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Diet composition and prey diversity of Tengmalm's owl *Aegolius funereus* (Linnaeus, 1758; Aves: Strigidae) in central Serbia during breeding

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Abstract: Annual variation in the diet, composition, and prey diversity of Tengmalm's owl *Aegolius funereus* (Linnaeus, 1758) was investigated in high-mountain coniferous forests of Mt. Kopaonik (central Serbia) during 3 consecutive years. Prey remains and decomposed pellets (detritus) were collected at the bottom of nest-boxes during 2 separate periods: during mating and after nesting. Prey remains such as maxillae, mandibles, beaks, or feathers were used for prey identification. In total, 438 prey items were separated and identified. Small mammals represented the most numerous class of prey (87.23%). The most frequent prey item was bank vole *Myodes glareolus* (23.29%). During the nesting season the proportion of voles eaten was significantly higher in comparison with the mating period. The mean prey weight was 20.74 g. In the study area, according to diversity index calculations, prey diversity was high and it seems that the number of breeding attempts by Tengmalm's owl showed dependence on the annual abundance of small rodents, but further research is needed to confirm this assertion.

Key words: *Aegolius funereus*, food habits, Kopaonik, Tengmalm's owl, voles, diversity indices

The European continent represents a breeding area for 13 owl species (Mikkola, 1983). Their diet has been well documented for most species, especially in central and northern parts of the continent (e.g., Uttendörfer, 1952; Mikkola, 1983; Birrer, 2009). These diet studies were performed in various habitat types during different seasons and across dissimilar time spans. However, despite such a large number of studies, feeding habits of breeding owl species are still unknown for many vast regions (e.g., mountain ranges). One species that is relatively poorly investigated in such areas, particularly in southeastern and eastern Europe, is Tengmalm's owl *Aegolius funereus*, a small forest-dwelling predator, which occurs in the taiga forest belt across Eurasia and North America (Mikkola, 1983; König and Weick, 2008). In the Balkan Peninsula, the Tengmalm's owl population is regarded as a postglacial relict population (Simeonov et al., 1990). In Serbia, this rare nocturnal predator inhabits high mountain areas (>1000 m) covered with mixed and coniferous forests in the western and southwestern parts of the country (Rajković et al., 2010). Across the European continent, this owl species has been in the focus of numerous feeding ecology studies (e.g., Fredga, 1964; Sulkava and Sulkava, 1971; Jäderholm, 1987; Korpimäki, 1988; Kloubec and Vacík, 1990; Sorbi, 1995; Henrioux, 2010; Zárybnická et al., 2011). Nevertheless, all these studies were carried out in northern and central Europe, whereas data regarding southern relict, isolated, and patchy populations such as those from the Pyrenees or Balkan Peninsula are scarce or completely lacking. So far, for the Balkan Peninsula, there is only one published article about the diet of Tengmalm's owl. This research, based on an investigation of only one family, was carried out on Mt. Rila in western Bulgaria (Simeonov, 1980). Data from other Balkan countries have not been published yet.

The main aim of this study was to describe and analyze the diet composition and prey diversity of Tengmalm's owl from the southeastern border of its distribution range in Europe recorded during the breeding period of 3 consecutive years.

Field work was conducted in part of Kopaonik National Park (hereinafter Mt. Kopaonik) in central Serbia (43.28°N, 20.80°E; altitudinal range 800–2017 m). The study area covered approximately 25 km^2 and is situated in the central part of the national park. About 75% of the study area consists of high-mountain forests (mostly Norway spruce, *Picea abies*), 22% of open grassland-rocky terrain, and 3% of built-up areas. A detailed description of the study area can be found in earlier publications (Rajković et al., 2010, 2013).

