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Diet composition of the lizard *Lacerta viridis* (Laurenti, 1768) (Reptilia: Lacertidae) in Bulgaria confirm its generalistic feeding behaviour

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Abstract: The eastern green lizard (*Lacerta viridis*) is a mostly insectivorous species, based on multiple studies from across its range. However, for Bulgaria the published data of such kind are limited to five publications. We investigated faecal samples from a total of 60 individuals of free-ranging *L. viridis* obtained from two localities in western Bulgaria. Our aim was to clarify the diet regarding its taxonomic composition, as well as some physical characteristics of the prey like hardness and evasiveness. For one of the study sites we compared the realised trophic niche (prey items from the faecal pellets) with the fundamental niche (invertebrates collected via pit-fall traps exposure). In our results, two invertebrate taxa had the largest share (both in frequency and abundance) in the food spectrum of *L. viridis*: Araneae and Coleoptera), respectively 21.2% and 17.6%. Regarding specific prey selectivity, analysis showed that Lepidoptera are most preferred (E* = 0.68), and Formicidae – most avoided prey items (E* = -0.79). We registered several cases of saurophagy (in four samples) and keratophagy (in two samples), two types of dietary items, which have not been reported for *L. viridis* so far.

Keywords: Balkan Peninsula, diet, keratophagy, Sauria, saurophagy

Introduction

The family Lacertidae represents the most diverse group among the lizards in Europe. Generally, lacertids feed on a wide variety of arthropods, mostly insects, and could be considered generalist predators (Arnold, 1987; Carretero, 2004).

The eastern green lizard *Lacerta viridis* (Laurenti, 1768) is relatively large in size [it can reach up to 150 mm SVL (see Vacheva et al., 2022)] and shaping the distribution and habitat use of many of the other smaller lizard species (Maura et al., 2011; Kovács & Kiss, 2016). *L. viridis* occurs in central and southern Europe (from eastern Germany and central Poland in the north, to southern Greece in the south, and from central Austria in the west, to eastern Ukraine in the east), as well as in northern Asia Minor (Ananjeva et al., 2006; Sillero et al., 2014). In Bulgaria, *L. viridis* is widespread from the sea level up to ca. 1200, and in some places up to 1600–1800 m a.s.l. (Stojanov et al., 2011). It inhabits open landscapes or meadows with sparse bush vegetation and forest edges, but also areas densely covered with bushes or sparse forests (Stojanov et al., 2011; Vacheva et al., 2020). *Lacerta viridis* is considered as a mostly insectivorous species and there are several studies on its diet from different parts of its range (e.g. Korsós, 1984; Arnold 1987; Sagonas et al., 2018). In Bulgaria, the diet of the species has been studied on the basis of stomach content by Angelov et al. (1966, 1972), Donev (1984), Donev et al. (2005), and Mollov et al. (2012). Taken together, these five publications give a fairly good idea of the *L. viridis* diet in Bulgaria, but it should be noted that they are based on material collected more than 40 years ago; furthermore, they do not provide comparisons of the food spectrum with the potential food resource in the habitats.

The main purpose of the present work was to collect up-to-date data on the feeding of *Lacerta viridis* in two regions of Bulgaria using a non-invasive...
method, as well as a comparison between consumed prey and the available food resources.

Material and methods

Field work was conducted in two sites, situated in western Bulgaria, as follows: (1) the area of Gabrovitsa Village, Sredna Gora Mts (N42.2602°, E23.9208°, 430–570 m a.s.l.; the site was visited periodically in the spring (April–June) and summer (July–September) of 2017–2018) (a total of 25 field days); (2) the eastern shore of the Ogosta Reservoir, Predbalkan Mts (N43.3739°, E23.2086°, 180–240 m a.s.l.; the site was visited sporadically in 2013–2016) (28 field days in total). Detailed descriptions of the studied sites are provided by Vacheva et al. (2020). In both sites, the lizards were captured by hand, measured [snout-vent length (SVL) to the nearest 1 mm via transparent ruler] and then placed individually in plastic boxes and kept in the laboratory until defection (up to ca. 48 hours); individuals were then released at the place of capture. Age class was determined based on size, external morphology and colouration. We considered adult SVL to be > 85 mm according to Tzankov (2007) and juveniles and subadults grouped in a single category (immatures), which were < 84.9 mm. The faecal pellets thus obtained were preserved in Eppendorf tubes with 75% ethanol. In Gabrovitsa, we assessed the potential prey availability for *L. viridis* by placing 24 pit-fall traps for collecting invertebrates. The pit-fall traps (plastic containers, 9.5 cm wide and 12 cm deep, filled with propylene glycol) were situated in different microhabitats (four series of six traps, 10 metres apart) and were exposed for a total of 79 days (2017: 23 days in spring (May and June) and 16 in summer (August and September); 2018: 17 and 23 respectively). Collected material was preserved in 75% ethanol.

Fixed material was examined under a stereomicroscope with a magnification of 10–40×. Both prey remains from the faecal pellets and invertebrates from the pit-fall traps were identified to the lowest possible systematic level and grouped into “operational taxonomic units” (hereafter OTU/OTUs). The OTUs from the faecal pellets were also categorised regarding their evasiveness [sedentary (E1), intermediate (E2), and evasive (E3)] and hardness [soft (H1), intermediate (H2), and hard (H3)] according to Verwaijen et al. (2002) and Vanhooydonck et al. (2007).

Correlation between abundance and frequency of the prey items, found in the faecal pellets, was described and tested via Spearman’s rank correlation coefficient (Rho). Chi-square (χ^2) test was used for a comparison between adults and immatures regarding the categories of evasiveness and hardness of the prey items. Statistical procedures were performed using PAST 4.07 (Hammer et al., 2001). Prey selection (for the samples from Gabrovitsa) was analysed on the basis of a comparison between relative abundance of the OTUs in the faecal pellets and in the pit-fall traps using the electivity index (E*) of Vanderploeg & Scavia (1979). The index represents a modification of the Ivlev’s forage ratio, but has better theoretical justification (Lechowicz, 1982). It takes values from -1 to +1 and can be explained as a measure of deviation from random feeding (E* = 0). In this study, the index values were interpreted as follows: E* > 0.5 (preferred OTUs); 0.5 ≥ E* ≥ -0.5 (neutral OTUs); E* < -0.5 (avoided OTUs). The OTUs represented by low relative abundance (< 0.2%) were excluded, because according to Lechowicz (1982) the index is vulnerable to sampling errors for food types that are rare.

