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Winter Diet of Long-eared Owls, *Asio otus* (L.), in a Suburban Landscape of North-Eastern Bulgaria

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Abstract: Winter diet of long-eared owls in a communal roost was studied by pellet analysis containing 3,151 prey specimens. Rodents formed the majority of the food (97.0% N, 97.2% B; N = number, B = biomass), while shrews, birds and beetles constituted a negligible portion of the diet (3.0% N, 2.8% B). The staple prey consisted of inhabitants of mainly open areas like voles *Microtus* spp. (45.6% N, 50.8% B) and mice *Apodemus* spp. (20.2% N, 22.2% B) and *Mus spicilegus* (11.5% N, 8.2% B). The proportion pattern of the preyed taxa in pellets reflected the dominant position of the prey in the diet in combination with habitat preferences of the hunted species according to the results of principal component analysis. More frequent catch on forest and bush birds at the expense of urban birds including sparrows *Passer* spp. distinguished significantly the present diet from the other Bulgarian long-eared owl diets.

Key words: pellet analysis, diet composition, feeding ecology, small mammals, birds

Introduction

Long-eared owl, *Asio otus* (L.) is a specialised predator on small mammals in its large Holarctic range where it preys mainly on rodents, such as voles (*Microtus* spp.), mice (*Apodemus* spp., *Mus* spp.) and rats (*Rattus* spp.) (Glutz von Blotzheim, Bauer 1994, Marks *et al.* 1999, Birrer 2009). The proportions of these rodents in the diet vary highly, mostly according to their population fluctuations and accessibility in the diversity of open habitats, which are preferred hunting areas by these owls (Tome 1994, 2009, Kafkaletou-Diez *et al.* 2008, Sharikov, Makarova 2014, Tulis *et al.* 2015b). However, when voles are available, they are preferred over other prey and the diet is not affected either by the species composition or the proportions of potential victims in the community of small mammals (Glutz von Blotzheim, Bauer 1994). Predominance of other animal taxa is rare and usually includes a higher catch on passerine birds (Glutz von Blotzheim, Bauer 1994, Laiu, Murariu 1998, Sándor, Kiss 2008, Cecere *et al.* 2013, Siracusa *et al.* 2015). Sometimes long-eared owls may feed also on carcasses, especially when food is scarce (Mori *et al.* 2014).

Long-eared owls spend the winter in communal roosts usually up to 30-40 birds preferring coniferous trees next to areas with good food supply (Glutz von Blotzheim, Bauer 1994, Mebs, Scherzinger 2000). This allows studying their diet based on numerous collections of pellets. Several Bulgarian studies have explained the diet composition of roosting owls in semi-natural and suburban landscape, where voles (*Microtus* spp.) and mice (*Apodemus* spp.) were the dominant prey forming together 57.4–84.4% by number (N) and 43.0-87.1% by biomass (B). White-toothed shrews (*Crocidura* spp.), mice (*Mus* spp.) and European water vole (*Arvicola amphibius* L.) have local importance for prey number, and Brown rat (*Rattus norvegicus* L.) for biomass (Simeonov 1964, 1966, Simeonov, Petrov 1986, Milchev *et al.* 2003).

The aims of this study were (i) to present the current winter diet of long-eared owls in a suburban landscape and (ii) to compare the characteristics of the diet with other diets of long-eared owls in Bulgaria.

Material and methods

The Dobrudzhansko Plateau in Bulgaria and Romania forms the easternmost part of the Danube Plain to the Black Sea coast. This mostly flat region in Bulgaria with temperate continental climate and fertile soils is called “Bulgarian granary” because of the intensive cereal production on arable lands developed on the place of former steppe habitats (Fet, Popov 2007). The town of Dobrich, with 91000 urban human population (NSI 2012), is the administrative centre of the plateau’s southernmost part. The roost of long-eared owls was located in the St. Georgi Park in the southern suburbs around 1.2 km from the city centre (N 43°33’; E 27°49’, 207 m a.s.l., Fig.1). The nearest arable lands were at least 1.3 km to the south. The areas with greenery between them and the roost were with planted forests, many open areas and several wetlands on the territory of the Zoo to the south-east, and a sparsely populated extensively managed village zone to the south-west. The area between present roost and the previously studied locality, Kobaklaka, around 4.5-5 km away (Simeonov 1966), was covered mainly with arable lands to the west of the suburbs of Dobrich.

