# The diet of the garden dormouse (*Eliomys quercinus*) in the Netherlands in summer and autumn

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**Abstract:** The food of the last remaining population of garden dormouse (*Eliomys quercinus*) in the Netherlands is studied by means of analysing faecal samples, collected in the summer and autumn of the year 2010. In total 139 scat samples were collected from 51 different nest boxes. The samples were visually analysed for the presence (or absence) of different animal and vegetable food items using a stereo microscope. Millipedes (Diplopoda), beetles (Coleoptera) and snails (Gastropoda) were found to be the main animal food sources. Important vegetable food remains were the fruit pulp of apples, pears and seeds. The identified seeds were the remains of blackberries (*Rubus* ssp.) and elderberries (*Sambucus nigra*). The results were skewed by someone feeding the garden dormice with apples and pears. All the other food items were collected by the garden dormice themselves. These animal and vegetable food sources were present in more than 20% of the samples. Hymnopterans (Hymenoptera), earthworms (Lumbricidae), spiders (Araneae), harvestmen (Opiliones) and wood mice (*Apodemus sylvaticus*) were present in 5% to 20% of the samples. Flies (Diptera), true bugs (Heteroptera), woodlice (Isopoda), pseudoscorpions (Pseudoscorpiones), butterfly larvae (caterpillars) (Lepidoaptera), songbirds (Passeriformes) and flowers were occasionally found. Invertebrates, especially millipedes, are the staple food during the entire active feeding period. In spring and early summer the garden dormouse eats relatively more vertebrates (possibly mainly the nestlings of birds and mice), gastropods, beetles and flowers, than in August-November. The first seeds of berries were identified in the beginning of August. The occurrence of seeds increased rapidly to 90% at the end of August and then decreased to 30% in September and 0% by the end of October. Garden dormice in woods seem to depend on the rich invertebrate fauna within the litter layer. Mesotrophic mull soils have a rich fauna of medium-sized to large invertebrates and these soils are disappearing from the Savelsbos as a result of traditional management practices being abandoned. Re-establishment of species-rich wood types that produce mesotrophic mull soils could be of benefit to the remnant population of garden dormouse in the Savelsbos.

*Keywords:* garden dormouse, *Eliomys quercinus*, dormice, faecal analysis, food.



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## Introduction

The garden dormouse (*Eliomys quercinus* Linnaeus 1766) is a critically endangered species in the Netherlands (Thissen et al. 2009). The only remaining and isolated Dutch population consists of about 70 animals and is located in the Savelsbos (Savel Wood) in southern Limburg. On the European Red List of mammals, the garden dormouse is classified as Near Threatened. This species has declined more than almost any other rodent in Europe and may have disappeared from as much as 50% of its former range over the last 30 years (Temple & Terry 2007). Diet studies can make an important contribution to developing appropriate management plans for this species (Litvaitis 2000). This was the rationale for carrying out a diet study in the Savelsbos during the summer and autumn of 2010.

Gil-Delgado et al. (2010) claim to be the first authors to report on seasonal variability in the food of the garden dormouse. They analysed a large number of faeces samples from Mediterranean Spain, a region with quite different conditions. A number of other authors have studied the food of garden dormice outside the Mediterranean region, but the diet was only studied for a limited period of the year or with little detail (Brosset & Heim de Balsac 1967, Holišová 1968, le Louarn & Spitz 1974, Gigirey & Rey 1999). These authors analysed the stomach contents of dead animals. Our study refrained from using lethal or invasive methods and used faecal analysis to acquire information on the diet of the garden dormouse.

## Methods

### Study area

The Savelsbos is a *Stellario-Carpinetum* woodland of 360 hectares in the extreme southeast of the Netherlands, situated on Maastrichtian limestone on the eastern slope of the Meuse valley near the town of Maastricht (Province of Limburg). The last population of garden dormouse in the Netherlands lives at the bottom of the slope (60 to 90 m above sea level), in some 6 ha of land covering a portion of woodland and some adjacent agricultural land (50º 47' 24" N 5º 44' 15" E). The garden dormice of the Savelsbos are only active at night or during twilight, which is normal for the species. In summer 2009 two females with transmitters each had home ranges of 2.5 ha and a male had a home range of 3.4 ha (based on 95% minimum convex polygon; Dutch Mammal Society, unpublished data).

