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Diet of Barn Owl *Tyto alba* in Central South Bulgaria as influenced by landscape structure

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Abstract: This study of the diet of Barn Owl *Tyto alba* analyzed pellets containing 18,810 prey specimens. Small mammals (98.2% by number, 97.5% by biomass) dominated, while birds, reptiles, amphibians, and insects constituted a negligible portion of the diet (1.8% by number, 2.5% by biomass). Voles (*Microtus* spp.) were the most numerous prey ($35.3 \pm 14.4\%$, range 14.6%–67.1%) in 9 localities (69.2%, $n = 13$ individually studied localities) and dominated the biomass in all diets ($51.4 \pm 14.1\%$, range 27.4%–78.2%). The lesser white-toothed shrew (*Crocidura suaveolens*) ($20.8 \pm 7.6\%$, range 7.3%–32.8%) was the most frequent prey in the other 4 localities (30.8%). The breeding localities with more similar proportions of habitats in their hunting territories had significantly higher diet overlaps ($r = 0.336$, $P < 0.01$). The amount of wetlands and the indices of habitat heterogeneity and topographic relief among the landscape characteristics of the hunting territories significantly influenced diet composition according to redundancy analysis. Larger areas of wetlands correlated with higher predation on wetland mammal species, as well as the European pine vole (*Microtus subterraneus*) and white-toothed shrews, and thus with broader food niche breadth.

Key words: Pellet analysis, feeding ecology, diet characteristics, hunting territory

1. Introduction

The Barn Owl *Tyto alba* preys opportunistically mainly on small mammals such as voles, mice, rats, and shrews over its large range. It usually specializes more on voles in productive humid zones and is more of a generalist with a broader food niche in drier conditions (Glutz von Blotzheim and Bauer, 1994; Taylor, 1994; Bruce, 1999; Mebs and Scherzinger, 2000). Owl diets depend on available prey assemblages, accessibility of preferred profitable prey species, and spatial and temporal differences and fluctuations of prey (Taylor, 1994; Love et al., 2000; Tores et al., 2005; Miltshev and Georgiev, 2009; Bernard et al., 2010; Frey et al., 2011; Paspali et al., 2013; Roulin and Christe, 2013). Barn Owl diets in Bulgaria most probably reflect the food supply in the regions of the country studied over the last decade. Barn Owls feed principally on voles (*Microtus* spp.) and white-toothed shrews (*Crocidura* spp.) in the moderate continental part of the Upper Thracian Plain (Milchev et al., 2006b). Mice (*Mus* spp.) displace voles in prey preference mostly in continental-Mediterranean Southeast Bulgaria (Miltshev et al., 2004). Irregular population peaks of voles in the latter region create immediate but short-term dominance of voles in Barn Owl diets (Miltshev and Georgiev, 2009).

The present study investigates the dependences of diet characteristics on the landscape structure in Barn Owl hunting territories in the Kazanlak Valley, Central South Bulgaria. The study also depicts the current state of Barn Owl food resources in the early phase of agricultural intensification, which is gaining strength since Bulgaria joined the European Union in 2007.

2. Materials and methods

2.1. Data collection

The Kazanlak Valley covers around 800 km² in the moderate continental climate zone between the Stara Planina Mountains to the north and the Sredna Gora Mountains to the south. Open areas with farmland, extensive pastures, and meadows dominate the landscape around villages in the valley (see also Milchev, 2012; Milchev and Gruychev, 2014). Food remains from both intact and disintegrated pellets were collected from around nests and roosting sites in 28 breeding localities in mid-June and early September 2012 and for 2 nests additionally in mid-July 2013, a total of 30 localities. Pellets were possibly deposited over several breeding seasons, but most of them came from 2012 deposits.

