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THE IMPORTANCE OF ANIMAL FOOD FOR *DRYOMYS NITEDULA* (PALLAS) AND *GLIS GLIS* (L.) IN BIAŁOWIEŻA FOREST (EAST POLAND): ANALYSIS OF FAECES

ABSTRACT: Fresh faeces of dormice found in nestboxes along the permanent transect in Białowieża Forest were analysed. The study area was a managed forest of diverse biotopes. In total, 196 samples of faeces of the forest dormouse (*Dryomys nitedula*) and 62 of edible dormouse (*Glis glis*) were examined. In the faeces analysed, the following categories of food remains were distinguished: chitin carapaces, calcareous shells, feathers, seeds, plant fibres. In the forest dormouse, chitin carapaces were found in 100% of samples, but in only 8% of the edible dormouse samples. Feathers were noted in 36% of samples of forest dormouse faeces, but only in 12% of samples from the edible dormouse. Calcareous shells were found in 14% of forest dormouse samples and 1.6% of edible dormouse faeces. Remains of animal food were found in 100% of samples of forest dormouse excrements, but only in 29% of samples from the edible dormouse. The highest percent of faecal samples with animal remains was found in the edible dormouse in July, while in the forest dormouse seasonal variation occurred only in some types of animal remains. Most of the chitin carapaces identified in forest dormouse faeces came from Chilopoda (45%), Hemiptera (33%) and Coleoptera (22%). In faeces of the edible dormouse the majority were remains of butterflies (55%). The results presented here suggest an almost total separation of the food niches of the two dormouse species.

KEY WORDS: *Glis glis*, *Dryomys nitedula*, diet, analysis of faeces, Białowieża Forest

1. INTRODUCTION

Composition of diet in rodents varies within the year and depends on food availability, its calorific value (or more generally – its quality) and feeding preferences of a given species. This diversity seems to reduce competition to a great extent in the community of rodents occurring in a given habitat. Understanding the diet, and importance of its components, in relatively closely related species such as the forest dormouse (*Dryomys nitedula* Pallas, 1779) and the edible dormouse (*Glis glis* Linnaeus, 1766) is crucial, especially in the case of animals that occupy similar habitats (Nowakowski and Boratyński 1997, Nowakowski and Manowiec 2000) and have a similar way of life (Pucek 1984), when competition may be particularly strong due to overlap of their geographical ranges (Storch 1978, Mitchell-Jones *et al.* 1999).

The diet of dormice (Gliridae, Rodentia) and interrelations of their food niches, including the edible dormouse and the forest dormouse, have not been well described

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hitherto. Only a few original papers investigate this issue in detail (e.g. Holišová 1968, Franco 1990, Lozan *et al.* 1990, Gigirey and Rey 1999) based on analysis of the stomach contents or faeces of these two species of dormice. Unfortunately, the number of samples analysed in these studies was small, in the case of such studies as Holišová (1968), Lozan *et al.* (1990) impeding any analysis of diet changes over time and making these results rather approximate. More information on the changes of the diet during the season, however considering only the edible dormouse, have been provided by Franco (1990) and Gigirey and Rey (1999). Other data in the literature are even less precise. Thus it is very difficult to define the diet of the edible dormouse, and in particular – of the forest dormouse, and hence their interrelations and role in the forest rodent community. Some authors state that the forest dormouse feeds mainly on plant food, although it also uses animal food (Serafiński 1972, Głazaczow 1994). However, other studies have shown that, at least in spring and summer, arthropods and eggs, nestlings and even adult birds play an important role in their diet (Golodushko and Padutov 1961, Angermann 1963, Holišová 1968, Lozan *et al.* 1990, Nowakowski 1995, Nowakowski and Boratyński 2000). Angermann (1963) assumed that forest dormice probably eat the food that is most abundant in their environment, and are thus opportunist feeders. Unfortunately, these assumptions were not supported by any convincing evidence.

Food of the edible dormouse is thought to be buds, fruits and seeds of trees, bark, twigs, with animal food only a supplement (Holišová 1968, Serafiński 1972, Pucek 1984, Lozan *et al.* 1990, Rossolimo *et al.* 2001).

In the present study we aimed to compare the diet composition of the forest dormouse and the edible dormouse and describe seasonal changes, especially in respect of animal food.

