

Vertical activity of the yellow-necked mouse (Rodentia: Muridae) at edge of a mixed forest

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A b s t r a c t. The vertical activity of small mammals was studied in Central Bohemia, the Czech Republic, from 2003 to 2005. In total, 424 individuals were captured by the CMR technique, in live traps placed at ground level or in trees at heights of 1 and 2 m. The most commonly captured was the yellow-necked mouse, *Apodemus flavicollis* (96.7 %). Other species captured in the trees were: the common dormouse, *Muscardinus avellanarius* and the pygmy shrew, *Sorex minutus*. Although mice captures on the ground (considered as 100 %) prevailed significantly over those in trees (84.2 % and 77.9 % at 1 and 2 m, respectively), vertical activity was still quite extensive. In the peak abundance year, mice visited trees more frequently than in the year with lower abundance. There was no clear seasonal variation in vertical activity during the May–October period. No significant difference between male and female vertical activity was found. There was a slight but non-significant positive relation between the weight of an individual and the frequency of its arboreal captures. Any preference for climbing a particular tree species was not found. Our results clearly demonstrate that tree climbing by the yellow-necked mouse represents an important component of its movement activities and this fact should be considered in future studies of its ecology.

Key words: *Apodemus flavicollis*, ecology, behaviour, arboreality

Introduction

Arboreal behaviour is one of the more important components of the spatial activity of small muroid rodents (superfamily Muroidea). However, until last decade, studies about arboreal activity in the European murids were rare. Indirect evidence of their occurrence on trees is found in papers about the damage caused by small mammals to forest or orchard trees (Kulicke 1963, Baxter & Hansson 2001). Other observations have documented the presence of the yellow-necked mouse, *Apodemus flavicollis* (Melchior, 1834) in bird or nest boxes (e.g. Balát & Pelikán 1959, Puchala 2004, Czeszczewik et al. 2008) or even in the top of trees about 20–30 m above the ground (Borowski 1962). More detailed studies of arboreality in muroid rodents have been performed by Holíšová (1969) in the Czech Republic, by Montgomery (1980), Tattersall & Whitbread (1994), Marsh & Morris (2000) and Buesching et al. (2008) in England, by Juškaitis (2002) in Lithuania, and by Sarà (2008) in Sicily.

Among reasons for the utilization of canopy layers by muroid rodents belong e.g. food resources (fruits, seeds, invertebrates) (Santos & Tellería 1991, Ida et al. 2004), nesting holes (e.g. Gillesberg & Carey 1991, Czeszczewik et al. 2008, Sarà 2008), holes for food stores (Balát & Pelikán 1959, Juškaitis 1995), predator avoidance (Montgomery & Gurnell 1985) or temporary refuges during flooding (Brtěk 1986, Williams et al. 2001). Arboreality can also reduce interspecific competition among species with similar habitat requirements. For example, Hoffmeyer

(1973) documented clear vertical separation between *A. sylvaticus* (submissive and less arboreal) and *A. flavicollis* (dominant and more arboreal) in both indoor and outdoor experiments. However, Montgomery (1980) contradicted these results.

Recently, small mammals have also been suspected of predation on tree nests in European passerine birds (Söderström et al. 1998, Weidinger 2002, Remes 2005). However, this has been poorly documented in natural conditions (Weidinger, pers. comm.).

The primary aims of this study are estimation of the extent as well as the seasonal and interannual variation in the vertical activity of the yellow-necked mouse.

Study Area

The study was conducted during the period 2003–2005, at edge of a mixed forest lined by an un-mowed meadow, near the town Mníšek pod Brdy (49°52' N, 14°16' E, altitude 385 m), in Central Bohemia, the Czech Republic. For the study plot, we chose a 250 m long forest edge and a narrow tree grove (length 80, width 5 m) situated parallel to it. The distance between the forest and the grove was ca 20 m. The forest was dominated by oaks (*Quercus robur*, *Q. petraea*, *Q. rubra*), hornbeam (*Carpinus betulus*), and beech (*Fagus sylvatica*); less common were pine (*Pinus silvestris*) and birch (*Betula pendula*), blackthorn (*Prunus spinosa*), hawthorns (*Crataegus* sp.), elderberry (*Sambucus nigra*) and brambles (*Rubus* sp.). The grove was vegetated by hawthorns, brambles, dog-roses (*Rosa canina*) and solitary pines. The herbaceous layer was well-developed in both places.

