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Diet of the wood mouse, *Apodemus sylvaticus* in three biotopes of Kabylie of Djurdjura (Algeria)

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A b s t r a c t . The diet of the wood mouse (*Apodemus sylvaticus*) was investigated over an annual cycle in three biotopes of Kabylie of Djurdjura, differing in the structure of the vegetation and the anthropic action (oak forest, maquis and cultivated zone). The analysis of 140 stomach contents was restricted to three main components: seeds, vegetative parts of plants and arthropod remains, expressed in dry weight and percentages of occurrence. Five independent variables were considered: habitat, sex, sexual activity, season and age. In the three biotopes wood mouse was primarily granivorous, seeds occurring in 99.3% of the stomachs, for 91.5% of dry weight; seasonal variations were significant, with higher occurrence of seeds in winter and summer. Vegetative items (leaves, stems and flowers) were overall rather frequent (occurrence: 19.3%; dry weight: 4.0%), mainly in winter and spring, in the cultivated zone. Arthropods, mainly insects, were frequently preyed by adults (occurrence: 26.4%; dry weight: 4,4%), particularly in the forest. This diet from Mediterranean habitats is discussed by comparing it with previous data in the same biome and in the northern part of the range.

Key words: food, *Apodemus sylvaticus*, habitat, season, age, Mediterranean

Introduction

The wood mouse (*Apodemus sylvaticus*) is widely distributed in the Western Palaearctic from Iceland and Scandinavia (south of 63°N) to the shores of the Mediterranean (M o n t g o m e r y 1999, M u s s e r & C a r l e t o n 2005). The only species of the genus in Africa, the wood mouse is rather widespread in the Maghreb from the Western High Atlas in Morocco to the North-East of Tunisia (B e r n a r d 1969, K o c k & F e l t e n 1980, A u l a g n i e r & T h é v e n o t 1986, K o w a l s k i & R z e b i k K o w a l s k a 1991). Its southern range is limited by desert habitats, and so it is absent in Libya and Egypt (O s b o r n & H e l m y 1980). In Algeria, K o w a l s k i (1985) captured wood mice in the coastal zone, as well as in the mountains, Tellian and Saharan Atlas, from sea level up to 2000 m in the Aurès region. In Kabylie of Djurdjura it was recorded up to 1800 m (K h i d a s 1993).

This vast distribution is associated with a latitudinal variation of body size (A l c a n t a r a 1991) but contrary to the rule of Bergman, the size increases towards the south. It is mainly associated with a great diversity of habitats providing some vegetation cover: forests with understorey, agricultural land with hedgerows, oldfields, maquis, etc. (Z e j d a 1965, S a i n t G i r o n s 1973, S p i t z 1974, C o n s t a n t 1976, K h i d a s 1993). In Morocco and in Algeria, wood mouse is usually common in quite wet and dense habitats, particularly in coastal forests of pines and cedar forests of the Atlas mountains, Aurès and Djurdjura (A u l a g n i e r & T h é v e n o t 1986, K o w a l s k i & R z e b i k

Kowalska 1991). The main rodent species in the mountain forests of Kabylie the wood mouse is associated with bushes, rocks and blocks (Khidas 1993). Living in so many habitats including heterogeneous landscapes the wood mouse is adapted to forage upon a large number of items according to vegetation phenology, and mainly to the production of seeds (Angelstam et al. 1987, Montgomery et al. 1991). Indeed this rodent proved to be granivorous (Hansson 1985, Butet 1986a, Montgomery 1989), but studies in various areas of Europe show a great deal of variability (Butet 1985). When seeds are rare or of low energy value, the wood mouse can prey on small invertebrates or even eat some plants with a high lipid content (Butet 1985). Animal concern in the diet is quite variable, at least seasonally, with an occurrence from 15 up to 80% (Miller 1954, Obrtel 1975, Obrtel & Holišová 1979, Butet 1986a, Zubaid & Gorman 1991). Green parts of plants are usually the smallest part of the diet, only less than 10% of the items (Watts 1968, Obrtel & Holišová 1979, Butet 1986a) with some exceptions (e.g. up to 85% of volume in fallow grounds, Rogers & Gorman 1995).