Results

A total of 60 faecal samples from *Lacerta viridis* were collected: respectively 49 from Gabrovitsa [15 from adult (SVL > 85 mm) and 34 from immature lizards (SVL<84.9 mm)] and 11 from Ogosta (from immature lizards only). The remains of invertebrates in the faecal pellets were attributed to 278 individuals belonging to 18 OTUs (respectively 238/14 for the sample from Gabrovitsa and 40/10 for those from Ogosta; Supplementary material 01: Appendix 1). The average number of (individual) invertebrate remains per the individual faecal pellets was 4.63 (from Sample from Gabrovitsa between 1 and 14, mean 4.86 and from Ogosta between 1 and 11, mean 3.64).

In the samples from Gabrovitsa, four of the OTUs (Coleoptera, Araneae, Auchenorrhyncha, and Orthoptera) were found in above 30% of the faecal pellets and three of them (Araneae, Coleoptera and Auchenorrhyncha) also prevailed in number of individual remains (over 10%). Divided the lizards into age categories (although samples are not equal in number), in the adults the predominant OTU (both in frequency and in abundance; respectively 60.00 and 30.88%) was the order Coleoptera, while in the im-
Diet composition of the lizard *Lacerta viridis* (Laurenti, 1768) in Bulgaria confirm its generalistic feeding behaviour matures it was the order Araneae (67.65 and 23.53% respectively). In the samples from Ogosta, the only predominant OTU (both in frequency and abundance) was Araneae (Fig. 1), but it should be kept in mind that this sample consisted only of immature lizards. Correlation between the abundance and frequency of occurrence of OTUs in the faecal pellets was positive with a high level of significance in both samples (Gabrovitsa: Rho = 0.987, p < 0.001; Ogosta: Rho = 0.912, p = 0.008). The invertebrates collected by the pit-fall traps from Gabrovitsa were attributed to 25 OTUs, with Formicidae and Araneae being the most abundant (Fig. 1; Supplementary material 01: Appendix 2). According to the electivity index values (Table 1) three of the OTUs were categorised as preferred prey of *L. viridis* (Lepidoptera, Orthoptera, and insect larvae), two as avoided (Formicidae and Diptera), and the rest as neutral.

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Fig. 1. Percentage share of the OTUs according to: number of faecal samples of *L. viridis* in which the OTU was found (Fr.); number of specimens registered in the faecal samples (N); number of specimens, collected by pit-fall traps (Tr.).
Regarding the evasiveness of the prey, in both study sites the sedentary prey predominated in the faecal samples (Fig. 2). In terms of hardness, hard prey items predominated in Gabrovitsa, and soft – in Ogosta (Fig. 2). When dividing the sample from Gabrovitsa into adults and immatures, the remains of prey with a medium degree of evasiveness and high degree of hardness predominated in the adults (respectively 50.00 and 67.19% of the identified invertebrates), while in the immatures the remains of low evasiveness and low hardness prevailed (respectively 51.90 and 48.73%). Differences between adults and immatures in this regard were statistically significant (evasiveness: $\chi^2 = 12.131$, df = 2, $p = 0.0023$; hardness: $\chi^2 = 15.286$, df = 2, $p = 0.0005$).

Besides invertebrates, remains of lizard body parts (an evidence for expression of saurophagy) and lizard shed skin parts (i.e. expression of keratophagy) were also found in the faecal pellets of *L. viridis* from Gabrovitsa. Saurophagy was recorded in 4 immature individuals: remains of *Ablepharus kitaibelii* Bibron & Bory de Saint-Vincent, 1833 in the faecal sample of a juvenile *L. viridis* (SVL = 36 mm) and remains of lacertid lizards (undefinable to species level) in the faecal pellets of 3 subadults. Keratophagy was observed in two immatures (subadult females). Plant remnants were observed in the faecal pellets of 6 immature and 3 adult individuals.

**Discussion**

Our results confirmed that *Lacerta viridis* is an active predator, whose diet includes a wide variety of invertebrates. Observed feeding activity (4.63 ingested invertebrate individuals on average) was higher than in previous studies of the species, where the given values ranged between 3.2 and 4.2 (Angelov et al., 1966, 1972; Donev, 1984; Donev et al., 2005; Sagonas et al., 2018). According to our results, the order Araneae and order Coleoptera have the largest share in the

![Table 1. Electivity index values (E*) for the sample from Gabrovitsa; symbols [>, [=], and [<] denote preferred, neutral, and avoided prey, respectively.](image-url)

![Fig. 2. Percentage share of the categories of evasiveness and hardness according to the number of categorised prey items from the faecal samples of *L. viridis* (Ad. = adults; Imm. = immatures; Tot. = the entire sample).](image-url)
food spectrum of *L. viridis*. The main role of Coleoptera as prey of *L. viridis* has been highlighted in other studies (Angelov et al., 1966, 1972; Scheberbak & Shcherban, 1980; Donev, 1984; Donev et al., 2005; Sagonas et al., 2018). However, there are also studies according to which Lepidoptera larvae (Korsós, 1984) or Orthoptera (Mollov et al., 2012) have the largest share in the diet of the species, but in both cases the second place falls to Coleoptera. Order Araneae have not been identified as a major component in the diet of *L. viridis*, while in our case exactly the Araneae were consumed the most both in frequency and in numbers (summarised for both samples). This is most likely due to the fact that our sample consisted mainly of immature lizards, whereas most similar studies seem to have been based mainly on adults.

