

ABUNDANCE OF COMMON SHREW (*SOREX ARANEUS*) IN SELECTED FOREST HABITATS OF MORAVIA (CZECH REPUBLIC)

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Abstract

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Abundance of common shrew (*Sorex araneus*) was evaluated on selected forest sites in Moravia, Czech Republic. Six types of habitats were assessed: forest clearings and mature forests in lowlands (173–233 m), uplands (360–600 m), and mountains (600–1200 m). Data were collected over five-year-long periods; 2006–2010 (uplands) and 2007–2011 (lowlands and mountains). Small terrestrial mammals were captured using snap traps laid in lines. In total, 200 individuals of common shrew were trapped. Relative abundance among different habitats was statistically evaluated. The highest relative abundance was found in mountain forest clearings ($n = 132$, $rA = 0.719$). Lower abundance was in upland forest clearings ($n = 15$, $rA = 0.384$), in mature mountain forests ($n = 32$, $rA = 0.355$), and in the lowland forest clearings ($n = 9$, $rA = 0.109$). The lowest abundance was in mature upland forests ($n = 9$, $rA = 0.031$) and in mature lowland forests ($n = 3$, $rA = 0.011$). Differences between sites were statistically significant. Among all altitudes, shrew populations in plantations were significantly more numerous than those in mature forests. Mountain forest clearings with dense herb layer proved to be the most suitable habitat while mature lowland forests with less developed herbaceous layer were the least suitable. Forest clearings proved to be an important refuge for the populations of common shrew.

Keywords: abundance, forests clearings, lowlands, mountains, mature forests, *Sorex araneus*, uplands

INTRODUCTION

Common shrew (*Sorex araneus* Linnaeus, 1758) is a common member of small terrestrial mammal communities in the cultural landscape of the Czech Republic (Anděra, 2010). It plays an important role as a consumer of invertebrates (Kolibáč, 1995). Like rodents, it has a relatively high reproductive capacity. Compared to rodents, however, it is limited by a prolonged postnatal development of offspring and thus the later maturation (Anděra and Gaisler, 2012). Although in years of very low density, early maturation of first spring generation in habitats of good quality was observed (Stein, 1961).

Generally, it is regarded a numerous mammal. When using appropriate methodology, common shrew is sampled quite frequently both in straight

research of small terrestrial mammals (Dudich and Štollmann, 1985; Šedivec and Whidden, 2006; Suchomel *et al.*, 2014), and a non-target organism in a research of epigeic insects (Dudich *et al.*, 1987). In recent decades, however, there is a significant decline in the abundance of its populations (this applies also to other *Soricidae* species). This is attributed to overall changes in the structure and management of landscape (Zejda, 1996), recently leading to massive loss of insects (Dirzo *et al.*, 2014). It may also be partly attributed to natural multiannual population fluctuations of shrews (Zub *et al.*, 2012). The largest decline was noted in the intensively cultivated agricultural lowlands (Suchomel and Heroldová, 2004; Heroldová *et al.*, 2007). Higher relative abundance remains in

mountain regions where shrews probably find more appropriate habitats (eg. Suchomel *et al.*, 2014). Forests in different stages of succession and under different types of management play a significant role for the existence of suitable habitats.

This is true both in the lowlands and mountain areas (eg. Zejda, 1976; Dudich and Štollmann, 1981; Zbytovský *et al.*, 2004; Anděra, 2010 etc.). However, the population of common shrew seems to decline even in forest habitats in recent years (Suchomel, 2007; Čepelka *et al.*, 2011 Suchomel *et al.*, 2014). This may indicate a reduction in the habitat quality or it may be associated with multiannual population fluctuations (Zub *et al.*, 2012). Forests and woody vegetation are particularly important for shrew populations in lowlands, heavily influenced by intensive agriculture (Suchomel *et al.*, 2012).

As far as we know, there is no direct comparison of shrew abundance within the vertical gradient of landscape (mountain, upland and lowland areas). The results have been only part of partial studies so far (see above) and therefore they can be compared only by discussion.

The aim of this work is to test the following hypotheses: (1) Are mountain stands the main refuge for populations of common shrew in a given area? (2) Are the forests of lowlands a sufficient refuge for shrew populations in intensively used agricultural landscape?