In North Africa the diet of wood mouse was only studied in a coastal zone of Morocco where it proved to be also granivorous (Harich & Benazzou 1990). As an additional contribution to the study of wood mouse plasticity in the Mediterranean area, we compared annual diets from three biotopes of Kabylie of Djurdjura: oak forest, maquis and cultivated zone. This study was carried out by analysing stomach contents, one of the most reliable methods for this purpose.

Material and Methods

Study sites

The study sites are located in Kabylie (Northern Algeria), in the Aït-Ghobri mountain (ca. 36°45' N and 4°27' E): Taourirt forest (750 m a.s.l.), Bou-Ilfane maquis and the cultivated zone nearby (500 m a.s.l.).

The Taourirt forest belongs to the humid bioclimatic stage when the lower altitude stations are in the sub-humid stage. This is a mixed forest of cork oak *Quercus suber* and Algerian oak *Quercus canariensis*. Trapping was carried out in a regular grove with poor understorey of *Cytisus triflorus*, *Erica arborea*, *Calycotome spinosa*, *Rubus* sp. and *Cistus salvifolius*.

The Bou-Ilfane maquis is a dense formation resulting from the degradation of the cork oak forest. Vegetation is generally more than 2m high, including a shrubby layer of cork oak and a lower layer of various bushes: *Myrtus communis*, *Genista tricuspidata*, *Cistus monspeliensis*, *Erica arborea*, *Calycotome spinosa*, *Pistacia lentiscus* and *Arbutus unedo*.

The cultivated zone is a cleared part of the maquis that supports an extensive agriculture by and for local people including crops and vegetables. Fields are interspersed by copses of *Cistus monspeliensis*, *C. spinosa* and *P. lentiscus*, and some grasslands.

Trapping and diet identification

Wood mice were trapped over 10 months, from October 1998 to July 1999. Snap-traps were set every 3 m in a line 150 m long and baited with bread mixed with sardine. Depending on external conditions, trapping was conducted over 2 to 4 days (Spitz et al. 1974, Orsini 1981, Kowalski 1985, Saint Girons & Fons 1986, 1987). The total number of night traps was 4467. Stomachs of the captured individuals were preserved in 10% formaline,

and 140 contents were identified following Hubert et al. (1981) and Moro & Hubert (1983): 31 from Taourirt forest, 86 from Bou-Ilfane maquis, and 23 from the cultivated zone.

Identifying components of the diet.

Stomach contents were identified under binoculars. Seeds (true seeds or fruits) can be identified by their colour and their structure. Vegetative parts of plants are easily identified by their colour which is preserved, and the presence of veins and fibres; identifying the species was not part of our study. Specific identification of arthropods was very difficult due to the very small size of crushed remains. However fragments of Orthoptera (legs and wings), Hymenoptera (legs of ants) and spiders were observed. Frequency of occurrence of these three components in the stomachs was the first variable studied. Then each component per stomach was weighted using an analytical balance (e = 0.001g) for a measure of dry weight that seemed more reliable than the volume measured by many former authors. Due to the low weight of vegetative parts and arthropods, the presence/absence of these two items was used for statistical analyses.

Statistical analyses

Besides comparing the three biotopes (forest, maquis and cultivated zone), four additional variables were considered: season (autumn: October, winter: November-January, spring: February–March, summer: April–July), sex (male *vs* female), age (juvenile, sub-adult, adult), and sexual activity (active *vs* inactive). Determination of age relied on dental wear by Felten (1952), using (but grouping) classes of Saint Girons (1973): classes I and II as juveniles, class III as sub-adults, and classes IV and V as adults. Active males had external testicles whose diameter exceeded 10 mm (Kowalski 1985). Activity of females was evaluated by external characteristics (opened *vs* closed vagina, size of teats) or internal genitals (aspect of uterus, development of embryos). Active females were either pregnant or lactating.

A preliminary factorial analysis on a matrix of the dry weight (expressed as percentages) and disjunctive independent variables (140 lines – individuals, 17 variables – columns) helped us to cluster months in seasons and revealed the need of separate analyses for each food item. Then the dry weight of seeds was analysed using a generalised linear model (GLM). Then, Kruskal-Wallis tests were computed for significant variables identified by the model, followed by ad-hoc multiple comparisons when the test was significant ($\alpha<0.05$). The presence/absence of vegetative parts and arthropods were analysed using logistic regressions, followed by Kruskal-Wallis tests on percentages of dry weight and multiple comparisons in the same conditions as above. All analyses were computed with Minitab 12.2.