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Materials for this diet study were collected during 3 consecutive breeding seasons (2011–2013) in mounted nest-boxes (n = 63) occasionally occupied by territorial males and nesting pairs of Tengmalm's owl. For the purposes of the study, the breeding season was divided into 2 different periods: mating (period before egg laying) and nesting (period after egg laying across incubation and chick raising). This separation is important because of different weather conditions in the period from March to July (e.g., snow depth), miscellaneous prey availability, and prey density in the field. During the mating periods of 2011–2013 all 63 nest-boxes were inspected at least once, and prey stored by territorial males was recorded and marked in order to avoid the possibility of double counting during later audits. Shortly after the end of each of the 3 breeding seasons in the beginning of July, all nest-boxes were inspected for a second time. During 2011 and 2012, no food residues were found during postbreeding nest-box inspection, because there was no successful nesting, but they were present during the nesting period in 2013. During that season, all food remains and decomposed pellets (detritus) were collected from the nest-boxes and separately stored in paper sacs or cardboard boxes. Pellet analysis is a widely accepted method for diet studies in owls including Tengmalm's owl (e.g., Mikkola, 1983). Detritus was air-dried at room temperature and then carefully examined for all diagnostic remains, such as skulls, mandibles, beaks, and feathers, which were separated for further prey identification. The resulting materials were measured and analyzed with a digital vernier caliper and binocular microscope. Prey items were identified to the lowest possible taxon level using a combination of several different identification keys (Tvrtković, 1979; Anděra and Horáček, 1982; Ujhelyi, 1989, 2016; Kryštufek, 1991; Macholán, 1996; Kessler, 2015). The minimum number of individuals (MNI) of each species in each nest-box was estimated by examining and pairing body parts such as maxillae and mandibles in mammals and beaks, sterna, pelvis, and feathers in birds. Biomass was calculated by using the mean body weight (MBW) of individual prey. The MBW of small mammals was taken according to Korpimäki and Sulkava (1987) and Korpimäki (1988), and for the bird prey specimens measurements with the techniques described by Korpimäki and Hakkarainen (2012) were used. Invertebrate prey remains such as chitin parts found in pellets and their residues were also collected, but not included in the results because they constituted a negligible proportion and biomass of the overall diet (n = 9). The data obtained were used to assess the diet of Tengmalm's owl, focusing specifically on prey diversity and diet specialization. Thus, the following indices were examined: species richness (Dmg), evenness (H'), and diet specialization (d). Species richness – number of species per unit area was computed using the Margalef index (Dmg) following the formula S – 1/ln(N), where S = number of species and N = total number of individuals (Magurran, 2004). Evenness – trophic diversity at species level was determined by the Shannon–Wiener index (Shannon entropy, H') calculated by the following formula: $H = -\Sigma (pi) (log2pi)$, where pi = proportion of total sample belonging to i species (Krebs, 1999). To rearrange this index, the obtained value was converted into the effective number of species (ENS), which represents the true diversity, and it is possible to compare this with other communities (Jost, 2006). The diversity of a community with the Shannon–Wiener index (H') equals that of a community with equally common species of exp (H') – the ENS. To investigate the degree of specialization in the diet of Tengmalm's owl, dominant prey was analyzed using the Berger–Parker dominance index (d) using the formula d = nimax/N, where N = total number of prey and nimax = number of most frequent prey item (Magurran, 2004).

The descriptive statistics and basic calculus were calculated using Microsoft Office Excel. Quantitative measurements of diversity indices were calculated using the Biodiversity Calculator (https://www.alyoung.com/labs/biodiversity_calculator.html). The used level of significance was $P < 0.05$.

During the research period, 21 nest-boxes were used by Tengmalm's owl: 12 were used as prey storage by males during the mating season (2 boxes in 2011, 4 in 2012, and 6 in 2013) and 9 by pairs during the nesting season (2013) as active nests. These nest-boxes contained 438 prey items (MNI): 60 of them were stored during the mating period and 378 belonged to remains from the nesting period (as shown in Table 1).

Analyzed prey animals belonged to 2 classes (Aves and Mammalia), which included 6 bird families (Turdidae, Phylloscopidae, Regulidae, Muscicapidae, Paridae, and Fringillidae) and 4 mammal families (Soricidae, Cricetidae, Muridae, and Gliridae). These were represented by 8 species of small mammals and 8 species of passerine birds (as shown in Table 2). Small mammals were the dominant taxonomic class, constituting 87.21% (mating 58.33% and nesting 91.8%) of identified prey items and 86.33% (mating

Table 1. The numbers of prey items recorded during three breeding periods (2011–2013) for Tengmalm's owl *Aegolius funereus* on Mt. Kopaonik, central Serbia.

Period/year	2011	2012	2013	Total
Mating	13	19	28	60
Nesting	0	0	378	378
Total	13	19	406	438

Table 2. The overall diet of Tengmalm's owl *Aegolius funereus* recorded during three breeding periods (2011–2013) on Mt. Kopaonik, central Serbia (MBW – mean body weight; MNI – minimum number of individuals; BF – biomass frequency).