### Nest boxes

Garden dormice use nest boxes as day roosts, for reproduction and even hibernation (Cortens & Verbeylen 2009a). Nest boxes for the garden dormouse have been provided in the study area since 2003. The design was developed by the Flemish organisation Natuurpunt (as described in Cortens & Verbeylen 2009b). A special feature of these boxes is that the entry is located at the back of the box, on the tree side. In 2007 the first garden dormice were detected in the nest boxes. In the summer and autumn of 2010, the year of this study, 84 nest boxes in the Savelsbos were checked for faecal matter.

### Faecal samples

The faeces of garden dormouse are rather large, 2 to 4 mm wide and 7 to 15 mm long, sometimes even longer. They can be readily distinguished from those of other mammals which also use the nest boxes, such as wood mouse (*Apodemus sylvaticus*) and bank vole (*Myodes glareolus*).

All the faecal samples found inside or on top of a nest box were collected. Each sample contained all the faecal matter collected from a given nest box on one visit. The collecting method was similar to Gil-Delgado et al. (2010). From 25 June to 18 November 2010 samples were collected every week, except in

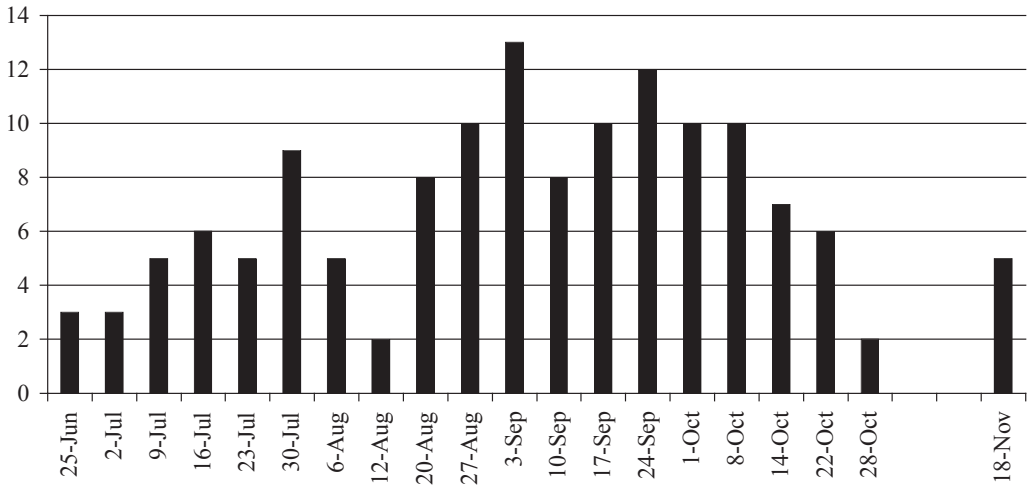



Figure 1. Number of faecal samples of garden dormouse collected per week in the Savelsbos in 2010.

the two first weeks of November. The samples were stored in 70% alcohol.

### Faecal analysis

First, boiled lukewarm water was added to the samples to make them soft. The container was shaken gently and the fluid in the container above the faecal matter was removed. The samples were then pulled apart in a dish, into pieces smaller than 3 mm. Then a subsample of 0.4 ml was taken in a measuring cylinder. Seventy per cent alcohol was added to make a total volume of 5 ml. The faecal samples were then analysed using stereo microscopes with a magnification of between 10x and 63x and the presence of the different food items was determined.

