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IMPORTANCE OF WETLAND REFUGIA IN AGRICULTURAL LANDSCAPE PROVIDED BASED ON THE COMMUNITY CHARACTERISTICS OF SMALL TERRESTRIAL MAMMALS

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Abstract

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Intensification of agriculture has led, among other negative consequences, also to drying out of wetlands. Nevertheless, some of the wetland biotopes were preserved as small spots. This paper discusses the importance of those areas serving as refugia for small terrestrial mammals. Because small terrestrial mammals in the middle of food webs, they serve as an indicator for the presence of food sources (plants and invertebrates) and suggest the potential of the area as a living space for predators. The experiment took place at lowland agricultural landscape with wetland patches in west and west-east Slovakia (Záhorská and Podunajská nížina lowlands) using catch-mark-release method from 2015 to 2017. The importance was assessed according to abundance, biodiversity, persistence of species during seasons and habitat preference of small terrestrial mammals and equitability of the biotopes. Overall 368 individuals belonging to 12 species were recorded. The lowest abundance and diversity were registered at field biotopes where *Apodemus sylvaticus* was the most abundant. *Microtus arvalis, Clethrionomys glareolus* and *Sorex araneus* dominate at wetland biotopes. The higher biodiversity and abundance of small mammals were recorded at the wetland refugia. The results, together with position of small mammals in food webs, lead to conclusion that the wetland refugia are important habitats for the overall preservation of biodiversity and maintaining them is a part of the strategy for sustainable agriculture.

Key words: small terrestrial mammals, refugia, agricultural landscape, wetlands.

Introduction

The Slovak landscape has been influenced and changed by agricultural intensification, similar to other European countries, mostly by two driving forces – 19th-century agricultural revolution and 20th-century intensive agriculture. Both of them were a result of bigger demand for food and technical crops due to increasing population (Skokanková et al., 2016).

Productive agriculture in post-socialist countries, like Slovakia, was intensively connected with collectivisation as well as by the recent changes in agricultural practices (Stoate et al., 2001). This trend, characterized by the extensive use of heavy mechanization, pesticides and fertilizers (Kuskova et al., 2008), has resulted in the expansion of agricultural land and the rapid reduction of the natural landscape and its pollution. The changes led to decreasing of diversity and abundance of organisms (Baessler, Klotz, 2006; Donald et al., 2001; Stoate et al., 2001; Storkey et al., 2011).

Even though agricultural landscape has enlarged, still some biocorridors were preserved in the Slovak landscape. Those may serve, obviously, as paths during migration or transferring of organisms but for fauna of smaller size, as well as refugia, as a proper and stable biotope.

Research of small terrestrial mammals in Slovakia started more significantly in the 1960s. At first, research was focused mostly on diseases that are spread by micromammals and centres of their expansion. Data about occurrence, abundance and biodiversity as secondary information were the focus of many studies from Ambros and Dudich (for example, Ambros, 1986; Dudich, 1994) but also from other authors (Elischerová, 1989; Gaisler et al., 1967; Kocianová, Kožuch, 1988). Research on the examination of owl pellets to define owl feed composition was also done (Latková, 2008; Obuch, Kürthy, 1995), which is unfortunately not a reliable source for the determination of exact localities where small mammals range. In past 25 years, more and more research aimed at their ecology, population characteristics and influence of landscape changes has been performed (Baláž, Ambros, 2012; Krištofík, 2001).

Marshall and Moonen (2002) presented an extensive summary explaining the functions and relationships between agricultural land and field margins. Most of the experiments were aimed at refugia in an agricultural landscape focusing on plant species (Fried et al., 2009; Smart et al., 2002) and invertebrates (Čejka et al., 2018; Harding et al., 2006; Šustek, 1994).

