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The small mammals (Eulipotyphla, Lagomorpha, Rodentia) of the Sakar Mts (South-eastern Bulgaria)

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Abstract. This paper presents a comprehensive summary of the distribution and diversity of small mammals (Eulipotyphla, Lagomorpha, Rodentia) in the Sakar Mountains region of Southeastern Bulgaria. Drawing on data collected over the past 20 years through a variety of methods—including pitfall and live trapping, analysis of owl pellets, direct observations, and roadkill records. Only in the barn owl pellets we identified 21 species of 6,513 specimens across 18 localities. Special attention is given to species of conservation concern such as *Myomimus roachi*, *Dryomys nitedula*, *Spermophilus citellus*, and *Nothocricetulus migratorius*. Distribution maps (10x10 km grid) are provided for key species, and we discuss notable changes in species composition and primary threats observed over the last two decades. The study also details recent intensive monitoring efforts on dormice populations and assesses European Hare density and Coypu distribution in the area.

Key words: Small mammals, owl pellets, distribution, conservation.

Introduction

Sakar Mountains is located in the south-eastern corner of Bulgaria and belongs to the continental–Mediterranean climatic zone (Kopralev 2002). The distinctive landscape, along with the combination of varied habitats and climatic features resulting from Sakar Mountains location, provides the conditions for a high diversity of small mammals.
South-eastern corner of the Balkans, where the Sakar Mts is located, is a hot-spot for small mammals' diversity (Kryštufek, 2004), typically species occurring in the area are – *Talpa martinorum, Suncus etruscus, Myomimus roachi, Microtus hartingi.*

The micromammalian fauna has been studied extensively since the late 1950s, when the first faunistic surveys began. In the Sakar Mountains area, the Mouse-tailed dormouse (*Myomimus roachi* Bate, 1937)—a new genus and species for Europe at that time - and the Grey dwarf hamster (*Nothocricetulus migratorius* Pallas, 1773) were recorded for the first time (Peshev *et al.* 1960a; Peshev *et al.* 1960b).

Information regarding the distribution of small mammals in the Sakar Mountains area can be found in several older publications focused on faunistics (Peshev & Angelova 1963, 1967; Markov 1964) or on parasitological studies (Touleshkov 1964; Christov 1964; Skuratowicz et al. 1982) concerning small mammals in Southeastern Bulgaria.

Georgiev (2004) summarised data on small mammals in Sakar Mountains, reporting 24 species and presenting the distribution of 14 species with conservation status. Since then, new data on micromammals have been accumulated, which we present here.

Material and Methods

Here we summarised all available information about small mammals from the published literature and our own data. We have been working in the area for 20 years collecting data about mammals' presence with various methods - pitfall traps, live-trapping, analysing diet of owls and raptors, direct visual observations and recording road kills. We analysed Barn owl (*Tyto alba* Scopoli, 1769) pellets from 18 locations, as follows - 1- Generalovo village (Svilengrad), 2 - Izvorovo village (Harmanli), 3 - Levka village (Svilengrad), 4 - Matochina village (Svilengrad), 5 - Polski gradets village (Radnevo), 6 - Pastrogor village (Svilengrad), 7 - Raikova mogila (Svilengrad), 8 - Svetlina village (Topolovgrad), 9 - Svirkovo village (Simeonovgrad), 10 - Sinapovo village (Topolovgrad), 11 - Sladun village (Svilengrad), 12 - Srem village (Topolovgrad), 13 - Studena (Svilengrad), 14 - Topolovgrad, 15 - Cherepovo village (Harmanli), 16 - Churarovo village (Topolovgrad), 17 – Branitsa (Harmanli), 18 – Oryahovo (Ljubimets). The materials were collected between 2003-2024, in which we identified 6513 small mammals from 21 species (Tab. 1). Sample size differs among the sites - 29-1056, median=285 identified small mammal. During 2017-2024 we did intensive monitoring on the dormice population by nest box (70 boxes) check and live trapping (about 10 000 trap nights) during the active period (March-November) of the dormice.

We also utilised data from the diet of the Eastern imperial eagle (*Aquila heliaca* Savigny 1809), which has been the subject of extensive study over the past 20 years (Demerdzhiev *et al.*, 2021; 2022); this dataset included 1,271 mammalian prey items.

Standard methods for aquatic mammals adapted for study area were established for determined distribution of Coypu (*Myocastor coypus* Molina, 1782) (Krebs 2014). The banks of 132 reservoirs and small dams were inspected between 2020-2025 years. All data from monitored individuals, trails, footprints and burrows were used to determine the presence of Coypu. To increase the probability of detecting individuals, we used 2 specially trained dogs to search water areas (typical German wirehaired pointer and Akita Innu). Each of the studied reservoirs was visited at least once during the study period, and for some localities we were able to establish breeding after observation of young individuals.

The density of European hare (*Lepus europaeus* Pallas, 1778) was assessed within quadrant MG 14 (35T) of the Universal Transverse Mercator (UTM) system, located in the western part of the Sakar region. Eight linear transects were surveyed between 2021 and 2025. For comparison, hare density was also estimated along the same transects in the same quadrant during 2014-2020 (Gruychev 2021). The total transects length was 35.2 km, with a survey strip width of 50 m (25 m of each side of the observer).

To improve detection during field surveys, trained dogs were employed to search within 50 m on either side of the observer. The dogs located hares but were not allowed to pursue them. Transects were systematically established to reflect the full diversity and proportional distribution of habitat types in the study area, ensuring representativeness of the sample. Six surveys were conducted annually between March and July.

Hares are not hunted within the study area due to their low density. Density was calculated as the arithmetic mean of all observations recorded during each respective year. Surveys were conducted in daylight, between 06:30 and 17:00. This methodology was applied by Gruychev (2021), and its use ensures the comparability of the data.

Data presentation and analysis were made by Excel ver. 17 and Paleontological statistics software package (PAST) (Hammer & Harper 2006).

Study area

The Sakar Mts is one of the lowest mountains, situated in the southeastern part of Bulgaria (Fig. 1). The mountain is approximately 40 km long and 12-15 km wide. The highest point is Vishergrad peak (856 m) (Nikolov & Jordanova 2002). The climate is characterized by hot summers and mild winters (January temperature above 0°C), low annual temperature amplitude, autumn-winter maximum in rain flow (Kopralev 2002). The xerotherm type dominates the vegetation. Remnants of wood patches are formed by mixed forests of Oaks (*Quercus frainero, Q. cepris, Q. pubescens, Q. vergiliana*) and *Carpinus orientalis.* Native oak forests were replaced by secondary forests of *Carpinus orientalis* and shrubs of *Paliurus spina-christi* (Kopralev 2002). Zoogeographically, the Sakar Mts lies in the Mediterranean region, as Mediterranean species of some invertebrates (Apoidea, Heteroptera, Orthoptera) make up more than 50 % (Kopralev 2002).

The border of the study area is defined according to the Special Protection Areas (SPA) Sakar BG0000212, which mostly overlap with the geographical border of the Sakar Mts, with an approximate area of 132,118 ha.

Distribution of small mammals is presented on a UTM grid 2x2 km, within a 10x10 km square (widely used scale in national atlases and publications) (Fig. 1).

Data set of small records in the Sakar Mountains is available at: https://www.gbif.org/dataset/a47115ae-6c6e-4abb-bad5-c073859d60fa

Fig. 1. Location map of the study area and 10 km UTM grid used for the species distribution presentation.

Results and Discussion

Altogether, applying different methods for study and registration, we identify 30 small mammals in the Sakar Mts. We identified 21 species as a part of the diet of *T. alba* (Tab. 1). Several elusive ones (*Suncus etruscus, Sorex araneus, Sorex minutus, Micromys minutus, Microtus subterraneus, Arvicola amphibius, Nothocricetulus migratorius*) were registered only in owl pellets.

Order Eulipotyphla Waddell *et al.* 1999

Family Erinacaidae Fischer von Waldheim, 1814

Northen white-breasted hedgehog (*Erinaceus roumanicus* Barret-Hamilton, 1900)

E. roumanicus is widespread in Bulgaria, mostly in the lowlands (Peshev *et al.* 2004). The species was recorded in a total of 21 10 km UTM squares (Fig. 2). It is a key prey for the Imperial Eagle (*Aquila heliaca*) in the Sakar Mts. In recent years, a significant increase in the presence of hedgehogs in the Imperial Eagle's diet has been noted, comprising up to 28.71% of the total prey biomass (Demerdzhiev *et al.* 2022). This phenomenon is likely related to the population decrease of one of the Eagle's most important local prey items—the European souslik (*Spermophilus citellus* Linnaeus, 1766) (see text below). Furthermore, the species is frequently a victim of road traffic.

Family Talpidae Fisher 1814

European mole (*Talpa europaea* Linnaeus, 1758)

It is the only mole species in the area, and it typically prefers moist habitats with a good soil layer. In the Sakar Mts, however, it is found even in xeric habitats with a thin soil layer and rocky substrate. During dry, hot summers, individuals may search for food on the surface. For instance, on 17.10.2022, west of Levka village, a mole was observed on the soil surface, eagerly searching for prey in the leaf litter. No molehills were detected nearby. This behaviour is not unique; Morris (1966) observed similar mole activities in the summer of 1964 (July–Sept.) in Cap Gris Nez, N France, where he observed 35 moles on the surface over five weeks.

A small, blind mole, Martino's mole (*Talpa martinorum* Kryštufek *et al.* 2018), also occurs in SE Bulgaria; it is thought to reach the east bank of the Tundzha river (N. Nedyalkov, unpubl. data). The European mole was recorded in a total of 17 10 km UTM squares.

Family Soricidae Fisher 1814

Common shrew (*Sorex araneus* Linnaeus, 1758)

Mesophilic species inhabiting mainly the mountains in Bulgaria but is also recorded from the lowlands (Peshev *et al.* 2004). Despite the large number of analysed owl pellets, the species has not been recorded. It was recorded in the diet of *A. heliaca*, by a single individual in two locations - Sladun and Levka villages (Demerdzhiev *et al.* 2022). It has been found in the neighbouring areas – Drama village (Greece) (Peshev & Mitev 1987). The Common shrew was recorded in a total of two 10 km UTM squares.