The diet of young *L. viridis* differs from that of adults, with juveniles preferring softer and smaller prey (Sagonas et al., 2018). Our data also showed a predominance of soft (and sedentary) prey in immaturity as opposed to adult lizards. To a large extent, this is determined by the amount of spider remains in the faecal pellets: Araneae was the most abundant and frequent OTU in immatures, but completely absent in adults. Differences in diet between adult and young lacertids may result from morphological differences, i.e. the smaller size of the immatures, especially in terms of head size, determines the smaller bite force (Herrel & O’Reilly, 2006; Urošević et al., 2013). Ontogenetic differences in feeding undoubtedly depend also on a number of ecological factors, e.g. microhabitat choice, thermal preferences, etc. (Herczeg et al., 2007).

The comparison between consumed prey and available food resources (done for the sample from Gabrovitsa) showed that at least two of the OTUs are subjects to active selection (positive or negative) by *L. viridis*: Lepidoptera, as preferred prey, and Formicidae, as avoided prey. Such kind of analysis (using electivity indices) has not been done regarding the feeding of *L. viridis* this phenomenon occurs rarely. Plant remains were recorded by us in 18% of the examined faecal pellets from Gabrovitsa, both in adult and immature lizards (in contrast to Sagonas et al. 2018, who recorded plant remains only in adult *L. viridis*). The origin of these plant parts is not clear; it is possible that they were accidentally ingested simultaneously with other food components or contained in the stomachs of ingested invertebrates. On the other hand, the presence of plant components in lacertids diet is not uncommon, especially in large species, as an addition to their basic food (Van Damme, 1999; Carretero, 2004; Sagonas et al., 2015; 2018). It should be noted that no evidence of saurophagy and keratophagy or ingestion of plant material was found by us from Ogosta, which could be explained by the significantly smaller size of this sample (11 individual faecal pellets from Ogosta vs 49 from Gabrovitsa).

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**Supplementary materials**

01

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New records of *Suncus etruscus* (Soricidae, Mammalia) and its current status in Bulgaria

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Abstract: We present 17 new records of *Suncus etruscus* in Bulgaria, and the first finding of the species north of Stara Planina Mountains. The species is recorded in the diet of three owl species – *Tyto alba*, *Asio otus* and *Athene noctua*, and one bird of prey – *Aquila heliaca*. The bulk of records originated from *T. alba*, in the rest raptor species it is taken randomly and consists negligible part of their diet. Additionally, five dead shrews were used, which provided hard evidence for the presence of *S. etruscus* in north Bulgaria. All data on the species distribution in Bulgaria are summarised and the roads for its invasion are discussed. Climate change is considered as an expansion trigger for spreading of the Etruscan shrew.

Keywords: climate change, distribution, Etruscan shrew, expansion, owl pellets

Introduction

The Etruscan shrew (*Suncus etruscus* Savi, 1822) is one of the smallest living mammals in the World, with a weight of 1.2–2.3 g. (Burgin & He, 2018). Because of its small size, it is difficult to study its ecology and biology with traditional methods for small mammal research – different models of live traps (Longworth, Sherman, Trip-Traps etc.) or snap traps. It is too small to trigger the traps, however, some improvements and modifications of traps have been made (Vogel, 2012). One of the best methods for mapping its distribution is the study of owl pellets (Kahmann & Altner 1956, Lipej & Kryštufek, 1991, Popov et al., 2004).

In Europe, it is strictly confined to the Mediterranean belt, including many islands (Spitzenberger, 1990; Libois & Fons, 1999). The distribution of *S. etruscus* is often explained via simple climatic factors such as isotherms. Kahmann & Altner (1956) suggest that its distribution is limited by mean annual isotherms of +12 °C. This viewpoint is adopted by Popov & Nijagolov (1991) for Bulgaria as well. According to Libois & Fons (1999) its distribution is limited to the mean July isotherm of 20 °C, while Lipej & Kryštufek (1991) propose that it is limited to the mean January isotherms of 0 °C. Vohralík & Sofianidou (2000) argue that such a simplification to only one climatic factor determining its distribution is unlikely, and some biological factors as competition with other shrews might limit its distribution.

The Etruscan shrew was first time found in Bulgaria relatively soon by Vohralík (1985) who reported a dead individual found near Burgas in 1980. Later, Popov et al. (2004) summarised its distribution (mainly from pellets of *T. alba*) in south-eastern Bulgaria. Since then, many new materials have been accumulated in different regional studies of small mammals or the diet of owls. This paper aims to provide new data about the distribution of *S. etruscus* and to
summarise and analyse all available information about it in Bulgaria.

**Material and methods**

During the period 2000–2023, we collected and analysed pellets and food remains from different birds of prey, and owls from various parts (mainly from the northeast and southeast) of Bulgaria. In total – 50173 individuals of small mammals are found in the pellets and food remains of the following species: the barn owl (Tyto alba Scopoli, 1769) – 38811 small mammals, from 108 localities; the eagle owl (Bubo bubo Linnaeus, 1758) – 168 from 5 localities, tawny owl (Strix aluco Linnaeus, 1758) – 569 from 7 localities; little owl (Athene noctua Scopoli, 1769) – 2230 from 35 localities; long-eared owl (Asio otus Linnaeus, 1758) – 6145 from 23 localities; long-legged buzzard (Buteo rufinus Cretzschmar, 1829) – 643 small mammals from 31 localities; and eastern imperial eagle (Aquila heliaca Savigni, 1809) – 1607 small mammals from 30 localities. Owl pellets are good and reliable tool for studying small mammal communities and detecting rare species (Heisler et al., 2016) and particularly S. etruscus (Kahmann & Altner, 1956; Lipej & Kryštufek, 1991). Some additional material from three dead shrews found in the vicinity of Samovodene Village (Veliko Tarnovo District, 1.04.2024, N 43.128426, E 25.578186, elevation – 322 m), and two shrews collected with pit-fall traps from Cape Emine along the Black Sea Cost – Irakli (NH73, 15.08.2010, N 42.758339, E 27.892144, elevation – 34 m) and Obzor City (NH74, 30.03.2010, N 42.783881, E 27.896111, elevation – 11 m), were used. The shrews from Samovodene Village were found mummified on the ground. The shrews are preserved in 96% alcohol and deposited in the mammalian collection of the National Museum of Natural History – Sofia (NMNHS), and in the zoological collection of the University of Forestry. Skulls were extracted and cleaned with dermestid beetles. On the upper jaw 4 unicuspids are visible, a characteristic feature that distinguishes *Suncus* from *Crocidura* shrews. Determination of materials is done following Peshev et al. (2004) and craniometrical data presented by Popov et al. (2004).

