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BARN OWL (*TYTO ALBA*) DIET COMPOSITION ON INTENSIVELY USED AGRICULTURAL LAND IN THE DANUBE LOWLAND

Tomáš Veselovský[1], Kristián Bacsa[1], Filip Tulis[1]

[1]Department of Ecology and Environmental Sciences, Faculty of Life Sciences, Constantine the Philosopher University in Nitra, Tr. A. Hlinku 1, 94901, Nitra, Slovak Republic

Abstract

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Based on pellets analysis from five localities in south western Slovakia (Malá Mužla, Malé Ripňany, Obid, Opatovský Sokolec and Tešedíkovo), we studied the diet composition of Barn Owl (*Tyto alba*) in intensively cultivated agricultural lands. A total of 6218 specimens of prey, 17 mammalian and 7 bird species were identified. The main prey species found in all food samples was the Common Vole (*Microtus arvalis*), varying between 56 % and 67 %. The proportion of synanthropic species (*Rattus norvegicus, Passer domesticus*) and species inhabiting agricultural landscapes (*Crocidura leucodon, Crocidura suaveolens, Mus* sp.) increases in localities with a lower ratio of the Common Vole. The results suggest land use affects the diet of Barn Owls, confirming conclusions which have been drawn in previous studies. From faunistic point of view, discovering the Pannonian Root Vole (*Microtus oeconomus mehelyi*) in the diet from Malá Mužla was important.

Keywords: Barn Owl, diversity, diet, land use, *Microtus oeconomus*

INTRODUCTION

The Barn Owl (Tyto alba) is a synanthropic species nesting and resting in agricultural structures and the ruins of buildings (Mikkola, 1983). This species hunts either in open farmland or grassland habitats (Taylor, 1994). In the environmental conditions of Central Europe, the major part of the Barn Owl's diet spectrum comes from the Common Vole (Microtus arvalis) (Vondráček and Hošek, 1984; Obuch and Kürthy, 1995; Horváth *et al.*, 2005; Kitowski, 2013), whose populations are characterised by fluctuating abundance (Kratochvíl, 1959; Baláž, 2010). While population outbreaks are commonly cyclical in Western Europe and Fennoscandia (Lambin *et al.*, 2006), populations in other regions of Europe seem to fluctuate irregularly (Jacob and Tkadlec, 2010). These patterns are also reflected in the large fluctuation of the Barn Owl's reproductive success (Klok and Roos, 2007). The diet of the Barn Owl has been well studied throughout its range (Colvin, 1984; Bontzorlos *et al.*, 2005; Milchev *et al.*, 2006; Sommer *et al.*, 2009; Marti, 2010; Paspali *et al.*, 2013; Petrovici *et al.*, 2013). Analysis of its prey offers an important source of information on the composition and dynamics of prey species communities within the Barn Owl's foraging area (Alivizatos and Goutner, 1999; Poprach, 2008). The Barn Owl's diet may be affected by the prey available in a particular geographical region (Bontzorlos *et al.*, 2005; Roulin and Christe, 2013) and densities of prey species (Bernard *et al.*, 2010), but also by land use or agricultural interventions (Cooke *et al.*, 1996; de la Peña *et al.*, 2003; Askew *et al.*, 2007; Teta *et al.*, 2012). Agricultural intensification is associated with a loss of natural habitat, loss of crop diversity and increased chemical inputs (Foley *et al.*, 2005). This kind of management is referred to as the main factor causing the Barn Owl population to decline in some regions (Salvati *et al.*, 2002; Kross *et al.*, 2016). Such a population decline was also recorded in

Slovakia (Danko 1994; Veselovský and Baláž 2015). Since 2008 there has been no recent information about the Barn Owl diet in Slovakia (Latková, 2008). The study aims (i) to analyse the Barn Owl's diet composition in intensively farmed land located in Slovakia's Danube Lowland region and (ii) to compare their diets according to different land use. Based on knowledge from the studies mentioned above, we expected the main part of a Barn Owl's diet would be the Common Vole.

MATERIALS AND METHODS

Study area

Pellets were collected at one time at each of the five localities during the summer of 2014. The pellets were found in the lofts of farm buildings. The various stages of pellet degradation (ranging from compact pellets to detritus) suggest the material was not regurgitated in the same year. The pellets were collected at five locations in south-western Slovakia: Malá Mužla (47.823N, 18.556E), Malé Ripňany (48.473N, 17.992E), Obid (47.782N, 18.640E), Opatovský Sokolec (47.903N, 17.817E) and Tešedíkovo (48.097N, 17.843E) (Fig. 1).

