INFLUENCE OF HABITAT CONDITIONS ON ABUNDANCE AND DIVERSITY OF SHREWS (*EULIPOTYPHLA*, *SORICIDAE*) IN MORAVIA

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Abstract: In the years between 2005 and 2012, this study has evaluated the relative abundance and diversity of insectivores of the shrew family (*Soricidae*) in lowland, upland, and mountain forest habitats of Moravia. In each of these three different elevation levels, two types of habitats were further defined. They include old growth forests, with tall, fruiting trees and a limited herbaceous forest floor, as well as forest clearings with dense undergrowth of herbs and grasses, which means a total of six types of habitats. Shrews were captured using snap traps set up in lines. A total of 302 individuals belonging to seven species were found. The most abundant and most dominant species was *Sorex araneus* (rA = 0.313; D = 73.45%), while other species were present in much lower numbers. To evaluate the communities, the used ecological indices included diversity, equitability, and similarity. The highest number of species was found in mountain clearings (n = 5), while the lowest occurred in old upland forests (n = 1). The highest diversity was in old growth lowland forests (H' = 1.194), the lowest in upland forests. In terms of abundance and diversity, forest clearings were richer than old forests, while mountain and lowland forests were richer than uplands forests. In terms of species, the most similar were communities of old growth mountain forests and mountain forest clearings. Forest clearings as early successional forest habitats with rich herbaceous undergrowth in lowlands and mountains proved to be important environmental refugia for this group of small mammals in the landscape.

Key Words: shrews, *Soricidae*, diversity, abundance, forest ecosystem, forest clearings

INTRODUCTION

Seven species of insectivores of the shrew family (*Soricidae*) occur in the Czech Republic. The common shrew *(Sorex araneus),* Eurasian pygmy shrew *(Sorex minutus),* Eurasian water shrew *(Neomys fodiens),* and the lesser white-toothed shrew *(Crocidura suaveolens)* occur nationwide, while the alpine shrew *(Sorex alpinus)*, southern water shrew (*Neomys anomalus)*, and bicolored shrew *(Crocidura leucodon)* occur regionally. The species *Sorex araneus, Sorex minutus,* and *Neomys fodiens* replicate with their elevation distribution of the occurrence the diversity of the relief of the Czech Republic. The species *Neomys anomalus* and *Crocidura leucodon* concentrate their occurrence in the middle positions of uplands (200 to 600 m above sea level), while *Crocidura suaveolens* occurs in the lowlands to uplands (140 to 400 m above sea level). Only the species *Sorex alpinus* has shifted its occurrence into foothills and mountain areas (Anděra 2010).

Due to intensive agriculture that is taking place today, the environment is changing, causing a total loss of shrews due to loss of habitat and food supply (Ryszkowski et al. 1973, Kozakiewicz and Kozakiewicz 2008). Compared with agricultural landscapes, larger populations of shrews occur in forests (Suchomel et al. 2012, 2014). Forests became for them important refugia in intensively farmed landscape, because their presence in the agrocoenosis is minimal (Heroldová et al. 2007).

The aim of this study is to assess the importance of selected types of forest habitats for the abundance and species composition of shrews. Up to this time, studies were concerned separately either with lowlands or mountains and moreover were parts of comprehensive studies of entire communities of small mammals, including rodents (Suchomel et al. 2012, 2014). Overall comparison of abundance and diversity of shrews at the altitudinal gradient is still missing.

MATERIAL AND METHODS

This study used data from surveys of small mammal communities from the years between 2006 and 2011. These surveys were carried out in the mountain forests of Moravian-Silesian Beskids and Hrubý Jeseník (High Ash Mountains), 640 to 1200 m above sea level, in the upland forests of Drahany Highlands and Kelečsko Upland, 450 to 660 m above sea level, and in the lowland forests of the Lower Morava Valley and Dyje-Svratka Valley, 173–233 m above sea level in Moravia, Czech Republic. Forest habitats were divided into six groups: (1) old growth lowland forests (2) lowland forest clearings, (3) old growth upland forests, (4) upland forest clearings, (5) old growth mountain forests, (6) mountain forest clearings.

Old forests are stands more than 100 years old, with a strong canopy and less developed herbaceous layer.