2. STUDY SITE

The studied transect was located in the southern part of Białowieża Forest (eastern Poland) within managed forests. This transect crossed diverse habitats, often changed by the forest management. They were tree stands of the age 50–250 years of different density (from 25% to 100% of crown closure), which can be divided into the following types: broadleaved forest (with the domination of the oak and hornbeam), mixed forest (with the domination of the oak, hornbeam, pine and spruce), mixed coniferous forest (with the domination of the pine or spruce and oak), coniferous forest (with the domination of the pine or spruce), and swamp forests (with the domination of the pine and spruce or alder and aspen). The understorey layer was usually rich and formed, depending on the biotope, by: *Corylus avellana, Sorbus aucuparia, Frangula alnus, Viburnum opulus, Euonymus europaeus, Prunus avium, Rubus idaeus, Rubus plicatus, Ribes* sp.; in the herb layer various species of *Vaccinium* sp. and *Fragaria sp.* were common.

3. MATERIAL AND METHODS

Dietary composition of the forest dormouse and the edible dormouse was described based on an analysis of faeces. Excrements were collected from about 190 nestboxes (their number varied in different years) occupied by these rodents. The boxes were distributed along a 13 km transect. Nestboxes were fixed to trees 3–4 m above the ground. Samples of faeces were collected in years 1996–1999 and 2001–2003, every week between April and September (edible dormice were found in nestboxes from May to September, thus data from April are lacking). During each weekly nestbox check we thoroughly removed excrements found inside. Therefore we were sure that during the following nestbox check we collected only fresh faeces, not older than one week. Samples came from individuals found in nestboxes (in such cases species identification of droppings was easy) as well as from abandoned nests (in these cases droppings were identified by their typical features according to Nowakowski and Boratyński 2000). The whole amount of faeces found during a check of a nestbox was treated as a single sample. A total of 196 samples

of faeces of the forest dormouse and 62 of edible dormouse were collected (Tables 1 and 2).

The collected material was conserved in 95% ethyl alcohol. Each portion was weighed just before preparation, as samples were at different stages of drying out when they were collected. As it was stated based on analysis of 10 samples, storing faeces in alcohol does not change their mass substantially in comparison with their mass during defecation. Faeces were dried on filter paper for 15 minutes before being weighed. After weighing each sample was placed on a glass, soaked with water, and than delicately separated under a microscope with tweezers and preparation needle. This allowed for calculation of the content of remains in one gram of faeces. Visible and recognizable food remains were segregated into the following groups: remains of arthropods (chitin carapaces), feathers, calcareous shells, seeds and plant fibres. Remains of arthropods were collected, dried, counted and described and then identified (Pławilszczikow 1972, Razowski 1987, McAney *et al.* 1991, Rachwald 1996). Identification of arthropods remains was not difficult, as relatively large, weakly crumbled fragments were left in the excrements of rodents. In the analyses only unambiguously identified remains were considered. In the remaining classes of food remains only their presence in a sample was recorded. Calcareous shells were not divided into bird egg shells and snail shells, due to difficulties in their identification. The category "seeds" represents only the remains of consumed soft fruits (e.g. raspberries, blueberries or rowan berries), as their seeds were not digested.

For comparisons of the number of remains of arthropods (per one gram of faeces) between consecutive months the non-parametric Kruskal-Wallis test (further referred to as K-W test) and *post-hoc* Dunn test were used (Zar 1999). To compare proportions of the distinguished types of food remains between subsequent months G test was applied (Sokal and Rohlf 2001).

4. RESULTS

In faeces of the forest dormouse all the specified classes of food were found, but it was often the case that not all kinds of food occurred in one sample. Some types were found in 100% of faecal samples, while others only in a small proportion (Fig. 1).