Material and Methods

Small mammals were captured by wooden Chmela live-traps (26 x 7.5 x 6.5 cm). In total, 54 traps were used. Thirty-five traps were placed along the forest edge in a line 250 m in length, and an additional 19 traps were placed in the grove. The distance between traps was between 5 and 8 m. At each trapping point, we successively placed a trap on the ground near a tree base (3 nights) and then on the trunk of the same tree at elevations of 1 m (3 nights) and 2 m (3 nights) above the ground, respectively. Thus, every trapping period lasted 9 nights (486 trap-nights). The position of traps was constant during the entire study period. In the case of heavy rain, trapping was interrupted and repeated the next day (three cases in total). In the trees, traps were placed on a wooden platform fixed to the main trunk, where we expected the most movement by small mammals (Santos & Tellería 1991). Trapping was performed in spring beginning in the first part of May, in summer at the beginning of August and in autumn in the second half of October. There was no trapping in the winter, to prevent mortality of captured individuals, and because during cold periods the surface activity of small mammals may decrease (Walton & Andrews 1981). We used liver pate as bait. All traps were open between sunset and midnight, and captured animals were examined for species, sex and weight. Weight was measured on a Pesola scale to the nearest gram. Captured animals were individually marked by cutting their fur in two spots located in various parts of their back, so that individuals were marked only temporarily, for one trapping period. Many previous studies (e.g., Holíčová 1969, Andrzejewski & Olzewski 1963) have used toe-clipping for marking, but we assumed that this handicap could negatively influence their climbing activity (Fairey 1982). After marking, the animals were released at the site of capture.

We identified tree species on which traps were placed, and measured their trunk diameters at a height of 0.5 m. The proportion of sampled tree species roughly coincided with the overall proportion of trees in the study area: hawthorn (16), oak (7), elderberry (10), blackthorn (7), hornbeam (7), pine (6) and birch (1).

There is a very important distinction between the number of individuals (NI) and the number of captures (NC). Some individuals were captured repeatedly during a single trapping period (i.e. between 2 and 9 times). Since the trapping at each elevation lasted three days, the number of trap-nights in the trees was double that on the ground.

Calculations were statistically evaluated using Chi-square goodness of fit test and Pearson correlation coefficient (NCSS 2001) at a probability level of 5 %.

Results

We captured 424 individuals (NI), the total number of captures (NC) of small mammals was 646. The yellow-necked mouse strongly dominated (NI = 410; 96.7 %, NC = 629; 97.4 %). In addition, we captured the bank vole, *Myodes glareolus* (Schreber, 1780), the common dormouse, *Muscardinus avellanarius* (Linnaeus, 1758) and the pygmy shrew, *Sorex minutus* Linnaeus, 1766. The bank vole occurred rarely (NI = 6) and only at ground level. The common dormouse was captured exclusively above the ground (NI = 7) and the pygmy shrew was captured just once, at the 2 m elevation. The wood mouse (*Apodemus sylvaticus*) was not found in the study area. Due to their sporadic occurrence, species other than the yellow-necked mouse (hereinafter only “mice”) were excluded from subsequent evaluations.