Prey mammals were identified according to Popov and Sedefchev (2003) and the author's own comparative

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collection. Because of difficulties in species determination of *Apodemus sylvaticus*–*A. flavicollis* and *Microtus arvalis*–*M. levis*, these species pairs are presented here as *Apodemus* spp. and *Microtus* spp., respectively. Birds were identified by their bone remains, based on comparisons with the osteological collection of the National Museum of Natural History, Sofia. The amphibian and reptilian remains were determined after Stojanov et al. (2011). The minimum number of individuals (MNI) of mammals was estimated mainly on the basis of the remains of crania, cranial fragments, and mandibles, while the MNI of other vertebrates was given based also on the bones of girdles and limbs. Estimates of MNI of insects were based mainly on head capsules and mandibles. Osteological material was deposited in the National Museum of Natural History. The biomass was calculated after Glutz von Blotzheim and Bauer (1994), and Popov and Sedefchev (2003).

Each of the 13 separately analyzed localities contained over 300 prey specimens. They formed 95% of the total number of prey. Samples having smaller numbers of prey animals were not examined separately to avoid bias from samples from a short time period and possibly from just a single bird. The numbering of the individual localities followed their placement in the valley from east to west. The localities with the lower numbers are from the easternmost and lower elevations, while the higher numbers come from the westernmost localities at higher elevations. The main hunting territory of Barn Owls during the breeding season falls within a circle with a 1-km radius from the nest (Taylor, 1994), for which 7 landscape variables were specified on 1:25,000 maps: 1) percentage of open areas (pastures, agricultural, and arable lands) ($60.6 \pm 16.4\%$, range 24.7%–81.5%, $n = 13$); 2) percentage of wetland habitats (open water area and areas covered with aquatic vascular vegetation) ($7.8 \pm 8.1\%$, range 0.9%–31.7%); 3) percentage of woodlands and shrublands ($8.6 \pm 11.8\%$, range 0.3%–39.3%); 4) percentage of urban areas (settlements, detached buildings, and main road networks) ($23 \pm 12.9\%$, range 5.3%–60.7%); 5) index for habitat heterogeneity—number of borderlines between the 4 main groups of habitats described above cut by the 2 diagonals in the cardinal directions N, S, E, and W (13.7 ± 5 , range 7–26); 6) index for variability in topographic relief—number of 25-m contour lines cut by the 2 diagonals in the cardinal directions N, S, E, and W (3.5 ± 2.6 , range 1–11); 7) elevation (m a.s.l.) of the nest site (335.5 ± 71.5 , range 260–480).

Food niche breadth (FNB) was calculated as follows:

$$FNB = \frac{1}{\sum_{i=1}^N p_i^2}$$

where p_i is the proportion of prey category i in the Barn Owl diet (Levins, 1968). Larger values of this index indicate a higher dietary diversity. To obtain results comparable to those of Marti (1988), mammals were classified to genera, while birds, amphibians, and insects were classified to the class level.

The overlaps of the food spectrum and of the habitats in the hunting territories were calculated as follows:

$$O = \frac{\sum p_i q_i}{\sqrt{\sum p_i^2 \sum q_i^2}}$$

where p_i is the proportion of prey type i in one dietary sample or the part of habitat i in one hunting territory, and q_i is the proportion of the same type in the other dietary sample or the part of the same habitat in the other hunting territory (Pianka, 1973). Overlap values are reported as percentages.

2.2. Statistical analysis

The correlations between the proportion of prey types in the diets, as well as with the characteristics of the hunting territory and food niche breadth, were calculated using the Spearman rank correlation coefficient. Statistical differences in the frequencies of the ecological groups of birds according to their preferred breeding habitats, excluding unidentified passerines (Passeriformes indet.), were calculated by chi-square test. Diet and habitat overlaps with arcsine-transformed values were correlated by Pearson correlation coefficient. The significance level was $P < 0.05$ in all statistical tests. The means are arithmetic mean \pm standard deviation.