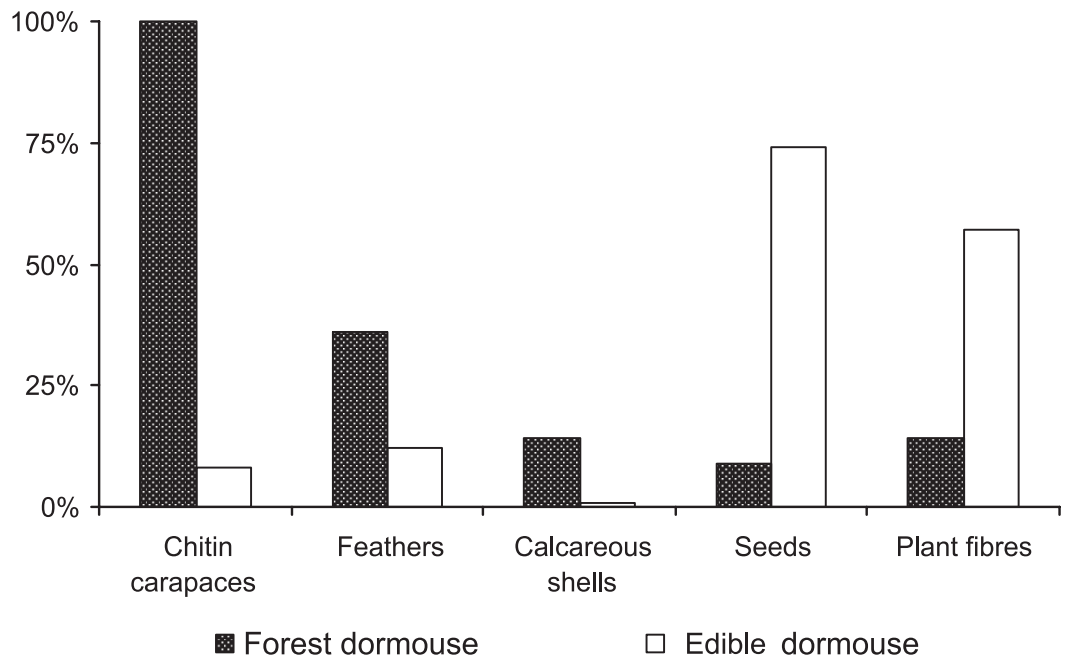

Fig. 1. Percentage (all months and years pooled together) of faecal samples of the forest dormouse and edible dormouse with remains of a given type of food.

Remains of arthropods were found in all samples of faeces collected in all months and years (100%). Bird feathers were absent only in samples from April. In other months (May–September) the proportion of samples that included feathers varied between 44% in May and 9% in August. In total, the proportion of samples containing feathers was 36%. Calcareous shells did not occur in samples from April and August. In the remaining period (May–July and September) shells were found in 15% of samples, and their overall proportion among all samples was 14%. In the forest dormouse remains of plant food (in 6% of all samples) were found in samples from all months, but in April seeds were not present. The proportion of samples with plant fibres varied from 1% in May to 22% in June, and seeds from 2% in June to 18% in August (Table 1).

In faeces of the edible dormouse all categories of food remains were found. Large differences in the percentage of samples including various types of food were observed (Fig. 1). The main component forming each portion of faeces consisted of plant fibres and a structureless greasy substance with high content of starch and cellulose grains (this was not analysed in more detail). Remains of arthropods were found in only one sample from July (overall proportion 1.6%), while bird feathers were found in samples from June and July, and those samples amounted to almost 18% of the total. The proportion of samples that included calcareous shells did not exceed 6%, although they were noted in excrements in the same months as feathers. All samples of faeces of the edible dormouse included plant remains, but seeds were absent in May. The proportion of samples that included plant fibres varied from 100% in May to 56% in July, and those with seeds – from 34% in June to 85% in September (Table 2).

The majority of recognisable remains of arthropods in faeces of the edible dormouse were parts of butterflies (Lepidoptera) – they comprised 55% of all these items. More detailed analysis of the species composition of animal food was not possible as only one sample of faeces contained chitin carapaces. In faeces of the forest dormouse most remains of chitin carapaces belonged to Hemiptera and Diplopoda (jointly 79% of all items). Remains of Coleoptera were also a relatively high proportion (Fig. 2). It is noteworthy that, in contrast to the edible dormouse, the remains of Lepidoptera formed less than 10% of chitin remains in each

Table 1. Percentage of samples of faeces (n = 196) of the forest dormouse containing different types of food in successive months of the activity period (Białowieża Forest).

Food type	Apr	May	June	July	Aug	Sept
Chitin carapaces	100	100	100	100	100	100
Feathers	0	45	42	22	7	25
Calcareous shells	0	18	13	11	0	12
Seeds	0	5	2	11	21	6
Plant fibres	0	8	22	17	21	19
Number of samples	14	74	60	18	14	16

Table 2. Percentage of samples of faeces (n = 62) of the edible dormouse containing given types of food in successive months of the activity period (Białowieża Forest).