MATERIALS AND METHODS

Study Area

Data from previous surveys were used for the study (uplands 2006–2010; lowlands and mountains 2007–2011). The research was conducted in selected forests of Moravia, Czech Republic, in lowlands (southern Moravia), uplands (Drahanská vrchovina, Kelečsko pahorkatina), and mountainous areas (Moravskoslezské Beskydy, Hrubý Jeseník). In each geographic level, clearings and mature forests were marked off, i.e. six groups of habitats in total: (1) mature mountain forests, (2) mountain forest clearings, (3) mature upland forests, (4) upland forest clearings, (5) lowland mature forests, (6) lowland forest clearings. Data obtained within the five-year-long monitoring at each habitat were summed together.

(1) Mountain mature forests

Forest stands in Beskydy are at the altitude of 940–1200 m a.s.l. nearby mountains Kněhyně and Smrk. They are mostly production forests of more than 100 years with small isolated faces of non-intervention reserves. The dominant species are Norway spruce (*Picea abies*), rowan (*Sorbus aucuparia*), and beech (*Fagus sylvatica*). More or less developed understory herb layer is dominated by bunch grass (*Calamagrostis arundinacea*) Alpine Lady-fern (*Athyrium distentifolium*), and blueberries (*Vaccinium myrtillus*). There were 9,000 trapnights (the

number of traps used and the total number of nights for which the traps were exposed).

(2) Mountain forest clearings

Plantations of beech mixed with *Picea abies* and *Abies alba*, located in Beskydy Mts and Hrubý Jeseník Mts at altitude of 600–1200 m a.s.l. At the beginning of monitoring, the age of trees was up to 10 years. Highly developed herb layer (coverage between 80–100 %) is dominated by grasses (*Calamagrostis* sp., *Deschampsia* sp., *Avenella* sp.), *Rubus* sp., and blueberries (*Vaccinium myrtillus*). There were 18,360 trapnights.

(3) Upland mature forests

Forests in the central part of the Drahany uplands (LDF MENDELU Rájec-Němčice research station) and Kelečská uplands (Forest High School in Hranice) at altitude 360–600 m a.s.l. Production forests include mixed stands (with the dominance of *Picea abies*, *Fagus sylvatica*, *Abies alba*) and the monoculture of *Fagus sylvatica* or *Picea abies*, 60–144 years old. Herb layer in monocultures was mostly undeveloped. In mixed stands, there was the dominance of *Rubus* sp., *Calamagrostis* sp., *Avenella flexuosa*, *Carex pilosa*, *Poa nemoralis* and ferns. The dominant species of herb layer were *Convallaria majalis*, *Lathyrus vernus*, *Euphorbia amygdaloides*, *Polygonatum multiflorum*, *Petasites albus* and others. There were 29,340 trapnights.

(4) Upland forest clearings

Beech plantations in Kelečská uplands are at the altitude 380–460 m a.s.l. At the beginning of the monitoring, they were 9–10 years old. The stand admixture contained *Fraxinus excelsior*, *Abies alba*, *Larix decidua*, *Alnus glutinosa*, *Acer pseudoplatanus*, *Quercus petraea*, *Tilia cordata*, *Carpinus betulus*, *Picea abies* and *Ulmus carpiniifolia*. Herbal layer was very well developed (80–100 % coverage), predominantly by grasses (especially with *Calamagrostis arundinacea*) and blackberry (*Rubus* sp.). There were 3,900 trapnights.

(5) Lowland mature forests

Production forests influenced by man to some extent. There are three large isolated fragments in agriculture landscape of southern Moravia (near Lednice in Moravia, Vranovice and Blučina u Brna). The average annual temperature is 9.5° C; Average annual rainfall of 545 mm; altitude 173–233 m a.s.l.; age of stands between 60–135 years. Natural forest composition: predominance of *Quercus robur*, *Q. petraea* and *Fraxinus excelsior*, mixed with *Tilia platyphyllos*, *Acer campestre*, *Corylus avellana* and *Robinia pseudoacacia*. Developed shrub layer of *Acer campestre*, *Fraxinus excelsior*, *Carpinus betulus*, *Tilia platyphyllos*, *Sambucus nigra* and *Sambucus ebulus*. Herbal layer was more or less developed and dominated by grasses. There were 26,625 trapnights.

(6) Lowland forest clearings

Plantations of *Quercus robur* or *Populus nigra* in southern Moravia are in altitude 173–233 m a.s.l. The stand admixture of *Carpinus betulus*, *Tilia* sp., *Fraxinus excelsior*; and other deciduous and coniferous trees. Strongly developed herb layer (coverage up to 100 %) was dominated by grasses and ferns. The age of the plantings was up to 5 years at the beginning of monitoring. Number of trapnights was 8,262.