Prey species (MBW)	MNI	Frequency (%)	BF (%)
Erithacus rubecula (17 g)	3	0.68	0.56
Turdus merula (90 g)	1	0.23	0.99
Turdus philomelos (67 g)	2	0.45	1.48
Phylloscopus collybita (8 g)	1	0.23	0.09
Regulus sp. (6 g)	8	1.82	0.53
Parus ater (9 g)	9	2.05	0.89
Fringilla coelebs (22 g)	7	1.60	1.69
Pyrrhula pyrrhula (34 g)	1	0.23	0.37
Loxia curvirostra (41 g)	6	1.37	2.71
Passeriformes	18	4.11	4.36
Aves total	56	12.77	13.67
Sorex minutus (3.5 g)	7	1.60	0.27
Sorex araneus (7.5 g)	19	4.34	1.57
Crocidura suaveolens (8 g)	1	0.23	0.09
Microtus arvalis (25 g)	1	0.23	0.27
Microtus subbteraneus (18 g)	72	16.44	14.27
Myodes glareolus (17 g)	102	23.29	19.09
Microtus sp. (25 g)	18	4.11	4.95
Apodemus flavicollis (35 g)	49	11.19	18.88
Apodemus sp. (25 g)	59	13.47	16.24
Muscardinus avellanarius (18 g)	54	12.33	10.7
Mammalia total	382	87.23	86.33
Total (Aves + Mammalia)	438	100	100

62.8% and nesting 89.99%) of biomass. The majority of prey within the taxonomic class of small mammals were *Microtus* and *Myodes* voles with a share of 44.06% of the total diet (mating 38.33% and nesting 44.97%). Significant differences in the diet composition of Tengmalm's owl between mating and nesting periods were found ($t = 2.42$, $df = 28$, $P < 0.05$). The amount of preyed voles (*Myodes* and *Microtus* species) was significantly higher in the nesting period than the mating period ($\chi^2 = 149.91$, $df = 1$, $P < 0.05$). Numerically, the most important prey species was bank vole *Myodes glareolus*, followed by European pine vole *Microtus subterraneus*, hazel dormouse *Muscardinus avellanarius*, and yellow-necked mouse *Apodemus flavicollis*. These species together formed 63.2% of the total number of caught animals and 62.9% of total biomass.

The mean prey weight was 20.74 g (SD = 8.85; range 3.5–90 g). The difference between the mean weight of preyed mammals in the mating (20.38 g) and nesting (20.80 g) periods was not statistically significant (Mann–Whitney U test; $U = 11962$, $Z = –0.16$). The mean weight of preyed bird items was slightly higher than that of mammals (22.17 vs. 20.71 g).

According to collected data, species richness increased from 2011 to 2013. Mean H' value converted into ENS has the diversity equal to a community with approximately 6 equally common species. By using the d index, it was found that Tengmalm's owl showed a low level of diet specialization (as shown in Table 3).

This study is the first to describe the diet of Tengmalm's owl in Serbia and the rest of the western Balkan Peninsula. Previous research in Europe reported that the diet of Tengmalm's owl during the breeding season is variable, although some general conclusions can be made. The European studies (n = 26), which were done during the breeding period, revealed that the diet of Tengmalm's owl consisted of small mammals from 92.1% on average (range: 34.0–99.2%; compiled by Korpimäki and Hakkarainen, 2012). The data about the average proportion of small

Table 3. Prey diversity and diet specialization during three breeding seasons (2011–2013) for Tengmalm's owl *Aegolius funereus* in Mt. Kopaonik, central Serbia.