Data visualisation is performed using ArcGIS 10.3.1 (ESRI, Redlands, CA, USA) and mean annual temperature (BIO1) from WorldClim 2 (Fick & Hij-
Remains of *S. etruscus* were uncovered from pellets of *T. alba*, *A. otus*, *A. noctua* and *A. heliaca* (Table 1). The bulk of records came from *T. alba* pellets. The Etruscan shrew was found in 71 localities (UTM 10×10 km square) in Bulgaria as 17 of them are new ones and most are close to already reported localities in the south-eastern part. The relative abundance of *S. etruscus* varies between 0.86–13.51% from all identified shrews in the samples, with an average of 2.27% of the shrews in samples consisting of more than 100 shrews. Among the other found shrew species are *Crocidura sueaveolens* Pallas, 1811, *C. leucodon* Hermann, 1780, *Sorex minutus* Linnaeus, 1766, *S. araneus* Linnaeus, 1758 and *Neomys milleri* Mottaz, 1907. The Etruscan shrew was a negligible part from the diet (<0.06%) of *A. otus, A. noctua* and *A. heliaca*, it was presented by a single individual. Despite the large sample size, we did not find *S. etruscus* in the diet of *S. aluco*, *B. bubo* and *B. rufinus*.

The Etruscan shrew was recorded for the first time from the Eastern Rhodopes Mountains – Malki Voden Village (UTM – MG11), and from the foothills of the mountain – Malko Gradishte (MG12) and Slaveevo Village (MF29). The records of *S. etruscus* from north Bulgaria should be highlighted – Samovodene Village (LH87) and Maslarevo Village (LG37). These are the first records of the species north of Stara Planina Mountains.

The presented current distribution of *S. etruscus* (Fig. 1) includes our new data and published ones.
(Vohralík, 1985; Popov & Nijagolov, 1991; Vohralík & Sofianidou, 2000; Popov, 2000; Popov et al., 2004; Georgiev, 2004; Georgiev, 2005; Stoycheva & Georgiev, 2005; Milchev et al., 2006; Milchev, 2012; Nedyalkov & Koshev, 2014; Milchev, 2022; Nedyalkov et al., 2023). All records, even those from the northern part of Bulgaria, are within the annual isotherms of +12 °C (Fig. 1). It seems this simple climatic factor could explain much of the species distribution.

Discussion

Despite its small size and imperfect thermoregulation, the Etruscan shrew shows great invasion and dispersal ability. For a long time it remained unclear and questionable the origin of *S. etruscus* in Europe, as several hypotheses were applied (García et al., 2020). The recent revision of paleontological materials (García et al., 2020) revealed its Asian origin, and that the species arrived in Europe via the Eastern Mediterranean area approximately 4000 years ago (Late Holocene). This colonisation route is also supported by genetics (Castiglia et al., 2023).

There are no fossil records from Bulgaria (Popov, 2018), unfortunately, there are a few Holocene sites with small mammals from south Bulgaria and the archaeological sites are not adequately sampled for small mammals.

According to Popov et al. (2004) *S. etruscus* invaded Bulgaria via the valleys of the Maritsa and Tundzha rivers, but not along the Black Sea Coast. The species occurs in the lowlands of SE Bulgaria – Thracian Valley and most of the records are along the basin of these two rivers. Our new records showed that *S. etruscus* has been also using the valley of the Arda River to penetrate the Eastern Rhodopes Mountains – supported by our records from Slaveevo (MG11) and Malki Voden (MG29). The Eastern Rhodopes are characterised by the Mediterranean climate and biota (plants and animals) spreading through the Arda River Valley (Gruev & Kuzmanov, 1999). Other Mediterranean species found in the area are Roach’s mouse-tailed dormouse (*Myomimus roachi* Bate, 1937), found together with *S. etruscus* in Malki Voden (MG11) (Nedyalkov, 2013) and Harting’s voles (*Microtus hartingi* Barrett-Hamilton, 1903) widely distributed and common in the lower part of Arda River (Ivailovgrad District).

The Balkan Mountains (Stara Planina) is a long mountain chain (560 km) with a width between 15–45 km and a mean height of 722 m (the highest peak – 2376 m). It stretches east-west across central Bulgaria serving as a bioclimatic barrier and dividing the country into two well-defined parts – southern with a Mediterranean (or sub Mediterranean) climate (excluding the high mountains), and northern – with a moderately continental climate (Kopralev, 2002). Stara Planina is a biological barrier and prevents the free exchange of plants and animals (Gruev & Kuzmanov, 1999).

One of the potential routes for invasion in north Bulgaria is via the mountain pass – Pass of Republic (highest point 700 m) and the valley of Belitsa and Yantra rivers, as both our records from the north are within or close to the valley of Yantra River. The highest record of *S. etruscus* from the Balkans is about 600 m (Vohralík & Sofianidou, 2000), but in Anatolia it is found up to 1300 m (Kryštufek & Vohralík, 2001). *S. etruscus* is reported from the southern slopes of Apls in Slovenia (Kryštufek, 2003).

This route is supported by records from the southern slope of Stara Planina – Kazanlak Valley, where the species has been found in owl pellets (Milchev, 2012).

Another invasion hypothesis of north part of Bulgaria includes overcoming of Balkan Mountains trough their edge at Black Sea Coast and subsequently using the Kamchia or Danube valleys to reach the Yantra Valley and the Danubian Plain. Similar distribution patterns could be recognised in a variety of other Mediterranean species (*Pelobates syriacus* Boettger, 1889, *Testudo graeca* Liannaeus, 1758, *Lacerta trilineata* Bedriaga, 1886, *Pseudopus apodus* Pallas, 1775, etc.) (Stojanov et al., 2011). Our record of the species in the Cape Emine area confirms such a hypothesis. However, it needs to be proved by more extensive work and sampling along the expansion routes.