Mosses were found in many samples, but these were considered not to have been consumed by the garden dormice. Many nest boxes contained nesting material, mainly mosses and feathers. While collecting excrements, these mosses must have been collected accidentally. For the same reason it was decided to only take feathers and hairs into account if there were many in the sample or if they were found in combination with bones. In some samples a few completely undamaged arthropods were found. These were not taken into account, because these arthropods were presumed to have been inhabiting the nest boxes and collected accidentally.

### Statistical analysis

In many weeks the number of samples collected was rather low. To get a clearer picture, periods of two weeks (and a last period of four weeks) were used to determine any seasonal variations. Data were expressed as the frequency of occurrence (i.e. percentage of samples containing a specific food item).

SPSS Statistics 17.0 was used for statistical analysis. Assuming independence among the samples, logistic binary regression was used to determine any decrease or increase in food items consumed during the research period. Tests were done for all food items separately, taking a probability limit of 1%.

## Results

### Food

In total 139 samples were collected from 51 different nest boxes. In more than half of the

Table 1. Occurrence (percentage) of food items (based on absence or presence) in 139 faecal samples of garden dormice in the Savelsbos in summer and autumn 2010.

| Food item | % | Subcategory | % |
|---|---|---|---|
| **Animal** | | | |
| True bugs (Heteroptera) | 4% | | |
| Caterpillars (Lepidoptera larvae) | 1% | | |
| Flies (Diptera) | 4% | | |
| Hymenopterans (Hymenoptera) | 11% | Parasitic wasps (Ichneumonidae) | 1% |
| | | Bees/bumblebees (Apidae) | 4% |
| | | Ants (Formicidae) | 4% |
| | | Not identified | 2% |
| Beetles (Coleoptera) | 35% | Ground beetles (Carabidae) | 6% |
| | | Click beetles (Elateridae) | 1% |
| | | Weevils (Curculionidae) | 1% |
| | | Carrion beetles (Silphidae) | 1% |
| | | Not identified | 23% |
| | | Coleoptera larvae | 4% |
| Snails (Gastropoda) | 22% | | |
| Millipedes (Diplopoda) | 70% | | |
| Woodlice (Isopoda) | 1% | | |
| Spiders (Araneae) | 7% | | |
| Harvestmen (Opiliones) | 7% | | |
| Pseudoscorpions (Pseudoscorpiones) | 1% | | |
| Earthworms (Lumbricidae) | 9% | | |
| Songbirds (Passeriformes) | 1% | | |
| Wood mouse (*Apodemus sylvaticus*) | 6% | | |
| **Plant** | | | |
| Fruit pulp/peel | 76% | | |
| Green plant parts | 66% | | |
| Seeds | 38% | Blackberry (*Rubus* ssp.) | 22% |
| | | Elder (*Sambucus nigra*) | 5% |
| | | Not identified | 29% |
| Flowers | 1% | | |

weeks less than six samples were collected (figure 1). In the two first weeks of November no samples were collected, as no field worker was available in that period.

Millipedes were the most frequent animal food item, followed by beetles and snails. Hymenopterans, earthworms, spiders, harvestmen and mice accounted for between 5 and 11% of the diet. Flies, true bugs, pseudoscorpions, woodlice, caterpillars and songbirds were occasionally present in the samples. The most frequently found vegetable food items were fruits, green plant parts and seeds (table 1).

## Seasonal variation

Millipedes were an important food item during the entire season, although with relatively low frequencies by the end of August, when there was a high proportion of berry seeds (figure 2). The occurrence of beetles and mice decreased significantly in the course of the season (logistic binary regression, $P<1\%$). Although statistically not significant, there also seemed to be a decrease in the occurrence of snails throughout the season. The animal part of the garden dormice's menu became