Food type	May	June	July	Aug	Sept
Chitin carapaces	0	0	13	0	0
Feathers	0	8	23	0	0
Calcareous shells	0	8	8	0	0
Seeds	0	33	83	78	83
Plant fibres	100	73	46	73	64
Number of samples	8	13	12	18	11

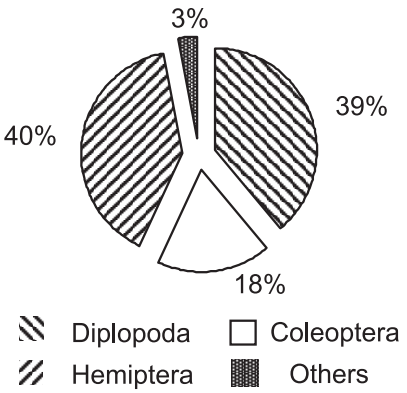

Fig. 2. Proportion of the most numerous remains of arthropods in all analysed samples of faeces of the forest dormouse.

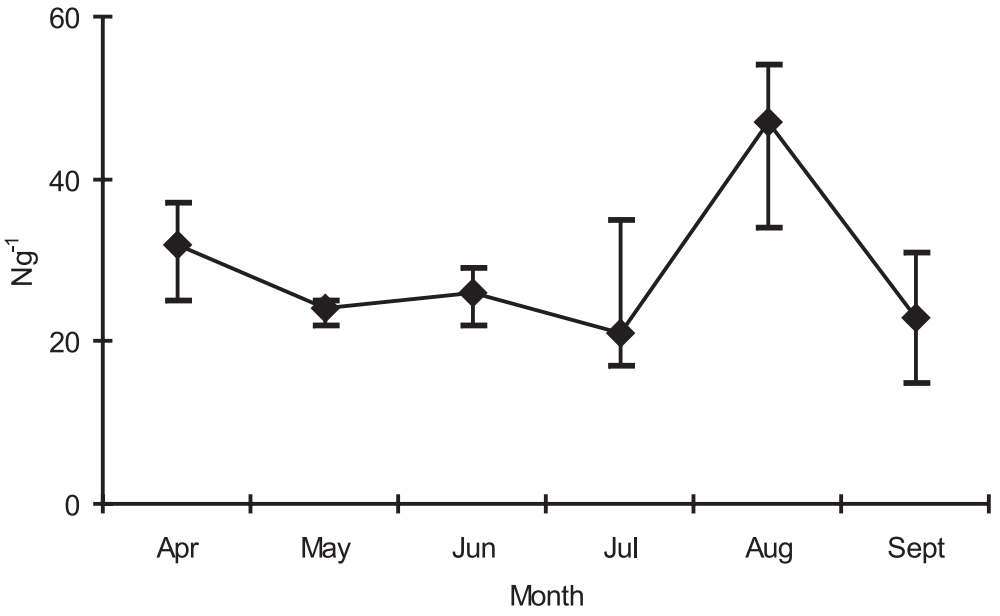

Fig. 3. Seasonal changes in the number of remains of arthropods (chitin carapaces) in one gram of faeces of the forest dormouse (all collected samples considered). Rhomb – median; vertical lines – range 25–75%; sample sizes for each month given in the Table 1.

sample. We revealed significant differences in the number of chitin remains in faeces of the forest dormouse in successive months – Fig. 3 (K-W test: $H_{5, 196} = 30.25$, $P < 0.0001$). The number of these remains differed significantly (*post-hoc* Dunn test) between August and May ($P < 0.0001$), June ($P < 0.0001$), September ($P < 0.05$). The number of chitin remains was also significantly higher in April than in May and June (*post-hoc* Dunn test: for both comparisons $P < 0.0001$). The lowest numbers of these remains were recorded in July – it was significantly lower than in May and June (*post-hoc* Dunn test: for both comparisons $P < 0.0001$). The numbers of chitin remains were intermediate in May and June and although the median values were close to that in September (Fig. 3), they both differed from that month (*post-hoc* Dunn test: for both comparisons $P < 0.0001$).