Intact and disintegrated pellets of long-eared owls were collected under 12 Austrian pines (*Pinus nigra*) and two box elders (*Acer negundo*) on 26 February and 15 March 2015 when the roost included 53 and 29 birds, respectively. Most of the pellets were gathered during the second visit. The materials collected during both visits were analysed as one sample. The intact and well-preserved pellets (n = 191) were collected and analysed separately in order to estimate the prey number and biomass per pellet. Prey mammals were identified following Popov, Sedefchev (2003), Görner, Hackethal (1987) and the author’s comparative collection. Because of difficulties in species determination of *Apodemus sylvaticus* (L.) – *A. flavicollis* (Melchior) (see Chassovnikarova, Markov 2007) and of sibling voles *Microtus arvalis* (Pall.) – *M. levis* Miller, these species pairs are presented here as *Apodemus* spp. and *Microtus* spp., respectively. Birds were identified using their bone remains and beetles using parts of their exoskeleton based on comparisons with the collections of the National Museum of Natural History, Sofia. The minimum number of individuals (MNI) of mammals was estimated mainly on the basis of the remains of crania and mandibles, while the MNI of birds was based also on bones of girdles and limbs. Estimates of MNI of beetles were based on head fragments, prothoraces, wingcases and legs. The possible cranial dimensions of two new mammal species for the area around Dobrich were taken under a stereo-microscope or with a vernier calliper measuring according to Popov, Sedefchev (2003). Descriptive statistics in Appendix 1 (Table 1, 2, and 3) represent the arithmetic mean ± standard deviation; minimum – maximum observed values; n – sample size. The material was deposited in the National Museum of Natural History, Sofia. The prey biomass was calculated after Glutz von Blotzheim, Bauer (1994), and Popov, Sedefchev (2003). The unidentified passerines were arranged in two weight groups: 1) size near *Erithacus rubecula* with biomass 15.5 g (n = 2 specimens); 2) size near *Passer montanus* with biomass 23.3 g (n = 4 specimens).

The food niche breadth (FNB) was calculated as follows:

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

where p_i was the proportion of prey category i in the long-eared owl diet (Levins 1968). Larger values of this index indicate a higher dietary diversity. In this calculation, the unidentified specimens of the

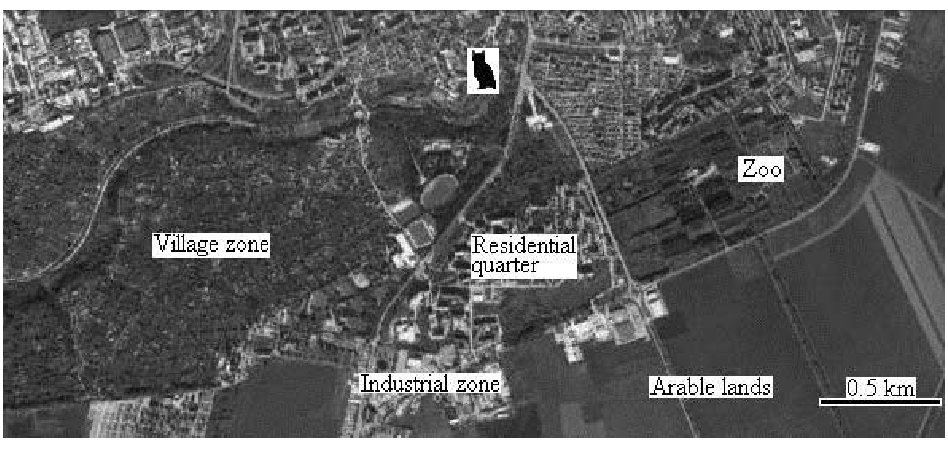

Fig. 1. Location of the winter roost of long-eared owls (*Asio otus*) in Dobrich, NE Bulgaria

genus *Mus* were assigned to species in the same proportion as their identified counterparts.

Statistical differences in the frequencies of the prey of long-eared owl diets from our and previous studies were tested using a chi-square test. In these calculations white-toothed shrews and mice were merged in genus *Crocidura*, *Apodemus* and *Mus*, respectively because of differences in levels of their species determinations in Simeonov (1966). The correlations between the proportions of birds in the diets with arcsine transformed values, excluding unidentified passerines (Passeriformes indet.) were tested with Pearson correlation coefficient. The significance level was $p < 0.05$. All means are arithmetic mean ± standard deviation.