Results

Diet of the wood mouse

The wood mouse is mainly granivorous in Kabylie of Djurdjura (Fig. 1). Seeds were present in 99.3% of stomachs, and composed 91.5% of dry weight. We easily identified whitish to brownish acorns of cork oak, the dark red fruits of myrtle (*Myrtus communis*) and akens of figs (*Ficus carica*). Vegetative parts of plants, stems and leaves, and also flowers (including flowers of *Calycotome spinosa*) were rather frequent (frequency of occurrence; Fo = 19.3%),

but with 4.0% of dry weight weakly contributed to the diet. Arthropods were frequently preyed (Fo = 26.4%) for only 4.4% of dry weight.

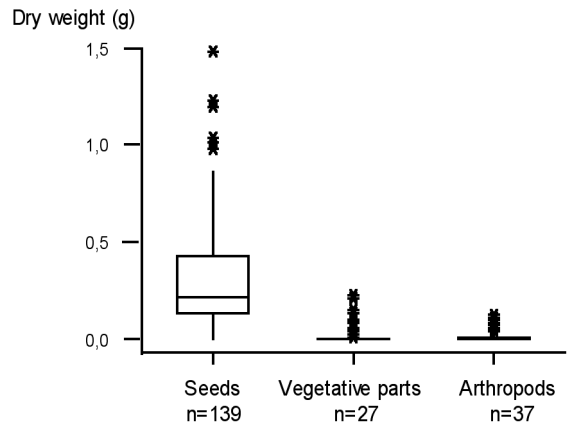

Fig. 1. Principal components of the diet (expressed in dry weight) of wood mouse in Kabylie of Djurdjura (Algeria). Box-plots are overtoped by stars that point out a departure from a normal distribution.

The consumption of seeds was not different among biotopes ($F_{2/130}$= 0.63; P = 0.536); it only varied significantly over the seasons ($F_{3/130}$ = 5.49; P = 0.001; Table 1). However the Kruskall-Wallis test failed to support this variation (H = 5.97; DF = 3; P = 0.113), the dry weight of seeds in the diet being quite similar in winter, spring and summer (Fig. 2). The lack of data in autumn, when the wood mouse densities are the lowest, possibly explain this discrepancy.

Table 1. Consumption of seeds (dry weight) by wood mouse in Kabylie of Djurdjura: results of GLM including all variables (DF: Degree of freedom, F: test value, P: risk associated to the test).

Source	Sum of squares	DF	Mean square	F	P
Biotope	0.07755	2	0.03877	0.63	0.536
Season	1.01790	3	0.33930	5.49	0.001
Age	0.22039	2	0.11019	1.78	0.172
Sex	0.14699	1	0.14699	2.38	0.125
Sexual activity	0.11258	1	0.11258	1.82	0.179
Individuals	8.03232	130	0.06179		

According to the logistic regression the consumption of vegetative parts varied significantly with the biotope and the season (Table 2). The Kruskal-Wallis test did not confirm the significant difference between biotopes (H = 4.48; DF = 2; P = 0.107) in spite of percentages of dry weight slightly higher in the cultivated zone (Fig. 3). The difference among seasons was significant (H = 9.28; DF = 3; P = 0.026). Vegetative parts were frequently present in winter and spring (Fig. 4), and absent in summer and autumn. The test of multiple comparisons did not reveal any significant differences within pairs of seasons (winter and spring; summer and autumn).

Besides, the consumption of arthropods varied significantly among biotopes (Table 3). Their frequency of occurrence was high in forest (61.3%), weak in maquis (20.9%) and especially in cultivated zone (0%). After a significant Kruskal-Wallis test (H = 28.7; DF = 2;

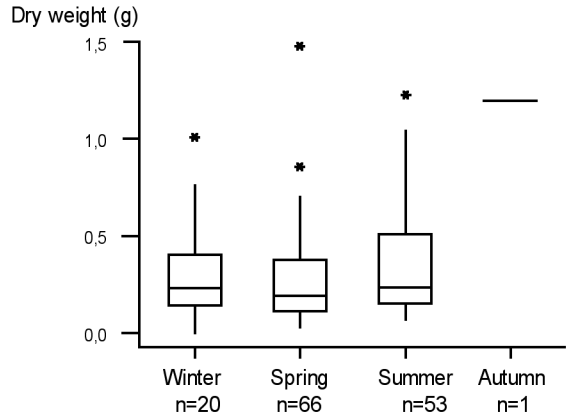

Fig. 2. Seasonal variations of seeds (dry weight) in the diet of wood mouse in Kabylie of Djurdjura (Algeria). See Fig. 1.

