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New Data on the Diet of the Tawny Owl *Strix aluco* (Aves: Strigiformes) from Bulgaria

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Abstract: We present new data on the diet of the tawny owl (*Strix aluco*), collected from eight locations over the past 20 years. In total, 759 prey items of 77 taxa were identified, with small mammals comprising approximately 75% of the diet. Field mice (*Apodemus* spp.) were the most common mammalian prey, representing about 50 % (by frequency, out of 569 mammal items). The second most important prey group was dormice (family Gliridae), represented by three species (out of four found in Bulgaria): fat dormouse (*Glis glis*), forest dormouse (*Dryomys nitedula*) and common dormouse (*Muscardinus avellanarius*). Ten bat species were also identified among the prey, with bats being significantly predominant at a single site, which may indicate behavioural specialisation or targeted hunting of bats by the owl. Birds made up 18.97% of the diet, with 32 species identified. Amphibians and reptiles comprised 4.6% of the total prey. A significant shift was observed in the diet of the tawny owl in comparison to previous studies.

Key words: Bat predation, feeding biology, diet shift, small mammals, tawny owl

Introduction

The tawny owl (*Strix aluco* Linnaeus, 1758) is widely distributed across Europe, from the Iberian Peninsula in the West, to Central Asia (Kazakhstan and Kyrgyzstan) in the East (Davletkeldiev 2006, König et al. 2008, Ryabitsev et al. 2014). Its feeding biology has been well studied in Central Europe (Uttendörfer 1952, Obuch 2012) but not as thoroughly researched in the eastern parts of its range (Cramp & Simmons 1988). The tawny owl is a generalist predator and feeds on a variety of animals, including small mammals, birds, frogs, lizards, insects and earthworms (Mikkola 1983). Most of its diet consists of small mammals such as mice, voles and shrews (Southern 1954, Wendland 1982). Like other owl species, the tawny owl produces pellets containing undigested parts of its prey, which are usually cast before going to roost (Southern 1954, Mikkola 1983), making dietary studies challenging.

In Bulgaria, the tawny owl predominantly inhabits mountainous regions and is restricted to wooded areas, with a more scattered presence in lowlands and plains. Its breeding population is estimated at 4,000–8,000 pairs (Nikolov & Georgiev 2007). The earliest studies on the diet of the tawny

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owl in Bulgaria were conducted by the Bulgarian ornithologist Simeon Simeonov (Simeonov 1963, 1985). Simeonov was a pioneer in researching the diets of various nocturnal and diurnal birds of prey in Bulgaria. In his first publication, he presented data on the seasonal variation (1955–1962) of the owl's diet from Lozen Planina (Simeonov 1963). He identified 46 taxa (mammals, birds, amphibians, reptiles and insects), with mammals comprising most of the prey, 95% of the biomass. In his second work, he presented extensive material (4371 prey items) from 19 locations collected across Bulgaria (Simeonov 1985). He identified 94 taxa from various groups, including mammals, birds, amphibians, reptiles and insects. Later, Obuch & Benda (1996) published data (from four locations, 390 prey items of 35 taxa) on its diet from south-western Bulgaria. To date, these are the only three publications dedicated to the tawny owl's diet in Bulgaria. Here, we present new data on the diet of the tawny owl collected from various regions across Bulgaria.

Materials and Methods

Pellets and food remains were collected from nesting and roosting sites. The pellets were carefully opened and indigestible parts, such as bones, skulls and teeth, were separated. Small mammals and birds were identified by their skulls, bone remains and teeth in the case of mammals, using the comparative collection of the National Museum of Natural History – Bulgarian Academy of Sciences (NMNHS-BAS). In Bulgaria, grey voles (subgenus *Mictorus*) are represented by two morphologically indistinguishable species – the common vole (*M. arvalis*) and east European vole (*M. rossiaemeridionalis*) (Peshev et al. 2004), therefore all identified voles are presented as *Microtus ex gr. arvalis*. Dr. Nikolay Tzankov assisted with the identification of amphibian and reptile bone remains. Data for the present study originated from eight sampling sites (Fig. 1) and were collected between 1984 and 2022, described as follows:

1 – Mandrata Cave (Devetashko Plateau, Lovech Province). The material was collected on 18.07.2014, 30.07.2014, 25.08.2014, 20.09.2016, 10.04.2017, 30.04.2019, 28.01.2022. 2 – Srutitsa Cave (Pleven Province), the Kaylaka Valley to the Tuchenitsa River. The material was collected on 18 and 22.10.2004 and 24.04.2005. 3 – Ruse Petrol Base (Ruse Province), a small cave on the banks of the Danube River (505 km). The material was collected on 12.07.2003, 4.08.2003 and 22.08.2004.

