

Influence of forest fragmentation on the distribution of small terrestrial mammals in fir-beech commercial forest

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ABSTRACT: Differences in abundance and spatial distribution of small terrestrial mammals were compared between the forest interior and clearing. In total, seven micromammalian species were detected. Of them, only three species were captured within the forest interior, whereas six species were recorded on the clearing. *Apodemus flavicollis* and *Clethrionomys glareolus* were dominant species. Another five species were recorded scarcely. Abundance of *Apodemus flavicollis* reached significantly ($P < 0.001$) the highest value in the forest interior. On the contrary, *Clethrionomys glareolus* was significantly ($P < 0.001$) attracted by the clearing. The distribution of two dominant rodent species probably reflected the high beechnut supply in the given period. The relationships between food supply and microhabitat preferences of *Apodemus flavicollis* and *Clethrionomys glareolus* were discussed.

Keywords: *Apodemus flavicollis*; *Clethrionomys glareolus*; microhabitat preferences

Forest fragmentation is recognized as one of the greatest threats to biological diversity. Recognizing patterns of environmental heterogeneity is important because they reveal the conditions under which the current species, communities, and ecosystems have developed. Small patches may no longer have interior forest conditions, and as a result they may undergo dramatic changes in the natural composition of mammalian species that existed when it was a continuous forest. The forest parts adjacent to the edge become a transition zone or ecotone and may undergo changes in microclimate, composition of species, and vegetation structure (STEVENS, HUSBAND 1998). A characteristic feature of clearings during the first 5–10 years after reforestation is their huge food supply for forest herbivores, including mainly some rodent species and hoofed game (BÚTORA 2004). Effects of forest fragmentation and edge effect as

well have been well-studied on birds, being considered as apposite indicators (e. g. BIBBY et al. 1985; YAHNER 1986; PROBST et al. 1992; BAKER et al. 2002). Small mammals have been used elsewhere as ecological indicators of the effects of forest management practices (PEARCE, VENIER 2005; KAMINSKI et al. 2007). The influence of fragmentation on small mammal populations has frequently been connected with their response to clearcutting. Small mammals may respond differently to clearcutting, depending on the species, form of clearcutting and probably there are also regional differences in the reaction of certain species to clearings. A positive response of small mammals to clearcutting has been observed by KIRKLAND (1977), McCOMB and RUMSEY (1982), ROOT et al. (1990) and SUCHOMEL et al. (2012). In contrast, several mammal species were reduced by clearcutting (PROBST, RAKSTADT 1987; YAHNER

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1988). However, results of empirical studies of habitat fragmentation are often difficult to interpret because many researchers measure fragmentation at different scales (FAHRING 2003). The knowledge of microhabitat preferences of forest rodents can help to prevent their impact by the herb layer management (SUCHOMEL et al. 2009). KAMLER et al. (2010) pointed out the role of the herb layer for the intensity of tree damage caused by rodents, when significant differences in the intensity of damage to trees at clearings were found in dependence on the structure of the herbaceous cover.

As part of a larger study, the reaction of small mammal species on small-scale clearcutting was investigated in a mixed forest. The aim was to ascertain (1) whether the clearcutting within an extensive forest complex causes a change in the composition of small mammal species and (2) how typical forest species respond to the creation of a clearing.

MATERIAL AND METHODS

Study area. The locality is situated in the Kremnické vrchy Mts. (Central Slovakia; 48°40'N, 19°01'E) geomorphologically belonging to the West Carpathians. The altitude is 850–860 m a.s.l. The research plot typologically belongs to the *Abieto-Fagetum* forest type group (classifications according to ZLATNÍK 1959). The mature forest (110 years of age) on two thirds of the research plot was composed of beech (*Fagus sylvatica* 36%), fir (*Abies alba* 34%), ash (*Fraxinus excelsior* 20%), sycamore (*Acer pseudoplatanus* 8%) and Scots elm (*Ulmus glabra* 2%). The shrub layer was poorly developed being composed of natural regeneration of the parent stand. One third of the plot was represented by a young plantation which was established in 1996 by forestation of a narrow clearing strip with the following species: beech (30%), European elm (25%), fir (10%), and sycamore (10%). A high portion of *Rubus* sp. in undergrowth and dense herbal cover are characteristic of this part of the plot.

