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The prey composition of the Barn Owl *(Tyto alba)* with respect to landscape structure of its hunting area (Zala County, Hungary)[x]

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Abstract The prey composition of the Barn Owl *(Tyto alba)* can be monitored indirectly by pellet analysis and we used this method to investigate less known small mammal species of Zala County. The number and abundance of small mammal species depend on the structure of the landscape of Barn Owls' hunting area, therefore we analysed landscape features in the surrounding circles with 2 km radius around the sampling sites. In 2016 we collected 1106 pellets from 13 sampling localities. From the pellets we identified 21 species of 3022 individuals of small mammals (more than 98% of prey). Among the 21 species there was the rare Parti-colured Bat *(Vespertilio murinus)* and a new species for the county the Steppe Mouse *(Mus spicilegus)*. Positive correlation was found between the diversity of the small mammal fauna of each sampling site and the landscape complexity (number of the landscape patches) of the Barn Owl hunting area. Relative abundance of the Wood Mouse *(Apodemus sylvaticus)* showed positive correlation with the number of landscape patches, while the abundance of the Lesser White-toothed Shrew *(Crocidura suaveolens)*, the Miller's Water Shrew *(Neomys anomalus)*, the Striped Field Mouse *(Apodemus agrarius)* and the Harvest Mouse *(Micromys minutus)* was higher in hunting areas with more homogenous landscapes. Significant correlations were found between the relative abundance of some small mammal species and the landscape structure of the potential hunting area of owls that confirmed the consistency in habitat preference of some species. Our results proved that the prey-composition of Barn Owls reflects the land use through the distribution and abundance of small mammal species, therefore this method is suitable for ecological analyses of landscape.

Keywords: diversity, habitat preference, landscape mosaic, pellets analysis, small mammals

Összefoglalás A gyöngybagoly *(Tyto alba)* köpetek elemzésével kimutatható a vadászterületükön előforduló kisemlősök faj- és egyedszáma. Ezt az indirekt módszert alkalmaztuk a kevésbé kutatott Zala megyei kisemlősfauna felmérésére. A kisemlősök fajszáma és gyakorisága függ a gyöngybaglyok vadászterületeinek tájszerkezetétől és mintázatától, ezért a köpetgyűjtés helyétől kb. 2 km sugarú körben elemeztük a táj jellemzőit. 2016-ban 13 településről 1106 köpetet gyűjtöttünk. Az előkerült 3022 zsákmányállat maradványainak több mint 98%-a kisemlős volt. A 21 azonosított faj között volt a ritka fehértorkú denevér *(Vespertilio murinus)*, valamint egy, a megyére nézve új faj, a güzüegér *(Mus spicilegus)*. Az egyes mintavételi helyek kisemlős faunájának diverzitása és a gyöngybaglyok vadászterületeinek mozaikossága (eltérő tájszerkezetű területfoltok száma) között pozitív korrelációt mutattunk ki. A közönséges erdeiegér *(Apodemus sylvaticus)* relatív gyakorisága pozitív kapcsolatban állt a táj mozaikosságával, míg a keleti cickány *(Crocidura suaveolens)*, a Miller-vízicickány *(Neomys anomalus)*, a pirók erdeiegér *(Apodemus agrarius)* és a törpeegér *(Micromys minutus)* relatív abundanciája nagyobb volt a homogén jellegű vadászterületeken. Egyes kisemlős fajok relatív gyakorisága és a baglyok potenciális vadászterületének tájszerkezete között szignifikáns összefüggéseket állapítottunk meg, amelyek többsége összhangban volt egyes fajok élőhely preferenciájával. Eredményeink rámutatnak arra, hogy a gyöngybaglyok zsákmányösszetétele az egyes kisemlős fajok egyedszámának megoszlásán keresztül tükrözi a tájhasználatot és így ez a módszer tájökológiai elemzésekre is alkalmas.

Kulcsszavak: diverzitás, élőhely preferencia, mozaikosság, köpet elemzés, kisemlősök

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Introduction

Barn Owls mainly feed on small mammals and the indigestible parts of the consumed animals are regurgitated in breeding and roost sites in the form of elongated round shape pellets (Mikkola 1983, März 2011). Pellet analysis (identification of species and their abundance on the basis of bone remains) can be used in survey of the small mammal fauna of the Barn Owls' hunting area (Taylor 1994, Seamon & Adler 1996). Pellets can be used as the most reliable methods of assessing small mammal populations and their change over time, however some prey proportion in pellets fluctuate and indicate non-selective feeding, or opportunism as adaptation to changing local circumstances in their foraging (Meek *et al.* 2012). Upon long-term studies of their diet content spatial and temporal changes of the small mammal composition in their hunting area can be detected (Bunn *et al.* 1982, Tores *et al.* 2005). This method is also suitable for detecting the effect of land use changes on small mammal communities (Cooke *et al.* 1996, de la Peña *et al.* 2003, Rodríguez & Peris 2007).