Principal component analysis (PCA) was used for studying the pattern of distribution of the prey taxa in pellets (CANOCO v. 4.5; ter Braak 1995). The samples were the separate pellets, while the variables were the proportions of prey taxa in the respective pellet. Birds and white-toothed shrews were categorised into class and genus levels, respectively because of rarity of separate species. The arrows on the ordination diagram present species variables. The angles between the arrows are an approximation of the correlations between variables. Most important in the analysis were species with longer arrows and sharper angles with the ordination axes (ter Braak 1995; Lepš, Šmilauer 2003).

Results

The analysis of the feeding range of the roosting long-eared owl was based on remains of 3151 specimens distributed among 39 identified animal taxa (Table 1). Common shrew (*Sorex araneus*) and Common pine vole (*Microtus subterraneus*) were found for the first time in the area around Dobrich (Appendix 1).

Small mammals were the main prey with 98.1% by number and 97.5% by biomass, while birds and beetles formed a negligible part (Table 1). Voles (*Microtus* spp.) were the staple prey representing around half of prey number and biomass. Field mice (*Apodemus* spp.) with Steppe mice (*Mus spicilegus*) were the most important other prey which accumulated together with voles at least 77.3% by number and 81.3% by biomass of the food. House mice (*Mus musculus*) were the only other species reaching 5% by number in the diet. The niche breath was 3.49 and exceeded to some extent the average value for Bulgaria (3.05 ± 0.11, range 1.74 – 4.28, Table 2).

The separate pellets (n = 191) contained 2.5 ± 1 (range 1 – 6) prey animals which formed 63.9 ± 25.2 g (range 19.3 g – 150 g) per pellet. The mean number of prey taxa per pellet was 1.7 ± 0.7 (range 1 – 4). These pellets contained 14.9 % of the total prey items belonging to 19 taxa. We did not find a statistical difference between the prey frequencies in the total diet and the sample with separate studied pellets (χ^2_{38} = 48.89, $p > 0.05$). The arrangement of prey taxa according to their proportions in the pellets is displayed in Fig.2. The voles (*Microtus* spp.) as a dominant and highly preferred prey did not match preferen-

Table 1. Diet of the long-eared owl (*Asio otus*) (Dobrich, NE Bulgaria); tr. – traces (<0.1%);[1] prey with less than 0.1% by total number – number of specimens

Prey	**Number**	**% by Number**	**% by Biomass**
Sorex araneus L.	6	0.2	0.1
Crocidura leucodon (Hermann)	2	0.1	tr.
Crocidura suaveolens (Pall.)	28	0.9	0.2
Micromys minutus (Pall.)	12	0.4	0.1
Apodemus spp.	637	20.2	22.2
Apodemus agrarius (Pall.)	88	2.8	2.6
Rattus rattus (L.)	2	0.1	0.2
Mus musculus L.	157	5.0	3.6
Mus spicilegus Petényi	362	11.5	8.2
Mus musculus/spicilegus	265	8.4	6.0
Microtus spp.	1436	45.6	50.8
Microtus subterraneus (de Selys-Longchamps)	96	3.0	3.4
Mammalia subtotal	3092	98.1	97.5
Alauda arvensis L.	4	0.1	0.2
Turdus merula L.	5	0.2	0.5
Turdus iliacus L.	3	0.1	0.2
Turdus philomelos Brehm	2	0.1	0.2
Turdus sp.	2	0.1	0.2
Regulus regulus (L.)	2	0.1	tr.
Cyanistes caeruleus (L.)	3	0.1	tr.
Parus major L.	2	0.1	tr.
Sturnus vulgaris L.	3	0.1	0.3
Passer domesticus (L.)	5	0.2	0.2
Passer montanus (L.)	2	0.1	0.1
Fringilla coelebs L.	2	0.1	0.1
Carduelis carduelis (L.)	4	0.1	0.1
Coccothraustes coccothraustes (L.)	3	0.1	0.2
Passeriformes indet.	6	0.2	0.1
Aves subtotal	57	1.8	2.5
Insecta, Coleoptera subtotal	2	0.1	tr.
Total	**3151**	**100.0**	**100.0**

[1] Mammalia: *Dryomys nitedula* (Pall.) – 1; Aves: *Dryobates minor* (L.) – 1; *Anthus* sp. – 1; *Erithacus rubecula* (L.) – 1; *Poecile* sp. – 1; *Pyrrhula pyrrhula* (L.) – 1; *Carduelis chloris* (L.) – 1; Fringillidae – 1; *Emberiza citrinella* L. – 1; *Emberiza cirlus* L. – 1; Coleoptera: *Anoplotrupes stercorosus* (Hartmann in L.G. Scriba) – 1; *Dytiscus* sp. – 1.