During the study period, we recorded considerable variation in the abundance of mice. In 2003, the relative abundance at the ground level varied between 3.1 and 4.9 NC / 100 trap-nights (Fig. 1). In the autumn, there was a heavy oak seed crop at the study site, which caused a considerable increase in mice abundance in the following year. Already in spring 2004, their abundance reached a value of 19.1, and then continuously increased up to 41.4 in autumn. During the winter 2004/2005 the abundance markedly decreased, down to just 7.4 in

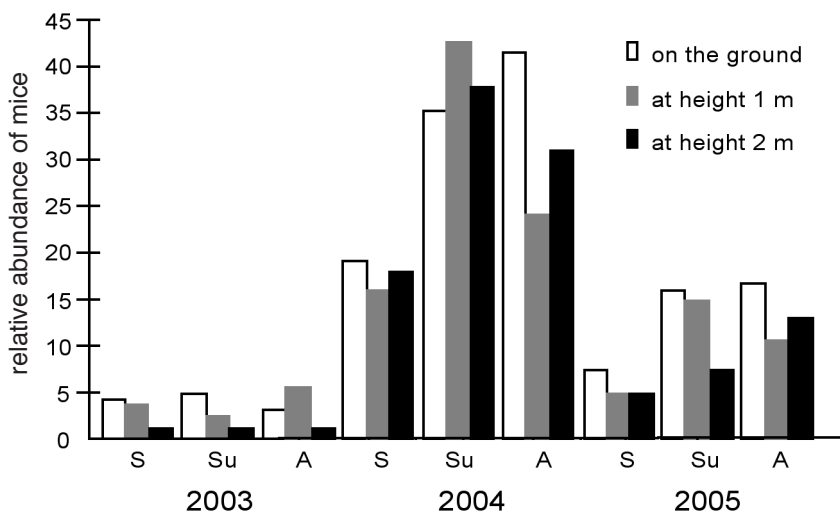


Fig. 1. Variation in the relative abundance of mice during the whole study period (computed as NC per 100 trap-nights; each value is based on 162 trap-nights), (S – spring, Su – summer, A – autumn).

Table 1. Captures of mice (NC, NI) during the study period (in %).

Year		2003		2004		2005		Total	
Season	Level (in m)	NC	NI	NC	NI	NC	NI	NC	NI
Spring									
	0	46.7	42.9	36.0	37.3	42.9	47.1	38.8	39.8
	1	40.0	42.9	30.2	35.6	28.6	29.4	31.0	34.9
	2	13.3	14.3	33.7	27.1	28.6	23.5	30.2	25.3
n		15	7	86	59	28	17	129	83
Summer									
	0	57.1	55.6	30.5	29.8	41.9	43.9	34.6	34.5
	1	28.6	22.2	36.9	38.7	38.7	39.1	36.9	37.9
	2	14.3	22.2	32.6	31.5	19.4	17.1	28.5	27.6
n		14	9	187	124	62	41	263	174
Autumn									
	0	31.3	33.3	42.9	44.8	41.5	42.9	41.8	43.1
	1	56.3	53.3	25.0	25.0	26.2	26.2	27.4	28.1
	2	12.5	13.3	32.1	30.2	32.3	31.0	30.8	28.8
n		16	15	156	96	65	42	237	153
Total		45	31	429	279	155	100	629	410

the spring. The next increases in summer and autumn (reaching 16.0 and 16.7, respectively) were less than half of the values from the previous year. Similar trends were also recorded in the above-ground trapping (Fig. 1) as well as in evaluation of NI.

Our analysis of the total data (NC = 629, NI= 410) revealed a prevalence of captures at the ground level (NC= 240, NI= 159) compared to the above-ground levels at 1 m (NC = 202, NI = 138) and 2 m (NC = 187, NI = 113). Differences between captures at the ground and in trees (combined for both tree levels) were statistically significant (NC $\chi_1^2 = 7.69$, $P = 0.01$; NI $\chi_1^2 = 6.04$, $P = 0.01$). Similarly, a comparison of captures at all three levels revealed significant differences (NC $\chi_2^2 = 8.31$, $P = 0.02$; NI $\chi_2^2 = 8.56$, $P = 0.01$). However, differences between captures at the 1 m and 2 m levels were not significant (NC $P = 0.41$; NI $P = 0.10$). Although captures at the ground were significantly higher, the proportion of the arboreal captures was fairly high, as seen in Fig. 1 and Table 1. If NC on the ground is considered as 100 %, the corresponding values for the 1 and 2 m elevations were 84.2 % and 77.9 %, respectively. Similarly, for NI these values were 86.8 % and 71.1 %, respectively. These data suggest that vertical activity in the yellow-necked mouse is considerable.