Small mammal community composition estimated upon pellets was better represented compared to estimates from the standard direct sampling methods, e.g. trapping (Heisler *et al.* 2016). Advantage of the pellet analysis in contrast to the trapping is that the rare small mammal species are more often detected by using this indirect method (Torre *et al.* 2004, 2015). Owls are an effective alternative for landscape-level assessments of small mammal communities (Heisler *et al.* 2016).

Pellet studies have a long tradition in Hungary, but this method has been used primarily in fauna surveys (e.g. Schmidt 1967a, Kalivoda 1999, Bihari *et al.* 2007). The collection of pellets was performed irregularly with the exception of some counties, so these results are difficult to use for ecological landscape analysis. In Zala County, during the last century there were only sporadic collections of pellets (Greschik 1911, Éhik 1953, Schmidt 1974, 1976, Lázár 1983, Ács 1986, Nagy 1994, Fehér 1996, Fehér *et al.* 2005, Bihari *et al.* 2007, Szép & Purger 2013), therefore little is known about the diet composition of the Barn Owls and the presence and abundance of small mammal species. In this county mosaic agricultural landscape predominated and nearly one-third of the area is covered by forests (Király *et al.* 2008, Dövényi *et al.* 2010). Our previous studies conducted in the north-eastern part of the county which showed that the small mammal communities were affected also by changes in land use (Szép & Purger 2013).

The goal of the present study was to collect Barn Owl pellets from different locations of Zala County, and on the basis of the prey remnants, to study the presence and abundance of small mammal species; to investigate the effect of landscape structure and mosaic of the Barn Owls' hunting areas on their prey composition.

Materials and methods

The collection of pellets in Zala County was carried out in 2016 by the members of the Barn Owl Foundation (BOF). More than 90 buildings, mostly churches were inspected and out of 13 locations 15 samples of pellets were collected. These pellets were obtained from the area of 9 UTM squares (XM16, XM25, XM26, XM37, XM46, XM47, XM58, XM65, XM66) *(Figure 1, Table 1a,b)*.