Seasonal changes in the content of different types of arthropods' remains were also revealed in the forest dormouse. The proportion of remains of Diplopoda in June

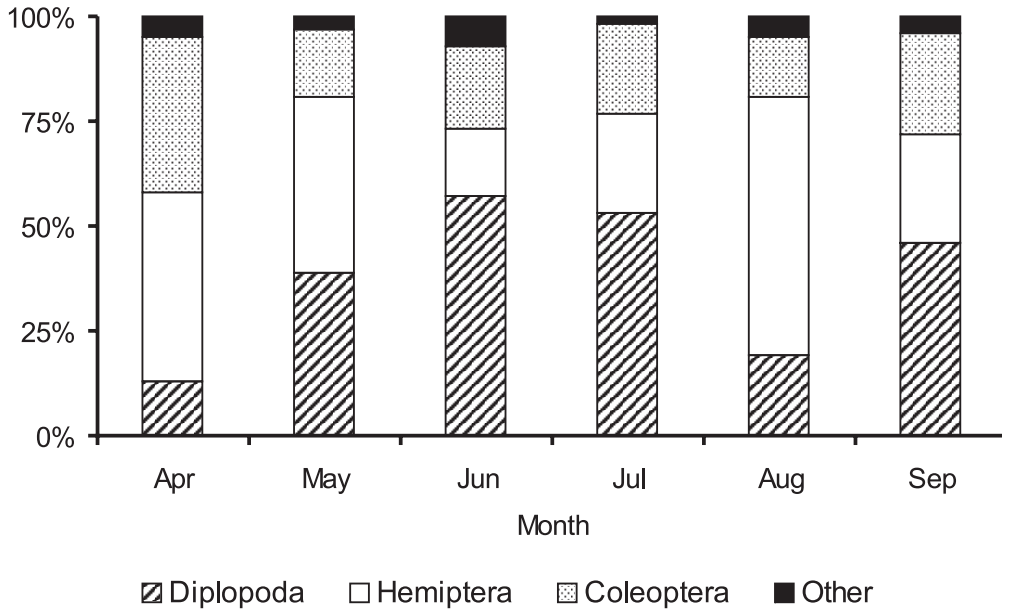

Fig. 4. Percentage of different types of arthropod remains in faeces of the forest dormouse during successive months (all collected samples considered).

and July exceeded 50%, and in September reached 46%. Remains of Hemiptera in August reached 62%, and in April and May it exceeded 40%. These were the most abundant types of remains in successive months (Fig. 4). Remains of Coleoptera were most numerous in April, amounting to 37%. Remains of Hymenoptera were the most abundant in June (4%) and Lepidoptera in August (2.5%). June, July and September samples did not differ significantly in their distribution of proportions of other types of remains, while June and August samples differed significantly ($G = 50.3$; $P < 0.0001$). April differed in this respect from May, June and August (respectively: $G = 22.8$; $P < 0.001$; $G = 49.5$; $P < 0.0001$; $G = 14.6$; $P < 0.01$).

5. DISCUSSION

When identifying animal food remains in faeces of forest and edible dormice (as well as in other animals) one should bear in mind that the data obtained can be imprecise. Many food types are impossible to detect in faeces (e.g. the soft caterpillars of butterflies, especially when the head is not eaten). This leads to underestimation of some types of food and overestimation of others. Wings of small dipterans are digested to a different extent compared with the thick carapace of coleopterans, while wings of butterflies are usually cut off and left by a consumer (author's unpublished data). On the other hand, it seems that hemipterans and orthopterans (if they are of a similar size) do not differ in their susceptibility to being digested, or in the state of preservation of their remains. Another problem lies in the identification of calcareous shells. They can be fragments of bird egg shells or shells of snails. Digestive enzymes extensively damage the structure of shells and remove pigments, which makes identification of these remains practically impossible. Calcareous shells are swallowed by the animals in very small pieces, rarely and rather accidentally while eating egg content, so that they do not reflect the actual number of eggs consumed, in contrast to chitin remains which are directly related to the number of eaten arthropods. However, one should remember that certain type of remains has the same level of preservation in all samples, and its proportion is thus possible to determine irrespective of its importance in a diet. This allows for cautious conclusions.

While assessing advantages and disadvantages of different methods of food analy-

sis it should be taken into account that some of the methods previously used in studies of dormice diet composition involve killing the animals (Angermann 1963, Holišová 1968, Lozan *et al.* 1990). Both studied species are legally protected in Poland and listed in the Red Data Book of Animals (2001), so that the analysis of faeces, although perhaps less accurate, is more suitable as a non-invasive method. It has been successfully applied by some authors (e.g. Abt and Bock 1998, Gigirey and Rey 1999). An additional advantage of this method is that it does not even require direct contact with the animals being studied.