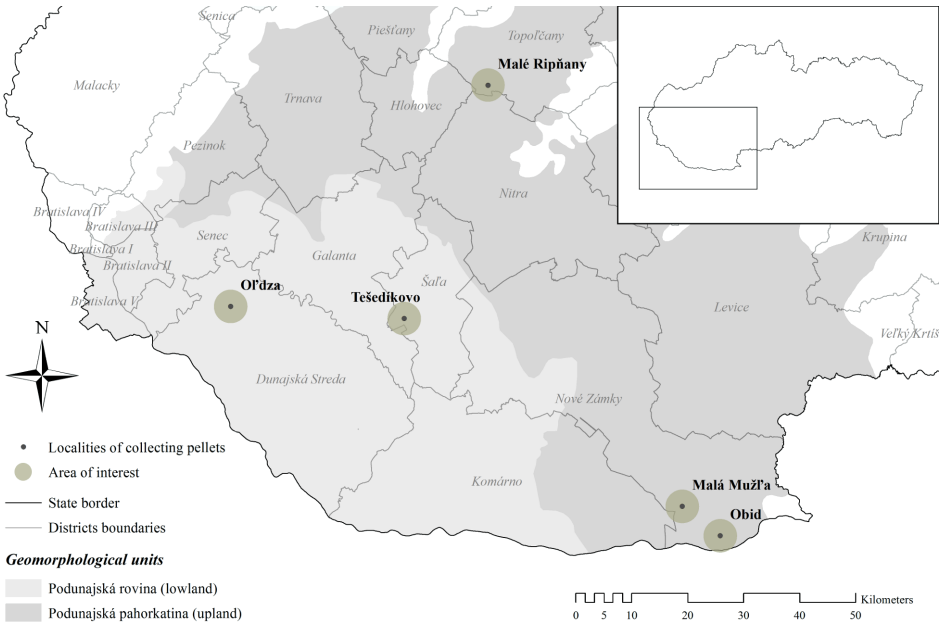
These locations are situated in the northern Pannonian Basin, specifically in the Danubian Lowland geomorphological area and at geomorphological units of the Danubian Plain and the Danubian Upland (Mazúr and Lukniš, 1986). The average annual air temperature in the study area is approximately 10°C (Lapin *et al.*, 2002) and average annual rainfall reaches 550 mm (Faško and Šťastný, 2002).

Pellet analysis

The pellets were placed in a 5 % sodium hydroxide (NaOH) solution to dissolve all undigested parts of the prey except the bones (Schueler, 1972). The lower jaws (mandibula) and skulls (maxilla) of mammals and the beaks (rostrum), feet (tarsometatarsus), shoulders (humerus) and metacarpal (metacarpus) bones of birds were separated from osteological material. No pelvic bone from frogs (os illium) or remains of insects were found. The separated bones were identified according to Baláž *et al.* (2013) and Anděra and Horáček (2005). Bird bones were identified from a collection of references. There was no differentiation of the House Mouse (Mus musculus) and the Steppe Mouse (Mus spicilegus) due to unclear morphological features and so they were further identified in this study as mouse species (Mus sp.)

Landuse analysis

Landscape elements were analysed within a three-kilometre radius buffer whose centre was the point where the pellets were collected. This radius was determined based on Barn Owl radio-tracking (Brandt and Seebass, 1994). Using the work of Petrovič *et al.* (2009), we identified 7 landscape elements, which were divided into four land-class groups according to the way of its utilization, namely: 1) urban land (urban area); 2) intensively farmed land (arable land); 3) extensive land use (permanent grasslands, orchards, vineyards); and 4) non-forest vegetation (windbreaks, wetland vegetation). The underlying vector layers were processed by QGIS Chugiak 2.4 (http://qgis.osgeo.org) from aerial photographs (Eurosense, 2004).



1: *Barn Owl pellet collection locations*

Statistical analysis

The number of individual prey items was estimated as the minimum number identifiable from the same anatomical parts of bones (Klein and Cruz-Uribe, 1984). The PAST software (Hammer *et al.*, 2001) was used to calculate the Shannon-Weaver (1949) index of diet and land diversity (H′). The diversity values were compared using the diversity t-test. Levin's (1968) formula was used to calculate the food niche breadth (FNB). Ordination methods in CANOCO 4.5 (Ter Braak and Šmilauer, 2002) were used to analyse the relationship between land use elements, land use diversity and diet composition. Redundancy analysis (RDA) was employed, using the gradient length in the DCA analysis (Ax1 0.465, Ax2 0.294). Values for the abundance of species were obtained from square-root transformation. Significance was tested using Monte-Carlo random permutation tests.