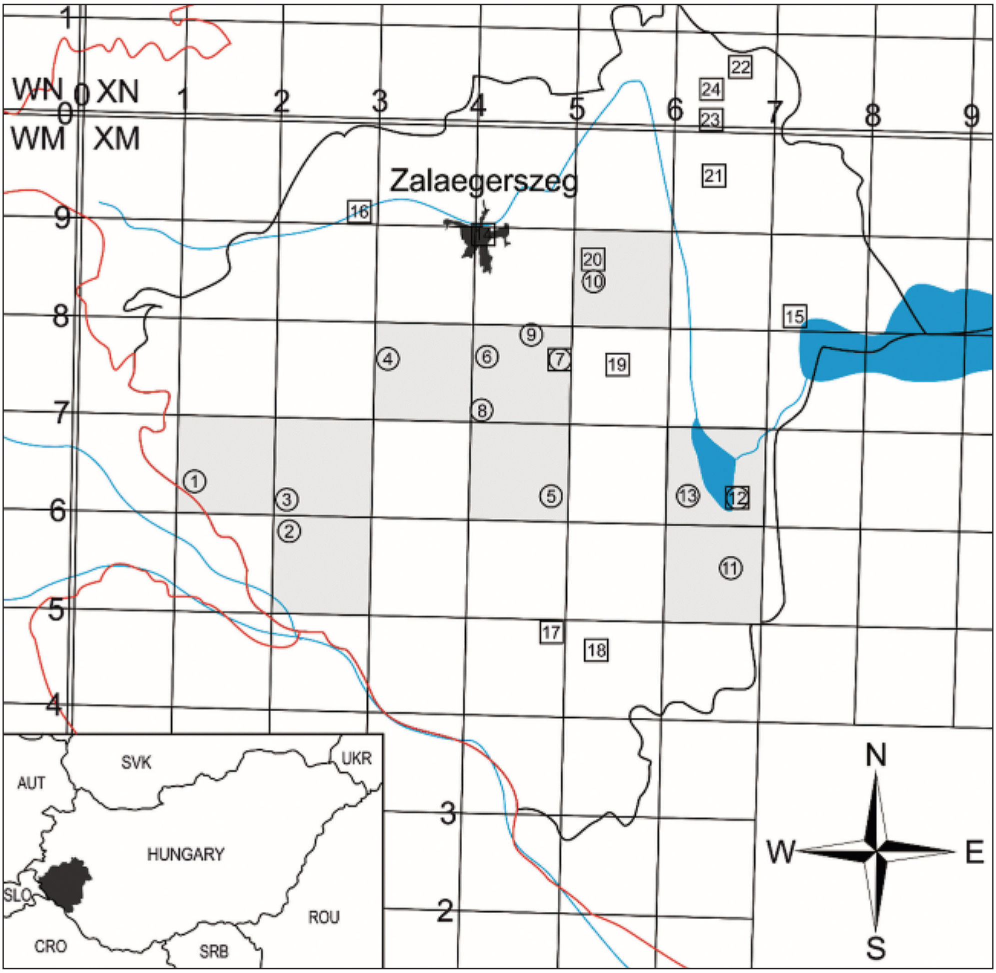

Figure 1. Sampling locations of own data in circle and data from earlier studies in square in the UTM map of Zala County (1 – Rédics, 2 – Szécsisziget, 3 – Iklódbördőce, 4 – Barlahida, 5 – Pölöskefő, 6 – Bak, 7 – Pölöske (Ács 1984), 8 – Söjtör, 9 – Zalaszentmihály, 10 – Misefa, 11 – Zalakomár, 12 – Balatonmagyaród (Nagy 1994, Fehér *et al.* 2005), 13 – Garabonc, 14 – Zalaegerszeg (Greschik 1911), 15 – Keszthely (Éhik 1953, Fehér 1996), 16 – Zalaszentgyörgy, 17 – Homokkomárom, 18 – Nagykanizsa, 19 – Pacsa, 20 – Nagykapornak, 21 – Vindornyaszőlős (Schmidt 1976), 22 – Mihályfa, (Lázár 1983), 23 – Kisgörbő és 24 – Óhíd (Szép & Purger 2013)

1. ábra A saját mintavételi helyek körökben, az irodalomban közölt mintavételi helyek négyzetekben Zala megye UTM térképén ábrázolva

In most samples the exact age of the pellets could not be estimated, they are considered to be formed during 2016, therefore the dates indicate the time of collection *(Table 1a,b)*. The pellets were disassembled under a fume hood using a dry technique and the single pellets were broken down by hand, using tweezers and toothbrushes (Schmidt 1967b). The number of small mammals was based on the number of skulls and their corresponding jaws. Small mammals were identified on the basis of skeletal parameters of skulls, jaws and teeth (Schmidt 1967b, Ujhelyi 1989, Kryštufek & Janžekovič 1999, März 2011). The identification of the species belonging to the *Sylvaemus* subgenus was done by following the method of Tvrtković (1979). The two species of the *Neomys* genus, the Water Shrew *(Neomys fodiens)* and the Miller's Water Shrew *(N. anomalus)* were identified by using description of Tvrtković et al. (1980). For the determination of the Eastern House Mouse *(Mus musculus)* and the Steppe Mouse *(M. spicilegus*) we used the identification key by Macholán (1996). Problematic or damaged skeletal items belonging to the *Apodemus, Mus* and *Rattus* genera were listed as *Apodemus* sp., *Mus* sp. and *Rattus* sp. *(Table 1a,b)*. The order of mammal species and the scientific names was used as described by Bihari *et al.* (2007).

The diversity of small mammals in each sampling site was characterised by the Shannon – Weaver (H) index (Shannon & Weaver 1949, Hammer *et al.* 2001). For landscape structure and mosaic analysis we used the map of the national scale CORINE Land Cover Project of 2012, 1:50 000 (Feranec *et al.* 1995). On this map circles with 2 km radius around the sampling sites were marked that represent the hunting areas of Barn Owls (Lovari *et al.* 1976, Martinez & Zuberogoitia 2004, Torre *et al.* 2015). In these circles we examined the distribution of CORINE Land Cover classes (e.g. broad-leaved forest, peatbogs, vineyards, etc.) as types of landscape structure using ArcGIS 10.0 program. The landscape mosaic was calculated as the number of patches within the circles. The relationship between landscape mosaic and diversity of small mammals was analysed by Spearmen's rank correlation (Hammer *et al.* 2001). Subsequently, by the same method, we investigated the correlation between the ratio of each landscape structure, mosaic and the relative abundance of small mammal species, and only the positive correlations were taken into consideration (Hammer *et al.* 2001).