Table 2. Consumption of green parts of plants (presence/absence) by wood mouse in Kabylie of Djurdjura: results of the logistic regression (SD: standard deviation; Z: test value, P: risk associated to the test).

Source	Estimates	SD	Z	P
Intercept	0.0638	0.9636	0.07	0.947
Biotope	0.7989	0.3867	2.07	0.039
Season	-1.2117	0.4127	-2.94	0.003
Age	0.3718	0.3356	1.11	0.268
Sex	-0.1649	0.4602	-0.36	0.720
Sexual activity	-0.4469	0.5523	-0.81	0.418

P = 0.001), multiple comparisons revealed significant differences between forest and maquis (Fig. 5), and forest and cultivated zone, with respectively Z = 3.31 and Z = 3.84 (threshold value: Z = 2.41), but not between maquis and cultivated zone (Z = 1.54). The consumption

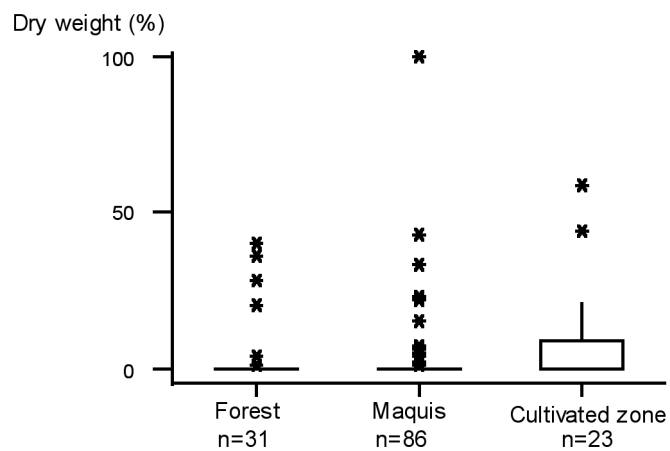

Fig. 3. Green parts of plants (relative dry weight) in the diet of wood mouse in three biotopes of Kabylie of Djurdjura (Algeria). See Fig. 1.

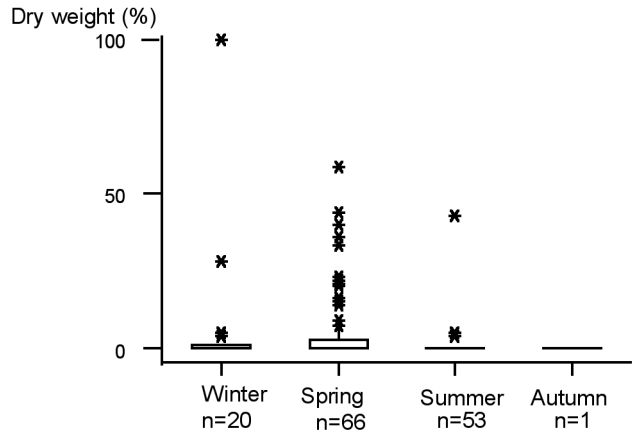

Fig. 4. Seasonal variations of green parts (relative dry weight) in the diet of Wood mouse in Kabylie of Djurdjura (Algeria). See Fig. 1.

Table 3. Consumption of arthropods (presence/absence) by wood mouse in Kabylie of Djurdjura: results of the logistic regression (SD: standard deviation; Z: test value, P: risk associated to the test).