RESULTS

Diet composition

Altogether, 6218 prey items, composed of 17 mammal and 7 bird species were determined.

In relative numbers, the diet comprised 99 % of mammals and 1 % of birds. The Common Vole was the most dominant prey species, found at all study locations and constituting more than 64 % of the species determined. The next abundant prey species were in summary *Mus* sp. (9.1 %), the Bi-coloured white-toothed Shrew (*Crocidura leucodon*) (5.5 %), the Lesser white-toothed Shrew (*Crocidura suaveolens*) (5.3 %), the Pygmy field Mouse (*Apodemus uralensis*) (3.3 %), the Brown Rat (*Rattus norvegicus*) (2.9 %) and the Common Shrew (*Sorex araneus*) (2.6 %). Other prey species were represented minimally (< 1.5 %).

The frequency of the Common Vole in particular locations varied from 55.9 % to 66.9 %. Its lower abundance in the diet led to the hunting of other

I: *Barn Owl diet composition at five locations in Slovakia's Danube Lowlands*

Species / Localities	Malá Mužla		Malé Ripňany		Obid		Opatovský Sokolec		Tešedíkovo		Total	
	n_i	%	n_i	%	n_i	%	n_i	%	n_i	%	n_i	%
Microtus arvalis	1721	66.9	475	63.8	314	56.0	706	61.7	719	60.1	3935	63.3
Microtus oeconomus	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.01
Microtus subterraneus	29	1.1	18	2.4	5	0.9	2	0.2	11	0.9	65	1.1
Clethrionomys glareolus	3	0.1	1	0.1	4	0.7	2	0.2	2	0.2	12	0.2
Arvicola amphibius	0	0.0	1	0.1	0	0.0	2	0.2	0	0.0	3	0.05
Cricetus cricetus	0	0.0	0	0.0	0	0.0	2	0.2	1	0.1	3	0.05
Rattus norvegicus	7	0.3	46	6.2	1	0.2	100	8.7	28	2.3	182	2.9
Muscardinus avelanarius	2	0.1	0	0.0	0	0.0	0	0.0	0	0.0	2	0.03
Apodemus flavicollis	27	1.0	4	0.5	5	0.9	0	0.0	12	1.0	48	0.8
Apodemus sylvaticus	52	2.0	15	2.0	9	1.6	18	1.6	26	2.2	120	1.9
Apodemus uralensis	74	2.9	24	3.2	19	3.4	50	4.4	35	2.9	202	3.3
***Mus* sp.**	183	7.1	39	5.2	48	8.6	89	7.8	208	17.4	567	9.1
Micromys minutus	19	0.7	16	2.2	18	3.2	14	1.2	10	0.8	77	1.2
Crocidura suaveolens	164	6.4	31	4.2	63	11.2	33	2.9	38	3.2	329	5.3
Crocidura leucodon	198	7.7	18	2.4	32	5.7	53	4.6	42	3.5	343	5.5
Sorex minutus	44	1.7	4	0.5	18	3.2	10	0.9	13	1.1	89	1.4
Sorex araneus	24	0.9	35	4.7	23	4.1	35	3.1	44	3.7	161	2.6
Passer domesticus	19	0.7	8	1.1	2	0.4	24	2.1	8	0.7	61	1
Passer montanus	2	0.1	1	0.1	0	0.0	0	0.0	0	0.0	3	0.05
Phoenicurus ochruros	2	0.1	6	0.8	0	0.0	0	0.0	0	0.0	8	0.1
Sylvia communis	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	1	0.02
Sturnus vulgaris	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	1	0.02
Parus major	1	0.0	0	0.0	0	0.0	2	0.2	0	0.0	3	0.04
Carduelis chloris	0	0.0	0	0.0	0	0.0	2	0.2	0	0.0	2	0.03
Total	2572	100	744	100	561	100	1144	100	1197	100	6218	100
H'	1.34		1.53		1.63		1.51		1.46		1.49	
FNB	2.15		2.37		2.93		2.49		2.52		2.39	

H' = Shannon-Weaver diversity index; FNB = food niche breadth

prey species with an impact on both the Barn Owl's food niche breadth, varying from 2.15 to 2.93, and its diet diversity, ranging from 1.34 to 1.63. The proportion of other abundant prey species also varied between localities (Tab. I). The locality of Malá Mužľa had significantly smaller diet diversity than any of the other study locations (Tab. II). A significant difference in diet diversity was also recorded between Tešedíkovo and Obid.