Results and discussion

In 1106 Barn Owl pellets collected in Zala County 3022 prey items were found *(Table 1a,b)*. In the diet of Barn Owls in the studied area small mammals were dominant (98.3%) while birds, amphibians and insects accounted only 1.7% *(Table 1a,b).* The dominance of small mammals can be explained by the fact that Barn Owl usually for hunting selects vole-rich habitats (Askew *et al.* 2007) and also by the tendency of decrease in abundancy of the other potential prey, e.g. invertebrates (Roulin 2016a).

Faunistic analysis of small mammals

The remains of 2972 prey individuals found in the pellets belong to 21 small mammal taxa *(Table 1a,b).* Altogether 35.33% of the mammalian prey of the Barn Owl belonged to the

Soricomorpha order. This is an average for the one year and for the large part of the Zala County and it is comparable with the values found in other regions, e.g. with the neighbours Somogy County where the proportion of Soricomorpha varied between 42 and 47% (Purger 2014, 2016). These proportions may refer not only to the character of the small mammal fauna, but also to the large-scale structure of the landscape (Szűcs *et al.* 2014). Proportion of insectivorous small mammals (shrews and moles) can also change in time, and its decline has been shown by the analysis of 815 papers about the diet of the European Barn Owl. According to Roulin (2016b) the consumption of shrews and moles declined between 1860 and 2014. This suggests that the impoverished invertebrate communities due to global changes affected a large range of animals up to top predators (Roulin 2016b).

Common Shrew *(Sorex araneus)* was detected in each sample and proved to be the most common species in Pölöskefő *(Table 1a,b)*, confirming the finding of Schmidt (1973) that this species has a dominant role in the diet of Barn Owls in the western part of Hungary. The Bi-coloured White-toothed Shrew *(Crocidura leucodon)*, the Lesser White-toothed Shrew *(C. suaveolens)* and the Pygmy Shrew *(S. minutus)* did not appear from the small samples *(Table 1a,b).* The four species mentioned above have already been shown in several settlements, in Pacsa (Schmidt 1976), Mihályfa (Lázár 1983), Pölöske (Ács 1984), Balatonmagyaród (Nagy 1994), Kisgörbő and Óhíd (Szép & Purger 2013). Only the Common Shrew, the Bi-coloured White-toothed Shrew and the Lesser White-toothed Shrew were found in Nagykapornak, and in Nagykanizsa only the Lesser White-toothed Shrew was detectable (Schmidt 1976). The remains of the Miller's Water Shrew were found in the area of six UTM squares, while the Water Shrew was identified in only four squares *(Table 1a,b).* The Water Shrew was found only in Pacsa (Schmidt 1976) and Balatonmagyaród (Nagy 1994), the Miller's Water Shrew was registered in Kisgörbő (Szép & Purger 2013), while both species were found already in Mihályfa (Lázár 1983), Pölöske (Ács 1984) and Óhíd (Szép & Purger 2013). The remains of Common Mole *(Talpa europaea)* were found only in Söjtör *(Table 1a,b)*, but previously was proved in Zalaegerszeg (Greschik 1911), in Pacsa (Schmidt 1976) and in Mihályfa (Lázár 1983). It is a common species (Bihari 2007a), but rarely preyed because of their underground lifestyle.

From the pellets collected at Szécsisziget a remain of the Parti-coloured Bat *(Vespertilio murinus)* belonging to bats (Chiroptera) was found *(Table 1a).* This species is considered rare in Hungary (Estók *et al.* 2007), so far in Zala County it has been known from Balatonmagyaród (XM66), and was found in Barn Owl pellets in 1995 (Fehér *et al.* 2005). The Barn Owls rarely prey bats, but in the pellets that were found in the county contained the remains of Noctule *(Nyctalus noctula)* in Keszthely (Fehér 1996) and Grey Long-eared Bat *(Plecotus austriacus)* in Pacsa (Schmidt & Topál 1971) and Óhíd (Szép & Purger 2013). Barn Owls in Europe usually capture bats opportunistically, therefore the share of bats their diet (0.12%) is low (Roulen & Christe 2013).