Jančová et al. (2008) studied the biodiversity of small mammals in ponds and fishponds near the town Nitra and considered them as important oases of life in a monotonous agricultural land. However, the study (Jančová et al., 2008) was focused mainly on species richness in the localities as the community characteristic and a comprehensive comparison was not done. Bryja and Zukal (2000) studied the population characteristics of species in new forestry biocorridors. Malzahn and Fedyk (1982) compared trappability of small mammals at a bog biotope transformed to intensively used meadows, wooded reserves and shelterbelts and proved that unmown meadows, shelterbelts and wooded reserves act like refugia for relict bog species. Atanasov et al. (2012) and Heroldová et al. (2007) claim that even intermediately disturbed habitat shows relatively low small mammal diversity and species evenness. That is why we expect wetland patches at fields to serve as a biotope for micromammals.

Small terrestrial mammals form an important part of an environment. These organisms have been chosen for their designation in the refugia of importance because they not only are herbivores and insectivores, which means that their presence indicates sufficient plant and invertebrate sources of nutrition but also they can serve as food source for secondary consumers (predators).

The purpose of this study is to examine the importance and rate of use of the wetland patches in agricultural landscape as refugia (shown by the difference in biodiversity and abundance of small mammals in the studied areas), point out how sustainable the environment for small mammals is through equitability, to compare results from studied lines at different localities to see the similarities in an identical environment but in different areas and to show the desirable environment for small terrestrial mammals expressed by the results of their habitat preference.

Material and methods

Study area

The experiment was performed at two localities (Fig.1) at Záhorská nížina lowland in the west of Slovakia – Káňa (K, N 48.506° E 16.940°) and Ploština (P, N 48.489° E 16.973°) and at one locality at Podunajská nížina lowland in the south-west of Slovakia – Veľké Kosihy (VK, N 47.769° E 17.859°). All the localities are situated in agricultural land that is arable periodically with some reed wetland patches, which may serve as refugia.

Mammalian sampling

Three trapping lines consisting of 25 „Chmela" type live traps with a 5 m distance between were laid at each locality for two to five nights from November 2015 to February 2017, and overall, four field works were carried out. Trapping lines A (VKA, KA, PA) at each locality were placed at ecotone between a field and wetland, lines B (VKB, KB, PB) at a field that was arable during late spring and summer and nonproductive during fall and winter season and lines C (VKC, KC, PC) at wetland type of biotope to see whether the higher abundance and diversity is at field or wetland type patches. The traps were checked twice a day (after sunrise and after sunset if possible). Oat flakes and larvae of *Tenebrio molitor* were provided as the feed. In colder months also, a piece of cloth in each trap was offered for better survival. Catch-mark-release method was used throughout the whole experiment.

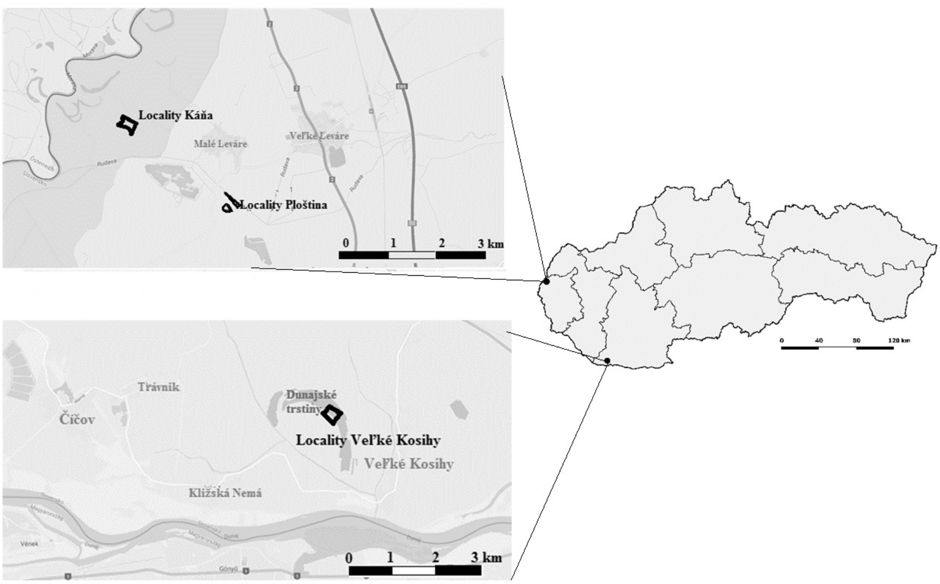

Fig. 1. The map of the studied localities.