Landuse analysis

Landuse analysis showed arable land to be the most abundant landscape element in all of the studied locations (>77.6 %). The highest proportion of arable land was around Malé Ripňany (87.7 %), while the lowest was in Obid (77.6 %). The second most represented landscape element was urban areas. Other landscape elements fluctuated within the particular locations studied (Fig. 2). There was low land diversity at all the research locations and no significant differences between them (diversity t-test).

Impact of landuse on diet composition

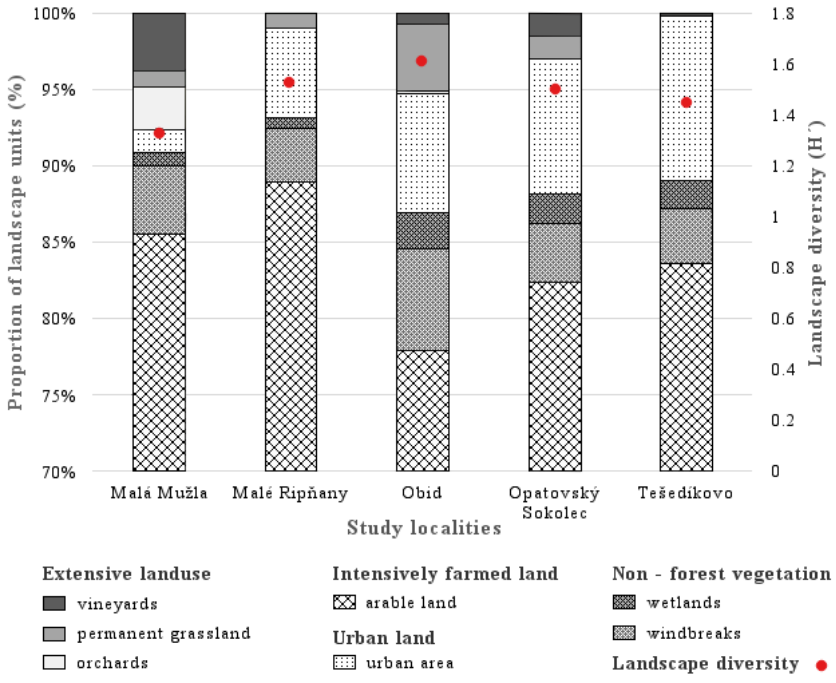
The first RDA analysis axis explains 71.8 % and the second axis explains 17.3 % of data variability in the Barn Owl's diet spectrum. Land-use factors suggest the gradient in the distribution of species along the first axis (Fig. 3).

Extensive land use alone has a significant effect on the proportion of the genus *Crocidura* in the diet ($F = 4.91$, $P = 0.002$). Other environmental factors only suggest the relationship between land use and diet composition. While a higher percentage of urban land use increases the proportion of synanthropic species in the diet, such as the Brown

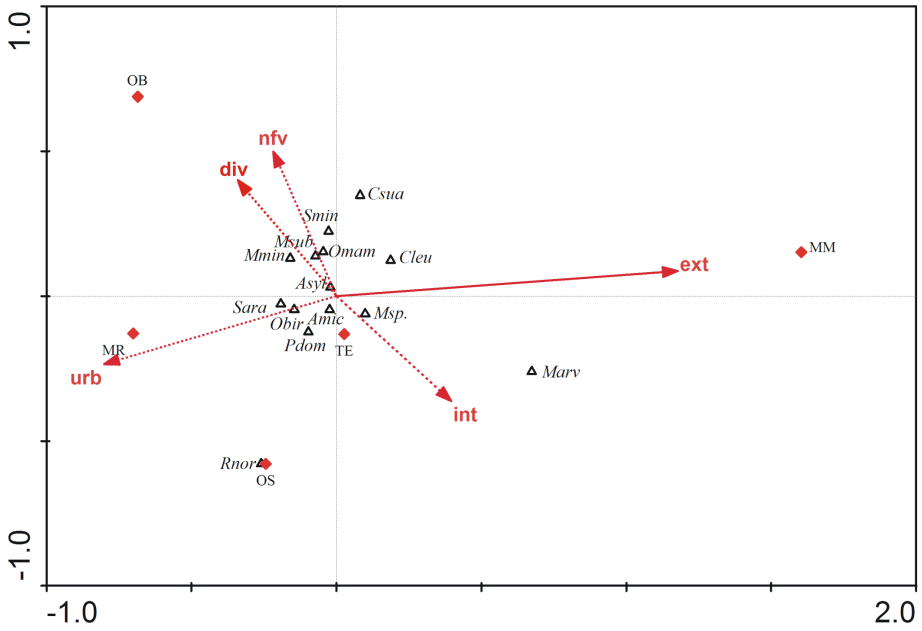
II: *Comparison of the Barn Owl diet diversity (diversity t-test) between localities*