In Zala County the largest proportion (64.64%) of the Barn Owl's mammalian prey was identified as rodents (Rodentia), while in Somogy County the proportion of rodents were lower (53-57%) (Purger 2014, 2016) and this difference can be explained by discrepancy in sampling methods, and by variance in land use. The presence of the Common Dormouse *(Muscardinus avellanarius)* was detected from the four largest samples (Söjtör,

Table 1a. Number of prey items in pellets of Barn Owls in sample sites (1–7)
1a. táblázat A köpet-lelőhelyekről (1–7) előkerült zsákmányállatok egyedszáma

Site number	1.	2.	3a.	3b.	4.	5.	6.	7.
Place (locality), date (collection)	Rédics (cath. church) 18.06.2016. (BOF)	Szécsisziget (cath. church) 18.06.2016. (BOF)	Iklódbördőce (belfry) 23.06.2016. (BOF)	Iklódbördőce (belfry) 21.09.2016. (BOF)	Barlahida (ev. church) 21.09.2016. (BOF)	Pölöskefő (farm building) 25.02.2016. (BOF)	Bak (farm building) 19.06.2016. (BOF)	Pölöske (cath. church) 19.06.2016. (BOF)
UTM (10 × 10 km)	XM16	XM25	XM26	XM26	XM37	XM46	XM47	XM47
Crocidura leucodon	9	5	42	9	3	8	0	7
Crocidura suaveolens	13	10	46	11	3	14	0	9
Sorex araneus	63	23	129	7	2	89	1	27
Sorex minutus	6	13	39	2	0	64	0	5
Neomys anomalus	0	1	28	2	0	31	0	23
Neomys fodiens	0	0	18	1	0	1	0	5
Talpa europaea	0	0	0	0	0	0	0	0
Vespertilio murinus	0	1	0	0	0	0	0	0
Muscardinus avellanarius	1	0	1	0	0	2	0	0
Microtus agrestis	8	4	27	5	2	7	0	15
Microtus arvalis	129	84	162	44	76	15	31	71
Microtus subterraneus	12	2	15	2	6	0	1	4
Arvicola amphibius	7	3	1	0	0	0	4	0
Myodes glareolus	4	1	6	1	0	4	1	4
Apodemus agrarius	20	2	9	1	0	3	2	11
Apodemus flavicollis	28	7	2	3	0	0	2	7
Apodemus sylvaticus	37	15	13	7	9	1	11	7
Apodemus sp.	22	14	7	3	2	2	3	4
Micromys minutus	1	1	4	0	0	11	0	7
Mus musculus	10	1	3	2	0	1	1	16
Mus spicilegus	2	0	0	0	0	0	0	0
Rattus norvegicus	0	0	3	0	0	0	0	1
Rattus sp.	1	0	0	0	0	0	0	0
Passer sp.	1	0	3	0	0	0	0	0
Sylvia sp.	0	0	3	0	3	0	0	0
Fringilla sp.	0	0	1	0	0	0	0	0
Hirundo sp.	0	0	0	0	0	0	0	0
Aves indet.	4	1	1	0	0	0	0	4
Anura *(Rana* sp.)	0	0	1	0	0	0	0	0
Insecta	0	0	0	0	0	0	0	1
Prey	**378**	**188**	**564**	**100**	**106**	**253**	**57**	**228**
Pellet	**150**	**76**	**156**	**50**	**60**	**46**	**33**	**85**

Table 1b. Number of prey items in Barn Owl pellets by sample sites (8–13)
1b. táblázat A köpet-lelőhelyekről (8–13) előkerült zsákmányállatok egyedszáma