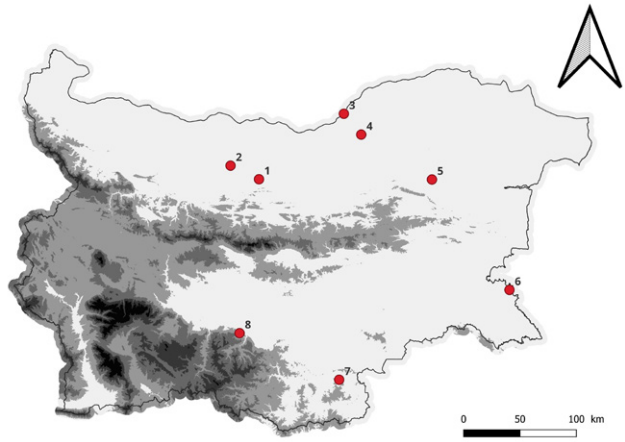

Fig. 1. Locations in Bulgaria from where the food remains and pellets of tawny owl (*Strix aluco*) were collected (for details of the locations, see the text).

4 – Svalenik Village (Ruse Province). A niche 4.5 km north-west of the village, above the Mali Lom River. The material was collected on 22.06.2004 and 1.11.2005. 5 – Shumensko Plateau. The material was collected by Victor Vasilev in 2006, 6 – Ravadinovo (Burgas Province) – roosting site in an old building, 2 km to the east of Ravadinovo Village. The material was collected on 30.04.2017. 7 – vicinity of Madzharovo (Kardzhali Province), several rock niches around the town (Malkata Kovan Kaya, Gyorgen Dere, Zhaltata Skala). The material was collected on 01.06.2007, 28.09.2007, 9-21.03.2008, 21.09.2008 and 9.11.2008. 8 – Ruen Village (Plovdiv Province) – Protsepa Cave, a short cave – 23 m long. The material was collected on 25.11.1984. The materials were deposited at NMNHS-BAS. Visualisation of the locations where the materials were collected was done in QGIS version 3.44.8.

Results

The pellets of the tawny owl are cylindrical in shape and grey in colour, measuring 34.3 × 19.9 × 16.5 mm (n = 4). The identified prey items were not evenly distributed among the eight sampling sites and ranged from 11 to 197 items per site, with a median of 88 prey items.

Across all eight sites, 759 prey items were identified in the diet of the tawny owl (Table 1), with mammals making up about 75% of the total number. They were represented by 32 taxa, with field mice (*Apodemus* spp.) being the most common, constituting about 50% of all mammals. The second most important prey among the mammals were dormice (Gliridae), comprising about 18.6% of all mammals. The European edible dormouse (*Glis glis*) was

Table 1. Prey items in the diet of tawny owls (*Strix aluco*) from Bulgaria (for details of the locations see Materials and Methods).