Data analysis

Population characteristics

Figures of Shannon diversity index were determined according to the equation

$$H = -\sum_{i=1}^{n} pi_i \ln$$

where $pi = \frac{\text{ni}}{\text{N}}$ (*N* is the number of all captured individuals, n_i the number of individuals belonging to one species), figures of Pielou´s evenness index according to

$$E = \frac{\text{H}}{\text{Hmax}}$$

where H_{max} stands for index of diversity with maximal equitability of all present species, which is determined by the equation H_{max}=ln *s* (*s* is the number of all present species in a community).

We determined the persistence of the species during the seasons by the equation

$$K = \frac{\text{ni}.100}{s} \quad (\%)$$

where *ni* is the number of trapping actions where a species was noticed and *s* is the number of all trapping actions.

Statistical analysis

Nearest-neighbour cluster analysis based on Euclidean space (Lacevic, Amaldi, 2010) showing which lines are the most similar was made using PAST 3.13 (Hammer et al., 2001).

Habitat preference of the species was estimated with CCA after applying DCA on species data (gradient length ≥3,2) using CANOCO 4.56 and CANODRAW for a diagram. The species *Mus* sp. was excluded because just one individual of this species was captured and CCA would not show the real preference for the species. Every single trapping of an individual was included in the analysis because we expect that individuals are trapped multiple times and they stay in the biotope and that is why we consider it is as suitable for them. Excluding those data would underestimate the suitability of the biotope. Environmental factors (variables) for the diagram were tested using Monte-Carlo permutation test under full model using 2999 iteration (at significance level α = 0.05) and selected according to how much (≥0.05) of the variability they explain.

Results and discussion

Altogether 368 individuals were noticed, with 121 individuals at the locality Káňa, 131 individuals at the locality Ploština and 116 individuals at the locality Veľké Kosihy. In the west of Slovakia (localities Káňa and Ploština) we observed nine species of small mammals: three species belonging to the order Eulipotyphla – *Sorex araneus* (Soar, 19.4%), *S. minutus* (Somi, 3.2%), *Crocidura leucodon* (Crle, 1.2%) and remaining to the order Rodentia – *Apodemus flavicollis* (Apfl, 7.5%), *A. sylvaticus* (Apsy, 21.4%), *Clethrionomys glareolus* (Clgl, 29%), *Micromys minutus* (Mimi, 3.2%), *Microtus arvalis* (Miar, 15.1%), *Mus* sp. (Musp, 0.4%) and 11 species in the south of Slovakia (locality Veľké Kosihy): two belonging to the order Eulipotyphla – *Sorex araneus* (Soar, 29.3%), *S. minutus* (Somi, 0.9%) and the remaining to the order Rodentia – *Apodemus agrarius* (Apag, 16.4%), *A. flavicollis* (Apfl, 2.6%), *A. microps* (Apmi, 4.3%), *A. sylvaticus* (Apsy, 10.3%), *Clethrionomys glareolus* (Clgl, 0.9%), *Micromys minutus* (Mimi, 8.6%), *Microtus arvalis* (Miar, 21.6%), *M. oeconomus* (Mioe, 5.2%), *Mus* sp. (Musp, 0.9%). The exact numbers of each of the species at each locality are shown Fig. 2.