The reported new records showed a rapid disperse of *S. etruscus* in Bulgaria, as it has managed to pass the main barrier between south and north Bulgaria – Stara Planina, probably it has happened in the last few decades. It seems the species invaded the new territories in Bulgaria via river valleys – Maritsa River, Tundzha River, Arda River and Yantra River. Potential routes for invasion of north Bulgaria are the mountain passes in the eastern part of Stara Planina or along the Black Sea Coast. The expansion of ther-
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moxerophilic Mediterranean species as *S. etruscus*, in areas with continental climate could be driven by climate change and warming of the region. Similar effect is registered on small mammals in Italy, where *S. etruscus* spread (for over 30 years) to new territories (Szpunar et al., 2008). Owl pellets are a powerful tool for mapping and tracing the distribution of *S. etruscus* in Bulgaria, more attention, and samples from the north and southwestern part of Bulgaria are needed. According to the map, there is potential suitable conditions for the species in the southwestern part of Bulgaria – valleys of Struma and Mesta rivers. The species is recorded in Greece close to the border (Hellenic Zoological Society, 2023).

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The terrestrial gastropods (Mollusca: Gastropoda) of the Mavrovo National Park, North Macedonia

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Abstract: Sixty-one species taxa of land gastropods are known for Mavrovo National Park, and 34% of them are species taxa of high conservation value. Considering the unsystematic surveys in the area, it can be assumed that in the future the number of species taxa will significantly increase. The status of Mavrovo as a national park under high protection, and there are no immediate threats to the malacoфаuna. Potential problems for invertebrate communities, including snails, would be big destructive changes in their habitats and especially the presence of hydropower projects and stone quarries. The protection of the species habitats from human activity and different types of modification is the best protection measures for the mollusk fauna in Mavrovo National Park.

Keywords: Bistra Mountain, Deshat Mountain, Korab Mountain, newly recorded taxa for the fauna of North Macedonia, protected area, Shar Mountain, Western Balkans

Introduction

Mavrovo National Park (Mavrovo NP) is the largest protected area in North Macedonia. Mavrovo NP is located in the northwestern part of the country and covers the area around lake Mavrovo, the upper and lower streams of the Radika River, as well as the Mountains of Korab, Deshat, the southwestern ends of the Shar Mountain, the greater part of Bistra and the northern parts of Krčin. The park protects high diversity of habitats and numerous rare and endemic animals, plants and fungi, and a significant part of its territory has a carbonate base (SSO, 2011; Melovski et al., 2013). While plant and vertebrate diversity is relatively well studied, knowledge of invertebrates, especially for land snails, is rather poor and fragmentary.

Summarising scientific publications on the terrestrial snails of Mavrovo NP or any of its subdivisions are practically non-existent. The published information about the malacoфаuna of the area is the result of unsystematic and episodic collections. Information on land snails from the area of Mavrovo NP can be found in the work of Pavlović (1911). The author reports several species from Mountain Bistra, mainly from and around the Galichnik Village: Chondrula tridens, Jaminia quadridens (as Chondrula quadridens Müll.), Laciniaria plicata (as Alinda plicata Drp.), Merdigera obscura (as Buliminus (Ena) obscurus Müll.), Oligolimax annularis (as Vitrina annularis Venetz.), Truncatellina cylindrica (as Isthmia minutissima Hartm.), Vallonia costata, Xerolenta obvia obvia (as Xerophila obvia (Ziegler.) Hartm.). Nordsieck (1974) described the species Euxinella radikae radikae for Bistra Mountain. Riedel (1985) found the species Gyralina (Spelaepatula) korabensis in the Macedonian
part of Korab Mountain, near the Žirovnichka and Kadina Dupka Caves. Wiktor (1996) lists the following species for the area: *Arion subfuscus* (Mavrovo NP), *Deroceras laeve* (Mavrovo NP, lake shore), *Deroceras turcicum* (Bistra Mountain, Carevec Ridge, limestone mountain pastures, 1400–1500), *Lehmannia brunneri* (Mavrovo NP, *Abies* forest, 1700–1900 and Carevec Ridge, limestone mountain pastures), *Tandonia albanica* (3 km before Mavrovi Hanovi on the road to Debar; 6 km before Tmica (the road to Debar) and St Jovan Bigorski Monastery (St John the Baptist), *Abies* forest; 1700–1900). Nordsieck (2008) published *Alinda biplicata* for Radika Valley below Mavrovi Hanovi; Mavrovo towards Galichnik, Bistra Mountain near Galichnik. In summary work on the genus *Montenegrina* Fehér & Szekeres (2016), for the area of the Mavrovo NP and its surroundings, reported the following taxa:

![Map of the studied localities in Mavrovo NP and surrounding areas.](image-url)
Materials and methods

The gastropods were collected by classical hand collection, soil-traps and by non-quantitative use (without exact volume of collected soil) soil sampling method (Dedov & Antonova, 2015). The method consists of collecting soil from suitable habitats. Each sample, in addition to the soil layer, also contains leaves and living plants from the corresponding square (“biomass sample”). The resulting sample is immersed in a standard bucket filled with water. The fraction that floats to the surface of the water is taken with a suitable plastic strainer. Using a rectangular plastic plate, the sample is transferred in a mesh (a thin stocking), and left to dry. The sample is then sieved under laboratory conditions through a system of sieves with different hole sizes. The fractions are examined under binoculars to separate the shells from the remaining particles in the sample. When each sample is collected, the point is marked with GPS.

The sampling localities are present on Supplementary material 01 and illustrated in Fig. 1. The full names of the species reliably recorded in the park and its immediate surroundings are given in Supplementary material 02.

Results

In total, 67 species of land snails and slugs were reported in the previous “Management Plan of Mavrovo National Park for the period 2012–2021, Annex – Mollusca: Gastropoda and Bivalvia” (Petkovski, 2011). Forty-four species from that list were confirmed during our field surveys (Supplementary material 02). Five species were not collected in the current study but are reliably reported in the literature: Chondrula tridentes, Gyralina korabensis, Lacinia plicata, Vallonia costata and Xerolenta obvia (Pavlovic, 1911; Riedel, 1985).