Taxon/ Location	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**	**Total %**
Erinaceus roumanicus							1		**1**	**0.13**
Talpa europaea	2	1	1						**4**	**0.53**
Sorex araneus				1	6				**7**	**0.92**
Neomys milleri			1						**1**	**0.13**
Crocidura suaveolens	13	8	4	1			1	6	**33**	**4.35**
Crocidura leucodon		1		0			5	1	**7**	**0.92**
Rhinolophus ferrumequinum	5			1					**6**	**0.79**
Rhinolophus hipposideros	1								**1**	**0.13**
Rhinolophus euryale	2								**2**	**0.26**
Nyctalus noctula			2					1	**3**	**0.40**
Myotis myotis	4							1	**5**	**0.66**
Myotis blythii	14								**14**	**1.84**
Myotis capaccinii	5								**5**	**0.66**
Myotis nattereri	2								**2**	**0.26**
Myotis daubentoni		1							**1**	**0.13**
Eptesicus serotinus	1							1	**2**	**0.26**
Chiroptera indet.							1		**1**	**0.13**
Muscardinus avellanarius	1								**1**	**0.13**
Dryomys nitedula	3	1		2			2	1	**9**	**1.19**
Glis glis	10	42	14	1			13	7	**87**	**11.46**
Apodemus agrarius	3		4				1		**8**	**1.05**
Apodemus sylvaticus		6	4	4				29	**43**	**5.67**
Apodemus flavicollis	14	15	14	32	1	6		3	**85**	**11.20**
Apodemus spp.	64	4	14		1	11	22	32	**148**	**19.50**
Mus spicilegus		1							**1**	**0.13**
Mus macedonicus								2	**2**	**0.26**
Mus musculus								3	**3**	**0.40**
Mus spp.			7		1			2	**10**	**1.32**
Micromys minutus			3						**3**	**0.40**
Rattus norvegicus			3						**3**	**0.40**
Rattus rattus	1		9			1	1	1	**13**	**1.71**
Microtus ex gr. *arvalis*	17	11	8	2		3	8		**49**	**6.46**
Microtus subterraneus					2				**2**	**0.26**
Chionomys nivalis							6		**6**	**0.79**
Arvicola amphibius				1					**1**	**0.13**
Mammals subtotal	*162*	*91*	*88*	*45*	*11*	*21*	*61*	*90*	***569***	***74.97***
Streptopelia turtur	2							2	**4**	**0.53**
Perdix perdix								1	**1**	**0.13**
Dendrocopos major	1								**1**	**0.13**
Galerida cristata								2	**2**	**0.26**

Table 1. Continuation.

Taxon/ Location	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**	**Total %**
Hirundo rustica	3								**3**	**0.40**
Delichon urbicum	1								**1**	**0.13**
Anthus trivialis	1								**1**	**0.13**
Melanocorypha calandra								2	**2**	**0.26**
Parus major	1							2	**3**	**0.40**
Poecile montanus	1								**1**	**0.13**
Sitta europaea	2								**2**	**0.26**
Coccothraustes coccothraustes	2		1					2	**5**	**0.66**
Fringilla montifringilla								2	**2**	**0.26**
Fringilla coelebs								2	**2**	**0.26**
Chloris chloris	1					1		2	**4**	**0.53**
Carduelis carduelis	2							2	**4**	**0.53**
Carduelis spinus								2	**2**	**0.26**
Pyrrhula pyrrhula								2	**2**	**0.26**
Serinus pusillus								2	**2**	**0.26**
Acanthis cannabina	1							2	**3**	**0.40**
Passer montanus								2	**2**	**0.26**
Passer domesticus						1			**1**	**0.13**
Curruca melanocephala								2	**2**	**0.26**
Sylvia atricapilla	1								**1**	**0.13**
Sylvia sp.	1								**1**	**0.13**
Motacilla alba	1								**1**	**0.13**
Erithacus rubecula	1								**1**	**0.13**
Luscinia megarhynchos	1								**1**	**0.13**
Turdus merula	3							1	**4**	**0.53**
Turdus viscivorus						1			**1**	**0.13**
Oriolus oriolus						1			**1**	**0.13**
Sturnus vulgaris	1					1		1	**3**	**0.40**
Garrulus glandarius	1								**1**	**0.13**
Aves indet.		6	63	5			3		**77**	**10.14**
Birds subtotal	*28*	*6*	*64*	*5*		*5*	*3*	*33*	***144***	***18.97***
Lacerta viridis	1								**1**	**0.13**
Reptilia indet.							1		**1**	**0.13**
Pelophylax ridibundus		7	1				4		**12**	**1.58**
Rana dalmatina							1		**1**	**0.13**
Pelobates fuscus			4						**4**	**0.53**
Pelobates spp.			3						**3**	**0.40**
Hyla arborea			8						**8**	**1.05**
Anura indet.	3						2		**5**	**0.66**
Coleoptera	3								**3**	**0.40**
Total	**197**	**104**	**168**	**50**	**11**	**26**	**72**	**131**	**759**	**100**

found at five out of eight sites; notably, at Srutitsa Cave, it accounted for 40% of all prey items.