The importance of the characteristics of the hunting territory on the structure of the diet was analyzed by redundancy analysis (RDA), the canonical form of principal component analysis, with the program CANOCO 4.5 (ter Braak, 1995). This method identifies the most important landscape variables within the hunting territory, which significantly influence the composition and abundance of the prey categories in Barn Owl diets. Significance of the variables was tested by a permutation test. The matrix with quantitative characteristics of the individual diets contains proportions of birds and insects at class level and of bats at order level. Small mammals were categorized at genus level only when their proportions in the diets correlated highly significantly and positively, and the pairs of congener species inhabited similar habitats (*Sorex* $r_s = 0.780$, $P < 0.01$; *Crocidura* $r_s = 0.621$, $P < 0.05$; *Mus* $r_s = 0.830$, $P < 0.01$). The species and landscape variables are represented by arrows and the samples by circles on the ordination diagram. The angles between arrows are an approximation of the correlations between variables (ter Braak, 1995; Lepš and Šmilauer, 2003).

3. Results

3.1. Diet composition

The feeding range was based on an analysis of the remains of 18,810 specimens distributed among 63 identified animal taxa (Table 1). Small mammals were the staple prey, while birds, reptiles, amphibians, and insects formed a negligible percentage, only 1.8% by total number and 2.5% by total biomass. Between 3 and 6 small mammal taxa (4.6 ± 0.8)

formed the main portion (cumulatively 80%) of individual diets, but between 2 and 7 taxa (4.6 ± 1.3) constituted the principal part of the biomass (cumulatively 80%; Table 1).

Voles (*Microtus* spp.) were the most numerous prey ($35.3 \pm 14.4\%$, range 14.6%–67.1%) in 9 localities (69.2%, $n = 13$) and dominated the biomass in all diets ($51.4 \pm 14.1\%$, range 27.4%–78.2%; Figure 1). The lesser white-toothed shrew (*Crocidura suaveolens*) ($20.8 \pm 7.6\%$, range

Table 1. Diet of the Barn Owl *Tyto alba* in the Kazanlak Valley, Central South Bulgaria; *: small mammals form 80% of the total prey by number or by biomass at individual localities ($n = 13$); 1 prey taxa with less than 0.1% by number - number of specimens.

Prey taxa	% occurrence at 28 localities	Number of specimens	% by number	% by biomass
<i>Sorex araneus</i>	21.4	81	0.4	0.2
<i>Sorex minutus</i>	17.9	47	0.2	0.05
<i>Neomys anomalus</i>	78.6	1464	7.8*	4.3*
<i>Crocidura leucodon</i>	82.1	2441	13.0*	7.4*
<i>Crocidura suaveolens</i>	96.4	3651	19.4*	6.1*
<i>Muscardinus avellanarius</i>	28.6	30	0.2	0.2
<i>Micromys minutus</i>	60.7	232	1.2	0.4
<i>Apodemus flavicollis/sylvaticus</i>	78.6	1361	7.2*	10.6*
<i>Apodemus agrarius</i>	67.9	356	1.9	2.4
<i>Rattus rattus</i>	32.1	43	0.2	1.0*
<i>Mus musculus</i>	71.4	870	4.6*	4.4*
<i>Mus macedonicus</i>	64.3	512	2.7*	2.6*
<i>Mus macedonicus/musculus</i>	39.3	497	2.6	2.5
<i>Microtus arvalis/levis</i>	100	6660	35.4*	52.9*
<i>Microtus subterraneus</i>	46.4	125	0.7	1.0
<i>Arvicola amphibius</i>	39.3	51	0.3	1.0
Mammalia subtotal	100	18,472	98.2	97.5
<i>Alauda arvensis</i>	32.1	17	0.1	0.2
<i>Hirundo rustica</i>	14.3	35	0.2	0.2
<i>Delichon urbica</i>	14.3	12	0.1	0.1
<i>Sturnus vulgaris</i>	25.0	19	0.1	0.4
<i>Passer domesticus</i>	53.6	69	0.4	0.5
<i>Passer montanus</i>	39.3	31	0.2	0.2
<i>Miliaria calandra</i>	28.6	10	0.1	0.1
Aves subtotal	64.3	276	1.5	2.3
Reptilia, <i>Lacerta viridis</i>	3.6	4	0.02	0.04
Amphibia, <i>Pelophylax ridibundus</i>	32.1	49	0.3	0.2
Insecta subtotal	14.3	9	0.05	0.004
Total	28	18,810	100	100