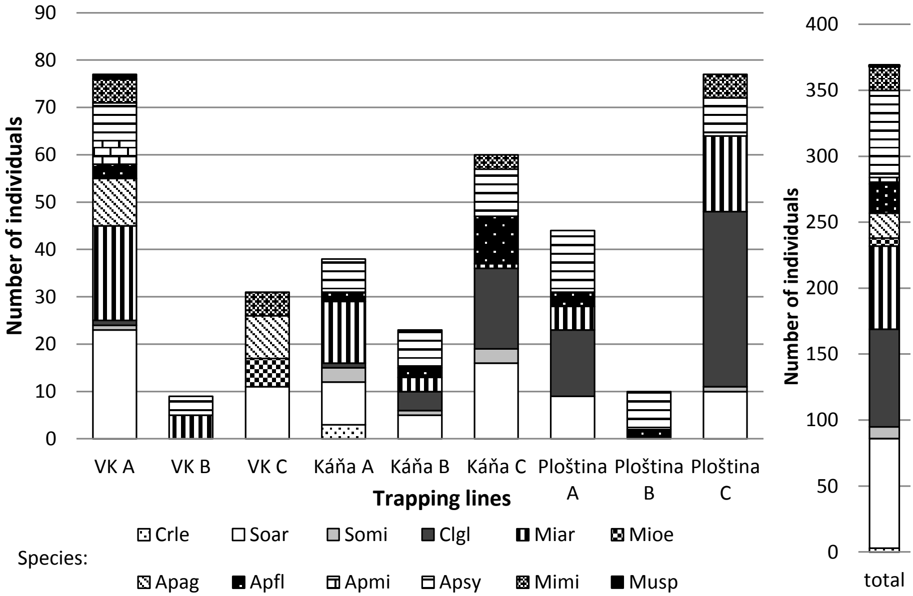

Fig. 2. An overview of caught individuals at each of the trapping lines at the localities.

Order Eulipotyphla at each trapping line is represented mostly by the species *Sorex araneus,* while *S. minutus* and *Crocidura leucodon* comprise just a small part of the communities. At Záhorská nížina lowland, the most abundant species is *Clethrionomys glareolus* and *Microtus arvalis.* On the other hand, in the Podunajská nížina, together with the species *M. arvalis*, a considerable part of the community is formed by the species *Apodemus agrarius* as well as the glacial relict and the endemic subspecies *Microtus oecomomus mehelyi* (Hulejová Sládkovičová et al., 2018). The difference in the structure of the communities between the west and south-west localities could be caused by the expansion of *Apodemus agrarius* that was proven to influence the abundance of the other species at some localities in south-western Slovakia (Tulis et al., 2016).

Even though the abundance of species at the trapping lines is markedly different, significant difference of the lines was confirmed by ANOVA test just at the locality Veľké Kosihy (F=3.77, p=0.0335) but not for the locality Káňa with F=1.79, p=0.1918 nor for the locality Ploština F=2.15, p=0.1409.

At the B lines, *A. sylvaticus* predominates (at Veľké Kosihy and *Microtus arvalis* just slightly). Similar results obtained by Heroldová et al. (2007), except that they observed also *Apodemus microps* in the field habitat, which is really rare at both of the studied regions. At trapping lines situated at wetland biotopes the most abundant species were *Microtus arvalis, Clethrionomys glareolus* and *Sorex araneus*. At forestry biocorridors, *Apodemus sylvaticus* was the most abundant (Bryja, Zukal, 2000).

Abundance and also biodiversity of small mammals at the lines located on a field biotope was lower than on the others, which can be caused by lack of vegetation (mainly causing lack of a shelter as crops provide plant food sources) or partly by using herbicides. Sullivan et al. (1998) found out that using herbicides negatively affects the abundance of small terrestrial mammals; on the other hand, Fisher et al. (2011) claim that organic farming is important mostly at conventional fields and at a type of landscape where our research was done, the diversity of the landscape increases biodiversity and abundance of small terrestrial mammals.