Methods

Regular trapping of small mammals was carried out at each of the selected experimental plots using snap traps (Pelikán, 1976). Traps were placed in line at a distance of 3–5 m. Oil lamp wicks were used as baits. They were coated with flour and fried in vegetable oil and finally raddled with peanut butter. Traps were left on plots for four days (i.e. 3 nights) and checked each morning. The number of traps per line (and the number of trapnights as well) at the plots differ because the data were collected in various projects. For further statistical comparison, these differences were eliminated by converting the number of trapped individuals into abundance (rA – see below). For number of trapnights in each habitat, see the Study area. It is also important to mention that under rainy conditions the catch of shrew increases (Šebela, 1980).

Captured animals were dissected in the lab. Body length, body weight, species and sex were determined by identification keys (Zejda *et al.*, 2002; Anděra and Horáček, 2005). All aspects of capture were in accordance with the EU Council Directive 86/609 / EEC for the use of experimental animals.

Population sizes at each habitat were compared using the relative abundance (rA) expressed by the equation: $rA = 100 * n / P$ (n – number of individuals trapped; P – number of trap nights).

Relative abundance among habitats was statistically evaluated using one-way ANOVA. Body weight and length of lowland and upland populations and relative abundance in mature forests and plantations were compared using T-test for independent samples. All calculations were performed using Statistica 12 CZ.

RESULTS

In total, 200 individuals of common shrew were trapped during the five years of monitoring. The highest abundance was found in mountainous regions (Fig. 1). Within the whole monitored area, higher abundance was in forest clearings than in mature forests (Fig. 2) across all vertical levels (mountains, uplands, lowlands; Fig. 3–5). The highest relative abundance was detected in (2) mountain forest clearings (n = 132, rA = 0.719). Lower abundance was in (4) upland forest clearings (n = 15, rA = 0.384), and in (1) mature mountain forests (n = 32, rA = 0.355). In other habitats of middle and lower positions, the abundances were significantly lower: (3) mature upland forests

(n = 9, rA = 0.031), (6) lowland forest clearings (n = 9, rA = 0.109), and (5) mature lowland forests (n = 3, rA = 0.011). For comparison of the relative abundance among clearings, see Fig. 6; for comparison of the relative abundance of old forests, see Fig. 7.

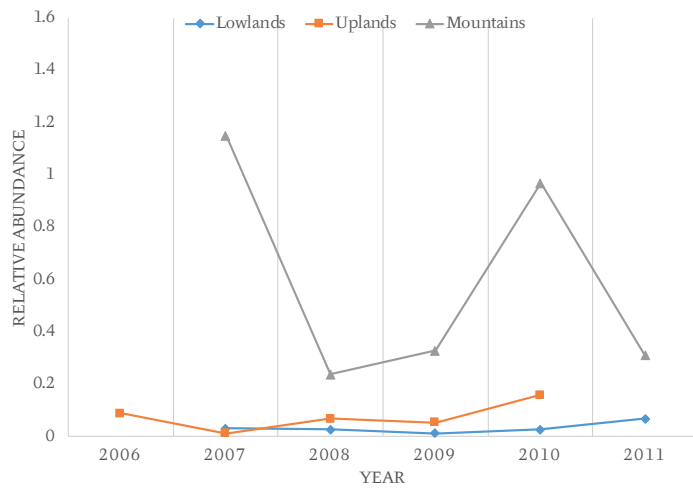
Populations of mountain clearings were statistically significantly higher than the population of mature upland forests (p = 0.018), mature lowland forests (p = 0.014) and lowland forest clearings (p = 0.039). Differences among other investigated habitats were not significant (p > 0.05).

Body weight and body length among lowland and upland populations were not significantly different (p > 0.05) but heavier animals were found in the mountains. The heaviest individuals: adult female 9.5 g in lowlands, adult female 13 g (adult female with embryos 16 g) in mountains.