Twelve species from the previous plan (Petkovski, 2011) have not been confirmed in the field, nor have reliable records of their presence in the park been found in the literature reviewed, but are very likely to occur within the boundaries of the protected area: Arion circunscriptus Johnston, 1828, Caucasoecrosa vindobonensis (C. Pfeiffer, 1828) (as Cepaea (Austrotacea) vindobonensis (Ferussac, 1821), Cernuella cisalpina (Rossmässler, 1837) (as Cernuella profuga (Schmidt, 1853)), Chondrula macedonica A. J. Wagner, 1914, Deroceras reticulatum (O. F. Müller, 1774), Ena concolor (Westerlund, 1887) (as Ena jugoslaviensis Wagner, 1922), Gyralina mirabilis Pintér & Riedel, 1973, Helix pomatia Linnaeus, 1758, Limax cinereoniger Wolf, 1803, Monacha cartusiana O.F. Müller, 1774, Strigilodes lima conspersa (L. Pfeiffer, 1848) and Xeropicta krynickii (Krynicki, 1833). A total of 8 land snail species should be removed from the list because they do not occur in North Macedonia: Arion lusitanicus Mabile, 1868, Cattania trizonata (Rossmässler, 1835) (as Helicogena rizona (Rossmässler, 1835), Chondrina avenacea (Bruguère, 1792), Helicopsis striata (O. F. Müller, 1774), Pseudojaminia seductilis seductilis (Rossmässler, 1837) (as Imparietula seductilis (Rossmässler, 1837)), Trochulus sericus (Draparnaud, 1801) (as Trichia sericea (Draparnaud, 1801)), Vitrea contracta (Westerlund, 1871) and Vitrea subrimata (Reinhart, 1871). One species should be removed because it is locally endemic to other parts of North Macedonia (Montenegrina attemsi attemsi (A. J. Wagner, 1914) for the Treska River Valley and Matka Canyon).

On the other hand, 15 species new to the Mavrovo NP were found during the field research (cf. Petkovski, 2011): Acanthynula aculeata, Arion silvaticus, Carychium minimum, Galba truncatula (an amphibious species often included in the lists of both freshwater and terrestrial snails), Gittenbergia sororcula, Lehmannia brunnieri, Montenegrina perstriata mavo-voensis, Montenegrina perstriata perstriata, Perpolia hammonis, Punctum pygmaeum, Pupilla alpica, Tandonia albanica, Truncatellina australis, Vertigo antivertigo and Vitrea botterii. Some of these species have been reported for localities in the park from publications not reflected in the previous plan.
The species *Perpolita hammonis* is recorded for the first time for the North Macedonian fauna (Fig. 2). For *Helicigona korabensis* there is no scientific confirmation of its occurrence in North Macedonia. In the current survey we confirm the species for the North Macedonian part of Korab Mountain (for details see Subai, 1997) (Fig. 3). *Deroceras laeve* is reported for Mavrovo NP by Wiktor (1996). Thus, a total of 61 species taxa of land snails are reliably known for Mavrovo NP (Supplementary material 02 [2]).

**Discussion**

**Taxonomy**

According to Bank & Neubert (2017) the subspecies *Cochlodina laminata albanica* Jaeckel, 1956 is present in North Macedonia. The type locality of this taxon is Daiti Mountain, near Tirana, the capital of Albania but it also occurs in the area from Bosnia to Albania and (North) Macedonia. Compared to the nominate subspecies *Cochlodina laminata albanica* it is characterised by its lighter shell with yellowish to yellowish-brown coloration and distinct shell striation (Gittenberger, 1967). Similar shells were found in Mavrovo NP. According to Gittenberger (1967), another subspecies of *C. laminata* – *Cochlodina laminata oreinos* (A. J. Wagner, 1914) could be found in the northern parts of the Shar Mountain (Ljuboten). This subspecies is most likely the high-mountain form of *Cochlodina laminata albanica*, and could be distinguished from it by its the compactly fusiform and irregularly striated shell, as well as weakly reduction clausiliary apparatus. Because of the unclear status of the *Cochlodina laminata* subspecies and the lack of a clear isolation barrier between different populations in the region, we refer all specimens to the nominate species.

According to Petkovski (2011) *Morlina glabra* (Rossmässler, 1835) and *Morlina glabra striarius* (Wresterlund, 1881) are found in Mavrovo NP, but only the subspecies *M. glabra nitidissima* is present in the western part of North Macedonia. This is confirmed by our findings.

*Perpolita hammonis* (Fig. 2) was found in pitfall-traps set in the high-mountain wetland “Lukovo Pole” of Shar Mountain. The taxon represents a new genus and species for the fauna of North Macedonia. This species is typical for acid soils, moderately humid or swampy habitats (Welter-Schultes, 2012)

*Helicigona korabensis* (Fig. 3B) was described by Subai (1997) from the Albanian part of Korab Mountain. We recorded this species from two sites in North Macedonia: high-mountain parts of Korab (Mala Planina Ridge, under Visoko Brdo Peak and Kepi Bard 2 Peak, near Boazi Peak). According to MolluscaBase (2023) the status of this species is uncertain.
and it is ‘taxon inquirendum’. We were not able to find any live adult specimens, so we are not sure of the exact genus of the species. We found shells and a juvenile only in high-mountain areas, in low abundance, on both silicate rocks with limestone admixture and pure limestone rocks. In our opinion, it is a valid species, endemic to the high areas of Korab Mountain.
Species with high conservation value

Twenty-one land snails of high conservation value were found in the Mavrovo NP. This number includes: Macedonian endemic (6 species) and 13 Balkan endemics (Welter-Schultes, 2012). According to the IUCN European Red List of Threatened Species (Neubert et al., 2019), *Euxinella radikae* and *Gyralina korabensis* are considered as Near Threatened (NT) (Supplementary material 02).

Two species have been identified as a food resource: *Helix lucorum* and the Balkan endemic *Helix vladica*. Although it is not yet known whether the second species is collected for food, it is difficult for non-specialists to distinguish it from *Helix pomatia* which is popular among the snail-collectors. Thus, we assume that *Helix vladica* is also collected for food by the local population.