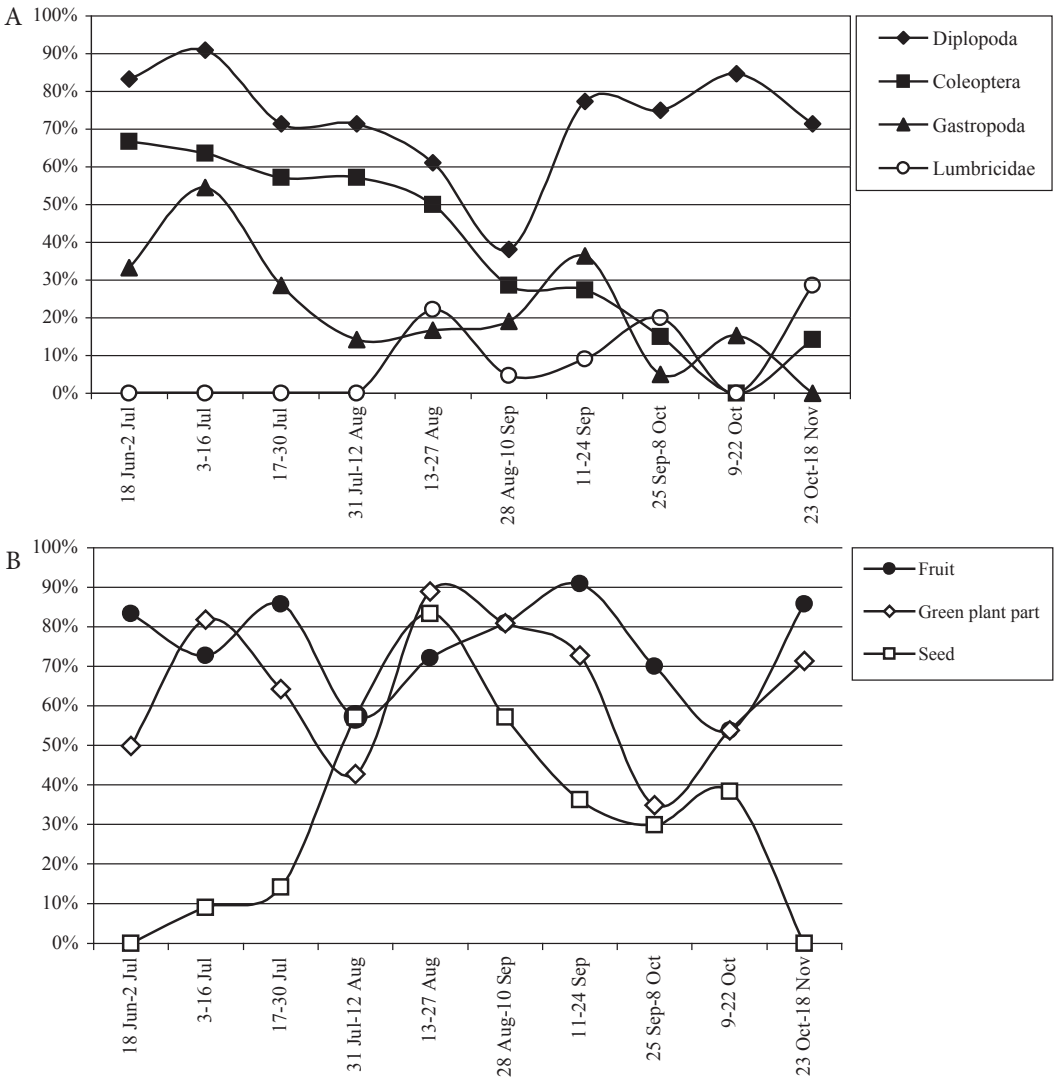



Figure 2. Seasonal variation of the occurrence (percentage) of main animal food items (A) and main plant food items (B) in faecal samples of garden dormice in the Savelsbos in summer and autumn 2010.

quite monotonous at the end of the season, by then mainly consisting of millipedes and earthworms. In June and July no earthworms were present in the food. Earthworm activity above the ground is correlated with rainfall (Darwin 1881). June was a very dry month and July had a normal amount of rainfall. Heavy rainfall occurred in the second half of August and from 6 to 14 November, and some rain fell from 23 September to 2 October.