Site number	8a.	8b.	9.	10.	11.	12.	13.	Σ
Place (locality), date (collection)	Söjtör (cath. church) 18.06.2016. (BOF)	Söjtör (cath. church) 18.06.2016. (BOF)	Zalaszentmihály (ref. church) 23.06.2016. (BOF)	Misefa (belfry) 21.09.2016. (BOF)	Zalakomár (cemetery chapel) 21.09.2016. (BOF)	Balatonmagyaród (com. centre) 25.02.2016. (BOF)	Garabonc (cemetery chapel) 19.06.2016. (BOF)	
UTM (10 × 10 km)	XM47	XM47	XM47	XM58	XM65	XM66	XM66	
Crocidura leucodon	17	1	6	1	0	23	1	132
Crocidura suaveolens	18	13	8	3	2	30	5	185
Sorex araneus	39	5	15	3	6	18	6	433
Sorex minutus	13	0	1	0	0	8	6	157
Neomys anomalus	2	2	14	0	1	6	4	114
Neomys fodiens	0	0	0	0	0	2	1	28
Talpa europaea	1	0	0	0	0	0	0	1
Vespertilio murinus	0	0	0	0	0	0	0	1
Muscardinus avellanarius	2	0	0	0	0	2	0	8
Microtus agrestis	4	2	2	0	0	6	0	82
Microtus arvalis	102	72	54	40	4	98	30	1012
Microtus subterraneus	5	8	0	6	0	3	0	64
Arvicola amphibius	4	2	0	0	1	1	0	23
Myodes glareolus	8	0	1	2	0	1	0	33
Apodemus agrarius	17	17	11	0	2	12	3	110
Apodemus flavicollis	31	14	3	20	0	3	16	136
Apodemus sylvaticus	24	5	6	24	2	6	4	171
Apodemus sp.	33	6	6	16	8	4	5	135
Micromys minutus	7	2	2	1	1	9	0	46
Mus musculus	7	1	6	1	2	3	2	56
Mus spicilegus	0	0	0	0	0	0	0	2
Rattus norvegicus	25	0	4	0	4	0	4	41
Rattus sp.	1	0	0	0	0	0	0	2
Passer sp.	0	0	1	0	0	0	0	5
Sylvia sp.	1	0	0	0	0	0	0	7
Fringilla sp.	0	0	0	0	0	0	0	1
Hirundo sp.	2	0	0	0	0	0	4	6
Aves indet.	3	0	2	0	2	4	4	25
Anura (*Rana* sp.)	0	0	0	0	0	0	0	1
Insecta	1	0	0	0	3	0	0	5
Prey	**367**	**150**	**142**	**117**	**38**	**239**	**95**	**3022**
Pellet	**167**	**60**	**47**	**54**	**23**	**55**	**44**	**1106**

Iklódbördőce, Rédics and Balatonmagyaród) *(Table 1a,b)*, whereas previously was proved only from Óhíd (Szép & Purger 2013). The Common Vole *(Microtus arvalis)* made up 33.48% of mammalian prey *(Table 1a,b)*, it has been shown in previous surveys in Nagykanizsa, Nagykapornak, Pacsa, Vindornyaszőlős, Zalaszentgyörgy (Schmidt 1976), Mihályfa (Lázár 1983), Pölöske (Ács 1984), Balatonmagyaród (Nagy 1994), Kisgörbő and Óhíd (Szép & Purger 2013). The Field Vole *(M. agrestis)*, the Common Pine Vole *(M. subterraneus)* and the Bank Vole *(Myodes glareolus)* were found in the pellets collected in seven UTM squares, the Water Vole *(Arvicola amphibius)* turned up in six squares *(Table 1a,b)*. These species have already been identified in Pacsa (Schmidt 1976), Pölöske (Ács 1984), Kisgörbő and Óhíd (Szép & Purger 2013). Furthermore, the Field Vole, the Common Pine Vole and the Bank Vole were found in Nagykapornak (Schmidt 1976) and Balatonmagyaród (Nagy 1994), as well as the Field Vole, the Common Pine Vole and the Water Vole were also found in Mihályfa (Lázár 1983). The presence of the Bank Vole has been shown in Homokkomárom and Vindornyaszőlős (Schmidt 1976). During our study the presence of the Root Vole *(M. oeconomus)* has not been confirmed, but it was previously found in the surroundings of Kis-Balaton, Keszthely (Éhik 1953) and Balatonmagyaród (Schmidt 1976).