Pygmy shrew (*Sorex minutus* Linnaeus, 1766)

Mesophilic species, common in the mountain area in Bulgaria, and patchy distributed in lowlands (Peshev *et al.* 2004). It was registered in 18 locations (out of 22 locations, Fig. 5) with owl pellets, and it contained 2.2 % of small mammals identified in the

diet of *T. alba* from the area. The Pygmy shrew was recorded in a total of 14 10 km UTM squares.

Mediterranean water shrew (*Neomys milleri* Mottaz, 1907)

The species prefers wet habitats along the whole country up to 2100 m a.s.l. Its distribution in the area is registered only in owl pellets; it was found in 14 out of 18 locations where the Barn owl pellets were collected. It consisted of 4.5 % of small mammals, the diet of *T. alba.* The Mediterranean water shrew was recorded in a total of 14 10 km UTM squares.

Bicolored shrew (*Crocidura leucodon* Hermann, 1780) and
Güldenstädt's shrew (*Crocidura gueldenstaedtii* Pallas, 1811) (former *C. suaveolens*)

The both white-toothed shrews are widely distributed in the lower part of the country (Peshev *et al.* 2004). They are common in the area, prefer open habitats - natural grasslands, but are also found at the edge of agriculture - alfalfa and cereal fields, they avoid woods. Both species made up 45.8% of small mammals, the diet of *T. alba*, as *C. gueldenstaedtii* was almost twice in number of *C. leucodon*. The Bicolored shrew was recorded in a total of 16 10 km UTM squares (Fig. 7). The Güldenstädt's shrew was recorded in a total of 16 10 km UTM squares.

Etruscan shrew *(Suncus etruscus* Savi, 1822)

The Etruscan shrew is the smallest mammal in the World (1.5-2 g), that's why it's difficult to be detected by traditional methods in study of small mammals - live or snap traps. It's current distribution in the country is mapped mostly based on the remains found in owl pellets (Popov *et al.* 2004; Nedyalkov *et al.* 2024). It consisted of a negligible part (0.73 %) of the diet of *T. alba.* Our result is like 0.09% reported to SE Bulgaria (Milchev *et al.* 2004). Current distribution summarized by Nedyalkov *et al.* (2024). The Etruscan shrew was recorded in a total of 10 10 km UTM squares.

Order Lagomorpha Brandt, 1855

Family Leporidae Fischer von Waldheim, 1817

European hare (*Lepus europaeus* Pallas, 1778)

The distribution of the European hare in the Sakar region is widespread, albeit with varying densities. The species occurs in both forested and open habitats. Its density ranged from 0.7 to 2.7 individuals per 100 ha during the period 2014-2025. Although annual fluctuations were recorded, no increasing trend was observed; rather, the density remained stable (Tab. 2).

Table 2. Density of European hare in Sakar Mts Density - ind./100ha±SD (min-max); Data between 2014-2020 by Gruychev 2021.

Year	Density
2014	1.8±1,6 (0-4)
2015	2.7±2,1 (0-6)
2016	1.4±0,8 (0-2,5)
2017	0.8±1 (0-2.6)
2018	0.7±0.9 (0-2)
2019	1.3±0.7 (0-2)

Year	Density
2020	1.2±1.2 (0-3.4)
2021	0.6±0.8 (0-2.5)
2022	1.3±1.1 (0-3)
2023	1.2±1.3 (0-4)
2024	1.4±1 (0-4)
2025	1.7±1.2 (0-4)

The density of European hare in Sakar is comparable to that reported of other parts of Bulgaria (Zhelev *et al.* 2013; Zhelev 2015), placing the region among areas with low population density of the species (Zhelev *et al.* 2013). The population dynamics during the study period remained stable, contrasting with the overall European decline in Hare populations (Hacklander & Schai-Braun 2019). Nevertheless, densities in Sakar are lower than those reported in some parts of Europe in recent years (Canova *et al.* 2019; Vizzari *et al.* 2024). The European hare was recorded in a total of 22 10 km UTM squares.

Order Rodentia Bowdich 1821

Family Sciuridae Fischer von Waldheim, 1817

Red squirrel (*Sciurus vulgaris* Linnaeus, 1758)

In Bulgaria, the species prefers old growth deciduous and mixed forests, up to 2000 m asl (Markov 1960). It is rare in the study area because of a lack of suitable habitats, and there is no big forest massive; most of the habitats are dominated by subterranean dry grasslands with sparse trees and tree islands. We observed the squirrel in the vicinity of Topolovgrad, Harmanli, Srem village, Mramor village, and on the road between Glavan and Balgarska polyana villages. It was found (a single individual) in the diet of the Imperial Eagle (Demerdzhiev *et al.* 2021). The Red squirrel was recorded in a total of 4 10 km UTM squares.

European souslik (*Spermophilus citellus* Linnaeus, 1766)

The species inhabit mainly pastures in lowlands, but some isolated mountain populations exist (up to 2500 m in Rila Mts) (Koshev 2008). Drastic decline in souslik population has been recorded, assuming 30 % had vanished in compression to the second part of XX century, due to habitat degradation and turning pasture in agriculture (Koshev 2008). Unfortunately, souslik populations on the Sakar Mts are not exempt from this negative trend.

Souslik density dropped almost twice in the last 20 years, from approximately 150 ind./ha in 1999-2001 to 70 ind./ha in 2014-2021. It was noticed also in the diet of the Imperial eagle (*Aquila heliaca*) (Demerdzhiev *et al.* 2022). According to the species report in SAC BG0000212 Sakar, there were 9 colonies and 2 had vanished, with overall conservation status – Unfavourable – Bad (Koshev 2014). Still, there is a good population of *Sp. citellus* east of Topolovgrad, but most of its natural habitats were plugged and turned into agriculture. Small and isolated colonies we recorded around Levka village, Kapitan Petko voivoda village, Shit village, and Matochina village. The species was recorded in a total of 16 10 km UTM squares.

Family Gliridae Thomas, 1897

Edible (Fat) dormouse (*Glis glis* Brisson, 1762)

The Edible (Fat) dormous prefers old growth deciduous forests *Fagus-Quercus*, which are limited in the Sakar Mts. Therefore the species occurs in low density. In the Sakar Mts, the species is active for about 5-6 months. It emerges from hibernation in the first part of June and could be active (in warm autumns) till mid-November. During the active season, it breeds once. Density was studied (2019-2023) in dry Mediterranean habitat – grasslands with tree lines and islands (mostly *Quercus vergiliana* and *Carpinus orientalis*), mean 0.8 ind/ha, as in 2021 no dormice were recorded. The species was recorded in a total of 3 10 km UTM squares.

Forest dormouse (*Dryomys nitedula* Pallas, 1778)

The most common glirid in Bulgaria. It occurs in the whole country up to 1850 m asl. (Peshev *et al.* 2004). It is also the most common dormouse in the area, it was found in various habitats - shrub areas, vineyards, orchards, single old trees (oak or pear tree) in agricultural fields, forest islands and tree lines in the sub-Mediterranean grasslands. It emerges from hibernation at the beginning of April and is active till October. During this active period, it breeds two or three times, giving up to 5 young per litter. Population ecology of *D. nitedula* were studied (2019-2024) by marked (pit tags) animals with average density of 3.3 (1.6-4.6) ind./1ha. The Forest dormouse was recorded in a total of 8 10 km UTM squares.

Fig. 2. The Forest dormouse (*Dryomys nitedula*) is the most common glirid in the Sakar Mts. (photo N. Nedyalkov).

Mouse-tailed dormouse (*Myomimus roachi* Bate, 1937)

The Mouse-tailed dormouse is one of the rarest and least known dormice in Europe. It is endemic to the Eastern Mediterranean - western coast of Anatolia, Turkish and Greek Thrace, SE Bulagria. Peshev *et al.* (1960) reported it as a new species for Bulgaria and Europe, based on 14 specimens collected during an opportunistic faunistic survey in SE Bulgaria. Markov (1964) reported 6 specimens from Svilengrad. Later Georgiev (2004) reported it from Ovcharovo village, Raikova Mogila village, and Pomoshtnik village. In 2017 we caught an adult individual about 10 km north of Svilengrad (Nedyalkov *et al.* 2018), and since then, we started a monitoring program by nest boxes and live trapping.

We found *M. roachi* syntropic with *D. nitedula* and *G. glis*. In Europe, it is exceptionally rare to see 3 or 4 glirids to co-exist together (Juškaitis 2008).

The Mouse-tailed dormouse was recorded in a total of 8 10 km UTM squares.

Fig. 3. The Sakar Mts to the exceptionally rare and little-known Mouse-tailed Dormouse (*Myomimus roachi*) (photo N. Nedyalkov).

Common dormouse (*Muscardinus avellanarius* Linnaeus, 1758)

The species is common in Bulgaria's mountains, and it's sparsely distributed in lowlands (Peshev *et al.* 2004; NN personal data).

Georgiev (2004) reported the species from Ovcharovo village and Pomoshtnik village, found in owl pellets. Despite our large sample from owl pellets (6513 identified small mammals), we could not confirm its presence in the recently studied area.

Family Cricetidae Fisher, 1817

Subfamily Cricetinae Fisher, 1817

Gray dwarf hamster (*Nothocricetulus migratorius* Pallas, 1773)

Bulgaria lies on westernmost edge of its range (Kryštufek *et al.* 2016), that why the species is rare and occurs in low numbers in the country. Peshev *et al.* (1960) reported the species from Levka village, they got 2 hamsters in almond garden and vineyards. Georgiev (2004) and Nedyalkov (2016) found the species' remains in owl pellets (*Athene noctua* and *Tyto alba*) from the following locations – Levka, Raykova mogila, Sladun, Shtit and Matochina villages. The species remains consist of a negligible part from the small mammals' community – 0.06 % from 27,449 small mammals found in pellets of SE Bulgaria (Nedyalkov 2016). Interestingly, here is a single sample (536 prey items) from Levka village, the hamster was presented by 11 individuals (2.05%). The species was recorded in of 5 10 km UTM squares.