Source	Estimates	SD	Z	P
Intercept	-0.8714	0.9829	-0.89	0.375
Biotope	-1.9163	0.4375	-4.38	0.000
Season	-0.0140	0.3630	-0.04	0.969
Age	0.6560	0.3507	1.87	0.061
Sex	0.7721	0.4794	1.61	0.107
Sexual activity	-0.0211	0.5519	-0.04	0.970

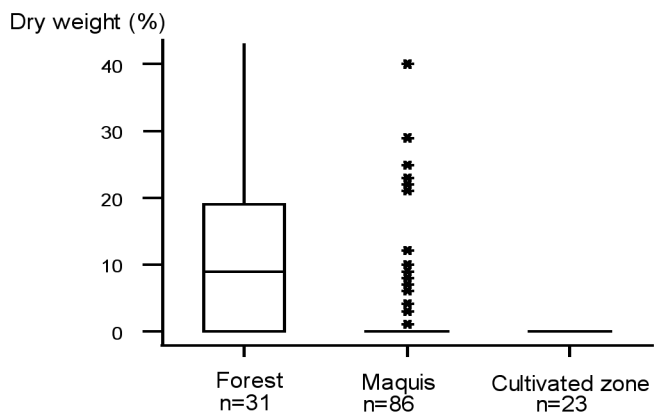

Fig. 5. Arthropods (relative dry weight) in the diet of wood mouse in three biotopes of Kabylie of Djurdjura (Algeria). See Fig. 1.

of arthropods also varied meaningfully according to the age of wood mouse (Table 3), being low for juveniles and high for adults (Fig. 6).

After a significant Kruskal-Wallis test (H = 7.52; DF = 2; P = 0.023) the test of multiple comparisons, very conservative, did not support any significant difference between couples of ages.

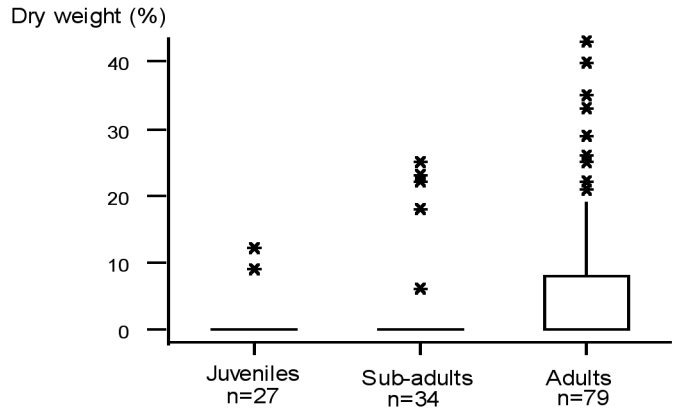

Fig. 6. Consumption of arthropods (relative dry weight) by the three age classes of wood mouse in Kabylie of Djurdjura (Algeria). See Fig. 1.

Discussion

Granivorous diet

In the three biotopes of Kabylie of Djurdjura, wood mouse was primarily granivorous; vegetative parts of plants and arthropods were part of the diet but in much smaller proportions, mainly in dry weight. Similar results have been obtained in the Moroccan arboretum of Oued Cherrate (Harich & Benazzou 1990) where wood mouse eat 75.5% of seeds (percentage of volume), and more or less vegetative parts and/or insects. In Europe the diet of wood mouse is also basically granivorous, but is more variable with 33 to 72% of seeds (Watts 1968, Obrtel 1975, Obrtel & Holišová 1979, Hansson 1985, Butet 1986a, Montgomery 1989, Canova & Fasola 1993).

Lipid-rich seeds are usually preferred (Obrtel & Holišová 1979, Butet 1986b), this has been proved to be supported by an accurate olfactive detection of lipids (Jennings 1976). However in Kabylie, wood mouse mainly fed upon acorns, the most abundant available seeds. Glucid-rich fruits, myrtle and fig, were also identified in the diet where they were available.

Vegetative parts of plants, mainly stems and leaves, are far less abundant, a result that is reported from most studies as they usually account for less than 10% of the diet when seeds are available (Watts 1968, Obrtel & Holišová 1979, Butet 1986a), but up to 87% in fallow grounds (Rogers & Gorman 1995). Flowers, that are often recorded in the diet (Butet & Paillat 1997), were still less abundant,. As for the types of seeds, wood mouse seems to be opportunist whichever food it prefer.