Diversity and evenness of the biotopes

The diversity of small terrestrial mammals shows variety and richness of the biotope, while the equitability (evenness) shows how sustainable the biotope is not only for them but also for species that condition their occurrence (plant and invertebrate food sources). We use both these indices to characterize the quality of biotopes and thus we present Shannon index (H) and Pielou´s evenness index (E) values calculated for each trapping line at the localities from data gathered during the whole experiment (Fig. 3).

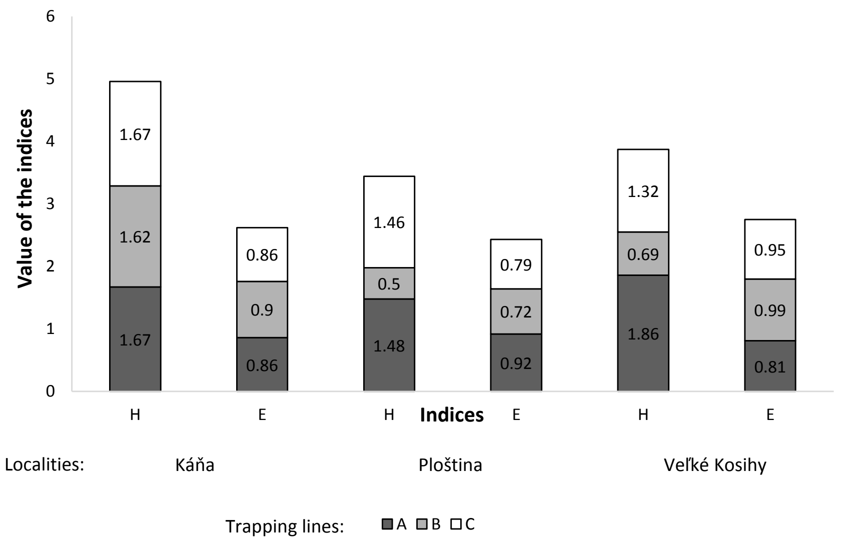

Fig. 3. Indices of diversity (H) and evenness (E) at the trapping lines in total (for all seasons).

Shannon index of diversity is the lowest at the B-lines (the traps laid on a field) at each locality showing that this biotope is suitable only to a less number of species than does the environment with more diverse vegetation. This differs from the results of Bryja and Zukal (2000) who reported lower diversity at forestry biocorridors. Also, the highest biodiversity index they noticed was in a forest habitat but slightly lower (1.8) than at Veľké Kosihy trapping line A (1.86) in ecotone wetland/field. Evenness shows how balanced the trapping lines are. Those numbers vary less at the lines, which is the result of capturing more individuals at lines with higher diversity and their even distribution at those lines.

Indices of diversity and evenness fluctuate a lot during the seasons. The highest diversity was mainly recorded in fall – after summer litters (KA-1.47, KB-1.54, KC-1.67, PA-1.42, VKC-1.31) and summer – after spring litters (PB-1.01, VKB-0.69). On the other hand, the lowest diversity was marked in winter (KA, KB, PB, VKB-0, PA-0.79) and spring (KB, PB, VKB, VKC-0) when conditions (food, temperature or gradation of individuals) are not befitting to such an extent as during rest of the year. Evenness was the lowest at Veľké Kosihy locality in summer 2016 (VKA-0.44, VKC-0.59), excluding spring 2016, because just one species was captured or no individuals were noticed at all. In general, evenness was high in autumn 2015 and summer 2016.