Locality	Malá Mužľa	Malé Ripňany	Obid	Opatovský Sokolec	Tešedíkovo
Malá Mužľa	-	-	-		-
Malé Ripňany	t = –2.89** df = 1166	-	-	-	-
Obid	t = –4.52*** df = 892	t = 1.27 df = 1283	-	-	-
Opatovský Sokolec	t = –3.21** df = 2256	t = –0.27 df = 1504	t = 1.71 df = 1196	-	
Tešedíkovo	t = –2.43* df = 2459	t = –0.92 df = 1457	t = 2.38* df = 1150	t = 0.75 df = 2329	-

*<0,05, **<0.01, ***<0.001



2: *Proportion of landscape elements within a 3 kilometre radius of study locations*



3: *Impact of land use on diet composition of the Barn Owl*
Localities: Malá Mužľa (MM), Malé Ripňany (MR), Obid (OB), Opatovský Sokolec (OS), Tešedíkovo (TE);
Species: *Apodemus microps* (*Amic*), *Apodemus sylvaticus* (*Asylv*), *Crocidura leucodon* (*Cleu*), *Crocidura suaveolens* (*Csua*), *Microtus arvalis* (*Marv*), *Micromys minutus* (*Mmin*), *Mus* sp. (*Msp.*), *Microtus subterraneus* (*Msub*), other birds (*Obir*, incl. *Carduelis chloris*, *Parus major*, *Passer montanus*, *Phoenicurus ochruros*, *Sturnus vulgaris*, *Sylvia communis*), other mammals (Omam, incl. *Apodemus flavicolis*, *Arvicola amphibius*, *Cletrionomys glareolus*, *Cricetus cricetus*, *Microtus oeconomus mehelyi*, *Muscardinus avelanarius*), *Passer domesticus* (*Pdom*), *Rattus norvegicus* (*Rnor*), *Sorex araneus* (*Sara*), *Sorex minutus* (*Smin*);
Environmental variables: landscape diversity (div), extensive land use (ext), intensively farmed land (int), urban land (urb), non – forest vegetation (nft); fill vector line = significant variable, dotted vector line = non significant variable

Rat and House Sparrow (*Passer domesticus*), a higher proportion of intensive land use increases the proportion of agricultural species such as *Mus* sp. and the Common Vole to the total species found in the Barn Owl's diet composition. The growing diversity of landscape elements increases the occurrence of rare species in the diet, the Barn Owl prey species such as the Pygmy Shrew (*Sorex minutus*), the Common pine Vole (*Microtus subterraneus*) and a group of other mammals that includes the Panonnian root Vole (*Microtus oeconomus mehelyi*), the Common Dormouse (*Muscardinus avellanarius*) and the Water Vole (*Arvicola amphibius*).

DISCUSSION

The Barn Owl as opportunistic predator hunts prey according to their availability (Mikkola, 1983) and its diet diversity directly reflects the community structure of prey species (Ba *et al.*, 2000). Our results show significant differences in the diet diversity between the locations studied. Love *et al.* (2000) have considered land use as a factor with an impact on the Barn Owl's diet diversity. Extensive land use has a significant impact on the proportion of the Bi-coloured white-toothed Shrew and the Lesser white-toothed Shrew in the Barn Owl's diet, something fully in accordance with their habitat preferences of orchards and vineyards (Baláž and Ambros, 2007). On the other hand, De la Peña *et al.* (2003) identified the genus Crocidura as the prey Barn Owls were hunting in diversified agricultural land. This disparity may be associated with the different methodology for land use analysis in the two studies. All of our study localities are characterised by uniform landuse structure where the dominant landscape element is arable land. Marti (1988) observed that the uniform land leads to an increased proportion of Common Vole in the diet of Barn Owl. As expected, the Common Vole was the most hunted prey species (more than 55 %), what is in agreement with the feeding ecology of the Barn Owl in conditions found in Central Europe (Vondráček and Hošek, 1984; Obuch and Kürthy, 1995; Horváth *et al.*, 2005; Latková, 2008; Kitowski, 2013). Agricultural intensification itself reduces the density of rare species, although it carries advantages for habitat-generalist prey species like Common Vole (de la Peña *et al.*, 2003). Since the pellets appear not to have been regurgitated in the same year, the differences in diet diversities between the locations may be affected

by fluctuations in the Common Vole's population (Jacob and Tkadlec, 2010).