Subfamily Arvicolinae Gray, 1821

East European vole (*Microtus rossieameridionalis* Ognev, 1924)

In Bulgaria, the grey voles (subgenus *Microtus* Schrank, 1798) are represented by two morphologically similar species - the Common vole (*M. arvalis* Pallas, 1778) and the East European vole (*M. rossieameridionalis*) (Peshev *et al.* 2004). The both species have different chromosome numbers - 2n=46 for the first one and 2n=54 for the second one, respectively, but there is no reliable morphological difference between them. While studying the distribution of these two vole species in Bulgaria in the last few years, we collected and karyotyped 10 voles from the Sakar Mts (N. Nedyalkov, I. Raykov, V. Koleva, unpubl. data). The East European vole was recorded in a total of 15 10 km UTM squares.

All karyotyped voles had a fundamental chromosomal number 2n=54. In our larger sample from SE Bulgaria, we have confirmed the presence of only grey voles (2n=54), and we can assume that in Sakar Mts are presented only *M. rossieameridionalis*. In the Thracian part of Turkey and Greece, only *M. rossieameridionalis* has been found (Kryštufek & Vohralik 2005).

Harting's vole (*Microtus hartingi* Barrett-Hamilton, 1903)

This is the only social vole (subgenus *Sumeriomys* Argyropulo, 1933), that occurs in Bulgaria, in the past reported as *Microtus guentheri* (Peshev *et al.* 2004). The largest vole from the genus *Microtus*. It can form big colonies; it gives a very specific alarm call which resembles those of the European souslik (*Sp. citellus*).

We recorded this species, in a total of 7 10 km UTM squares, near Topolovgrad, Mramor, Kapitan Petko voyvoda, Sinapovo, Knyazhevo, Oreshnik, Srem, Filipovo, and Radovets villages. It prefers open dry habitats, sometimes degraded and overgrazed, as well as alfalfa and cereal fields, which could cost damage in the years of outbreak. In the summer of 2024, the density of the Harting's vole in alfalfa was 3.1 active holes/m^2 (2.1-3.7, ±0,58 n=7).

In the last few years, it has been registered expansion of this vole in Sakar Mts, probably benefiting from a newly introduced practice for grasslands clearing with shredders and decreasing *Sp. citellus* population in the area, due to turning pastures into agriculture. The Harting's vole was rarely found together with *M. rossiaemeridionalis*, as usually *M. hartingi* is found in open fields, and *M. rossiaemeridionalis* are found on the edge of the fields, in bushes and high grasslands communities.

European pine vole (*Microtus subterraneus* de Selys Longchamps, 1836)

The species is common and numerous in our mountains, but it is also found at lower altitudes (Peshev *et al.* 2004). We found this species, in a total of 5 10 km UTM squares, only in barn owl pellets from the following locations – Kolarov, Branitsa, Cherepovo, Izvorovo, Levka, Oryahovo and Sladun villages. It contained a negligible part of the diet of the Barn owl - 0.25 % (out of 6513 identified small mammals). The result is similar with data of 0.23 % European pine vole (24,711 prey items) found in the diet of the Barn owl in SE Bulgaria (Milchev et al. 2004).

European water vole (*Arvicola amphibious* Linnaeus, 1758)

The species occurs narrow range on the territory of Sakar Mts, probably because the mountain is very dry. The European water vole was recorded in a total of 5 10 km UTM squares. It was recorded in the diet of *T. alba* in two locations - Matochina and Levka villages, as formed up a negligible part from it is diet - 0.08 % (6513 identified small mammals). It was recorded in the diet of the Imperial Eagle (Demerdzhiev *et al.* 2021). Probably the water vole has broader distribution along the Maritsa River and Tundzha River, but small brooks and streams dry up during the summer (July-September).

Family Muridae Illiger, 1811

Yellow-necked mouse (*Apodemus flavicollis* Melchior, 1834) and Wood mouse (*Apodemus sylvaticus* Linnaeus, 1758)

Both species are among the most common rodents in Bulgaria, widely distributed throughout the country. Within the study area, *A. flavicollis* is associated with forest habitats, and the species is a dominant in the guild of small mammals (data from live trapping). Data from long-term monitoring by live-trapping (May-August) shows drastic fluctuation in its density (Fig. 4). The Yellow-necked mouse was recorded in a total of 13 10 km UTM squares.

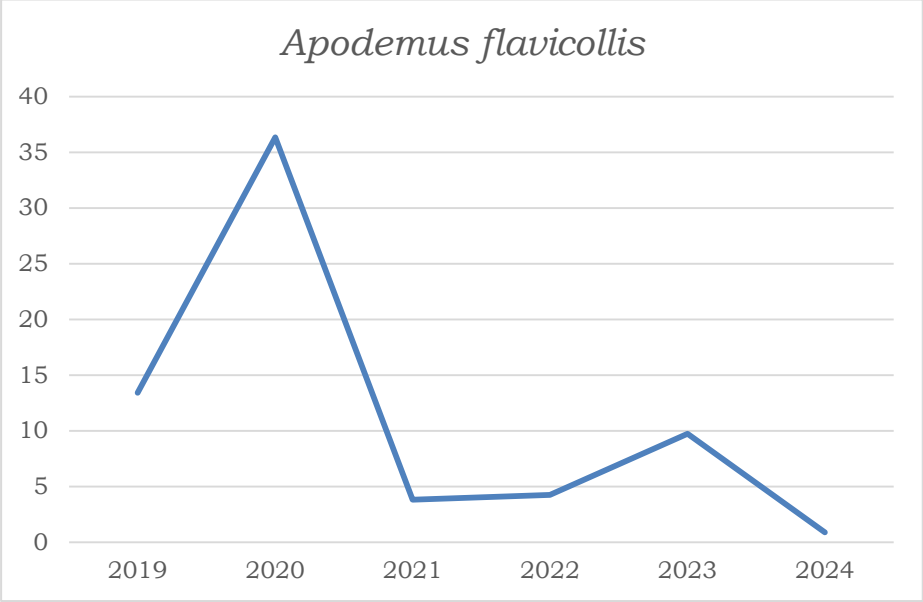

Fig. 4. Population dynamic of *A. flavicollis* 2019 – 2024. The population dynamic is shown as relative abundance - animals per 100 trap-nights. Mice were not marked, so recaptures are possible.

In the winter *A. flavicollis* occupied the dormouse nest boxes, as they stored oak acorns in the boxes (Fig. 5).

Fig. 5. Food cache of *A. flavicollis* stored in the dormouse's next box (photo N. Nedyalkov).

In the Sakar Mts, the Wood mouse (*A. sylvaticus*) was mostly recorded in the agricultural fields and on the edge of the forest with agricultural fields – barley, wheat, alfalfa fields, where it's a common species. The species was recorded in a total of 14 10 km UTM squares.

Striped field mouse (*Apodemus agrarius* Pallas, 1771)

In N Bulgaria the species is ubiquitous, but in S Bulgaria it shows intrazonal distribution - mostly associated with wet habitats close to water bodies (rivers, lakes, riparian forests, channel, rise fields). The species' preference of wet habitat types determines its rare occurrence on the territory of Sakar Mts. The species was recorded in a total of 7 10 km UTM squares. During the extensive live trapping (2019-2024), on area of approximately 3 ha, we trapped only one *A. agrarius* among 819 *A. flavicollis* and 8 *A. sylvaticus*. Mice were not marked, so recaptures are possible. These results are supported by the data of the diet of *T. alba*, where *A. agrarius* is presented by 0.09 %.

Harvest mouse (*Micromys minutus* Pallas, 1811)

The harvest mouse is difficult to be trapped (live or snap traps), and we recorded it only based on owl pellets (0.55 %). We recorded the species in a total of 11 10 km UTM squares from the vicinity of the settlements Topolovgrad, Rajkova mogila, Levka, Studena, Sladun, Pastrogor, Matochina, and Chukarovo villages.

Macedonian mouse (*Mus macedonicus* Petrov, Ruzic, 1983)

The only one outdoor living house mouse in S Bulgaria (Peshev *et al.* 2004). We got it in grasslands – shrub communities and agricultural fields, often along serial fields - barley, wheat, and oats. The Macedonian mouse was recorded in a total of 14 10 km UTM squares.

House mouse (*Mus musculus* Linnaeus, 1758)

In Bulgaria the species is represented by two parapatrically/allopatrically distributed subspecies - *M. m. musculus* and *M. m. domesticus* Schwarz and Schwarz, 1943. The nominate one occurs in N Bulgaria and the latter one in S Bulgaria (Peshev *et al.* 2004). It has been recorded only in owl pellets. There was no special attention to study synanthropic rodents. We were recorded the House mouse in a total of 14 10 km UTM squares.

Black rat (*Rattus rattus* Linnaeus, 1758) and Brown rat (*Rattus norvegicus* Berkenhout, 1769)

In the past, in the country there was organized monitoring and controlling campaigns against synanthropic rodents (Mateva & Christov 1986), but since 1990's this program was stopped. According to summarized data Black rat is more common in S Bulgaria, as Brown rat being more common in the northern part (Mateva & Christov 1986). We recorded *R. rattus* in owl pellets from five locations, probably it has a wider distribution. We observed *R. norvegicus* along the Maritsa Riverbanks in Svilengrad town. The species is a good swimmer and prefers wet habitats, in contrast to *R. rattus*.

We recorded the Black rat in a total of 6 and Brown rat in a total of 4 10 km UTM squares.

Family Spalacidae Gray 1821

Lesser blind mole-rat (*Nannospalax leucodon* Nordmann 1840)

The species is common and widely distributed in the area. It prefers open grasslands but is also found in agricultural fields, such as alfalfa and cereals. Digging activity is more prolific in winter and spring, which is the breeding period. It has been found in the diet of the Eastern Imperial eagle, but forms only a negligible part – 0.04% (of 1,961 prey items) (Demerdzhiev *et al.* 2021). The Lesser blind mole-rat was recorded in a total of 12 10 km UTM squares.