The first berry seeds were identified in the beginning of August. The occurrence of seeds increased rapidly until the end of August, coinciding with the ripening of elderberries and blackberries. In September the occurrence decreased to 30% and was zero by the end of October.

The occurrence of fruit pulp stayed more or less constant during the course of the season. This seems illogical as fruit, like berries,

should be less available at the beginning of the year. We discovered that somebody had been feeding the garden dormice by putting apples and pears in the nest boxes. (Many remains of apples and pears were found in nest boxes). The occurrence of fruit pulp in the samples must have been strongly influenced by this artificial feeding. The dormice only consumed the pulp and peel but not the cores with the seeds. In fact it was not easy to recognise the remains of apples and pears in the samples of excrements. As far as we know, no other food was supplied.

## Discussion

The garden dormouse is omnivorous, eating a large proportion of animal food (Storch 1978). Our study also found a high proportion of plant food (table 1). Fruit pulp and berries are known to be preferred food items (Brehm 1865, Gigirey & Rey 1999, Gil-Delgado et al. 2010). Green plant parts were frequently found in our samples, but in low quantities. In line with studies of stomach contents, such as that by Holišová (1968), we concluded that green plant parts are only of minor importance in the Savelsbos.

The results of our faecal analysis are in line with other studies on the food of garden dormice, which used stomach analysis (table 3). In table 3 we have arranged the studies from left to right, following a north-south gradient. Millipedes are the most frequent animal food item in woods in more northern regions. Holišová (1968) compared the food of four Gliridae in an oak-hornbeam wood on chalkstone in southern Slovakia, examining the stomachs of ten garden dormice. She found that garden dormice chiefly consume animal food throughout summer and autumn: about 90% of the stomach contents consisted of animal matter. This was a much higher rate than for edible dormouse (*Glis glis*), common dormouse (*Muscardinus avellanarius*) and forest dormouse (*Dryomys nitedula*). Gigirey & Rey (1999) examined the stomachs of 20 garden dormice from a montane oak wood in the Sierra del Invernadeiro in north-western Spain in September and October 1985. Once more, millipedes were the most frequent food item. Apart from grasshoppers or crickets, spiders, hazelnuts and acorns, the diet they found was more or less similar to our results.

The three studies from Mediterranean Spain show quite a different picture from the three studies in woods in more temperate regions. The stomachs of 40 garden dormice collected in April 1970 on the Balearic island of Formentera showed high frequencies of snails, lizards and beetles and, to a lesser extent, mice (wood mouse and house mouse (*Mus musculus*)), spiders and ants (Formicidae) (Kahmann & Lau 1972). The high frequency of vertebrates in this study, which was carried out in spring, is remarkable. A study of twenty-seven stomachs – mainly from autumn – from Coto Doñana found high frequencies of beetles, hymenopterans (mainly honey bees (*Apis mellifera*) and ants), grasshoppers and crickets and Phoenician juniper (*Juniperus phoenicea*) berries (Palacios 1975). The third study in Spain (Gil-Delgado et al. 2010) was carried out in an orange plantation near Valencia. The method used here was quite different, and so the results have not been included in table 3. Garden dormice at this location are active the whole year round and even reproducing in autumn and winter, when their main food is oranges. In spring and summer, when there are no ripe oranges, the main food was arthropods. Gastropods were less frequently consumed. They did appear throughout the year in the faecal samples, but in low proportions in autumn.