1 Mammalia: *Talpa europaea* - 8, *Suncus etruscus* - 3, *Myotis* cf. *mystacinus* - 7, *Plecotus austriacus* - 1, *Nyctalus noctula* - 2, *Pipistrellus pipistrellus/pygmaeus* - 1, *Hypsugo savii* - 6, *Vespertilionidae* - 6, *Miniopterus schreibersii* - 1, *Dryomys nitedula* - 7, *Glis glis* - 2, *Myodes glareolus* - 2, *Rattus norvegicus* - 5. Aves: *Coturnix coturnix* - 4, *Jynx torquilla* - 1, *Galerida cristata* - 5, *Anthus* sp. - 4, *Motacilla flava* - 5, *Turdus merula* - 2, *Turdus philomelos* - 5, *Acrocephalus* sp. - 1, *Sylvia atricapilla* - 1, *Phylloscopus* sp. - 2, *Sylviidae* - 5, *Parus major* - 1, *Parus caeruleus* - 1, *Carduelis chloris* - 3, *Carduelis carduelis* - 2, *Coccothraustes coccothraustes* - 1, *Emberiza citrinella* - 1, *Emberiza melanocephala* - 1, *Passeriformes* indet. - 38. Insecta: *Grylotalpa* sp. - 2, *Gryllus campestris* - 1, *Decticus* sp. - 3, *Platycleis affinis* - 1, *Tettigonia* sp. - 1, *Copris* sp. - 1.

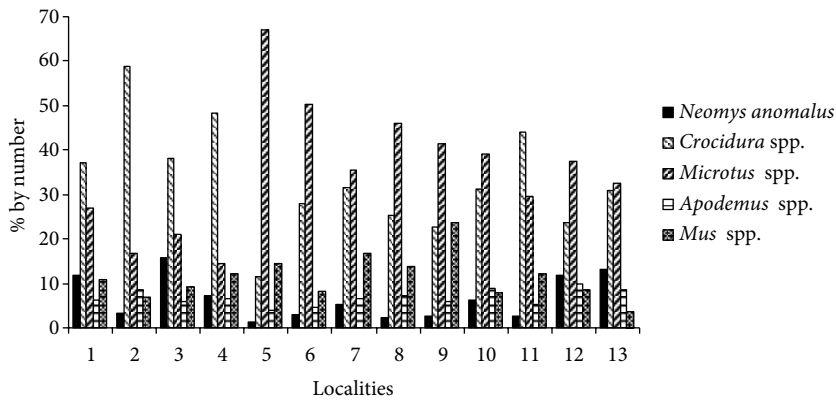


Figure 1. Frequency (% by number) of major prey in Barn Owl *Tyto alba* diets in 13 breeding localities of the Kazanlak Valley, Central South Bulgaria.

7.3%–32.8%) was the most frequent prey in the other 4 localities (30.8%, $n = 13$, location numbers 1–4), which are all located in the lower eastern part of the valley. The proportions of white-toothed shrews (*Crocidura* sp.) correlated significantly and negatively with those of voles ($r_s = -0.890$, $P < 0.01$) and mice (*Mus* spp., $r_s = -0.556$, $P < 0.05$).

Over the last century, Barn Owls have caught significantly more birds inhabiting open areas and woodlands in Kazanlak Valley than in diets with higher numbers of urban inhabitants ($\chi^2_6 = 290.80$, $P < 0.001$; Table 2). Comparison with other Bulgarian diets from the last decade indicated significantly more frequent capture of birds in open habitats and less frequent capture of birds in the wetlands of the valley ($\chi^2_6 = 13.85$, $P < 0.05$).