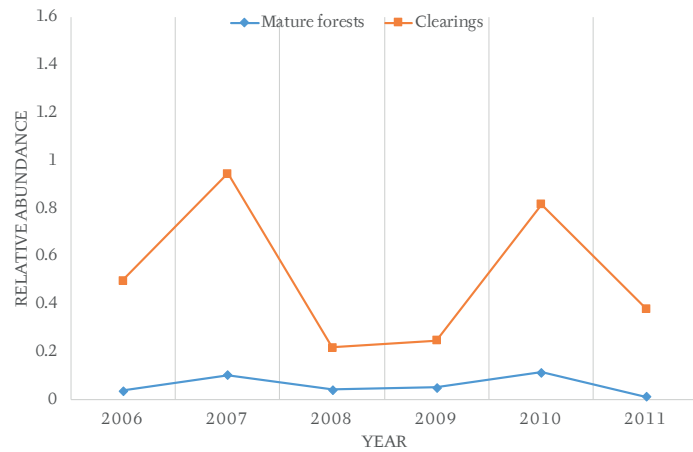
The comparison of relative abundances among regions (lowlands, uplands and mountains) proved to be significant only between lowlands and mountains (p = 0.009), not elsewhere (p > 0.05).

Relative abundance of common shrews in mature forests were significantly lower than in plantations (t = -3.685, p = 0.000).

Trend shows common shrew population (rA value) increase with altitude (Fig. 8).



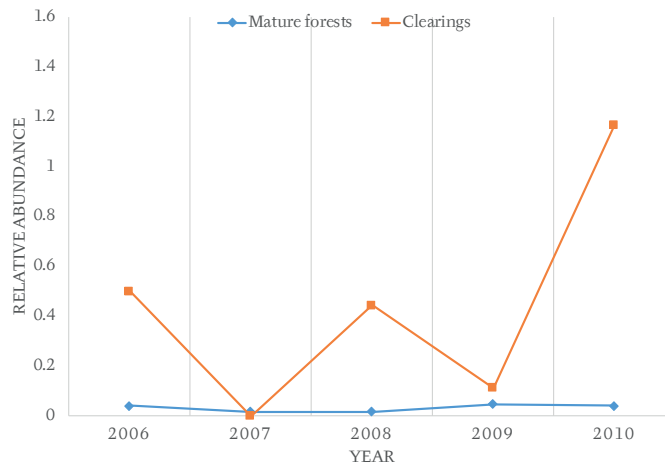
1: Fluctuations in the relative abundances of common shrew during the monitoring period in the mountains, lowlands and uplands
Source: authors



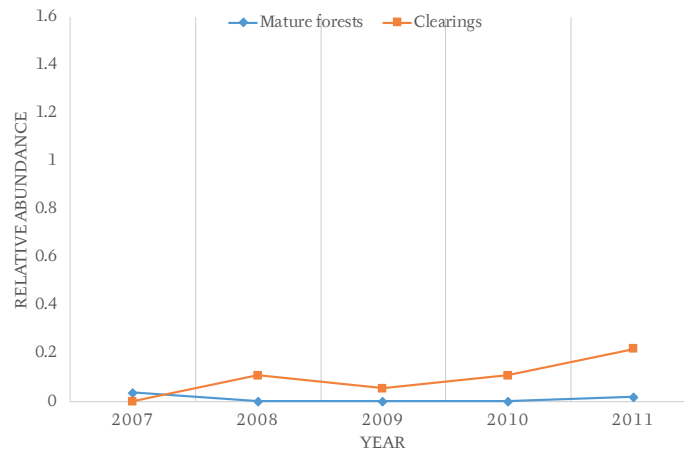
2: Fluctuations in the relative abundance of common shrew in the clearings and mature forests
Source: authors



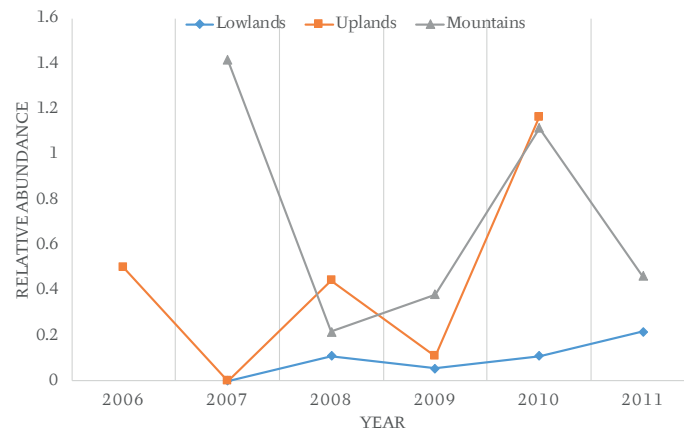
3: Fluctuations in the relative abundance of common shrew in the clearings and mature forests in mountain areas
Source: authors