Methods. The research was carried out in 2006 to 2007. The CMR (capture-mark-release) method was used to obtain data. The wooden Chmela-type live traps baited with dry cat food granules were used for capturing small mammals and were placed at each capture point on the 10 × 10 grid with 10 m spacing (0.81 ha; PELIKÁN 1975). To compare the spatial distribution of two dominant rodent species, the rows were divided into

three sections: A – forest interior (six rows inside the forest); AB – forest edge (one row at the forest edge); B – clearing (three rows in a clearing). The traps were checked twice a day (morning and evening). The trapped individuals were identified according to the species, marked individually by toe-clipping, sexed, weighed, and released at the site of capture.

Two parameters were tested: (1) mean total number of captures per one trapping point in three parts of the study plot; (2) mean trapping efficiency in three parts of the study plot. The first parameter was calculated by summing all captures per each trapping point during 2006–2007 and divided by the number of trapping points belonging to the given section. The second parameter comprises the mean portion of occupied traps during each trapping day calculated separately for each part of the study plot (forest interior – 60 trap points; edge – 10 points; clearing – 30 points). Trapping day consisted of 24 hours with two controls.

The differences in these parameters were analysed using the nonparametric Mann-Whitney *U*-test. All statistical analyses were conducted using the computer package STATISTICA 7.0 (SPSS, Tulsa, USA). Significant difference was assumed at the 5% level of significance.

RESULTS AND DISCUSSION

In total, seven species were detected within the study plot during 2006–2007 (Table 1). Only three species were captured within the forest interior, whereas six species were recorded on the clearing. Only *Apodemus flavicollis* (only AF in the text below) and *Clethrionomys glareolus* (only CG in the text below) were recorded as dominant. Another five species were recorded scarcely. *Microtus subterraneus* is considered to be a typical element at

Table 1. Species richness captured in the forest interior (A), forest edge (AB) and clearing (B)

Species	A	AB	B	Total number of captures
<i>Clethrionomys glareolus</i>	148	27	161	336
<i>Apodemus flavicollis</i>	230	30	61	321
<i>Sorex minutus</i>	–	–	1	1
<i>Sorex araneus</i>	–	–	2	2
<i>Neomys anomalus</i>	–	–	1	1
<i>Microtus subterraneus</i>	–	–	1	1
<i>Crociodura leucodon</i>	1	–	–	1

early successional stages (DUDICH 1970). During the entire research period, only one individual was captured on the clearing. The low abundance of insectivores is rather surprising, since *Sorex araneus* (reached dominance only 0.2%) is generally considered to be one of the most abundant forest mammals (BALÁŽ, AMBROS 2005). The capture of a forest-steppe element *Crocidura leucodon* in such conditions is an extraordinary record (LEŠO et al. 2008), possibly related to the increasing fragmentation of the extensive forest complex in recent years. The individual was captured in the forest interior. Similar captures from several sites located within the forest interior in southern Alps were also reported by KRYŠTUFEK (2009). SUCHOMEL and PURCHART (2011) recorded even a relatively abundant population of *C. leucodon* in plantings of floodplain forests in southern Moravia.

Thus, on the basis of our results, the forest fragmentation caused a higher number of species recorded on the clearing. This conclusion corresponds also with results from a mature forest with similar tree composition located only 200 m apart from the study plot (LEŠOVÁ et al. 2010), where within the identical area using 100 live traps, only four micromammalian species were recorded during the same period. Similarly, in a mature fir-beech forest located three km apart from the study plot presented in this paper, LEŠO and KROPIL (2010) confirmed the occurrence of five species during 2005–2006, using live traps and pitfalls. All results have one thing in common – a very low abundance of insectivores. It was confirmed by using different traps (Chmela and pitfalls) and bait (LEŠO, KROPIL 2010). ČEPELKA et al. (2011) confirmed that population densities of small terrestrial mammals were higher in plantations than in mature stands. BRYJA et al. (2002) found out that if the forest fragmentation was relatively small (clearings < 3 ha), the structure and diversity of micromammalian assemblages did not differ from those of the parent forest stand. Our results document the great importance of the small-scale fragmentation of homogeneous commercial forest stands for biodiversity conservation, as demonstrated also by SUCHOMEL et al. (2012).