FNB varied between 2.1 and 4.4 (3.5 ± 0.7). It decreased significantly with the increase of the mean prey weight

(19.9 ± 2.8 g, range 15.7–23.8 g) in the diets ($r_s = -0.775$, $P < 0.02$). The increasing capture of voles significantly decreased the FNB (Table 3). Contrasting correlations are present between the FNB and proportions of white-toothed shrews and some inhabitants of moist habitats. The overlap of the food spectrum in the Kazanlak Valley is $87.7 \pm 10.7\%$ (range 49.5%–99.3%).

3.2. Influence of landscape structure on diet

Habitat overlaps ($86.9 \pm 14.6\%$, range 43.3%–99.9%) between the localities correlated weakly but highly significantly with their food niche overlaps ($r = 0.336$, $P < 0.01$). Correlations between habitat or food niche overlaps and distances between localities (28.7 ± 18.2 km, range 1.2–72.9 km) were insignificant.

Redundancy analysis shows that wetland habitats ($P = 0.002$ with 499 permutations), index of heterogeneity ($P = 0.012$ with 499 permutations), and index of topographic

Table 2. Distribution of birds in the diet of the Barn Owl *Tyto alba* in Bulgaria according to their preferred breeding habitats (% by number).

Habitat	Simeonov (1978)	Simeonov et al. (1981)	Milchev et al. (2006b)	Milchev et al. (2006a)	Present study
Open areas	0.5	3.1	10.1	15.7	19.7
Wetlands	0	3.4	3.0	3.3	0.4
Urban areas	99.4	90.1	72.7	65.0	69.7
Woodland/shrubland	0.1	3.4	14.1	16.0	10.1

Table 3. Significant correlations of the food niche breadth (FNB) with the proportions of small mammals in 13 Barn Owl diets, Kazanlak Valley: * $P < 0.05$, ** $P < 0.01$.

	<i>Microtus</i> spp.	<i>Crocidura</i> spp.	<i>Neomys anomalus</i>	<i>Micromys minutus</i>	<i>Microtus subterraneus</i>
FNB	-0.852**	0.604*	0.879**	0.753**	0.593*

relief ($P = 0.024$ with 499 permutations) were the landscape variables of significant importance for the composition of the individually studied diets. The first ordination axis (eigenvalue 0.265) correlates positively with the extent of wetlands and negatively with indices of heterogeneity and relief (Figure 2). The localities (Nos. 2, 3, 4, 13) with more wetlands in their hunting territories and with the highest proportions of white-toothed shrews, European pine vole (*Microtus subterraneus*), and typical wetland inhabitants (*Neomys anomalus*, *Micromys minutus*, *Arvicola amphibius*) correlate positively with the axis. Hunting territories with smaller total wetland areas and more habitat heterogeneity correlate with a predominance of voles and higher proportions of mice (*Mus* spp.) in the opposite part of the diagram (Nos. 5, 7, 8, 9). The proportion of voles correlates positively with the area of open habitats ($r_s = 0.567$, $P < 0.05$).

The second ordination axis (eigenvalue 0.165) correlates negatively with indices of heterogeneity and relief. The vole-dominated diets in localities 10 and 13, with fewer mice (*Mus* spp.) and more amphibians and inhabitants of mainly forests and shrubs (*Apodemus* spp., *A. agrarius*, *Sorex* spp., *Muscardinus avellanarius*), correlate positively with this axis. These 2 localities are distinguished by monotonous flat relief and the lowest levels of habitat