Family Echimyidae Gray, 1825

Coypu (*Myocastor coypus* Molina, 1782)

Koshev *et al.* (2022) noted that the coypu is common in the river basins of the Maritsa and Tundzha rivers and has likely spread from there into neighbouring regions of Turkey and Greece. Gruychev (2017) investigated the distribution of the coypu in the lower reaches of the Maritsa River and reported a density of 0.35 individuals per kilometre, with an average social group size of 1.6 ± 0.9 (range: 1–4 individuals; n = 42). Groups of 4–7 coypus of varying ages are frequently observed near the old Ottoman bridge in Svilengrad town. The Coypu was recorded in a total of 16 10 km UTM squares

In 2023 and 2024, six new localities of the coypu were recorded in the Sakar Mts, with reproduction documented in three of them. In 2025, there was no further increase in the number of sites, most likely due to severe drought and the drying up of many small water bodies in the area during the summer of 2024. The scarcity of water resources persisted into 2025, when no new sites were detected. Nevertheless, the already established populations remained, albeit with reduced numbers of individuals. Our observations indicate that the average size of social groups at the newly recorded sites ranged from three to six individuals. At one site, two reproductive events per year were documented, whereas at the remaining sites, reproduction was limited to a single generation annually. In September 2024, when water levels in one of the reservoirs dropped considerably, the coypus relocated beneath the dam, where they constructed a burrow and remained throughout the winter period (November 2023 – March 2024). Although the coypu is an invasive species with an expanding distribution in Bulgaria, the climatic constraints caused by drought in the Sakar region are likely to restrict its further spread into the interior of the mountain. In the study area, the coypu was found in the diet of the red fox (*Vulpes vulpes*), the Eastern Imperial eagle (*A. heliaca*), and the Eagle owl (*Bubo bubo*) (Gruychev 2012; Demerdzhiev *et al.* 2021; Milchev & Spassov 2024).

Zoogeographical characteristics

In the Sakar Mts, we identified 30 small mammals, representing 68.2% of all recorded small mammals in Bulgaria. Georgiev (2004) reported 24 species; twenty years later, we have added six species to the list, an increase of 25%. Zoogeographical characteristics were determined in accordance with Popov (2007), who proposed four zoogeographical complexes with several subcategories. Small mammals from the Nemoral complex accounted for more than half the species (53.8%), followed by Mediterranean and Boreal species (see Fig. 6).

Zoogeographical characteristics as follows:

1. *Boreal faunal complex* (4 species):
   - Eurosiberian forest element – *Sorex minutus, Sorex araneus, Arvicola amphibius*
   - Eurosiberian forest-steppe element – *Lepus europaeus*
2. *Nemoral faunal complex* (14 species):
   - Transpalearctic (species associated with forested area) – *Apodemus agrarius, Micromys minutus, Sciurus vulgaris*
   - South (East) European and (West) Asian element – *Erinaceus roumanicus, Crocidura leucodon, Dryomys nitedula, Microtus rossiameridionalis*
   - European element – *Talpa europaea, Neomys milleri, Glis glis, Muscardinus avellanarius, Apodemus flavicollis, A. sylvaticus, Microtus subterraneus*
3. *Mediterranean faunal complex* (5 species):
   - Widely distributed in southern areas – *Suncus etruscus*
   - Submediterranean element – *Crocidura gueldenstadtii*

- East Mediterranean element – *Myomimus roachi, Microtus hartingi, Mus macedonicus*

4. *Eurasian -Steppe faunal complex* (3 species):
   - East European–West Asian element – *Nothocricetulis migratorius*
   - Balkan (and Southeast European) element – *Nannospalax leucodon, Spermophilus citellus*

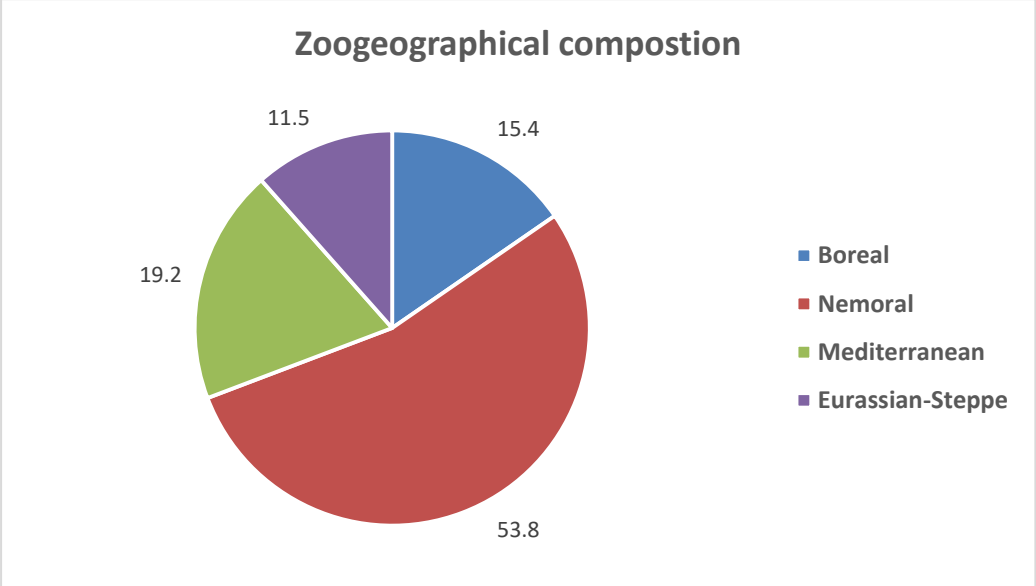

Fig. 6. Zoogeographical composition of small mammal fauna in the Sakar Mts.

The Boreal faunal complex is represented by four species, all of which occur in low abundance within the small mammal communities. For example, *Sorex araneus* and *Arvicola amphibius* are found in only a few locations. The European hare (*Lepus europaeus*) is present at very low densities in the Sakar Mts.

The Mediterranean faunal complex is well represented, comprising approximately one-fifth of all small mammals. An expansion of some species has been recorded in the past few decades. The Etruscan shrew (S. *etruscus*) was first reported in Bulgaria 40 years ago and is now found across most of south-eastern Bulgaria (Nedyalkov *et al.* 2024). Georgiev (2004) found the species in three out of 11 locations, and 20 years later, we recorded it in nine out of 18 locations.

Harting's vole (*M. hartingi*) likely arrived in the area around 30 years ago from western Strandzha and Dervent Heights and is now quite common on the eastern slopes of Sakar. Several outbreaks have been recorded in alfalfa and wheat fields. Soon, this species could cause serious damage to crop.

In summary, the Sakar Mts occupy a marginal position between the Mediterranean and Continental faunal complexes and are also at a crossroads between Europe and Asia. Many Mediterranean species have spread through the valleys of the Maritsa and Tundzha rivers (Popov *et al.* 2004; Nedyalkov *et al.* 2004).

The Eurasian steppe complex is represented by three species, as a large part of their natural habitats has been converted to agricultural land, which has significantly affected *Spermophilus citellus*.

In the study area 4 alien and invasive species were recorded – *Mus musculus*, *Rattus rattus*, *R. norvegicus* and *Myocastor coypus*.

In terms of species composition, the small mammal fauna of Sakar is very similar to that of the neighbouring regions – the Thracian Plain (Markov 1964), Strandzha Mts, and Dervent Heights (Peshev *et al.* 1963, 1967), and to a lesser extent, the Eastern Rhodopes (Peshev *et al.* 1967; Minkova 2004) (Fig. 7). It appears that the Maritsa River, which is the only geographical barrier between Sakar Mts and the Eastern Rhodopes, has played an important role in the dispersal and exchange of small mammals.

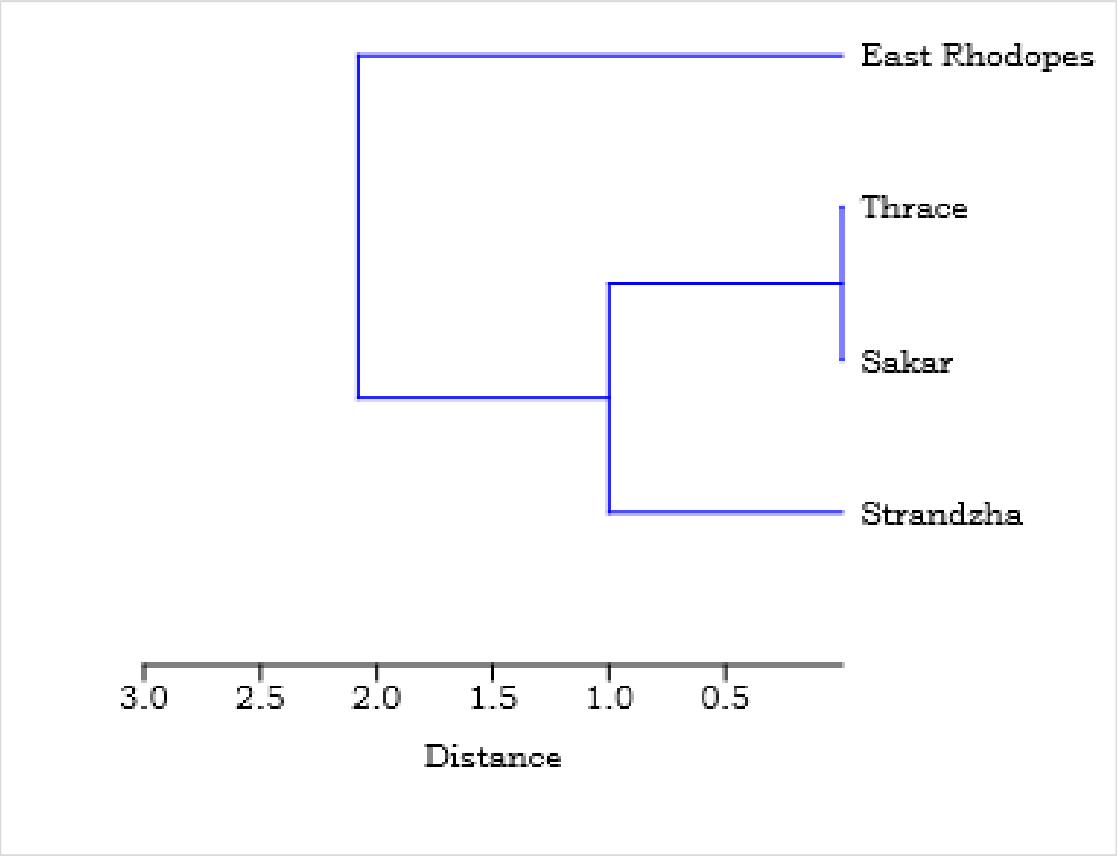

Fig. 7. Faunistic similarity of small mammal fauna of the Sakar Mts and the neighbouring regions (UPGMA algorithm, Euclidean distance).