It is remarkable that garden dormice eat so many millipedes especially since millipedes have odoriferous glands that produce chlorine, iodine, benzaldehyde and hydrogen cyanide, which leads most predators to avoid them. We surmise that garden dormice might have a general resistance to these poisonous substances. They are also very resistant to

Table 2. Occurrence (percentage) of the main food items of garden dormice, comparing this study with four other studies and the pilot study. Only food items that made up at least 10% of the total in one or more of the studies are included.

| Source | Pilot study in the Savelsbos | This study | Holišová 1968 | Gigirey & Rey 1999 | Kahmann & Lau 1972 | Palacios 1975 |
|---|---|---|---|---|---|---|
| Method | Faeces | Faeces | Stomachs | Stomachs | Stomachs | Stomachs |
| Region | | The Netherlands | Slovakia | NW Spain | Formentera | Coto Doñana |
| Number of samples | 46 | 139 | 10 | 20 | 40 | 27 |
| Time of year | Spring | Summer and autumn | Summer and autumn | Autumn | Spring | Mainly autumn |
| Millipedes | 85% | 70% | 60% | 65% | 18% | 11% |
| Centipedes (Chilopoda) | | | | | 28% | 11% |
| Beetles | 65% | 35% | 20% | 35% | 90% | 48% |
| Hymenopterans | 28% | 11% | | | 53% | 48% |
| Earthworms | | 9% | 10% | | | |
| Snails | | 22% | 10% | 10% | 100% | |
| Grasshoppers and crickets (Orthoptera) | 2% | | | 20% | | 26% |
| Spiders | | 7 % | | 55% | 60% | 11% |
| Lizards (Lacertidae) | | | | | 93% | |
| Mammals | 11% | 6% | | 20% | 68% | 11% |
| Song birds | 13% | 1% | | | | |
| Hazelnuts, acorns, pine and maple seeds | | | 10% | 15% | | 7% |
| Blackberries and raspberries (*Rubus* ssp.) | | 22% | | 60% | | 7% |
| Phoenician juniper berries (*Juniperus phoenicea*) | | | | | | 26% |
| Green plant parts | 70% | 66% | 50% | | ? | 11% |
| Fruit pulp | ? | 76% | | | ? | |
| Flowers | 43% | 1% | | | ? | |

snake venom (Storch 1978).

Millipedes make up a large proportion of the food of garden dormice living in woods in Europe. Millipedes can reach high densities in woods on chalkstone soils. Kime (1992) recorded densities of more than 700 millipedes per $m^2$ in forests with mull soils on limestone in Belgium, for example in the Fouron Region, close to the Savelsbos. In forests on calcic mulls the burrowing julidans (Julida) and glomeridans (Glomerida) are strongly represented. In Europe, Atlantic forests are probably the most favourable habitats for millipedes (Kime & Golovatch 2000). There is perhaps another reason why dormice eat millipedes. These arthropods contain 10-13% (dry matter) calcium; a hundred times more than other arthropods (Graveland & van Gijzen 1994). Vegetable matter, such as fruits, berries and acorns, has a much lower calcium content. Possibly millipedes are an important source of calcium for garden dormice.

We started to collect faecal samples from 25 June 2010. In the spring of 2010 a similar pilot study carried out in the same area, which