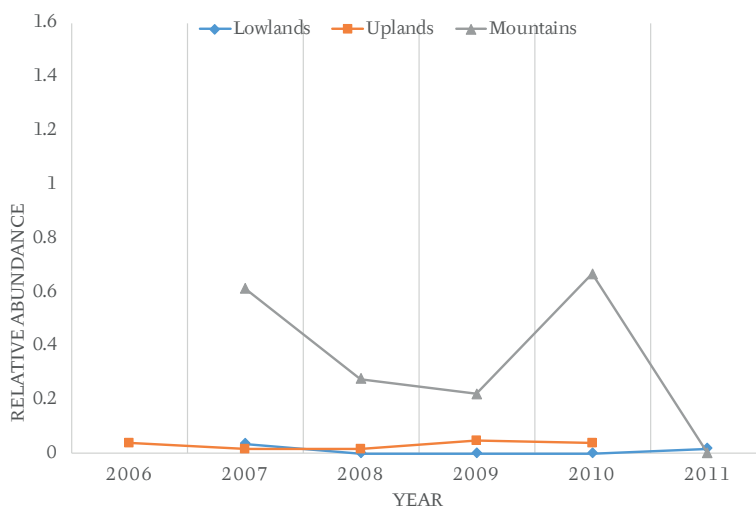
4: Fluctuations in the relative abundance of common shrew in the clearings and mature forests in uplands
Source: authors



5: Fluctuations in the relative abundance of common shrew in the clearing and mature forests in lowlands
Source: authors

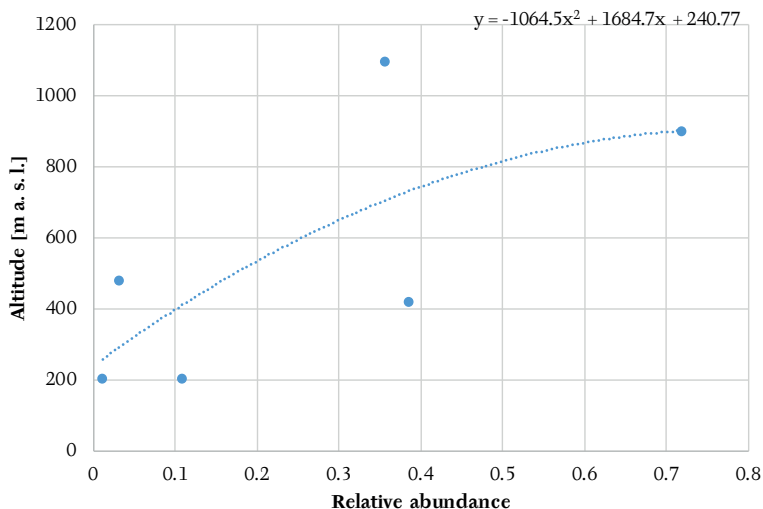


6: Fluctuations in the relative abundance of common shrew in the clearings in the mountains, lowlands and uplands
Source: authors



7: Fluctuations in the relative abundances of common shrew in mature forests in the mountains, lowlands and uplands

Source: authors



8: Influence of vertical gradient on average relative abundance of common shrew

Source: authors

DISCUSSION

Common shrew population density (rA) reflects the condition in mountainous environment which remain more close to nature and so food quality and quantity is higher. It is also a matter of moisture conditions there. The most important are forest clearings in mountains and uplands. Clearings represent early successional stages of forest with a rich herb layer and provide optimum conditions with sufficient amount of food and shelter options (Anděra, 2010; Suchomel *et al.*, 2014). Abundance in the clearings in mountainous areas, however, almost doubled the abundance in the uplands. It may be associated with higher amounts of precipitation in the mountains. Sufficient rainwater keeps wetter habitats that provide suitable microclimate conditions and wider spectrum of invertebrates,

which are essential for shrews (Baláž, 2005). Numerous shrew populations are in mountainous areas not only in clearings but also in other sites with sufficiently developed herb layer, eg. large air pollution clearcuts (Bryja *et al.*, 2002) and old sparse decaying forests (Bryja *et al.*, 2002; Čepelka *et al.* 2011, Suchomel *et al.*, 2014). Lower abundance in plantations of uplands (rA = 0.384) corresponds to further studies in the region. For example, Suchomel and Urban (2011) present rA = 0.22–0.54 in plantations of Kelečská uplands.