Conservation and threats

Four species are listed in the Habitat Directive annexes – *Spermophilus citellus, Dryomys nitedula, Myomimus roachi* and *Muscardinus avellanarius* (Table 3).

Myomimus roachi is one of the least known European mammals. Over the past 20 years, its remains have been found in owl pellets at several locations in south-eastern Bulgaria (Georgiev 2004; Milchev & Georgiev 2012; Nedyalkov *et al.* 2018), with almost half of the records coming from the Sakar Mts area. In Sakar, the only known population of *M. roachi* in Bulgaria has been monitored extensively since 2019.

In recent years, wildfires have posed a serious threat to small mammal populations. Not only do they cause direct mortality of individuals, due to the animals' limited ability to escape, but they also destroy habitats with long-lasting effects. In 2023, wildfires severely damaged the habitat of the Mouse-tailed dormouse, affecting over 10 000 decares (see Fig. 8). In the following year, 2024, another wildfire occurred, once again affecting approximately 10,000 decares. In 2025, wildfires covered an area of around 60,000 decares.

Fig. 8. Destroyed Mouse-tailed dormouse (*M. roachi*) habitat by wildfires in 2023 (photo Anton Stamenov).

The clearing of grassland–shrub communities, undertaken to keep pastures and grasslands open, has a serious negative impact on small mammal populations. A newly introduced technique involving the mechanical removal of shrubs and small trees using shredders or mulchers directly destroys valuable habitats and shelters for certain species (*L. europaeus, E. roumanicus*, and others) (Fig. 9). On the other hand, grassland clearing benefits Harting's vole (*M. hartingi*), a species which prefers open habitats. This is likely one of the reasons supporting the expansion of its distribution in Sakar Mts.

Fig. 9. Destroyed shrub habitats by shredders and a hedgehog (*E. roumanicus*) killed by shredder (photo Georgi Popgeogiev).

Table 3. Conservation status of small mammals found in Sakar Mts.

№	Species	BA 2002	RDB	IUCN	Bern	92/43
1	*Erinaceus roumanicus*	III	LC	LC	III	
2	*Talpa europaea*		LC	LC		
3	*Sorex araneus*		LC	LC	III	
4	*Sorex minutus*		LC	LC	III	
5	*Neomys milleri*		LC	LC	III	
6	*Suncus etruscus*	III	LC	LC		
7	*Crocidura gueldenstadtii*		LC	LC	II	
8	*Crocidura leucodon*		LC	LC	III	
9	*Lepus europaeus*		NT	LC	III	
10	*Sciurus vulgaris*		NT	LC	III	
11	*Spermophilus citellus*	II	VU	EN	II	II, IV

№	Species	BA 2002	RDB	IUCN	Bern	92/43
12	*Glis glis*		LC	LC	III	
13	*Muscardinus avellanarius*	II, III	NT	LC	III	IV
14	*Dryomys nitedula*	II	NT	LC	III	IV
15	*Myomimus roachi*		VU	VU		II, IV
16	*Myocastor coypus*		NE			
17	*Nannospalax leucodon*		LC	LC		
18	*Micromys minutus*		NT	LC		
19	*Apodemus agrarius*		LC	LC		
20	*Apodemus sylvaticus*		LC	LC		
21	*Apodemus flavicollis*		LC	LC		
22	*Mus macedonicus*		LC	LC		
23	*Mus musculus*		NE			
24	*Rattus norvegicus*		NE	LC		
25	*Rattus rattus*		NE	LC		
26	*Nothocricetulus migratorius*	II, III	VU	LC		
27	*Arvicola amphibius*		LC	LC		
28	*Microtus hartingi*		NE	LC		
29	*Microtus rossiaemeridionalis*		LC	LC		
30	*Microtus subterraneus*		LC	LC		

Legend:

BA 2002 – Biodiversity Protection Act (State Gazette, No.77 from 9 August 2002), Appendix 2 and Appendix 3 – protected species on the territory of Bulgaria.

92/43– Directive 92/43/EU or Recommendation No.43 on the conservation of threatened mammals in Europe (1995) and its Amendment (1996) adopted by the Standing Committee of Council of Europe; Annex II – species whose conservation requires the designation of special areas of conservation, Annex IV – species of community interest in need of strict protection;

Bern - Bern Convention on the conservation of European wildlife and natural habitats, adopted by the Council of Europe in 1998: Appendix II – strictly protected fauna species, Appendix III – protected species;

IUCN – The 2013 IUCN Red List of Threatened Species (IUCN 2013); Categories: (CR) – Critically Endangered; (EN) – Endangered; (VU) – Vulnerable; (NT) – Near Threatened; (LC) – Least Concern; (DD) – Data Deficient; (NE) – Not Evaluated;

RDB (Red Data Book of Bulgaria, Vol. 2 Animals, 2015, Golemansky 2015) Categories: (EX) Extinct or possible extinct (?EX); (CR) – Critically Endangered; (EN) – Endangered; (VU) – Vulnerable; (NT) – NearThreatened; (LC) – Least Concern; (DD) – Data Deficient; (NE) – NotEvaluated;

Acknowledgments: Our work in the area through the last 20 years, has been supported by numerous projects, we want to tank a few of them incl. "Restoration and sustainable management of the Imperial eagle's foraging habitats in key Natura 2000 sites in Bulgaria" (LIFE14 NAT/BG/001119); Conservation measures for the Lesser Spotted Eagle and its habitats in Bulgaria (LIFE18 NAT/BG/001051. The monitoring program of dormice was supported by the Habitat Foundation (The Netherlands) and People Trust (PTES) via the project "Saving the Mouse-tailed Dormouse – one of the rarest mammal species of Europe", and many people who donated for that work.

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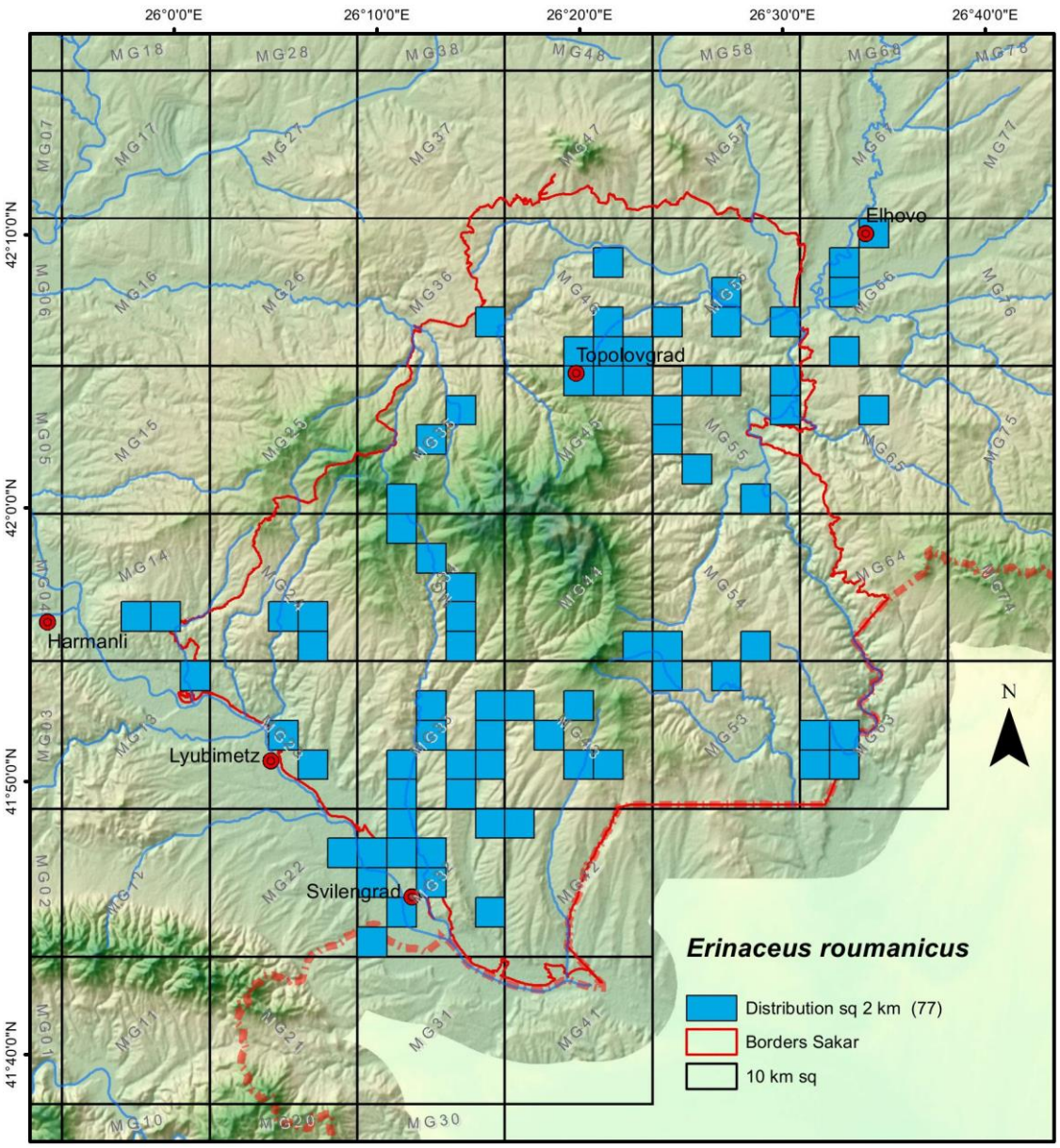
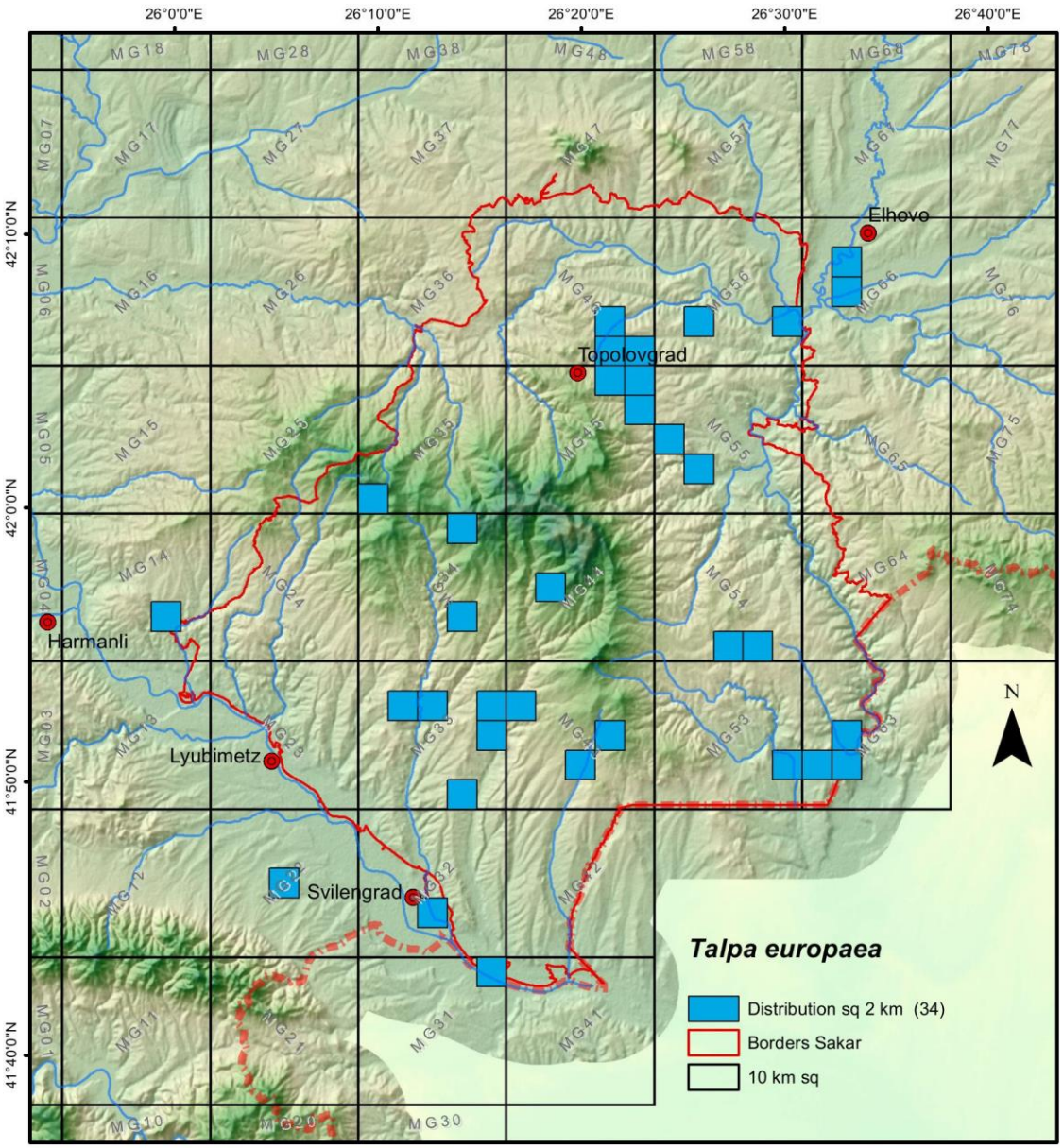
Appendix 1. Distributional maps.