Forest clearings (plantations of young trees) represent early successional stages of forest growths that are not older than seven years, with the least-developed canopy and strongly developed herbaceous layer with coverage up to 100 per cent.

In each group of habitats, regular trapping of small mammals was carried out in the spring and autumn seasons, using snap traps. Traps were placed in a line at distances of 3 to 5 meters apart. Kerosene lamp wicks were used as bait. They were wrapped in flour, fried in vegetable oil, and then smeared with peanut butter. Traps were left in place for four days or three nights (so-called trap-nights), and checked each morning (Pelikán 1976). The numbers of used traps in individual areas differed due to the fact that they were parts of earlier independent research trappings. Table 1 summarises the total number of trap-nights at individual locations. All aspects of capture were in accordance with the provisions of EU Council Directive 86/609/EEC on the protection of animals used for experimental and other scientific purposes.

The study evaluated basic synecological characteristics such as the number of species (n), dominance (D) (Tischler 1949), as well as species diversity and similarity. For evaluation of diversity, the Shannon & Wiener index (H') was used, and equitability (E), which expresses the degree of equitable representation of individual species in biocoenosis. To determine the species similarity of different groups of biocoenoses, Jaccard index (Ja) (Magurran 1988) was used.

Due to different trapping methodologies (different numbers of traps) at individual locations, it was necessary to determine the relative abundance (rA). This is expressed as: rA = 100 n/P, where n is the number of captured individuals and P is the number of trap-nights.

RESULTS AND DISCUSSION

A total of 302 individuals of seven shrew species were trapped. The most abundant species was common shrew *(Sorex araneus)* (n = 245, rA = 0.313, D = 73.45%), followed by bicolored shrew *(Crocidura leucodon)* (n = 34; rA = 0.051, D = 15.41%), both species were eudominant (D > 10%). Eurasian pygmy shrew *(Sorex minutus)* (n = 13; rA = 0.040; D = 7.01%) was dominant (D = 5–10%). The lesser white-toothed shrew *(Crocidura suaveolens)* was a subdominant species (D = 2–5%, n = 6; rA = 0.004, D = 3.18%. The alpine shrew *(Sorex alpinus)* (n = 2, rA = 0.002; D = 0.45%), Eurasian water shrew (*Neomys fodiens*) (n = 1, rA = 0.002; D = 0.40%) and the southern water shrew (*Neomys anomalus*) (n = 1, rA = 0.001, D = 0.10%) were the least abundant species and all were subrecedent (D < 1%). Table 1 shows the number of trapped individuals and their dominance at each of the locations.

Sorex araneus was the most abundant species in all monitored habitats. This is a very adaptable insectivore species. It lives in all forest types, meadows, bogs, windbreaks, in agrocoenosis and parks. However, it prefers wetter types of forests with deep soil and hygrophilic undergrowth, where it finds suitable living conditions, such as wide range of invertebrates and suitable microclimatic conditions. In contrast, it avoids the dry forest stands with the poor herb layer (Anděra and Horáček 2005, Baláž 2005, Anděra 2010). It seems that if the essential habitat requirements are met, then it may occur relatively frequently in a wide range of altitudes, both in mature stands, as well as in early successional stages such as forest clearings. It was most common in mountain forest clearings (n = 158, rA = 0.717) and least common in old growth upland forests (n = 9, rA = 0.027). This may be due to the fact that they are mostly same-age production monocultures of *Picea abies* and *Fagus sylvatica,* with the least developed herbaceous layer, which are poorly suited for the presence of small mammals (Suchomel and Urban 2011). Table 1 indicates that other species of shrews were significantly less common, and in comparison with the common shrew occurred only marginally or occasionally.