We identified ten bat species of two families: Rhinolophidae and Vespertilionidae, together making up 5.5% of the total prey. Vesper bats were much more prevalent, outnumbering horseshoe bats about 3.5 times. Interestingly, bats formed a significant part of the owl's diet at one sampling site, Mandrata Cave, where eight bat species were identified, most of them cave dwellers. Here, bats accounted for 17.2% of the total prey (197 prey items).

Birds were the second most common prey, represented by a variety of species (32 identified), ranging from the grey partridge (*Perdix perdix*), weighing about 350 g, to the red-fronted serin (*Serinus pusillus*), weighing about 11.5 g, with passerines being the most represented order. Birds comprised about 19% of the owl's diet. Amphibians and reptiles accounted for 4.6% of all prey.

Discussion

The tawny owl is a generalist predator and can adapt to different prey sources and various environmental conditions (Cramp & Simmons 1988, Obuch 2012). We found about 77 different taxa in its diet, including mammals (insectivorous, bats and rodents) from various ecological groups and birds, mostly small passerines.

The main prey of the tawny owl are muroid rodents - mostly field mice (*Apodemus* spp.) and voles (*Microtus* spp. and *Clethtionomys* spp.), as they can make up to 86% of its diet (Mikkola 1983, Cramp & Simmons 1988). In previous studies from Bulgaria, mammals represented 54-85% of the diet (Simeonov 1963, Simeonov 1985, Obuch & Benda 1996). In a large sample (4371 prey items) from across the country, Simeonov (1985) found that voles (*Microtus* spp.) were the most common prey with 28.3% (23.4% by biomass), followed by field mice (*Apodemus* spp.) at 25% (18.3% by biomass). In our study, we observed a significant drop in vole abundance by a factor of four, in comparison to Simeonov (1985). In our sample, field mice (*Apodemus* spp.) outnumbered voles (*Microtus* spp.) by a factor of five (Table 2).

This may be due to fluctuations in vole populations; however, our samples spanned over a period of more than 20 years and one could assume that they were randomly sampled through time and space. Over the past ten years, we have noticed a significant decline in populations of field voles (*Microtus* spp.) across Bulgaria (N. N., unpubl. data from live trapping over the last 20 years). This decrease could be linked to climate-related events. Precipitation during the second half of the summer (July-September) is of considerable importance for the field voles (subgenus *Microtus*) in Bulgaria (Straka & Gerasimov 1971). That study showed that individuals born after the second part of August formed the nucleus of the overwintering population. In case of shortage of plant biomass (lower precipitation), the reproduction process ended as early as July-August (Straka & Gerasimov 1971). In the last decade, a significant drop in precipitation was noticed, exacerbated by July-August (even September), which could lead to declines in field vole (subgenus *Microtus*) populations in Bulgaria.

The tawny owl is a primary predator of dormice among European owls (Juškaitis 2023). Dormice can comprise up to 44% of its diet and four out of the five European glirid species have been recorded in its diet, except for the mouse-tailed dormouse (*Myomimus roachi*) (Juškaitis 2023).

Owls are considered a major threat to bats (Mikula et al. 2024); in particular, the tawny owl can

Table 2. Comparison of the diet composition of the tawny owl (*Strix aluco*) in Bulgaria.

Taxa	**Simeonov, 1985**	**This study**
Bats (Chiroptera)	0.22	5.53
Voles (*Microtus* spp.)	28.32	6.72
Field mice (*Apodemus* spp.)	18.27	37.42
Dormice (Gliridae)	4.61	12.78
Other Mammals	23.67	12.5
Birds	14.25	18.97
Reptiles	0.83	0.26
Amphibians	1.36	4.35
Insects	7.99	0.40
Gastropoda	0.48	
Total	**100**	**100**

include up to 30% bats in its diet (Sieradzki & Mikkola 2020). Simeonov (1963) did not find any bats among the 1785 prey items from Lozen Planina. Later, Simeonov (1985), in a large sample (4371 prey items) from across the country (19 localities), identified four bat taxa: the common noctule (*Nyctalus noctula*), mouse-eared bat (*Myotis* sp.), common pipistrelle (*Pipistrellus pipistrellus*) and common bent-wing bat (*Miniopterus schreibersii*). Still, bats comprised less than 1% of the prey.