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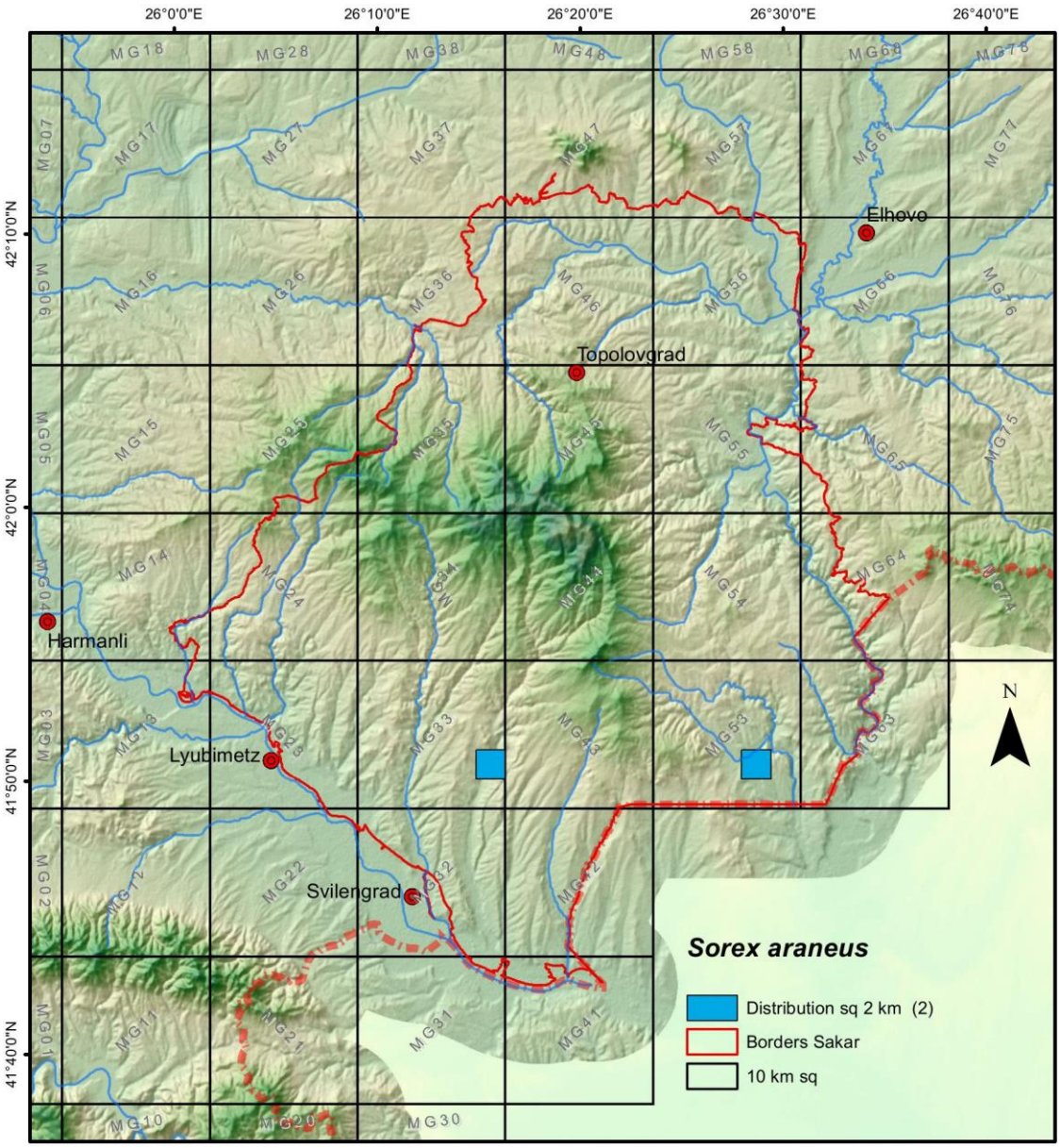
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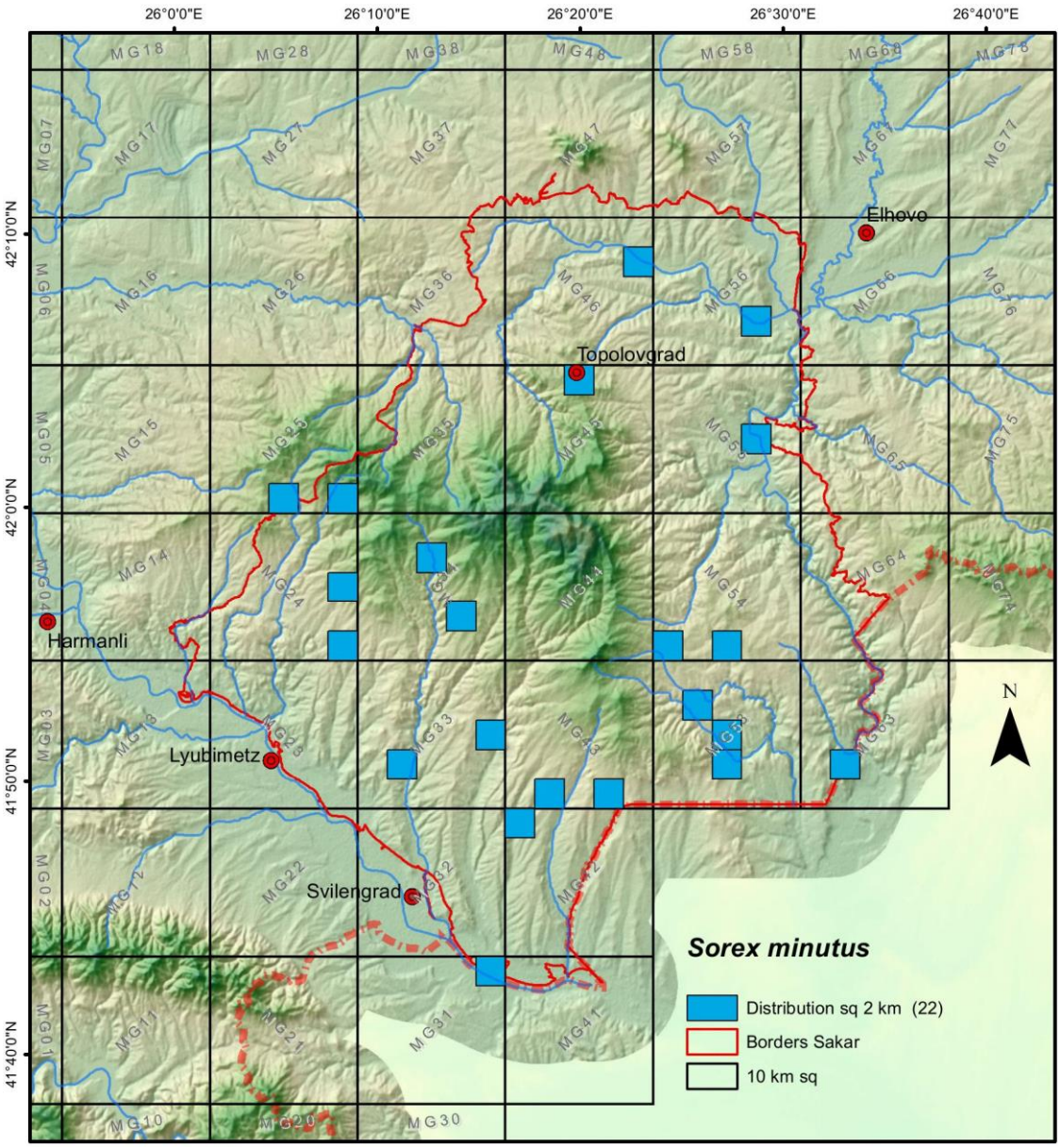
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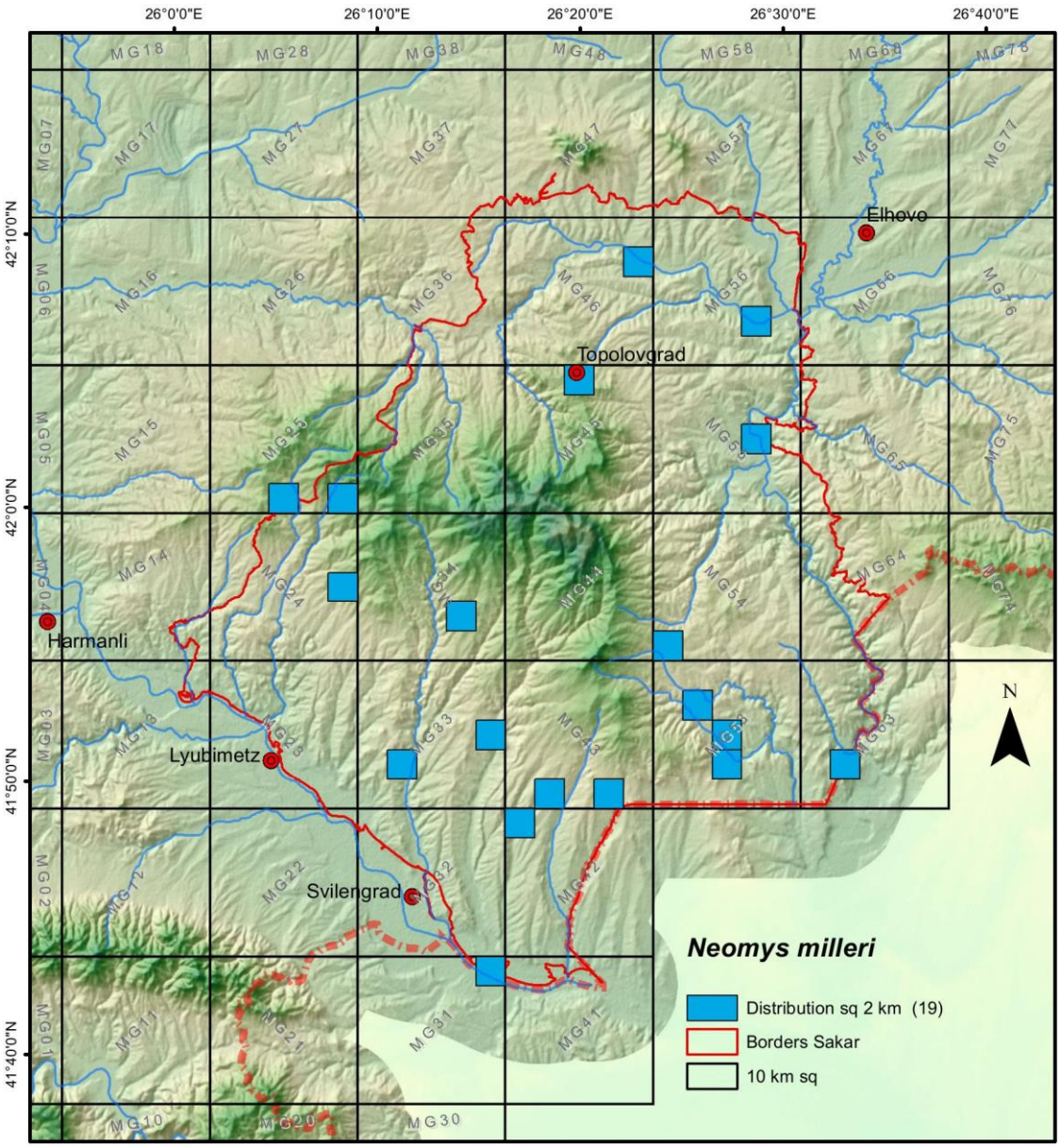
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Distribution sq 2 km (19)
Borders Sakar