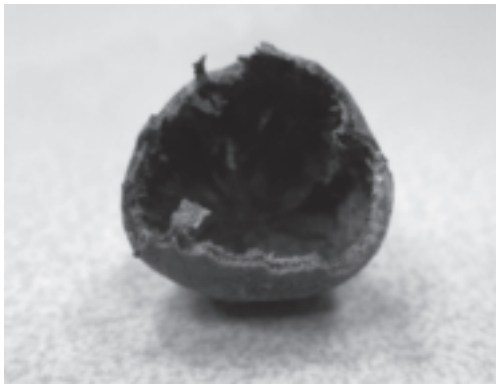


Figure 3. Remains of acorn, eaten by garden dormouse. *Photograph: J. Scholten.*

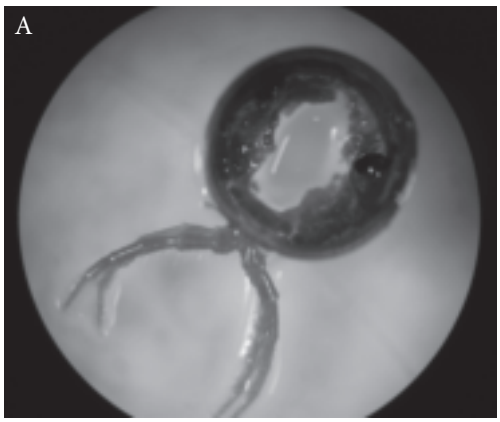
also analysed faecal samples. As the method employed was different, the unpublished results have not been included in the analysis within this article. The key findings of this study are worth discussing and are included in table 2. The study found a higher proportion of the remains of flowers and vertebrates, including bird eggs, and five birds. The flowers were possibly blackberry or raspberry (*Rubus* ssp.). *Rubus* flowers are a common food item of the common dormouse in spring (Juškaitis 2007).

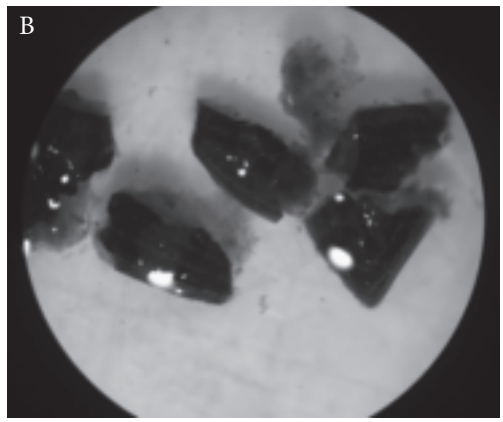
On 21 May 2010 two garden dormice were seen in a nest box in the Savelsbos, sitting on top of the remains of great tit (*Parus major)* nestlings. In other years similar observations of garden dormice eating the nestlings of birds have been made in spring. In Lithuania garden dormice have been recorded as eating the eggs and nestlings of birds in nest boxes and there were even three cases when adult starlings (*Sturnus vulgaris*), nesting in nest boxes, were killed by these rodents (Juskaitis 1999). In orange plantations in Spain, garden dormice were recorded as eating bird eggs, nestlings and adult birds, both from nest boxes and natural bird nests (Gil-Delgado et al. 2009).

Eight of our samples contained the remains of wood mouse, a species that regularly uses the nest boxes in the Savelsbos. After 10 September no wood mouse were found in the samples. It is possible that the garden dormouse predates (mainly young) wood mice. In fact it is long known that garden dormice kill and eat mice and birds (Brehm 1865, cf. Gil-Delgado et al. 2009). Occasionally they even eat rabbits (Palacios 1975).

The animal part of the menu of the garden dormice in this study became quite monotonous in autumn, but it may well be that they supplemented their food in that period with beech nuts (*Fagus sylvatica*) and acorns. Garden dormice are known to eat beech nuts and acorns (Brosset & Heim de Balsac 1967, Gigirey & Rey 1999). We found no remains of beech nuts in the faecal samples, but we did find remains of acorns eaten by garden dormice in the nest boxes (figure 3). Possibly their remains could not be identified in the samples.

Garden dormice mainly search for their food on the ground (Storch 1978, Bertolino et al. 2003). Their diet, containing many millipedes (figure 4A), ground beetles (figure 4B) and earthworms (figure 4B) confirms this. Garden dormice in woods depend on a rich invertebrate fauna that inhabits the litter layer. Areas with a large accumulation of litter have low densities of millipedes, whereas mesotrophic mull soils have very high densities (Kime 1992). Willers et al. (2012) describe that the depth of the layer of accumulated litter within the Savelsbos is inversely related to the local coverage by trees with fast decomposing leaves. Vegetation changes since 1955 indicate that mesotrophic mull soils are disappearing from the Savelsbos. In the middle of the slope, just above the small relict zone with garden dormice, rich types of *Stellario-Carpinetum* wood have changed into poorer wood types. It might be possible to re-establish species-rich wood types that produce mesotrophic mull soils by selectively felling beech and by planting tree species with good litter quality (elm and lime). Felling trees allows more light to reach the forest floor, leading to better decomposition of the accumulated litter (Bobbink et al. 2008). Traditionally the Savelsbos was managed as coppice-with-standards. Coppice man-