The Striped Field Mouse *(Apodemus agrarius)* was found in most of our samples and in previous studies in Homokkomárom (Schmidt 1976), Pölöske (Ács 1984), Balatonmagyaród (Nagy 1994), Kisgörbő and Óhíd (Szép & Purger 2013). The Yellow-necked Mouse *(A. flavicollis)* were found in the larger samples and the Wood Mouse *(A. sylvaticus)* in all samples *(Table 1a,b)*. In most of the previous studies these two species were not distinguished due to the difficulties in identification of the skeletal parameters (Cserkész & Horváth 2007). Therefore, few data is known from pellets about the distribution of these species: e.g. Kisgörbő and Óhíd (Szép & Purger 2013). The Harvest Mouse *(Micromys minutus)* was presented in most of the samples with a small number of individuals *(Table 1a,b)*. It has already been known from Homokkomárom, Nagykapornak, Nagykanizsa, Pacsa, Zalaszentgyörgy (Schmidt 1976), Mihályfa (Lázár 1983), Pölöske (Ács 1984), Balatonmagyaród (Nagy 1994), Kisgörbő and Óhíd (Szép & Purger 2013). The Eastern House Mouse was found in the pellets in all samples with the exception of Barlahida *(Table 1a,b)* and earlier it was found in Zalaegerszeg (Greschik 1911), Homokkomárom, Nagykapornak, Pacsa, (Schmidt 1976), Mihályfa (Lázár 1983), Pölöske (Ács 1984), Balatonmagyaród (Nagy 1994), Kisgörbő and Óhíd (Szép & Purger 2013). The remains of the Steppe Mouse were detected only from Rédics *(Table 1a,b)*, previously there was no data about the occurrence of this species in Zala County (Bihari 2007b). The remains of the Brown Rat *(Rattus norvegicus)* were found in half of the samples *(Table 1a,b)*, but earlier were found only from the pellets collected in Óhíd (Szép & Purger 2013).

Analysis of the landscape structure and mosaic

A positive correlation ($R = 0.60$, $P = 0.032$) was shown between the diversity of small mammal fauna and the landscape complexity of the hunting area *(Figure 2)*. It is well-known that the diversity of the wildlife is also increasing with the diversity of the environment and its

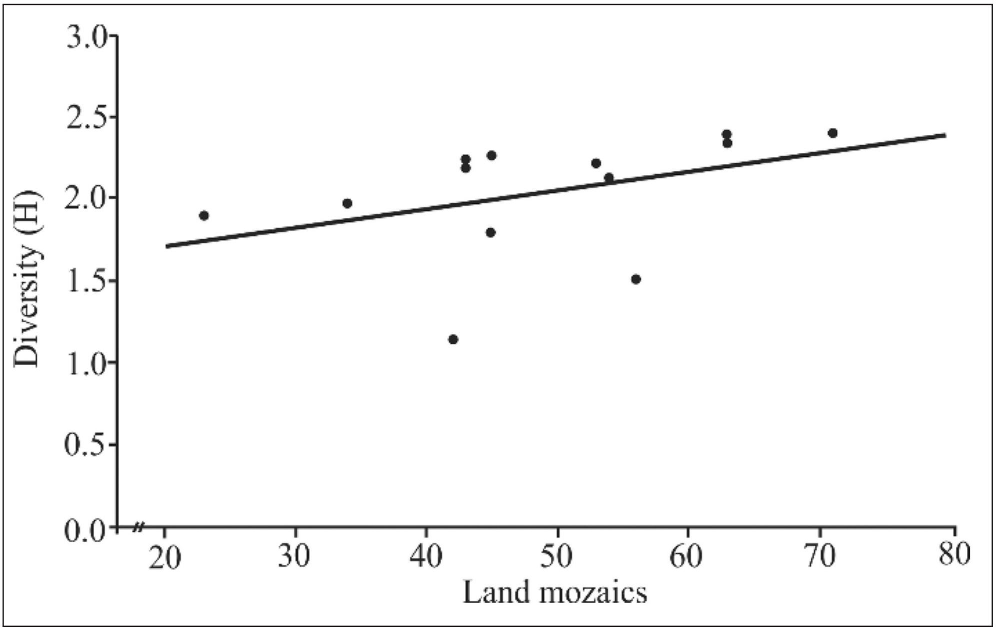

Figure 2. Variation of the diversity of the prey species depending on the landscape complexity of the hunting area

2. ábra A zsákmányolt fajok diverzitásának változása a vadászterület mozaikosságának függvényében

resources (Tews *et al.* 2004). As the number of various habitat patches is growing, the proportion of edges and the diversity of small mammal fauna are also increasing (Butet *et al.* 2006), which may be advantageous for the Barn Owl that prefers linear landscape features during their hunting (Martinez & Zuberogoitia 2004).

The relative abundance of Wood Mouse showed significant positive correlation with the landscape mosaic *(Table 2)*. Negative relationship was found between the relative abundance of Lesser White-toothed Shrew, the Miller's Water Shrew, the Striped Field Mouse and the Harvest Mouse with the landscape mosaic *(Table 2)*.