Compensation between animal preys, mainly insects, and seeds, associated to the scarcity of vegetative parts of plants, has often been suggested in the diet of wood mouse (Miller 1954, Watts 1968, Obrtel 1975, Obrtel & Holišová 1979, Butet 1986a, Harich & Benazzou 1990, Zubaid & Gorman 1991). The most compensatory results are provided by Watts (1968) who recorded up to 88% (volume) of animal preys in May, 43% in June, and none during the rest of the year when the diet of wood mouse depends on seeds. Obrtel & Holišová (1979) reported a higher annual abundance of 51.6%, with preys being larvae of insects and adult Coleoptera. Such

a diet, basically granivorous and secondary insectivorous, is frequent in rodents, mainly in mice: *Apodemus* spp. and also in *Micromys minutus*, etc., contrary to voles (*Microtus* spp.) whose diet is basically based on the vegetative parts of plants. *Apodemus sylvaticus* has a digestive physiology that is not suitable with cellulose-rich parts of plants, and requires food highly concentrated in proteins or lipids (Hansson 1971). More than an ubiquist species, wood mouse can use the complementary habitats to develop an opportunist food strategy (Hansson 1971, 1985, Butet 1990b).

Variations of the diet

The consumption of seeds by wood mouse varied slightly among the seasons, however no significant pattern could be identified, probably because in this Mediterranean area cultivated or wild fruits and seeds, mainly acorns, are available over most of the year. On the contrary vegetative parts of plants were eaten in winter and spring when the vegetation just started growing. Rogers & Gorman (1995) also report seasonal variations of the diet in fallow grounds of the United Kingdom. They suggest that the scarcity of seeds in spring and summer, that is later than in Algeria, is compensated by the consumption of other items including green parts that are rich in glucids at the early stages of the plant growth. Further Butet (1986b, 1990b) stresses that wood mouse optimises its energetic intake over the annual cycle.

Arthropods were also preyed mainly in winter and spring even if variations were not significant. The common hypothesis of a balance between seeds and other items (Butet & Paillat 1997) could be superseded by the need of proteins for keeping up the sexual activity of adults. Thus, our results proved that the consumption of arthropods was higher in adults than in younger animals. Moreover, arthropods occurred mainly, but not significantly, in the diet of wood mouse during the period of sexual activity in the Mediterranean area (Khidas 1993, Fons & Saint Girons 1993).

Like Watts (1968) in the United Kingdom, we did not notice any significant difference between sexes. However, according to Shenk (1979) females would have lower intakes but pile up more reserves than males. For Harich & Benazzou (1990), females prey more insects than males to fill protein requirements associated with reproduction. In the same way, Bonaventura et al. (1992) reported that sexually active females were proportionally more numerous in habitats with large amounts of food (seeds) and thick vegetal cover.

Last but not least, we found significant differences among biotopes only for the consumption of vegetative parts of plants and arthropods. If vegetative parts were indeed more available in the cultivated zone, arthropods do not seem to be more abundant in forests as it might be suggested by the diet. This result supports both the opportunism of wood mouse to adapt locally its diet to the availability of resources (the understorey is poor in the forest and seeds are produced seasonally) and the importance of seeds in the three biotopes. Unless daily movements between joint biotopes, maquis – cultivated zone for example (unpubl. data), could homogenise the diet. So Butet (1990a) identified “permanent” biotopes that can fill trophic requirements and then accommodate a population over the annual cycle, and “temporary” biotopes that can be used only at one period of the year. In “permanent” biotopes (shrubs, scrubs, and all habitats with several vegetal layers) wood mouse can rely on a long production of seeds, an availability of animal preys and additional resources. On the contrary, animals can include in their range “temporary” biotopes where

they feed opportunistically when resources are available. Our cultivated zone could be one of these "temporary" biotopes, and animals could feed on seeds in adjacent biotopes concealing possible differences in diet among trapping biotopes.

Conclusion

The diet of wood mouse in the three Mediterranean biotopes differing by the structure of vegetation and the human impact proved to be mainly granivorous, vegetative parts of plants and arthropods were only incidental, varying according to seasons. Indeed, wood mouse adapts its diet to the phenology of plants and mainly over the annual cycle. Vegetative parts are mainly fed upon in the cultivated zone. Arthropods are mainly preyed in the forest by adults. However the overall differences among the three contrasted biotopes are quite weak. This result can be due to the ability of wood mouse to move among biotopes in fragmented landscapes (here the cultivated zone is surrounded by maquis). It can also be due to the rough determination of the items as some seeds could be different in open and close habitats. This comparison between wood mouse populations among three biotopes could now be extended to other individual or population variables like development (fluctuating asymmetry), demographic parameters and mainly space use.

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