluntary initiative ProSylva.

The current conservation status of dormice in Hungary can be considered as stable. The distribution data show several areas where the three dormouse species co-exist. It would be practical to look for potential target areas, and in them, to start monitoring with nest box colonies. The forest dormouse should be managed in a more specific way, through the development of a special conservation programme for this species – based on the NBMS system.

PUBLICATIONS RELATED TO THE THESIS

Peer-reviewed articles published in scientific journals

Foreign language journals, with impact factor

HECKER K., BAKÓ B. & CSORBA G. (2003): Distribution Ecology of the Hungarian Dormouse Species, Based on the National Biodiversity-Monitoring System. Acta Zoologica Hungarica, 49 (Suppl. 1): 45-54. (IF: 0.564)

BAKÓ B. & **HECKER K.** (2006): Factors Determining the Distribution of Coexisting Dormouse Species (Gliridae, Rodentia). Polish Journal of Ecology 54(3): 379-386. (IF: 0.51)

Hungarian journals, no impact factor

HECKER K., BAKÓ B. & CSORBA G. (2003): Új adatok a magyarországi pelefajok (Gliridae) elterjedéséhez [New data on the distribution of dormice (Gliridae) in Hungary]. Állattani Közlemények 88(2): 57-67.

Book part

HECKER K., BAKÓ B. & BERTY L. (2010): Emlősök a Naszály hegyen [Mammals on the Naszály-hill]. IN: PINTÉR B. & TÍMÁR G. (szerk.): A Naszály természetrajza, Rosalia (Duna–Ipoly Nemzeti Park Igazgatóság tanulmánykötetei) 5, pp. 791–800.

Conference proceedings

HECKER K. & BAKÓ B. (2008): Comparison of the occupancy of different nest box types by dormice. Proceedings. VIIth International Dormouse Conference, September 2008, Shipham, Somerset, UK. 7 pp. (elektronikus kiadvány)

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