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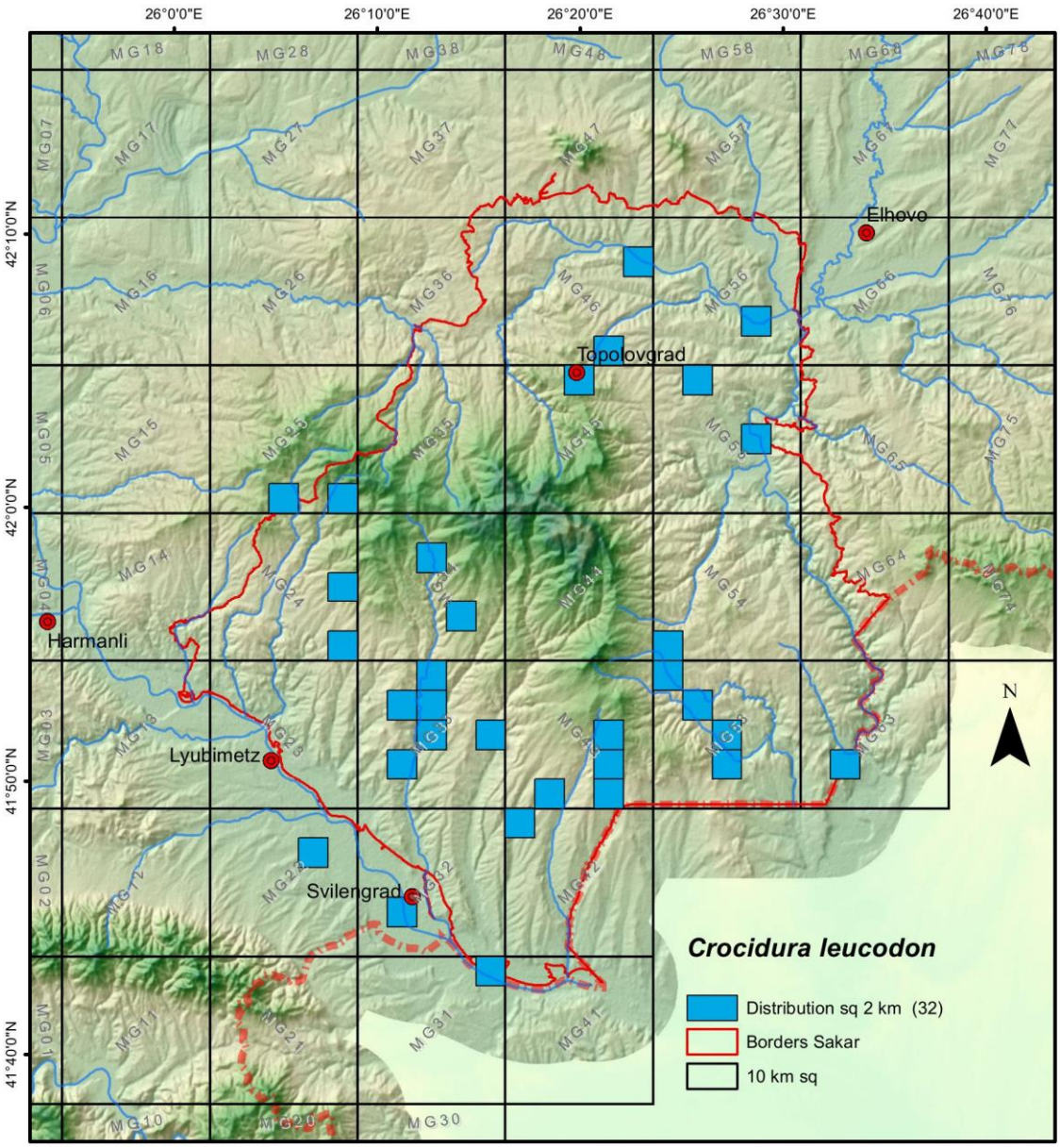
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Harmanli
Lyubimetz
Svilengrad
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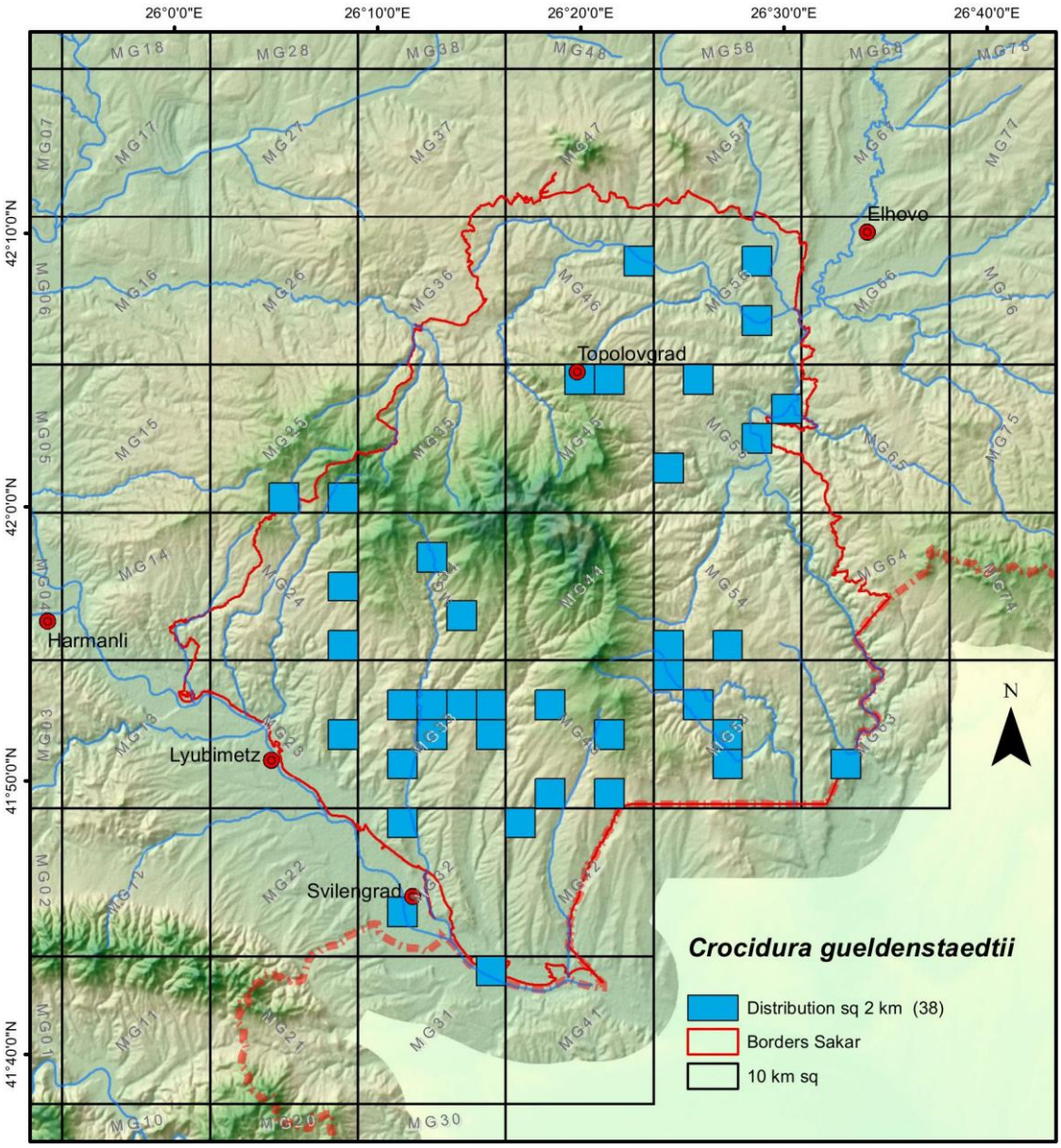
Crocidura leucodon
Distribution sq 2 km (32)
Borders Sakar
10 km sq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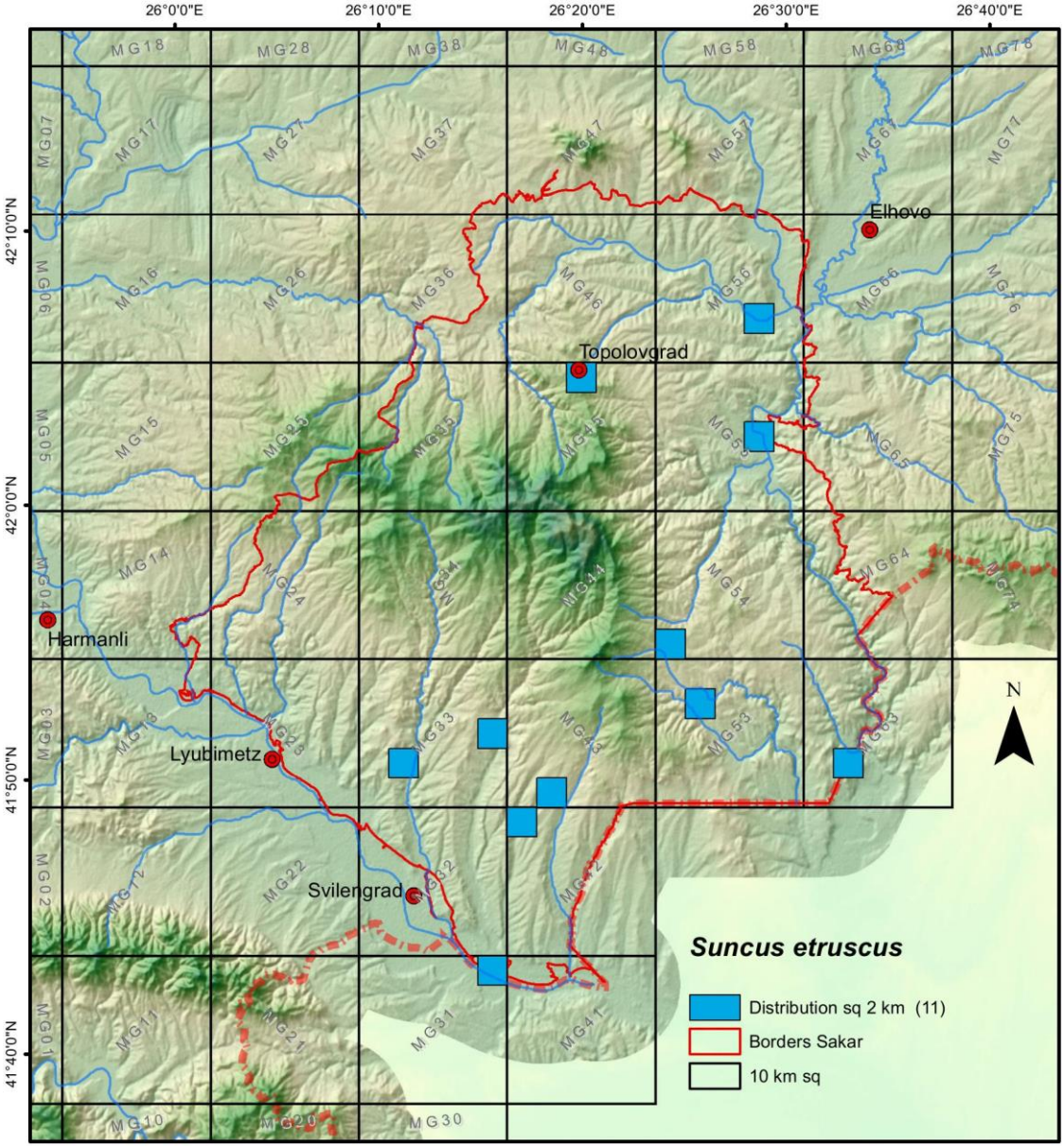