Localities and habitat important for the biodiversity of land gastropods

As mentioned above, the area of Mavrovo NP is not well studied from the point of view of land snails’ diversity, but based on the available information, the high mountain area of Korab, especially the carbonate rocks and grasslands on the path from Karaula Strazimir to Golem Korab Peak can be defined as particularly important for the biodiversity of land gastropods. Many endemic species inhabit the carbonates, including in and around the caves along the Radika River, as well as the areas around the Rivers Adžina, Mavrovska, Ribnica, as well as other smaller rivers. Other important sites are the areas around the Galichnik Village.

In the carbonate-based habitats (mainly rocky, but also alpine pastures, slopes and scrub), an interesting species assemblage occurs: *Candidula rhabdotoides*, *Gyralina korabensis*, *Helicigona korabensis*, *Pseudotrizona inflata*, *Montenegrina perstriata mavrovoensis*, *Montenegrina perstriata perstriata*.

The deciduous forests of Mavrovo NP, especially the beech forests, form a diverse and rich complex of species, in which a number of endemic and rare species are found (e.g. *Allaegopis skandergianus*, *Alinda golesnicensis* golesnicensis, *Dinarica serbica*, *Helicodonta albanica*, *Morlina glabra nitidissima*, *Pseudotrizona inflata*, *Tandonia albanica*, *Triloba thaumasia*, *Vitrea illyrica*).

Species with high conservation value are present on (Fig. 3A–G).

In our opinion if a better study is to be conducted, the list of species taxa will increase, and the discovery of new species for science is very likely.

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References


The terrestrial gastropods (Mollusca: Gastropoda) of the Mavrovo National Park, North Macedonia


Supplementary materials

01 Document title: Table 1. Studied localities in Mavrovo NP and surrounding areas
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02 Document title: Table 2. List of the terrestrial gastropods from Mavrovo NP and surrounding areas
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Two plant bug genera *Euryopicoris* Reuter, 1875 and *Solenoxyphus* Reuter, 1875 (Hemiptera: Heteroptera: Miridae) new for the Bulgarian fauna

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Abstract: Two plant bug species, *Euryopicoris nitidus* (Meyer-Dür, 1843) and *Solenoxyphus lepidus* (Puton, 1874), are reported for the first time for Bulgaria. Their habitats, host plants, and reasons for the late discovery in the country are briefly discussed. The genera *Euryopicoris* Reuter, 1875 and *Solenoxyphus* Reuter, 1875 have not been previously reported in Bulgaria as well.

Keywords: Balkans, Bulgaria, Halticini, new records, Orthotylinae, Phylinae, plant bugs

Introduction

The Bulgarian plant bug fauna is relatively well studied (Josifov, 1986; Josifov & Simov, 2006), with about 369 species from 123 genera reported so far (Kerzhner & Josifov, 1999; Aukema et al., 2013; Aukema, 2018). In the present work, we provide the first country record of the genera *Euryopicoris* Reuter, 1875 with the species *Euryopicoris nitidus* (Meyer-Dür, 1843) and *Solenoxyphus Reuter, 1875* with the species *Solenoxyphus lepidus* (Puton, 1874).

Material and methods

The material for the present study was collected by the authors from mountainous areas in southwestern Bulgaria and the Thracian Lowland between 2015 and 2024. Net sweeping as well as hand collection from the food plants were used in the field work. The pictures were taken with digital cameras Olympus TG-4 and Canon PowerShot SX420 IS (Figs 1, 3), Olympus SZ61 stereomicroscope, equipped with a digital camera Canon EOS 2000D (Fig. 2), and Carl Zeiss STEMI 2000 stereomicroscope, equipped with a digital camera Canon EOS 2000D (Fig. 4). The material is preserved in the Zoological Collection of Sofia University “St Kliment Ohridski”, Faculty of Biology, Sofia, Bulgaria (BFUS), and in the collection of the National Museum of Natural History, Sofia, Bulgaria (NMNHS). Habitat classification follows the EUNIS (Davies et al., 2004; European Environment Agency, [2024]) and Red Data Book of Bulgaria (Biserkov & Gussev, 2015).

Results and discussion

Family Miridae

Subfamily Orthotylinae

*Euryopicoris* Reuter, 1875

*Euryopicoris nitidus* (Meyer-Dür, 1843)

Material: SW Bulgaria: Zemenska Planina Mountain, NE of Polska Skakavitsa Village, 42°24'46.64"N,
22°41′02.04″E, 650 m a.s.l., roadside grassland, 30.iv.2019, 12 ♂, 14 ♀, net sweeping on grass and Salvia nemorosa L., N. Simov leg. [NMNHS]; Western Balkan Mts, NW of Bezden Village, 42°53′08.2″N, 23°05′44.57″E 24.v.2019, 5 ♂, 4 ♀ observed and photographed N. Simov; Verila Mountain, NE of Dren Village, 42°24′53.52″N, 23°09′53.40″E, 830 m a.s.l., roadside herbaceous vegetation (Fig. 1A), 24.v.2022, 3 ♂, 4 ♀, on Verbascum sp., D. Gradinarov & Y. Petrova leg. [BFUS] (Fig. 2 A, B, D); the same locality, 23.iv.2023, 10 ♂, 7 ♀, on Poaceae, Myosotis sp. (Boraginaceae), and dry grasses, D. Gradinarov & Y. Petrova leg. [BFUS]; Lozenska Planina Mountain, N of Dolni Pasarel Village, 42°33′25.1″N, 23°29′47.8″E, 830 m a.s.l., mountain meadows (Fig. 1B), 07.v.2023, 13 ♂, 18 ♀ (including two macropterous specimens), on different plants (Verbascum speciosum Schrad., Galium album Mill. and G. verum L., Vicia sp., Cirsium ligulare Boiss., Tordylium maximum L. and Fragaria vesca L.), D. Gradinarov leg. [BFUS] (Fig. 2 C); Radomir Valley, Dolni Rakovets Village, 42°28′28.6″N 23°00′46.0″E, 639 m a.s.l., 28.iv.2023, 15 ♂, 17 ♀, on different Poaceae, N. Simov, F. Konstantinov, S. Grozeva, D. Stoyanova leg. [NMNHS]; Mount Chepan, N of Dragoman, 42°56′50.5″N 22°56′16.7″E, 984 m, mountain steppe, 26.v.2024, 1 ♂, 1 ♀, on Verbascum sp., Y. Petrova leg. [BFUS].