An important factor is the diversity of herb layer with sufficient representation of dicots (*Rubus* sp., *Vaccinium* sp., etc.) which is tied to a rich variety of invertebrates (Thomas and Marshall, 1999). The relationship between abundance of shrews and coverage of dicots in herb layer has been proved also in Beskydy (Suchomel *et al.*, 2014).

Shrews are also numerous in natural mountain spruce forests. For example, common shrew was the most common small mammal in Šumava. At the end of the 20th century, it reached dominance (D) over 50 % while the share of all Soricids was 71.8 % (Anděra and Burger 1992). The main reason is the natural age and spatial composition of climax spruce stands. This promotes higher diversity of habitats and bounded organisms including invertebrates (Svoboda and Pouska, 2008). In contrast, even-aged spruce monocultures with no or only poor herb layer are unsuitable for shrews (lack of food and shelter). For example, Zejda (1981) stated dominance of common shrew in spruce monocultures only 2.3 %; Suchomel *et al.* (2010) $rA = 0.06$ and Čepelka *et al.* (2015) $rA = 0.02$.

The abundance of shrews in mature upland forests and lowlands forest was compared to the mountain forests significantly lower. Mature upland forests consist mainly of Norway spruce monocultures with lower proportion of beech. Low abundance and dominance of common shrew in such habitats is confirmed by many studies (Zejda, 1981; Suchomel, 2007; Suchomel *et al.*, 2010; 2011; Čepelka *et al.*, 2015). For example, Suchomel *et al.* (2010) reported abundance in both types of forest only $rA = 0.06$; Suchomel and Urban (2011) states $rA = 0.04$ both in the old mixed forest and in the beech monoculture. Spruce monocultures are unsuitable for shrew population also in the long term. This claim is supported also by results from the Dražanská uplands. The dominance of common shrews on the same plots was low in the seventies of the 20th century (D = 2.3 %, Zejda 1981) as well as thirty years later (D = 2.9 %, Suchomel *et al.*, 2010).

The lowest abundance of shrews was in the lowland forests of southern Moravia. The abundance in plantations ($r = 0.109$) was higher than in mature forests ($r = 0.011$) in southern Moravia. Also other studies from this region reported very low abundance of common shrew. E.g. Suchomel and Heroldová (2004) found $rA = 0.03$ – 0.08 in the forest with normal hydric regime and in the floodplain forest $rA = 0.15$ in 2002–2003. In recent decades, a significant decline of Soricid insectivores occurred in the forests of southern Moravia due to significant landscape and land use changes. They consisted mainly in agricultural intensification and water management (Zejda, 1996).

E.g. Zejda (1991) presents a rapid decline in the dominance of shrews in the floodplain forest from D = 14.7 % before water regulation to D = 1.08 % after it. Even after all those changes, lowland forest habitats remain an important refuge for shrews. Their proportion in the community of small mammals is very low (D = 1.23 %; Suchomel *et al.*, 2012) but it is still higher than in the surrounding agricultural landscape (D = 0.51 %; Heroldová *et al.*, 2007). Low abundance of common shrews in the lowland forests can be influenced by limited area of forest habitats surrounded by agricultural landscapes (Suchomel and Heroldová, 2004; Suchomel *et al.*, 2012).

Such landscape can be more suitable for Soricids who prefer more open habitats, such as Bicolored shrew (*Crocidura leucodon*). This species had higher dominance (D = 1.6–7 %) but its population dynamically fluctuates (Suchomel and Purchart, 2011).

CONCLUSION

The most important habitats for populations of common shrew in Moravia were mountain areas. The highest abundances were found in mountain forest clearings. Mature mountain forests and clearings in uplands seem also suitable as the abundance of shrews was comparable there. The least suitable habitats were mature forests in the uplands and lowlands. Generally, there is a great importance of forest clearings where much more shrews occur than in mature forests throughout the altitude gradient. The lowest numbers of common shrews were in the lowland forests, despite their abundance here was still higher than in surrounded agrocenosis (compared to Heroldová *et al.*, 2007). The lowland forest clearings seem as the key habitats. Results support the hypothesis that mountain forests are the most important refuge for common shrew in Moravia, and that lowland forests (especially clearings) are the most important refuge for shrew in the agricultural landscape. Current forest management resulting in the formation of clearings with the presence of a suitable herb layer with ideal microclimate conditions thus appears to be optimal for the occurrence of common shrew populations.

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