Obuch & Benda (1996) found seven bat species in their samples from tawny owls from southwestern Bulgaria: whiskered bats (*Myotis mystacinus*), lesser mouse-eared bats (*M. blythii*), serotine bats (*Eptesicus serotinus*), common noctules, grey long-eared bats (*Plecotus austriacus*), common bent-wing bats and European free-tailed bats (*Tadarida teniotis*), as bats accounted for about 5.8% of the total prey (390 prey items).

Altogether, 15 bat species were found in the diet of the tawny owl, representing 45% of the 33 bat species recorded in Bulgaria (Simeonov 1963, Simeonov 1985, Obuch & Benda 1996, this study). Bats make up a very small portion of the diets (0.2%) of European owls (Sieradzki & Mikkola 2020). The barn owl (*Tyto alba*) and tawny owl catch the most bats among European owls, accounting for 47.1% and 42.6% of all bats eaten by Eurasian owls (Sieradzki & Mikkola 2020). According to the authors, the most common prey for owls among bat species are common pipistrelles (16.0%), greater mouse-eared bats (*Myotis myotis*) (15.2%), Kuhl's pipistrelles (*Pipistrellus kuhlii*) (11.9%), parti-coloured bats (*Vespertilio murinus*) (9.8%), common noctule (9.1%) and serotine bats (7.3%). These six most frequently eaten species represent 70% of all consumed bats (Sieradzki & Mikkola 2020).

Some individuals of the tawny owl may specialise in hunting bats, especially near large cave colonies (Kowalski & Lesinski 1990, Obuch 1992). For example, in certain sites in Slovakia, bats accounted for more than 50% of all identified mammalian prey (Obuch 1992). In our sample from the Mandrata Cave, bats were a significant component of the owl diet (17.2%), which could be a result of a feeding specialisation of the tawny owl at this site. The Mandrata Cave is permanently inhabited (during both the breeding and wintering seasons) by 5–7 bat species (data from the Bat Research and Conservation Centre – NMNHS-BAS), including lesser horseshoe bats (*Rhinolophus hipposideros*), Mediterranean horseshoe bats (*R. euryale*), greater horseshoe bats (*R. ferrumequinum*), greater mouse-eared bats, lesser mouse-eared bats, long-fingered bats (*Myotis capaccinii*) and common bent-wing bats, which can form colonies of up to 1560 individuals during the breeding season. One of the most numerous species is the common bent-wing bat, forming colonies of up to 1200 individuals in the breeding season. Interestingly, this species has never been found in the owl diet in Bulgaria, but is a relatively frequent prey elsewhere in Europe, as Sieradzki & Mikkola (2020) report 55 common bent-wing bats eaten by barn owl, 39 by tawny owl, one by Eurasian eagle-owl (*Bubo bubo*) and one by little owl (*Athene noctua*).

However, little is known about how bats avoid predation, especially from nocturnal predators such as owls (Strigiformes). A recent study found that some bat species can produce distress buzzes: sounds that mimic those of hymenopteran insects (like hornets and honeybees) to deter owls (barn owl and tawny owl) (Ancillotto et al. 2022).

Bird composition in the diet was very close to that found in the previous studies, as passerines took the bulk (94.3-100 %) of the bird prey (Simeonov 1963, Simeonov 1985, Obuch & Benda 1996). Interestingly, we identified the red-fronted serin in a sample from Ruen Village (Western Rhodopes). This species was reported twice from Bulgaria: from Tazha Hut (Stara Planina Mountain) (Ivanov 2011) and Durankulak (Black Sea coast) (BUNARCO 2013). The closest breeding site is in Western Anatolia (Uludağ Mountain) (Shirihai & Svensson 2018) but it is accidentally found in Austria and Greece (Cramp & Perrins 1994).

In a previous study, conducted by Simeonov (1985), reptiles were presented by three lizard species and one snake, the grass snake (*Natrix natrix*). According to Simeonov (1988), the tawny owl is the most batracholophagous Bulgarian owl, which we can confirm in our study.

Conclusions

A significant diet shift was recorded in the diet of the tawny owl in Bulgaria – vole (*Microtus* spp.) abundance dropped four times in comparison to the previous study (Simeonov 1985). It was compensated by the increasing abundance of bats, field mice and dormice in the diet of the owl. These changes could be a result of climate-related fluctuations in vole populations in Bulgaria.

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