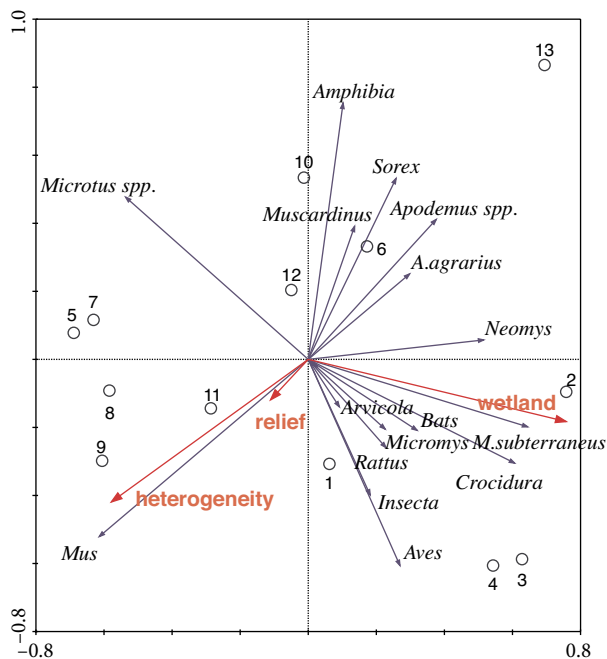


Figure 2. RDA ordination plot showing the distribution of individual diets and prey taxa according to the landscape variables in Barn Owl *Tyto alba* hunting territories in the Kazanlak Valley, Central South Bulgaria. Only the prey taxa with the highest weights (the most frequent ones) were selected for display. Open points: 13 individual diets; thinner arrows: prey taxa; thicker arrows: landscape variables.

fragmentation among all studied hunting territories. Localities (Nos. 3 and 4) with the highest catches of birds and insects in the diets, which are dominated by white-toothed shrews, are at the opposite pole of the second axis.

4. Discussion

4.1. Diet composition

The predominance of voles and other small mammals as the staple food in the Kazanlak Valley are similar to Barn Owl diets in temperate Europe and North America (Glutz von Blotzheim and Bauer, 1994; Taylor, 1994; Mebs and Scherzinger, 2000; Marti, 2010). Preference for hunting voles is the explanation for the negative correlation between their proportions in the diets and FNB. Owl diets in the valley are among the more varied diets including voles (Marti, 1988; Taylor, 1994). White-toothed shrews hold the second position, as in other parts of South Europe (Glutz von Blotzheim and Bauer, 1994; Taylor, 1994). Their share has ranged between 32% and 35% by number in diets from South Bulgaria for the last decade (Miltshev et al., 2004; Milchev et al., 2006b). Voles and white-toothed shrews have predominated in Barn Owl diets in the Kazanlak Valley as in the northwestern Upper Thracian Plain with the same moderate continental climate (95.6% diet overlap; Milchev et al., 2006b). Mice (*Mus* spp.) were the dominant prey in SE Bulgaria (Miltshev et al., 2004) with a drier and hotter continental-Mediterranean climate, but formed a 3-fold smaller percentage in diets in the Kazanlak Valley (86.1% diet overlap). These 3 main taxa in the diets from South Bulgaria may reflect the available food supply in the preferred open habitats for hunting by Barn Owls in accordance with climate peculiarities; however, there are no recent data about the small mammal communities of the region. Hristov (1974) studied the small mammals in the western part of the valley for 6 years in the 1960s, when wood mice (*Apodemus sylvaticus* and *A. flavicolis*) formed 50.6% ($n = 1336$ specimens) by number of all mammals trapped. Wood mice predominated in all kinds of open habitats, orchards, and riverside forests. Voles (6.3%), mice (*Mus* spp., 6%), and white-toothed shrews (11.2%) were much rarer at that time. The considerable difference between the composition of the small mammal communities in the 1960s and Barn Owl diet 45 years later is most probably the result of changes in the communities, rather than highly selective hunting by Barn Owls on voles and white-toothed shrews and a strong avoidance of wood mice. The 5 new species and many new localities of small mammals in the valley from the Barn Owl diet 45 years later (Milchev, 2012) support this hypothesis.

The position of the Kazanlak Valley between 2 mountain ranges should favor a higher proportion of typical mountain mammals for Bulgaria in Barn Owl diets. However, these species (*Sorex araneus*, *S. minutus*,

Muscardinus avellanarius, *Myodes glareolus*, *Microtus subterraneus*) occurred in the same proportion (1.5% by number) of Barn Owl diet as in more deforested, drier parts of SE Bulgaria distant from mountain ranges (Miltshev et al., 2004). The distribution of some small mountain mammals in the plain and foothill parts of the country might be a norm rather than an exception, as proposed by Popov and Sedefchev (2003).