Table 2. Birds in the diet of long-eared owls (*Asio otus*) in Bulgaria according to their preferred habitats (% by number): A – Simeonov (1964), Sofia; B – Simeonov (1964), Sliven; C – Simeonov (1966); D – Simeonov, Petrov (1986); E – Milchev *et al.* (2003); F – present study

Habitat	**A (12.8 % birds, n=1223)**	**B (13.6% birds, n=567)**	**C (4.4 % birds, n=8087)**	**D (9.0 % birds, n=25531)**	**E (8.7 % birds, n=6773)**	**F (1.8 % birds, n=3151)**
Urban areas (*Passer* sp.)	44.6 (44.6)	61.0 (61.0)	59.3 (58.4)	60.3 (60.1)	56.5 (43.3)	19.6 (12.3)
Woodland/ shrubland	51.0	20.8	37.9	35.1	36.4	70.6
Open areas	4.5	13.0	2.5	4.1	6.4	9.8
Wetlands	0.0	5.2	0.3	0.6	0.6	0.0
FNB of total diet	2.20	4.28	2.97	4.04	1.74	3.49

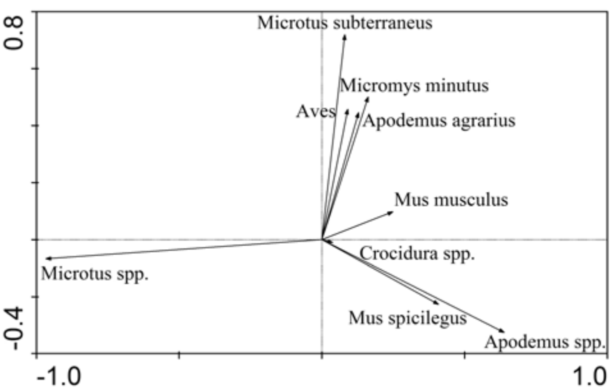

Fig. 2. PCA ordination of prey taxa in the pellets of wintering long-eared owls (*Asio otus*) in Dobrich, NE Bulgaria. Arrows: prey taxa

tially with any other taxa. Voles formed the largest number of pellets containing only one taxon (56.6%, n = 83 pellets). Only voles correlated negatively with the first ordination axis (eigenvalue 0.150). Mice (*Apodemus* spp.) with two species of the genus *Mus* were in the opposite part of the diagram as the next three prey after voles by percent of number. The first axis interprets the grouping of prey in the pellets according to the gradient of their domination in the diet. Several not numerous taxa (*Microtus subterraneus*, *Micromys minutus*, *Apodemus agrarius* and Aves), which correlated positively with the second axis (eigenvalue 0.130) were hunted mostly together. This group included inhabitants of mainly moister grassy and shrub-woody habitats and their finding in pellets was neutral to prey of *Microtus* spp. The catch of the numerous inhabitants of open habitats *Mus spicilegus* and *Apodemus* spp. correlated negatively with the second axis and highly positively with each other. The house mouse (*Mus musculus*) remained in isolation on the diagram as the only more numerous synanthropic species in the diet. The second axis explained the grouping of prey taxa in pellets mainly in terms of habitat gradient.

The present diet from the area near Dobrich differed significantly with the results of Simeonov (1966; χ^2_{48} = 1796.4, p<0.001): At present more frequently were preyed *Mus* and *Microtus* while *Crocidura* and *Apodemus* had lesser shares.

Despite the taxonomic variety of birds with a minimum of 23 taxa, they participated less in the diet of the long-eared owl in the country among this class (Table 2). The present diet differed very highly from other Bulgarian ones according to the habitat distribution of preyed birds (χ^2_{15} = 103.38, p<0.001); woodland and scrubland birds were preyed with the highest frequency while the opposite applied to urban birds. The proportions of woodland/shrubland birds in the Bulgarian diets correlated significantly and negatively with these of urban birds (r = -0.818, p<0.05), and close to significance with sparrows (r = -0.793, p=0.06). The catch of sparrows correlated significantly and positively with the proportion of urban birds (r = 0.982, p<0.01), and close to significance with the part of birds in the diets (r = 0.791, p=0.06).