As an opportunistic predator (Bernard *et al.*, 2010), the Barn Owl hunts different species, with the ability to switch to other prey species depending on their abundance (Murdoch, 1969; Andersson and Erlinge, 1977). The lower proportion of the Common Vole in the diet was partially substituted by alternative prey species like Mus sp., Bi-coloured white-toothed Shrew, Lesser white-toothed Shrew, Brown Rat and the genus Apodemus. Bernard *et al.* (2010) recorded an increased consumption of genus Sorex during the period when the Common Vole's population was declining. There are many other factors that can influence selective and opportunistic hunting behaviour of Barn Owls, such as prey size, time of the year and the antipredator strategies of the potential prey (Marti *et al.*, 2005). The primordial factor determining individual diet is evidently the list of available prey in the neighbourhood of the owl. In fact, these prey animals must not only be present, but still available, accessible (Mikkola, 1982). Our results from the RDA analysis also suggest that different land use has an effect on the diet composition of the Barn Owl. Increasing proportion of urban areas leads to higher proportion of Brow Rat and birds in diet what is consistent with Salvati *et al.* (2002) and Teta *et al.* (2012). But in cases with a higher proportion of intensive land use, we recorded an increase in the proportion of the Common Vole, or Mus sp., most likely of Steppe Mouse (Mus spicilegus), a common species found in the agricultural land within the study area (Baláž *et al.*, 2013). The growing abundance of forests increases the quantity of edgezones, resulting in a higher proportion of Apodemus sp. or the Bank Vole (Clethrionomys glareolus) in the Barn Owl diet (Horváth *et al.*, 2005). In all of the studied locations, the forest habitat was represented minimally and so was not included in the analysis. However, Obuch (2004) states that the average representation of the genus Apodemus in the Danubian Lowlands is 10.6 %, slightly above the average in comparison to our findings. Besides the factors discussed above, there are many others which also have an impact on the diet spectrum, such as vegetation cover (Marti, 1988), the proportion of different agriculture crops (Cook *et al.*, 1996) and agro-technical interventions, for example the frequency of mowing (Askew *et al.*, 2007). Interesting faunistic information is the discovering of the Pannonian Root Vole in the diet of Barn Owls hunting around Malá Mužla. The nearest confirmed occurrence is in the wetlands of the Parížske Močiare Nature Reserve near the village of Gbelce, 4 kilometres away (Ambos *et al.*, 1999), encroaching onto the Barn Owl's potential hunting range (Taylor, 1994). The absence of the Striped field Mouse (Apodemus agrarius) in the diet of Barn Owls at Obid and Malá Mužla is also remarkable, although the mammal's presence in the area was first discovered in 2010 as its range expanded into southwest Slovakia (Ambros *et al.*, 2010; Tulis *et al.*, 2016). This suggests the pellets to be possibly several years old and to have been regurgitated before the species expanded or right at the start of its expansion.

CONCLUSION

The total of 6218 items (17 mammalian and 7 bird species) were determined from an examination of pellets collected at five locations in the Danubian Lowlands. The main prey in intensively farmed land was the Common Vole (55.9–66.9 %). Other species most hunted by the Barn Owl include the House Mouse and Steppe Mouse, combined in this study as *Mus* sp., the Lesser white-toothed Shrew and the Bi-coloured white toothed Shrew. Currently, the proportion of the genus *Crocidura* found in the diet has been significantly affected by extensive land use. With increasing urban landuse, the proportion of synanthropic species such as the Brown Rat and birds, especially the House Sparrow has been increased. Opportunistic behaviour of the Barn Owl in diversified land was reflected in the higher proportion of rare prey species found in its diet, which are otherwise less numerous than in intensively farmed land.

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Contact information

Tomáš Veselovský: veselovsky.tom@gmail.com
Kristián Bacsa: bacsa.kristian@gmail.com
Filip Tulis: ftulis@ukf.sk