Similarity of the trapping lines

Based on abundance of the species at the lines, the most similar are trapping lines B that were in the field environment. At all of these lines, abundance and diversity were shown to be low. Even though microclimate at the Veľké Kosihy locality is different (slightly warmer because of the position in the south of Slovakia) and the localities are quite distant, the trapping lines at the localities were not compound to one cluster. However, the results are in agreement with the nature of the environment at the lines. Vegetation is one of the most important factors for the presence of small terrestrial mammals. It does not only serve as a food source for herbivore species but also acts as a living space and a shelter for all of the present species. Vegetation at trapping line Káňa A was reduced rapidly during our research, which makes it closer to the B-line type of habitat. The furthest is Ploština C with distinct community characteristic. The remainder of the trapping lines were located at more or less dense reed vegetation and their position in the dendrogram (Fig. 4) corroborates with the uniformity of the trapping lines.

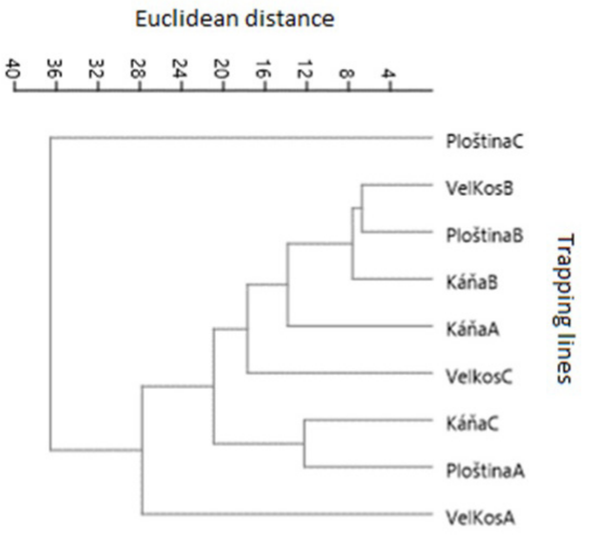

Fig. 4. Cluster analysis of the trapping lines at the surveyed localities.

Persistence of the species during seasons (%)

Persistence of the species (based on presence/absence of a species during a trapping action) is in general the lowest at the lines B at all the localities for every species (Table 1). The only exception is *A. sylvaticus*, which is the most likely caused by significant mobility of the species and ability to move quickly and for longer distances. That is why it might be able to survive also in the long term at field biotopes even when it is not covered by crops. Other species reside at these biotopes just occasionally as the figures of persistence confirm. Even though the B lines present the most of null values (prompted bold), there is no significant difference proved by ANOVA test (localities: Veľké Kosihy - F=1.79, p=0.185, Káňa – F=1.03, p=0.3756, Ploština – F=2.1, p=0.148) between the localities.

T a b l e 1. Persistence of the species during the research at particular trapping lines

	VK A	**VK B**	**VK C**	**K A**	**K B**	**K C**	**P A**	**P B**	**P C**
Crle	0	0	0	25	**0**	0	0	**0**	0
Soar	75	**0**	75	50	25	100	100	**0**	100
Somi	25	**0**	0	25	25	50	0	**0**	25
Clgl	25	**0**	0	25	50	100	100	**0**	100
Miar	75	75	0	50	50	25	25	**0**	100
Mioe	0	**0**	50	0	0	0	0	0	0
Apag	25	**0**	75	0	0	0	0	0	0
Apfl	50	**0**	0	50	50	75	75	25	0
Apmi	25	**0**	0	0	0	0	0	0	0
Apsy	50	50	0	100	75	75	100	100	75
Mimi	25	**0**	50	0	**0**	25	0	**0**	50

Habitat preference of the species

Sorex araneus and *Clethrionomys glareolus* are, according to the position in the diagram (Fig. 5), considered as generalist species. In accordance with a recent research (Lešo, Kropil, 2017) *Sorex araneus* should not be considered as a forest species as it was present before and its habitat preference recorded during this research affirm the statement. More movable species such as *Apodemus flavicollis* and *A. sylvaticus* prefer an environment with bare soil and less vegetation, concurs with the result of Baláž et al. (2016), which explains their occurrence at the B lines. On the other hand, Klimant et al. (2015) categorized these species as exoanthropic (lesser affinity to humans). That could mean that even the field biotopes changed by human activity are more suitable for those species more than suburban and urban landscape. Other species are more attached to wetland type of biotope with the growth of *Phragmites* sp. and *Carex* sp., fallen vegetation and occurrence of *Cirsium* sp.