Discussion

The long-eared owls hunted mainly voles (*Microtus* spp.) and other small rodents in the present study, as well as in the most of European and North American diets (Marks *et al.* 1999, Birrer 2009). Mice *Apodemus* spp. and *Mus spicilegus* were a subdominant prey. They inhabit a variety of open habitats in NE Bulgaria (Popov, Sedefchev 2003), which owls prefer for hunting (Glutz von Blotzheim, Bauer 1994). Although the roost was in the city outskirts, the wintering owls hunted mainly on the most numerous inhabitants of the open areas. Such preferences are reported in similar studies for urban and suburban roosts (Milchev *et al.* 2003, Sharikov 2006, Dziemian *et al*. 2012, Mori, Bertolino 2015). This result is consistent with radio-tracked long-eared owls that avoid built-inhabited areas for hunting (Tulis *et al*. 2015a). House mice were the only urban inhabitants in the current study with a significant contribution to food unlike previous studies in Bulgaria, where rats formed up to 28% of the biomass of food (Simeonov 1966, Simeonov, Petrov 1986). Precise comparison of the proportion of the urban mammals was not possible because in previous studies the house mice with their related wild species *Mus macedonicus* Petrov, Ruzic from Southern Bulgaria and *Mus spicilegus* from Northern Bulgaria (Popov, Sedefchev 2003) have been determined as *Mus* sp..

Simeonov (1966) reported two species of hamsters (*Cricetus cricetus* (L.) and *Mesocricetus newtoni* (Nehring)) with 101 specimens (4.6% by number, n=8087) in the long-eared owl's diet in the vicinity of Dobrich. These typical steppe inhabitants were included as "vulnerable" species in the Bulgarian Red Data Book (Golemanski 2015) and were not captured in Dobrudzha in the recent years (Murariu *et al*. 2009). Currently, their absence as prey of the long-eared owls corresponds most probably to their very low population number. The wider food niche minimises the probability of their omission by owls because of high catch of preferred prey as voles in these habitats. The present study confirmed a new locality of two typical mountain mammals (*Sorex araneus*, *Microtus subterraneus*) in Bulgaria with sporadic findings in mainly wet forests in the lowlands (Popov, Sedefchev 2003). Their more widespread distribution here might be triggered by the development of the system of forest shelter belts in the open plains of Dobrudzha since the middle of the last century. The significant differences in the proportions of several mammalian taxa between two samples from Dobrich correspond most probably to irregular plagues of voles in Northern Bulgaria every 2 – 6 years (Popov, Sedefchev 2003) and changes in the hunting strategy of the long-eared owl according to the fluctuation of voles (Glutz von Blotzheim, Bauer 1994, Tome 1994, 2009).

Our results of prey number and biomass per pellet were within the known ranges (Glutz von Blotzheim, Bauer 1994, Mebs, Scherzinger 2000). The proportion pattern of the preyed taxa in pellets agreed with the dominant structure of the current diet where voles predominated. Voles *Microtus* spp. were preyed upon preferentially in open habitats. They formed half of the pellets containing only one taxon. Their proportions in the pellets did not correlate positively with that of any other taxon. Two taxa of mice, *Apodemus* spp. and *Mus spicilegus* as alternative prey from similar habitats, were found more often together and dominated pellets without or with single *Microtus* spp. The habitat preferences of the hunted taxa within a separate pellet were with secondary importance for the variance in the pellet contents. This is explained by hunting mostly in a kind habitat of the animals whose remains were found within the owl pellet.

Long-eared owls generally hunt more birds in poor availability and accessibility of the preferred small mammals (Glutz von Blotzheim, Bauer 1994, Marks *et al*. 1999, Mebs, Scherzinger 2000). Birds represent about 11 % (by number) in the diet of long-eared owls in SE Europe (Birrer 2009). Sparrows and finches with communal roosts usually prevail in the winter diet when the first group forms around half of the birds (Glutz von Blotzheim, Bauer 1994, Mebs, Scherzinger 2000). Most of these regularities apply to Bulgarian diets (Simeonov 1964, 1966, Simeonov, Petrov 1986, Milchev *et al*. 2003) with the exception of our study. Long-eared owls reduced the relative share of birds in the present diet 2- to 8-fold in comparison with previous data. The sparrows were between four and five times less in the avian prey and preying upon significantly more birds of woodland and shrubland habitats did not compensate the much less urban birds in the diet. More studies are needed to prove all these tendencies.Similar patterns have been already observed in the diet of the barn owl (*Tyto alba* (Scopoli) in Bulgaria (Milchev *et al*. 2006, Milchev 2015) and in other parts of Europe (Roulin 2015). Barn owl is a typical inhabitant of urban and suburban landscape. It prefers open habitats for hunting territories like the long-eared owls, and mainly preys opportunistically upon small mammals (Marks *et al*. 1999, Mebs, Scherzinger 2000, Milchev 2015).