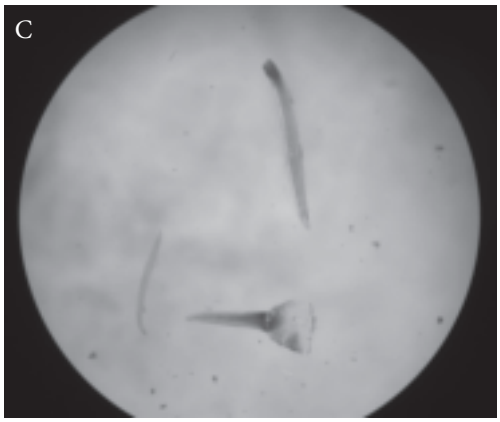




Figure 4. Segment with feet of a millipede (A), elytra fragments of a ground beetle (B), and bristles of earthworms (C), from faeces of garden dormouse. *Photographs: L. Kuipers en J. Scholten.*

agement favours a range of wildlife, often of species adapted to open woodland and shrubs.

## Conclusions

Invertebrates, and especially millipedes were the staple food of the garden dormouse throughout the active feeding period. In spring and early summer more beetles, snails, vertebrates (possibly young) and flowers were eaten (compared to August-November). These latter food items were replaced from August by berries, especially blackberries, and earthworms. However, the feeding on earthworms from August may have been caused by the start of heavy rain in August.

The garden dormice in the Savelsbos seem to depend on the rich invertebrate fauna within the litter layer. Mesotrophic mull soils have a rich fauna of medium-sized to large invertebrates. Management measures that focus on re-establishing species-rich wood types should be carried out in parts of the Savelsbos, adjacent to the relict zone at the bottom of the slope, in order to help maintain and encourage the remaining Dutch population of garden dormice.

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## Samenvatting

### Het voedsel van de eikelmuis (*Eliomys quercinus*) in Nederland in zomer en herfst

Het voedsel van de enige Nederlandse populatie eikelmuizen is onderzocht door middel van analyse van uitwerpselen, verzameld in de zomer en de herfst van 2010. In totaal werden 139 monsters van uitwerpselen verzameld uit 51 verschillende nestkasten voor eikelmuizen. De monsters werden onderzocht op aan- of afwezigheid van diverse dierlijke en plantaardige voedselresten met behulp van een stereomicroscoop. Miljoenpoten, kevers en slakken bleken de meest frequent voorkomende, dierlijke voedselbronnen. Vruchtvlees en zaden waren veel voorkomende voedselresten, zoals zaden van braam en vlier. Helaas voerde iemand de eikelmuizen met appels en peren. De hierboven genoemde dierlijke en plantaardige voedseltypen kwamen alle voor in meer dan 20% van de monsters. Vliesvleugeligen (vooral bijen en mieren), regenwormen, spinnen, hooiwagens en bosmuizen zaten ieder in 5 tot 20% van de monsters. Ongewervelden, speciaal miljoenpoten, zijn stapelvoedsel. In het voorjaar eet de eikelmuis meer gewervelden, slakken, kevers en bloemen dan in het najaar. De eerste resten van zaden van bessen doken begin augustus op in de uitwerpselen. In de loop van augustus steeg het voorkomen van zaden tot 90%. Daarna zakte het aandeel van zaden weer sterk. Eikelmuizen in bossen lijken qua voedsel afhankelijk van een rijke ongewerveldenfauna van de strooisellaag. Mesotrofe bodems met goed door de bodem gemengde humus (mull bodems) hebben een rijke fauna van relatief grote ongewervelden. Het lijkt er op dat in het Savelsbos mesotrofe mull bodems aan het verdwijnen zijn. Dit kan tegengegaan worden door selectieve kap van beuken en aanplant van bomen met een goede bladkwaliteit, zoals iep en linde. Verder is het gewenst om door dunning meer licht toe te laten.

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