When the spatial distribution of two dominant species within the study plot is compared, the clear pattern is apparent. The mean number of AF captures per one trapping point (Fig. 1) reached the highest value in the forest interior (3.83 captures on average). The same species reached almost a half abundance on the clearing (2.03 captures per

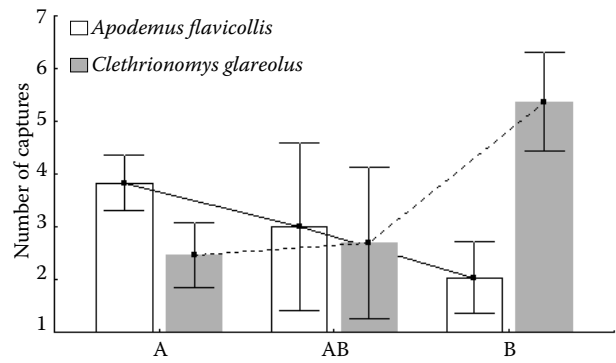


Fig. 1. The mean number of captures of two rodent species per one trapping point in forest interior (A), forest edge (AB) and clearing (B)

one trapping point, on average), and the difference between the forest interior and clearing was significant (Table 2). The forest edge was a transitional zone. On the contrary, CG was significantly

Table 2: Mann-Whitney *U* test of the mean total number of captures per one trapping point

Type of plot	AF		CG	
	U	P	U	P
A/AB	1.158070	0.246836	-0.629386	0.529097
AB/B	1.124451	0.260823	-2.82675	0.004703*
A/B	3.718977	0.000200*	-4.98146	0.00001*

*statistically significant difference

attracted by the clearing. The mean number of its captures per one trapping point reached a double value (5.37) in comparison with the interior or edge (2.47–2.70).

Similar results are apparent from the comparison of mean values of trapping efficiency within three different parts of the study plot (Fig. 2). The highest value of AF mean trapping efficiency was detected within the forest interior, where 16.01% (on average) of traps were occupied by AF during each trapping day. This variable reached a half value on

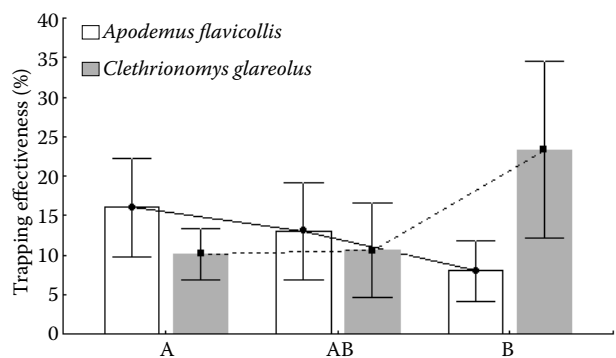


Fig. 2. Capture effectivity of two species in forest interior (A), forest edge (AB) and clearing (B)

Table 3. Mann-Whitney U test of the mean trapping efficiency in three parts of the study plot

Type of plot	AF		CG	
	U	P	U	P
A/AB	0.911721	0.361916	0.933690	0.350464
AB/B	0.768921	0.441941	−1.63670	0.101693
A/B	1.922303	0.054568*	−1.19732	0.231183

*statistically significant difference

the clearing (7.97%) in comparison with the interior, and the difference was significant (Table 3). The forest edge reached moderate values (13.04% on average). On the contrary, CG was the most frequently captured on the clearing, where, on average, 23.33% of traps were occupied by this species during each trapping day. On the other two parts of the plot, the variable reached significantly lower values (10.14–10.58%).

As supposed, the difference between one edge row and the forest interior was not significant. Ultimately, it was not a goal of the study to reveal a relationship between the edge distance and the abundance of certain micromammalian species. For that purpose, a much larger area should be covered with traps positioned towards the strongest environmental gradient. Moreover, the forest edge was exposed to the north, which made the boundary between the forest interior and the clearing sharp, without gradual transition of vegetation cover.