Table 1 Values of Dominance (D); relative abundance (rA); number of individuals (n); number of trap-nights (NTP); Shannon index (H') and equitability index (E) among individual species on particular plots (1-6)

Species/Biotope	1			2			3			4			5			6			Total		
	n	D (%)	rA	n	D (%)	rA	n	D (%)	rA	n	D (%)	rA	n	D (%)	rA	n	D (%)	rA	n	D (%)	rA
Sorex araneus	10	52.63	0.024	10	23.81	0.099	9	100.00	0.027	15	78.95	0.714	43	89.59	0.299	158	95.75	0.717	245	73.45	0.313
Sorex minutus	2	10.53	0.005	1	2.38	0.010	0	0.00	0.000	4	21.05	0.190	3	6.25	0.021	3	1.82	0.014	13	7.01	0.040
Sorex alpinus	0	0.00	0.000	0	0.00	0.000	0	0.00	0.000	0	0.00	0.000	1	2.08	0.007	1	0.61	0.005	2	0.45	0.002
Neomys fodiens	0	0.00	0.000	1	2.38	0.010	0	0.00	0.000	0	0.00	0.000	0	0.00	0.000	0	0.00	0.000	1	0.40	0.002
Neomys anomalus	0	0.00	0.000	0	0.00	0.000	0	0.00	0.000	0	0.00	0.000	0	0.00	0.000	1	0.61	0.005	1	0.10	0.001
Crocidura suaveolens	3	15.79	0.007	0	0.00	0.000	0	0.00	0.000	0	0.00	0.000	1	2.08	0.007	2	1.21	0.009	6	3.18	0.004
Crocidura leucodon	4	21.05	0.010	30	71.43	0.297	0	0.00	0.000	0	0.00	0.000	0	0.00	0.000	0	0.00	0.000	34	15.41	0.051
Total	19	100.00	0.046	42	100.00	0.416	9	100.00	0.027	19	100.00	0.905	48	100.00	0.333	165	100.00	0.749	302	100.0	0.413
Number of species	4			4			1			2			4			5			7		
NTP	41385			10098			33000			2100			14400			22032			123015		
H'	1.194			0.760			0.000			0.515			0.433			0.207			0.518		
E	0.861			0.548			0.000			0.742			0.312			0.129			0.432		

The richest habitat in terms of species were (6) mountain clearings with 5 species, while the poorest habitat for species were (3) old growth upland forests with 1 species. Evaluation of dominance points to a greater or lesser extent disturbed habitats, because all habitats displayed superiority of eudominant or subrecedent species (Tischler 1949). The highest diversity index and the most balanced community was identified in (1) old growth lowland forests (H' = 1.194; E = 0.861), while the lowest values of both indices were in (3) old growth upland forests (H' = 0; E = 0). Overall, in terms of diversity and abundance of populations, lowlands and mountains appear richer than uplands. Even though shrews, mainly the common shrew, may in some forest habitats, especially in mountain forests with dense and species-rich herbaceous layer, achieve dominant values in the communities of small mammals (Suchomel et al. 2014), their abundance in forests, in comparison with other small mammals (mainly rodents), is relatively low (Suchomel et al. 2012, 2014). The same ratio is also in other types of habitats, including agrocoenoses (Heroldová et al. 2007). As the main cause of low abundance of shrews are quoted to be changes in the landscape due to human activity (intensive agriculture, climate change), leading to loss of suitable vegetation cover and food sources (Ryszkowski et al. 1973, Kozakiewicz and Kozakiewicz 2008). Despite the low proportion of insectivores in the community of small mammals, lowland forests (including isolated fragments) represent important habitats in intensively farmed landscape for the conservation of their populations and diversity (Suchomel et al. 2012). In this respect, mountain forests are then even more important refugia, especially in terms of their abundance (Suchomel et al. 2014).

In terms of species, the most similar habitats were (5) old growth mountain forests and (6) mountin forest clearings (Ja = 80 %). In contrast, the least similar habitats were (3) old growth upland forests and (6) mountain forest clearings (Ja = 20%). Table 2 shows the species similarity among other forest habitats.

Table 2 Jaccard index (%)

Biotope	(6) mountain forest clearings	(5) old growth mountain forests	(4) upland forest clearings	(3) old growth upland forests	(2) lowland forest clearings
(1) old growth lowland forests	50.00	60.00	50.00	25.00	60.00
(2) lowland forest clearings	28.57	33.33	50.00	25.00	-
(3) old growth upland forests	20.00	25.00	50.00	-	-
(4) upland forest clearings	40.00	50.00	-	-	-
(5) old growth mountain forests	80.00	-	-	-	-

Table 1 shows the important role of forest clearings in lowlands as well as uplands and mountains. Table 1 also indicates that the number of shrew species and their abundance are significantly higher in forest clearings than in the old growth forests. This is because their richly developed herbaceous layer provides the necessary protective cover, to which a number of insect species is tied as a food source. The most suitable in this respect are mountain forest clearings. Their herbaceous layer is richly diverse with many species of monocotyledon grasses and dicotyledon herbs (Suchomel et al. 2014). Regardless of the method of management, the presence of early successional stages of forest growths (plantations of young trees) is very important because as open habitats near forest, they serve as refugia for populations of both forest species and species of open habitats (Suchomel et al. 2012).