Like Heroldová et al. (2007), our research confirms that at non-crop habitats, communities are more diverse and species more abundant. Bryja and Zukal (2000) observed moving of small mammals from fields to newly planted biocorridors during part of the season, as a con-

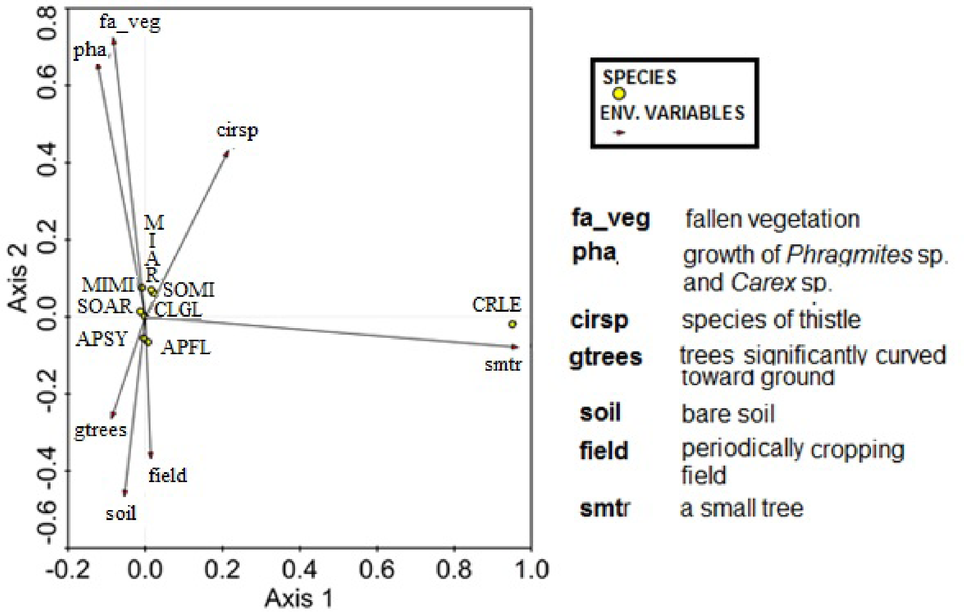

Fig. 5. Habitat preference diagram of the listed species.

sequence of the food scarcity or the threat from agricultural actions. Dennis and Fry (1992) found out that field margins do not serve as the only wintering refugia for arthropods. However, we did not notice this tendency probably because the wetland patches are old and have been serving as refugia for a long time and they serve as stable habitat throughout the year.

Semi-natural habitats like the wetland refugia that we studied are not only important for abundance and diversity of small mammal but also it is proven (even though more research in other segments is needed to be done) that they provide many ecosystem services like soil conservation, support of biological control and much more (Holland et al., 2017).

Conclusion

The higher abundance and biodiversity of small mammals were recorded at the wetland habitats. Most of the observed species show preference for habitats with diverse vegetation, as a source of diverse food and more shelters, and simultaneously do not tend towards field habitats. The presence and numbers of top predators are naturally dependent on the prey abundance and, despite the yet not concluded debate on the low ability of predators to influence numbers of their prey (see review of White, 2013), the small mammals are important part of their food base. That leads us to the conclusion that the presence of small terrestrial mammals in the wetland refugia offers an opportunity as a food source for higher components of food webs, shows sufficiency of plant and invertebrate food resources occurring also in the properly composed agricultural landscape and contributes to higher biodiversity overall. That is why the refugia should be considered as important habitats and a point of interest for future sustainable agriculture and retention of diverse landscape and biodiversity.

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