Variation between years

Because of the considerable variation in abundance of mice between individual years (cf. Fig. 1), we evaluated their vertical activity in each year separately. In 2003, the abundance of mice was extremely low, and therefore that year was omitted from the analysis. In 2004, the total NC on the ground was 155. If this is considered as 100 %, corresponding values for NC at the 1m and 2 m levels were 86.5 % and 90.3 %, respectively. In 2005, the total NC on the ground was 65, and corresponding values of NC at 1 m and 2 m reached only 75.4 % and 63.1 %, respectively. An evaluation of the total data from 2004 did not reveal any significant difference between captures on the ground and in trees (NC $P = 0.14$; NI $P = 0.20$). On the

Table 2. Number of mice (NI) individually marked on the ground and captured during the same trapping period in trees.

Year	Season	Ground		Trees	
		n	n	n	%
2004	Spring	22	11	11	50.0
	Summer	37	27	27	73.0
	Autumn	43	22	22	51.2
2005	Spring	8	5	5	62.5
	Summer	18	8	8	44.4
	Autumn	18	10	10	55.6

contrary, in 2005, mice were captured significantly more frequently on the ground than above the ground (NC $\chi_1^2 = 5.78$, $P = 0.02$; NI $\chi_1^2 = 5.50$, $P = 0.02$). These results suggest that in the peak year, mice visited trees more frequently than in the year of lower abundance. Similarly, the proportion of mice individually marked on the ground and captured during the subsequent six days in the trees suggests a considerable increase in their vertical activity during the summer of the peak year (Table 2).

Seasonal variation

Variations in the NC and NI from the years 2003–2005 at each elevation is shown in Table 1. An evaluation of the pooled data only revealed statistically significant differences between captures on the ground and in trees in autumn (NC $\chi_1^2 = 9.07$, $P = 0.0026$; NI $\chi_1^2 = 7.39$, $P = 0.0065$). The total autumn NC on the ground was 99. If this is considered as 100 %, corresponding values for NC at 1, and 2 m were only 65.7 % and 73.7 %, respectively. On the contrary, in summer, NC at 1m and 2 m reached as high as 107.6 % and 82.4 %, respectively.

The separate statistical evaluation of captures in individual years (excluding the year 2003) revealed a highly significant prevalence of captures on the ground in autumn 2004 (NC $\chi_1^2 = 9.56$, $P = 0.0020$; NI $\chi_1^2 = 7.07$, $P = 0.0079$). This decrease in vertical activity should most probably be ascribed to strong winds which occurred in two of the three days in which traps were placed at the 1 m level. This event consequently also affected results of the evaluation of the total data. In summer 2005, NC at the 1 m level significantly prevailed over those at the 2 m level ($\chi_1^2 = 4.50$, $P = 0.0339$). Also noteworthy is the clear but non-significant prevalence of tree captures in summer 2004 (Fig. 1) when the abundance of mice was at its maximum. These results suggest an intensive utilisation of trees by mice throughout all the seasons studied.

Sex differences in the mice vertical activity

In the year 2003, the sex of captured mice was not determined. In the pooled sample from years 2004 and 2005, the male : female ratio calculated from NC was 111 : 109 on the ground and 178 : 186 in trees (i.e., 92 : 91 and 86 : 95 in levels of 1 m and 2 m, respectively). These differences in sex ratio were not significant ($P = 0.89$ and $P = 0.67$, respectively). Similarly, the sex ratios calculated from NI on the ground (70 : 76) and in trees (113 : 120) were also non-significant ($P = 0.62$ and $P = 0.65$, respectively).