The results of spatial distribution of two dominant rodent species correspond to the general knowledge of their microhabitat preferences in temperate forests. They are both considered as forest generalists, but CG seems to be more selective in habitat use than AF. At the microhabitat scales, CG relies mainly on dense undergrowth (PUCEK 1983; MAZURKIEWICZ, RAJSKA-JURGIEL 1987; CHETNICKI, MAZURKIEWICZ 1994; MIKLÓS, ŽIAK 2002; HLŮŠKA, SANIGA 2005; BUESCHING et al. 2008). Besides protection against predators, the preference of dense undergrowth in CG results from its foraging requirements based mainly on forbs and forb-like vegetation, tree leaves, large tree seeds and fungi (HANSSON 1985). Seeds become a dominant food in the period of seed crop (OBRTEL, HOLÍŠOVÁ 1974; HEROLDOVÁ et al. 2008). The food habits of CG may differ depending on the type of forest, season, food supply and population density (HOLÍŠOVÁ 1971; HANSSON 1985). Its role in damage to buds and shoots is naturally several times higher in

the years of gradation (SANIGA 2003). In general, AF is considered as a granivore (DUDICH 1970; HOLÍŠOVÁ, OBRTEL 1980; HEROLDOVÁ 1994). Better seed availability may be one of the reasons for preferring older forests. Resources of seeds within forests are thought to be of particular importance for the largely granivorous AF (DUDICH 1970; MARSH, HARRIS 2000). The distribution of two dominant rodent species during 2006–2007 corresponds with beech seed supply in the same period. A seed year of beech was noted in 2006 in the given area, attended by massive beechnut production in mature forests. Different food supply within a small area scale resulted in sharp differences in the distribution of small mammals.

LEŠOVÁ et al. (2008) studied microhabitat preferences of AF and CG on two parallel plots representing natural and fragmented commercial fir-beech forests. The commercial forest was represented by the identical study plot described in this study. During 2007, a significant positive correlation between the abundance of AF and tree density (resulting in poor vegetation cover) was ascertained in both types of forest. On the contrary, CG significantly preferred dense herbal and undergrowth vegetation (occurring at the sites with opened canopy) on both study plots.

Similar results were reported by SUCHOMEL and URBAN (2011) on seven plots representing various successional stages of beech forest. AF predominated in older production stands (age of 60 to 144 years), whereas CG was the most abundant at open sites of plantings (9–10 years). SUCHOMEL et al. (2012) pointed out the preference of dicotyledonous plants, particularly in combination with *Rubus* spp. by CG.

On the contrary, LEŠO and BÚTORA (2010) found out different distribution of AF and CG in fragmented fir-beech forests of different age. AF significantly preferred open young forest stands occurring within the clearing after wind-break. Increasing density of mature trees negatively influenced its abundance. CG significantly preferred microhabitats with mature trees and it was a dominant species in mature stand. The low seed supply in mature fir-beech forest during periods between seed years of beech may be a reason for different microhabitat preferences of two dominant rodent species. AF might have preferred the clearing due to the higher food supply provided by various gramineous plants, and as a stronger competitor, push out CG to the temporarily suboptimal habitats. SUCHOMEL et al. (2012) considered beech plantations with high abundance of AF as a

temporary habitat (during migration when looking for food) for that species, particularly due to the limited supply of tree seeds.

On the basis of the comparison of our results with those of LEŠO and BÚTORA (2010), obtained from similar habitats, different microhabitat preferences of two dominant rodent species were determined. As mentioned above, different food supply within certain habitats may be the main factor that influences the spatial distribution of the studied micromammals. The same was observed by CASTIEN and GOSALBEZ (1994). They found out no preference of mature beech forest by *Apodemus flavicollis* during the period without beechnuts crop, contrary to a positive correlation with the arboreal cover when the forest crop was available. It may also be a reason why various authors discover different habitat preferences of the same species. Perhaps the additional quantification of food supply besides microhabitat analysis itself may help to solve that discrepancy.

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