The relative abundance of small mammal species was also related to certain types of landscape structure of the hunting area. The frequency of Common Shrew positively correlated with the total area of non-irrigated arable land ($R = 0.59$, $P = 0.033$). Previous studies conducted in Hungary suggested that this species prefers the wet habitats with dense vegetation (Horváth 2007a), though in Czech Republic it has also been caught in sugar beet and alfalfa fields as well as in tree lines on the edge of the fields (Heroldová *et al.* 2007). In England the results of

Table 2. Species related to landscape complexity, correlation coefficients *(Rs)* and significance level *(P)*

2. táblázat A táj mozaikosságával kapcsolatban álló fajok korrelációs koefficiensei *(Rs)* és szignifikancia szintjei *(P)*

Species/Faj	*R*	*P*
Crocidura suaveolens	–0.61	0.026
Neomys anomalus	–0.74	0.004
Apodemus agrarius	–0.56	0.044
Micromys minutus	–0.83	0.001
Apodemus sylvaticus	0.75	0.003

trapping also showed a positive correlation between the abundance of this species and the proportion of arable land (Fischer *et al.* 2011).

The relative abundance of Common Dormouse was also correlated with non-irrigated arable land (R = 0.63, P = 0.020). This species prefers forest habitats (Bakó 2007), occurs in tree lines, hedges and small forest patches but also rarely moves in open areas (Büchner 2008).

Based on our results, the relative abundance of Field Vole positively correlated with natural grassland area (R = 0.69, P = 0.009). Literature data also showed that most important habitats of this species are wetland meadows and grazed grasslands (Horváth 2007b).

The relative abundance of Common Vole positively correlated with the proportion of broad-leaved forests in Barn Owls' hunting areas (R = 0.63, P = 0.024). This species prefers the agricultural areas (Gubányi & Horváth 2007) and it mostly avoids forest habitats (Gouveia *et al.* 2016). The positive correlation in our study can be explained by the fact that there was a large number of farmlands around each sampling site, where the Common Vole was probably abundant.

The relationship between the relative abundance of Common Pine Vole with the coniferous (R = 0.80, P = 0.001) and mixed forests (R = 0.59, P = 0.033) was positive. This is partly supported in the literature, as according to Horváth (2007c) this species prefers deciduous forests.

The Stripped Field Mouse showed a positive correlation with the discontinuous urban fabric (R = 0.69, P = 0.010). Its strong dependence on urbanized habitats has already been observed in other areas as it may appear in village buildings, and this species tolerates degraded habitats (Bihari 2007c, Łopucki *et al.* 2013).

The relative abundance of Yellow-necked Mouse positively correlated with the vineyards in the hunting area (R = 0.57, P = 0.043). Individuals of this species often come from woody areas but are far less common on the edge of agricultural land (Cserkész & Horváth 2007). Since Barn Owls rarely hunt in the closed forests, it is likely that they are caught in edges (Taylor 1994).

The relative abundance of the Wood Mouse showed a positive relationship with several landscape types, the land principally occupied by agriculture, with significant areas of natural vegetation (R = 0.70, P = 0.007), the broad-leaved forests (R = 0.60, P = 0.031) and the coniferous forest (R = 0.65, P = 0.016). As a generalist species it can tolerate wide scale of the environmental factors and often occur in forests beside agricultural land as well (Tattersall *et al.* 2001, Schlinkert *et al.* 2016).

The abundance of Eastern House Mouse showed positive correlation with the discontinuous urban areas (R = 0.63, P = 0.021) and the peat bogs area (R = 0.56, P = 0.047). The species are most often found in settlements (Bihari 2007d, Lesiński & Gryz 2011), but according to our knowledge it's occurrence in the peat bogs is not usual.

The Brown Rat also had a positive relationship with the discontinuous urban fabric areas (R = 0.58, P = 0.038), as it is like the Eastern House Mouse synantropic species and linked to human settlements (Horváth 2007d, Lesiński & Gryz 2011).

We found a positive correlation between the landscape mosaics of the hunting area and the diversity of the preyed small mammals. Significant correlations were found between the relative abundance of some small mammal species and the landscape structure of the potential hunting area of owls, most of which were consistent with the habitat preference of some species. Our results show that the analysis of the Barn Owls' diet, by the distribution of the number of common small mammal species is in accordance with the land use and thus also suitable for landscape ecological analysis.

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