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Appendix 1

Table 1. Mandible measurements (mm) of *Sorex araneus* and *Microtus subterraneus* from pellets of long-eared owls (*Asio otus*) (Dobrich, NE Bulgaria)

Dimensions	*Sorex araneus*	*Microtus subterraneus*
LMd – length	9.73 ± 0.18; 9.48 – 9.87; n = 5	13.53 ± 0.43; 12.28 – 14.55; n = 85
LMd+I_1 – length of mandible with I_1	12.01 ± 0.20; 11.84 – 12.34; n = 5	14.94 ± 0.47; 13.65 – 16.12; n = 83
LDL – lower diastema length	-	2.98 ± 0.21; 2.46 – 3.60; n = 93
LcI_1–M_3 – coronal length of I_1–M_3	8.16 ± 0.11; 8.04 – 8.29; n=5	10.62 ± 0.49; 9.28 – 11.65; n = 67
LcM_1–M_3 – coronal length of M_1–M_3	3.95 ± 0.04; 3.92 – 4.00; n=5	5.27 ± 0.18; 4.87 – 5.97; n = 64
HMd/M_2 – height of horizontal ramus under M_2	1.43 ± 0.06; 1.34 – 1.50; n=5	2.24 ± 0.13; 1.93 – 2.67; n = 96
LcP_4–M_3 – coronal length of P_4–M_3	4.97 ± 0.04; 4.95 – 5.03; n = 5	-
HPC – height of coronoid process	4.68 ± 0.12; 4.53 – 4.79; n = 5	-
LM_1 – length of M_1	-	2.53 ± 0.11; 2.10 – 2.80; n = 96
WM_1 – width of M_1	-	0.93 ± 0.05; 0.83 – 1.00; n = 96

Table 2. Cranial measurements (mm) of *Sorex araneus* from pellets of long-eared owls (*Asio otus*) (Dobrich, NE Bulgaria)

Dimensions	Sorex araneus
PL – palatal length	7.54 ± 0.12; 7.42 – 7.72; n = 6
ZW – zygomatic width	5.52 ± 0.09; 5.41 – 5.62; n = 6
IOW – interorbital width	3.83 ± 0.29; 3.54 – 4.23; n = 4
PGW – postglenoid width	5.75 ± 0.17; 5.46 – 5.88; n = 5
LcI^1-M^3 – coronal length of I^1–M^3	8.99; n = 1
LaI^1-M^3 – alveolar length of I^1–M^3	7.53 ± 0.31; 7.27 – 8.10; n = 6
LcP4-M^3 – coronal length of P4–M^3	4.81 ±0.12; 4.74 – 4.95; n = 3
LaP4-M^3 – alveolar length of P4–M^3	4.55 ± 0.07; 4.48 – 4.64; n = 5
LcM^1-M^3 – coronal length of M^1–M^3	3.37 ± 0.06; 3.30 – 3.40; n = 3
LaM^1-M^3 – alveolar length of M^1–M^3	3.24 ± 0.07; 3.14 – 3.30; n = 5
LcA^1-A5 – coronal length of A^1–A5	2.89; n = 1
LaA^1-A5 – alveolar length of A^1–A5	2.20 ± 0.17; 1.86 – 2.32; n = 6

Table 3. Cranial measurements (mm) of *Microtus subterraneus* from separately studied pellets (n = 191) of long-eared owls (*Asio otus*) (Dobrich, NE Bulgaria)

Dimensions	*Microtus subterraneus*
RW – maximal rostral width	4.20 ± 0.18; 3.69 – 4.50; n = 15
IOW – interorbital width	3.65 ± 0.10; 3.54 – 3.87; n = 15
IFW – foramina incisive width	0.97 ± 0.09; 0.87 – 1.13; n = 15
IFL – foramina incisive length	3.83 ± 0.20; 3.50 – 4.13; n = 15
PBL – palatal bridge length	4.77 ± 0.30; 4.40 – 5.57; n = 15
DL – diastema length	6.23 ± 0.33; 5.60 – 6.96; n = 15
PL – palatal length	10.97 ± 0.40; 10.25 – 11.77; n = 14
LcM^1-M^3 – coronal length of M^1–M^3	5.13 ± 0.17; 4.73 – 5.40; n = 16
AOW – anterior interorbital width	2.87 ± 0.15; 2.60 – 3.13; n = 15
LW – lacrimale width	5.22 ± 0.14; 4.93 – 5.43; n = 13