Barn Owls have reduced the relative share of birds in their diets by 5- to 10-fold in the last decade, as compared to data from the 1960s and 1970s (Milchev et al., 2006a). The significant decline in the share of synanthropic birds, mostly House Sparrow (*Passer domesticus*), has been a feature in recent Barn Owl diets (Milchev et al., 2006a). This finding is likely consistent with more careful harvesting and storage of harvests and a decline in traditional livestock breeding, which favored commensal species, since the privatization of agricultural lands in the 1990s. Birds of other habitats have not compensated for the smaller share of House Sparrows in the diets of Barn Owl in the valley, as has happened in other parts of South Bulgaria (Milchev et al., 2006a).

4.2. Influence of landscape structure on diet

Barn Owl diets usually depend on food supply and accessibility of prey in their hunting territories according to habitat characteristics and general opportunistic feeding strategy (Taylor, 1994; Bond et al., 2004; Horváth et al., 2005; Tores et al., 2005; Charter et al., 2009; Arlettaz et al., 2010; Marti, 2010; Frey et al., 2011). Diets in breeding localities with similar proportions of habitats in the Kazanlak Valley have statistically significant but weak overlaps, perhaps because only the wetlands in hunting territories significantly influence the food spectrum. This result confirms that habitat composition in individual territories could determine the Barn Owl's prey structure. At the same time, a richly structured agrarian landscape in the valley creates significant dissimilarity in the food range between neighboring nests.

Wetlands have an effect on diet composition, and wetland proportion in individual territories correlated positively with food niche and the presence of wetland inhabitants in the diet. The southern water shrew (*Neomys anomalus*) has been mostly a prey species only in the western parts of the Balkan Peninsula (Tome, 1992; Paspali et al., 2013) and Romania (Duma et al., 2009; Sándor, 2009). Increasing predation on European pine voles might be explained by their preference for moist habitats in the Bulgarian lowlands (Popov and Sedefchev, 2003). The importance of the use of wetlands for hunting by Barn Owls has already been reported in other parts of South Bulgaria (Miltshev et al., 2004; Milchev et al., 2006b)

and might correlate with the robust condition of the small mammal communities inhabiting them.

Voles have been preferred and their proportions have correlated negatively with those of other prey species or have been neutral on the ordination diagram. Open habitats have had a positive impact on the hunting of voles, but an insignificant one on the variety of diet compositions. Barn Owls can readily switch to other species if the preferred prey species decline below a certain level (Mikkola, 1983; Taylor, 1994; Tores et al., 2005; Granjon and Traoré, 2007; Charter et al., 2009; Meek et al., 2009; Miltshev and Georgiev, 2009; Bernard et al., 2010). This switch has happened mostly in the easternmost part of the valley and at the lowest elevations (localities 1–4), where the amount of wetlands is greater in Barn Owl hunting territories. White-toothed shrews have replaced voles as the most numerous prey there. However, the higher share of white-toothed shrews in localities with more wetland areas cannot explain shrew preference for such habitats, because white-toothed shrews inhabit mainly open grass and shrubby plots (Popov and Sedefchev, 2003). Additional data on small mammal communities and a more precise habitat classification could clarify this result, as well as the dependence of the proportions of mice (*Mus* spp.) and forest inhabitants on the indices of heterogeneity and relief in the hunting territories.

The breeding population of Barn Owls in the Kazanlak Valley is currently robust and resilient (Milchev and Gruychev, 2014), indicating that the extant diversity of the agricultural landscape provides the necessary food supply. The preservation of the species richness of small mammal communities is an element of sustainability meriting serious consideration for wildlife conservation, as the industrial intensification of agriculture has progressed since Bulgaria joined the European Union. Conservation considerations should at least be reflected in the management plans for Natura 2000 protected zones in the valley. Measures for conservation could guarantee stable populations of the Barn Owl and many other protected predatory animals in the context of sustainable agricultural development.

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