A separate analysis of the total NC from 2004 and 2005 for males (M) and females (F) did not reveal any significant difference between captures on the ground and in trees

(combined for both tree levels) (males $P = 0.07$, females $P = 0.19$). An evaluation of NI yielded similar results. In conclusion, this evaluation did not reveal any sex differences in the mice climbing activity.

The relation between mouse weight and vertical activity

The rate of arboreal behaviour of an individual mouse can be expressed by the number of its tree captures during one trapping period. We categorised these results into seven categories, corresponding to the number of tree captures (TC), from 0 till 6. An examination of the relation between the weight of a particular mouse (recorded at its first capture) and its rate of vertical activity in combined samples from 2004 and 2005 showed a slight positive correlation (not shown); however, weight differences between the seven categories of mice were not significant ($r = 0.09$). Although, in all samples evaluated separately according to sex and year, there was weak positive correlation between the weight of a mouse and its vertical activity (with the exception of males caught in 2004), the results were never significant.

Relations between vertical activity and tree species and trunk diameter

The preference of mice for individual tree species was examined from NC data using the Chi-square goodness of fit test and calculated relative to the proportion of each tree species in the evaluated tree sample. The sole birch at the study site was not included in this analysis. In the pooled sample from 2004 and 2005 (Fig. 2), there was no significant preference for individual tree species ($P = 0.89$). Also, separate evaluations of the individual years and seasons did not reveal any preference.

The effect of the trunk diameter was analysed by correlation of NC from all captures with the exception of those on the birch. A positive correlation between NC and trunk diameter was observed only in elderberry and hawthorn, while there was a negative correlation in hornbeam, pine, oak and blackthorn. The correlation between NC and trunk diameter was only significant in oak; those in hawthorn, elderberry, pine, blackthorn and hornbeam were not significant.

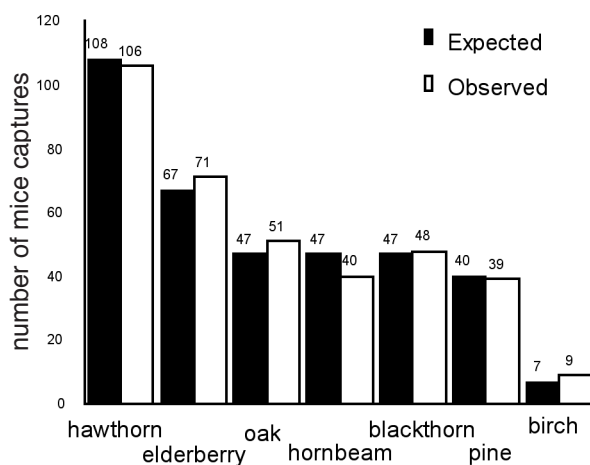


Fig. 2. NC in individual tree species (pooled data from the years 2004 and 2005).

Discussion

The yellow-necked mouse strongly prevailed among captured species. The absence of the wood mouse could be explained by interspecific competition between both species. The yellow-necked mouse negatively affects the distribution and activity of the wood mouse both in natural and laboratory conditions (Hoffmeyer 1973, Montgomery 1978, Čiháková & Frynta 1996). Rare captures of the bank vole, and only on the ground, was surprising because there is frequent evidence of its arboreal habit (Holišová 1969, Montgomery 1980, Tattersall & Whitbread 1994). The rare presence of the pygmy shrew in trees is in agreement with similar observations by Holišová (1969) and Marsh & Morris (2000).

During the autumn 2003 we observed a heavy seed crop in oaks, and the following spring we recorded a conspicuous increase in mice abundance. This high abundance persisted until autumn, but by spring 2005 only a low number of mice were found. This corresponds well with the long-term population cycle of the species described by Pucek et al. (1993) and Stenseth et al. (2002).

Although numeric values may differ, the frequent captures of mice on trees are in good agreement with observations by other authors. In an oak-hornbeam forest of southern Moravia, captures in trees (at elevation 3 m) were 42.8 %, compared with 100 % on the ground (Holišová 1969); in a deciduous woodland of Gloucestershire, England, captures in trees (at elevations of 0–1 m and 1–3 m) even attained values of 123.9 % and 131.1 %, respectively (Montgomery 1980). The frequent presence of mice in bird nest boxes has also been recorded by Balát & Pelikán (1959) and Juškaitis (1995, 2002).