Index	2011 mating	2011 nesting	2012 mating	2012 nesting	2013 mating	2013 nesting	Mean
D_{mg}	1.56	-	2.04	-	2.08	2.65	2.08
H'	1.52	-	1.91	-	1.69	1.86	1.74
d	0.31	-	0.21	-	0.33	0.31	0.29

mammal prey obtained in this study almost completely overlap with data collected in central and north Europe. On the other hand, in comparison with a previous study from the Balkans, from Mt. Rila (Simeonov, 1980), there are notable differences in the proportions of prey classes and species. First, the proportion of mammal prey was significantly lower in the Bulgarian sample than in this study. Second, the share of voles from Mt. Rila was markedly lower compared to this study and studies conducted elsewhere in Europe (Korpimäki and Hakkarainen, 2012). However, results from Mt. Rila should be interpreted with caution, because the research was carried out during only 1 summer study period at 1 nest site. In the present study from Mt. Kopaonik, it seems that bird species also represented only a periodical food source, which correlates with the data from the rest of Europe (Simeonov, 1980; Mikkola, 1983; Korpimäki and Hakkarainen, 2012).

If we focus on lower taxonomic categories, in northern Europe, the diet of Tengmalm's owl consists mainly of voles (e.g., Korpimäki, 1986a; Jäderholm, 1987; Korpimäki, 1988; Hörnfeldt et al., 1990). However, in central Europe this was not the case for a significant proportion of conducted studies (Scheuren, 1970; Klaus et al., 1975; Zang and Kunze, 1978; Mezzavilla et al., 1994; Schwerdtfeger, 1988; Zárybnická et al., 2013). It should also be kept in mind that *Apodemus* mice are rare or completely absent in northern Europe in comparison with central parts of the European continent (Jäderholm, 1987).

The Tengmalm's owl population of Mt. Kopaonik mainly fed on voles, but it should also be noted that alternative prey species are a very important part of the diet, at least in poor vole years. For example, hazel dormouse seems to have played a significant role in the diet and high numbers were preyed upon, especially in the early stage of the nesting period (March to early April). This is an unusual phenomenon for early spring because the majority of individuals of this dormouse species should be in hibernation at this time (Kryštufek, 1991). The proportion of hazel dormouse with 11.3% of the total diet represents the highest such prey rate ever recorded in Europe (Korpimäki and Hakkarainen, 2012).

Across Europe, proportions of dominant prey species or genera vary considerably and mostly depend on population cycles of small mammals (Hanski et al., 1991; Hörnfeldt, 1994; Pykal and Kloubec, 1994; Pokorný et al., 2003). In years with high abundance of small mammals Tengmalm's owl breeds successfully, but when there are fewer rodents (particularly voles) available, the owls usually skip breeding or migrate to other areas in search of food (Korpimäki, 1992a, 1992b, 1992c). As Tengmalm's owl in Mt. Kopaonik seems to be affected by fluctuations in the populations of small mammals, the present study implies that the above mentioned statement is true, at least for the central part of Serbia.

The mean weight of the prey of Tengmalm's owl in Europe was 20 g (Korpimäki and Hakkarainen, 2012). In this study we obtained a very similar value for Mt. Kopaonik. The number of *Sorex* and *Crocidura* shrews (low-weight prey) on Mt. Kopaonik was lower in comparison with most European studies. The number of *Apodemus* mice (heavy-weight prey) was higher in comparison with most European studies, especially from the northern part of the continent. Common vole *Microtus arvalis* represents an unusual prey item, which is only rarely found within closed native high-mountain coniferous forests in Serbia (Petrov, 1992).

The diversity of prey species recorded during this study was higher in comparison with other European studies and clearly correlates to the central and southern European pattern of this parameter, i.e. the number of species of alternative prey in overall diet increases southwards (Korpimäki, 1986b; Korpimäki and Hakkarainen, 2012).

The values using the H' index also demonstrated moderate or high prey diversity, which is the opposite of the d index. Schoener (1971) stated that diet diversity of predators should increase when the abundance of preferred prey decreases. This would be true for Mt. Kopaonik if we agreed that the most commonly selected prey items of Tengmalm's owl were voles. An inverse correlation has been found between the index H' and d, which indicates regularity in diet, which probably indicates that the main prey of Tengmalm's owl consists

of voles (primarily *Myodes glareolus* and *Microtus subterraneus*) and that some exceptions in diet are caused by changes in the abundance of this obviously crucial trophic resource (Love et al., 2000). In the case of Mt. Kopaonik, these deviations consisted of a significant share of *Apodemus* mice and hazel dormouse as alternative prey in the owl's diet. As a conclusion from the findings in this paper and according to the feeding habits of Tengmalm's owl on Mt. Kopaonik, this nocturnal species can be characterized as facultative predator on small mammals and a more generalist than specialist avian predator in central Serbia.

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