New record for Bulgaria.
Two plant bug genera *Euryopicoris* Reuter, 1875 and *Solenoxyphus* Reuter, 1875 new for the Bulgarian fauna


*Euryopicoris nitidus* is distributed from Southern through Central Europe to the Far East of Russia and Northern China (Tatarnic & Cassis, 2012; Konstantinov & Namyatova, 2009; Aukema, 2018). In Europe, its range reaches the northernmost regions, including the tundra biome (Lammes & Rinne, 1990; Zinovyeva & Dolgin, 2006; Zinovyeva, 2013; Roth &
Coulianos, 2014). In Central Europe (Hradil et al., 2019), Balkan Peninsula (Greece, Albania, North Macedonia), parts of Serbia (Kormilev, 1936; Josifov, 1986; Günther, 1990; Protić, 2018), Italy (Carapezza & Faraci, 2006), as well as in Iran (Mohammadi et al., 2020), *E. nitidus* is limited to mountainous areas. In

Fig. 3. *Euryopicoris nitidus* on its host plants in Bulgaria – (A) Polska Skakavitsa locality, on *Salvia nemorosa*, (B) Dren locality, on *Verbascum* sp., (C) Dren locality, on Poaceae, (D) Dolni Pasarel locality, on *Galium* sp., (E) Dolni Pasarel locality, on *Vicia* sp. (F), Dolni Pasarel locality, on *Cirsium ligulare*. 
Two plant bug genera *Euryopicoris* Reuter, 1875 and *Solenoxyphus* Reuter, 1875 new for the Bulgarian fauna

In our study, the species was found in mountainous regions of southwestern Bulgaria. All the specimens collected and observed were found in the low mountain zone (from 650 to 980 m a.s.l.), mainly in steppe-like grasslands. The species is probably more widespread in this part of the country, but has a patchy local distribution.

In the field, we have observed adults of *E. nitidus* on herbaceous plants of various families, as well as on dry stems of grasses (in the localities near Dren Village and Dolni Rakovets). Feeding, often causing characteristic damage on the food plants (chlorosis), has been observed on *Salvia nemorosa* (Lamiaceae), *Verbasum* spp. (Scrophulariaceae), *Myosotis* sp. (Boraginaceae), *Galium album* and *G. verum* (Rubiacaeae), *Vicia* sp. (Fabaceae), *Cirsium ligulare* (Asteraceae), *Tordylium maximum* (Apiaceae), and *Fragaria vesca* (Rosaceae), as well as on unidentified Poaceae species (Fig. 3). Tatarnic & Cassis (2012) indicate grasses (Poaceae) as hostplants of *E. nitidus*, while according to Kerzhner & Jaczewski (1964) the species occurs on herbaceous legumes (Fabaceae). Our observations indicate a broader host preference range, and in the Bulgarian localities, *E. nitidus* seems to be polyphagous on various herbaceous plants.

**Fig. 4. Solenoxyphus lepidus** – male from Blatets locality, Southeastern Bulgaria – (A) general view, (B) vesica of aedeagus. Scale bars: 1 mm (A), 100 µm (B).

**Subfamily Phylinae**

**Tribe Phylini**

*Solenoxyphus* Reuter, 1875

*Solenoxyphus lepidus* (Puton, 1874)

Material: Bulgaria, Tundza River Valley, S from Blatets Village 42°37′00.9″N; 26°32′11.4″E, on *Camphorosma annua* Pall., 11.vii.2015, 146 m a.s.l., 9 ♂, 14 ♀, N. Simov leg. (NMNHS) (Fig. 4).

New record for Bulgaria.

The habitat of this species in Bulgaria – saline steppes, pastures, and marshes (EUNIS: E6.221 and E6.223) (Fig. 1C, D) – is rare and endangered according to the new edition of the Red Data Book of Bulgaria (Tzonev & Gussev, 2015).
The range of *S. lepidus* includes Europe: France, North Macedonia, European Kazakhstan, Romania, Russia (South European Territory), Spain, Ukraine; North Africa: Algeria; Asia: Armenia, Asian Kazakhstan, China, (Northern and Northwest Territories), Kyrgyzstan, Mongolia, Russia (East Siberia), Turkmenistan, Uzbekistan (Kerzher & Josifov, 1999; Aukema et al., 2013; Aukema, 2018). The habitat preferences of the species in the Balkan Peninsula (North Macedonia, Vardar River Valley near Gradsko (Göllner-Scheiding, 1978)) are very similar to our findings. *Bassia prostrata* (L.) A.J.Scott, (as *Kochia prostrata* (L.) Schrad.), *B. laniflora* (S.G.Gmel.) A.J.Scott (as *Kochia laniflora, K. arenaria* (Maerkl.) Roth), *Camphorosma monspeliaca* L. and *Camphorosma* sp. (Chenopodiaceae) are reported as host plants of *S. lepidus* (Konstantinov, 2008). Our records indicate *Camphorosma annua* as a new host plant and well correspond with the previously published host associations with the tribe Camphorosmeae (Amaranthaceae sl). The host association with Asteraceae (Qi & Nonnaizab, 1996) is rather doubtful (Konstantinov, 2008).

Both species mentioned above remain overlooked despite the intensive studies of the Bulgarian true bug fauna in the second half of 20th and the first two decades of 21st century. The reason for the late discovery of *E. nitidus* could be the focus of the entomological studies on parts of the country with Mediterranean climate influence in Southern Bulgaria while the fauna of the small mountains west of Sofia has been neglected.

Regarding *S. lepidus*, the collection of plant bugs and other insects on the *C. annua* is quite difficult with standard entomological technique and equipment. Careful examination of each plant or suction trapping with a handheld leaf blower (vacuum combo) are the best technique for successful collection. In addition, the saline habitats in Bulgaria develop at specific conditions and usually the areas they cover are fragmented and not large (Tzonev & Gussiev, 2015). These habitat and host plant particularities could probably explain the late discovery of *S. lepidus* in Bulgaria.

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**References**


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