Our results suggest a positive correlation between vertical activity and mice abundance. Similarly, Balát & Pelikán (1959) and Juškaitis (1995) observed higher autumn bird-box occupancy by mice in years with higher abundance. In contrast, Holišová (1969) reported that the proportion of individuals captured in trees increased with decreasing population density. However, Holišová (l. c.) evaluated only a single trapping period covering approximately 9 months (between July and March), which consequently reflects seasonal and not interannual variation.

We did not see clear seasonal variation in vertical activity of the yellow-necked mouse. Holišová (1969) reported the presence of mice in trees only between July and January, with a maximum abundance between the end of August and October. Montgomery (1980), who captured this species in trees during the whole year, recorded a peak of arboreal occurrence in May and June. In bird boxes, Balát & Pelikán (1959) also recorded mice throughout the year; minimal occupancy was found in the May–June period, then considerably increased to October followed by a continuous decrease until the following May. In bird boxes in Slovakia, Puchala (2004) always found these mice between October and March, with the peak in October. However, Marsh & Morris (2000), who checked dormouse boxes only between March and November, found the highest mice abundance during summer and autumn. These data indicate that in bird boxes, mice are most abundant from late summer to autumn, which can be easily explained by the search for shelter. Trapping in trees has provided mixed results, since the intensity of arboreal activity has differed between years and regions. It could be that during spring and summer, mice in trees are mostly looking for food.

We did not find any significant sex differences in the mice vertical activity. However, Holišová (1969) and Montgomery (1980) mentioned that males are more arboreal

than females, and Marsh & Morris (2000) also recorded a predominance of males over females in dormouse boxes in some localities. The most plausible explanations refer to larger home ranges for males Marsh & Morris (2000), or to social relationships within the population (Montgomery 1980).

Our results revealed a slight but non-significant positive relation between the weight of an individual and its vertical activity. Although the separate evaluation of samples divided according to year and sex sometimes showed the opposite (the negative correlation in males in the peak year), our evaluation of the total material as well as of the mice captured in the year of lower abundance suggests that this phenomenon was probably real. Holišová (1969) did not find any difference in the weight composition of yellow-necked mice captured on the ground and in trees. It is of interest that in the region where this species occurs sympatrically with the wood mouse, Montgomery (1980) found a higher proportion of juvenile yellow-necked mouse individuals in tree captures than on the ground, while in the wood mouse this trend was reversed.

In the wood mouse, a close correlation between body weight and age has been documented, both in captivity (Gurnell & Kne 1984, Frynta & Žižková 1992) and in the field (Verhagen & Vandorpe 1980, Vandorpe et al. 1981). Similar relations are clear from data on the weight variability within individual age groups of the yellow-necked mice collected in the field in Poland (Adamczewska 1959) and Austria (Steiner 1968). Therefore, we assume that in our mice the vertical activity slightly increased with the age of an individual.

We did not find any preference for climbing any of the tree species evaluated. This is in agreement with conclusions by Blát & Pelikán (1959), who, in addition, stated that the yellow-necked mouse is able to climb any tree species including those with smooth bark. The correlation between NC and trunk diameter (negative in four tree species and positive in two tree species) found at our locality is problematic, and we have no explanation for this. The negative correlation in oak is seemingly in contrast to results by Holišová (1969) but thick trunks (above 41 cm in diameter) were not included in her study. However, it should be noted that yellow-necked mice often use arboreal runways for movement between individual trees without climbing down, (Montgomery 1980), which could have biased our results.

These results clearly demonstrate that tree climbing in the yellow-necked mouse represents an important component of its movement activities, and this fact should be considered in studies of its ecology. However, causes of this behaviour remain unknown and could be a promising field for further research.

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