Previously it had been thought that in both forest and edible dormice plant food was the main basis of their diet and animal food was consumed only occasionally with only a supplemental importance (Serafiński 1972, Pucek 1984, Serafiński and Wielgus-Serafińska 1988, Głazaczow 1994). However, studies of Lozan and co-authors (1990) showed that the proportion of animal food in the diet of both these rodents was relatively high, amounting to about 59% of all remains found in stomachs of forest dormice and 41.2% of edible dormice. That paper did not mention eating bird eggs or nestlings by the forest dormouse. The present study confirmed the results of Lozan *et al.* (1990) and showed that the opinion about the supplementary role of the animal food in the diet is at least imprecise for the forest dormouse. This type of food seems to play even the basic role as its remains were found in 100% of samples of faeces. Distinct differences in the amount of animal remains in faeces were revealed between the forest dormouse and the edible dormouse. In the latter species the animal food indeed seems to be only marginal. It should be emphasised at this point that high brood losses in *Parus* and *Ficedula* caused by forest dormice have been described (Nowakowski 1995, Nowakowski and Boratyński 2000), which is on one hand supported by the results of the present study, but on the other hand it is opposite to the data of Lozan *et al.* (1990). However the period from which the stomachs analysed by the cited authors originated was not specified – obviously the remains of shells and chick feathers can be found in excrements only in certain times of a year. Records of edible dormice destroying bird nests are lacking, but such a case was observed during the present study. The data presented here concerning groups of invertebrates in the food of forest dormice are in accordance with those presented by Lozan *et al.* (1990). Among insects they found in stomachs of forest dormice, coleopterans were the most frequent (24% of food items). The second most frequent were butterfly caterpillars (18%), followed by dipterans and orthopterans (less than 10%). Similarly, in the present paper a high proportion of food remains in faeces were fragments of Coleoptera and Hemiptera. In contrast to data presented by Holišová (1968) and Lozan *et al.* (1990), Diplopoda, which have not been considered as a part of the forest dormouse diet, in the present study were found to be an important proportion of food items. Proportion of remains of dipterans and orthopterans in faeces of this rodent was very low. Based on analysis of faeces it is difficult to estimate a real proportion of insect larvae, especially caterpillars, in the diet of the forest dormouse, as remains of this type of food are very poorly preserved, being digested almost completely.

The results obtained do not allow us to discuss the importance of different types of arthropods for the edible dormouse. We would like to point out only that the quantity of chitin remains in faeces of this rodent was much lower than expected, based on data in the literature (Holišová 1968, Lozan *et al.* 1990, Franco 1990, Gigirey and Rey 1999).

In the present study, changes during the season were observed in the relative proportions of arthropod remains recognised in faeces of the forest dormouse. This can be interpreted as the effect of changes in availability of each type of prey. Seasonal changes in the diet were described in many different species of rodents by Drożdż (1966), Holišová (1971), Gębczyńska (1976) and Abt and Bock (1998).

The analysis of faeces showed that the forest dormouse fed on invertebrates during all months of its activity, but in April and August their occurrence increased. In April this was probably associated with the end of

hibernation and animal's need to restore its body mass as quickly as possible, and recover its general physical condition. The August increase in the amount of consumed invertebrates happened at the same time as the increase in activity described by Pucek (1984), which was interpreted as a behavioural aspect of the animals' preparation for hibernation. In September, a decrease in the number of arthropods was observed, which could be caused on the one hand by lower availability of insects, but also by seasonal occurrence of abundant highly nutritious food such as tree seeds, mainly in the form of acorns and hazelnuts (Grodziński 1961). The number of invertebrates consumed by the forest dormouse did not increase in June during its reproduction period (Sidorowicz 1959), and does not support the suggestion that pregnancy and lactation cause an increased proportion of animal food in its diet, as observed in other rodents (Gębczyńska 1976).

The present study demonstrated that food niches of the forest dormouse and the edible dormouse are completely separate. The first species appeared to be mostly a predator only supplementing its diet with plant food, while the main basis of the diet of the second species is clearly plant food with only a small addition of animal material.

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