The current forest management, through creating clearings and clearcuts and their subsequent reforestation, creates appropriate living conditions for small terrestrial mammals, both in terms of their numbers and diversity. Although mostly dominant are species that come in conflict with forest management (Heroldová et al. 2012), especially the various species of rodents, the forest clearings may represent important refugia even for insectivores. This situation may change, for example due to prolonged exposure of negative factors, such as climate change, associated with harmful abiotic and biotic factors that would force the forestry operation to adopt different ways of management.

CONCLUSION

This study highlights the importance of forest habitats as refugia for shrew insectivores. Most important in this respect are mountain forests, especially the forest clearings, where shrews are most abundant. This may be related to local conditions, especially with plenty of moisture, which allows a rich growth of vegetation and sufficient amounts of invertebrates tied to it. Of considerable importance are lowland forests, where the frequency of shrews is significantly lower, but the detected diversity is the highest. For this reason, the importance of lowland forests in agricultural, intensively farmed landscape is considerable. Among the forest habitats, the forest clearings are more important than older forests, due to harbouring more species and larger populations. As for the shrews, the forest habitats are most important for the common shrew, which represented the most abundant and most dominant species (D > 70%) of all shrew insectivores.

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REFERENCES

Anděra, M. 2010. Current distributional status of insectivores in the Czech Republic (Eulipotyphla). *Lynx, n. s. (Praha),* 41: 15–63.

Anděra, M., Horáček, I. 2005. *Poznáváme naše savce*. 2. vyd. Praha: Sobotáles.

Baláž, I., Ambros, M. 2005. *Biológia, ekológia a rozšírenie druhov rodu Sorex na Slovensku*. Nitra: Univerzita Konštatntína Filozofa v Nitre, Fakulta prírodných vied.

Heroldová, M., Bryja, J., Jánová, E., Suchomel, J., Homolka, M. 2012. Rodent Damage to Natural and Replanted Mountain Forest Regeneration. *The Scientific World Journal*. 1: 1–16.

Heroldova, M., Bryja, J., Zejda, J., Tkadlec, E. 2007. Structure and diversity of small mammal communities in agriculture landscape. *Agric Ecosyst Environ,* 120(2): 206–210.

Kozakiewicz, M., Kozakiewicz, A. 2008. Long-term dynamics and biodiversity changes in small mammal communities in a mosaic of agricultural and forest habitats. *Annales Zoologici Fennici,* 45(4): 263–269.

Magurran, A. E. 1988. *Ecological diversity and its measurement*. London: Chapman and Hall.

Pelikán, J. 1976. The estimation of population density in small mammals. In: Petrusewicz E.D.K. (ed.): *Secondary Productivity of Terrestrial Ecosystems*. Warszawa: Panst-wowe Wydawnictwo Naukowe, pp. 167–273.

Ryszkowski, L., Goszczynski, J., Truszkowski, J. 1973. Trophic relationships of the common voles in cultivated fields. *Acta Theriol*, 18(7): 125–165.

Suchomel, J., Čepelka, L., Purchart, L. 2012. Structure and diversity of small mammal communities of lowland forests in the rural central European landscape. *European Journal of Forest Research*. 131(6): 1933–1941.

Suchomel, J., Purchart, L., Čepelka, L., Heroldová, M. 2014. Structure and diversity of small mammal communities of mountain forests in western Carpathians. *European Journal of Forest Research*, 133(3): 481–490.

Suchomel, J., Urban J. 2011. Small mammals of a forest reserve and adjacent stands of the Kelečská pahorkatina Upland (Czech Republic) and their effect on the forest dynamics. *Journal of Forest Science,* 57(2): 50–58.

Tischler, W. 1949. *Grundzüge der terrestrischen Tierökologie*. Braunschweig: Friedrich Vieweg und Sohn.