41°50'0"N
41°40'0"N
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Crocidura gueldenstaedtii
Distribution sq 2 km (38)
Borders Sakar
10 km sq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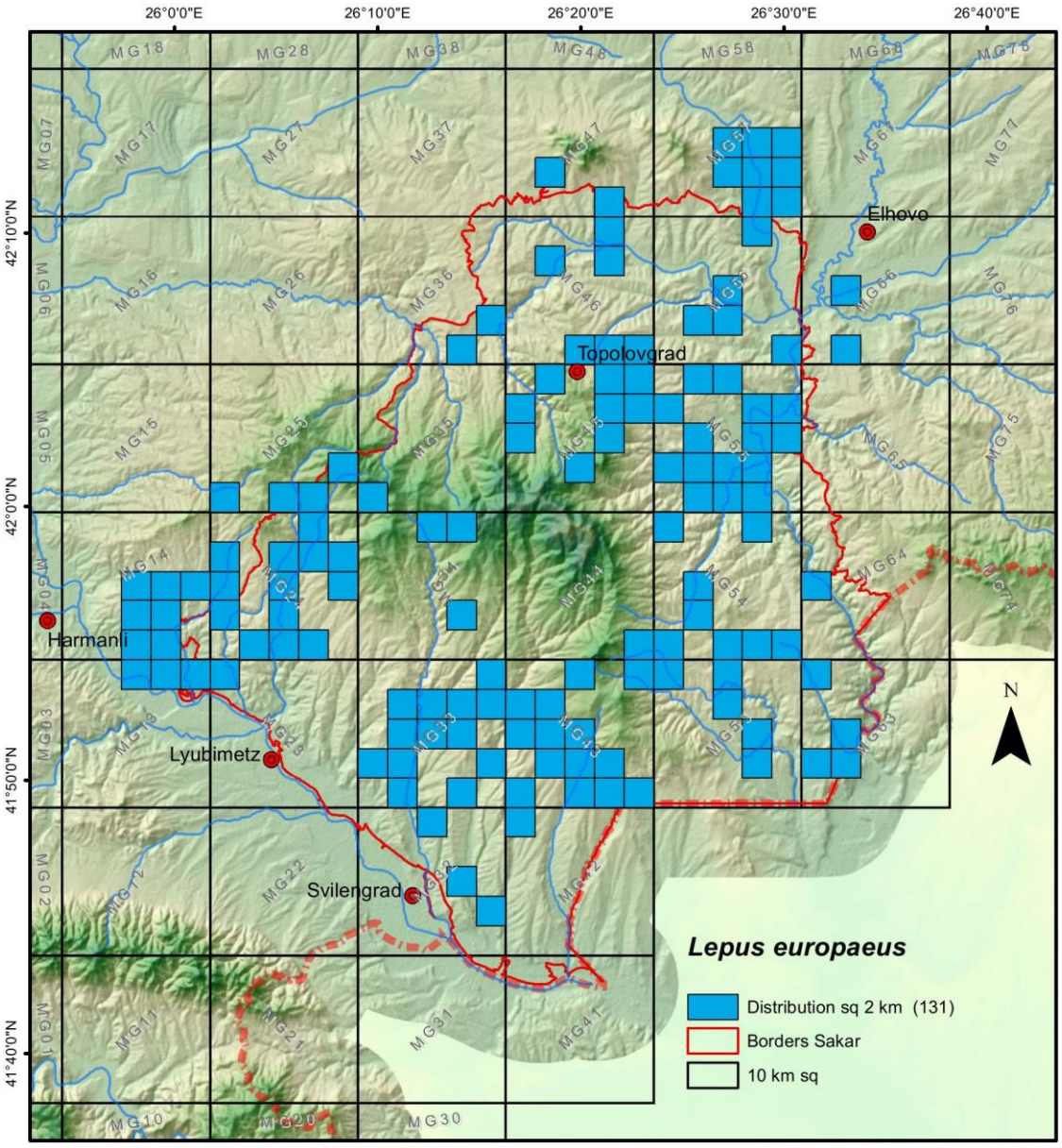
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Suncus etruscus
Distribution sq 2 km (11)
Borders Sakar
10 km sq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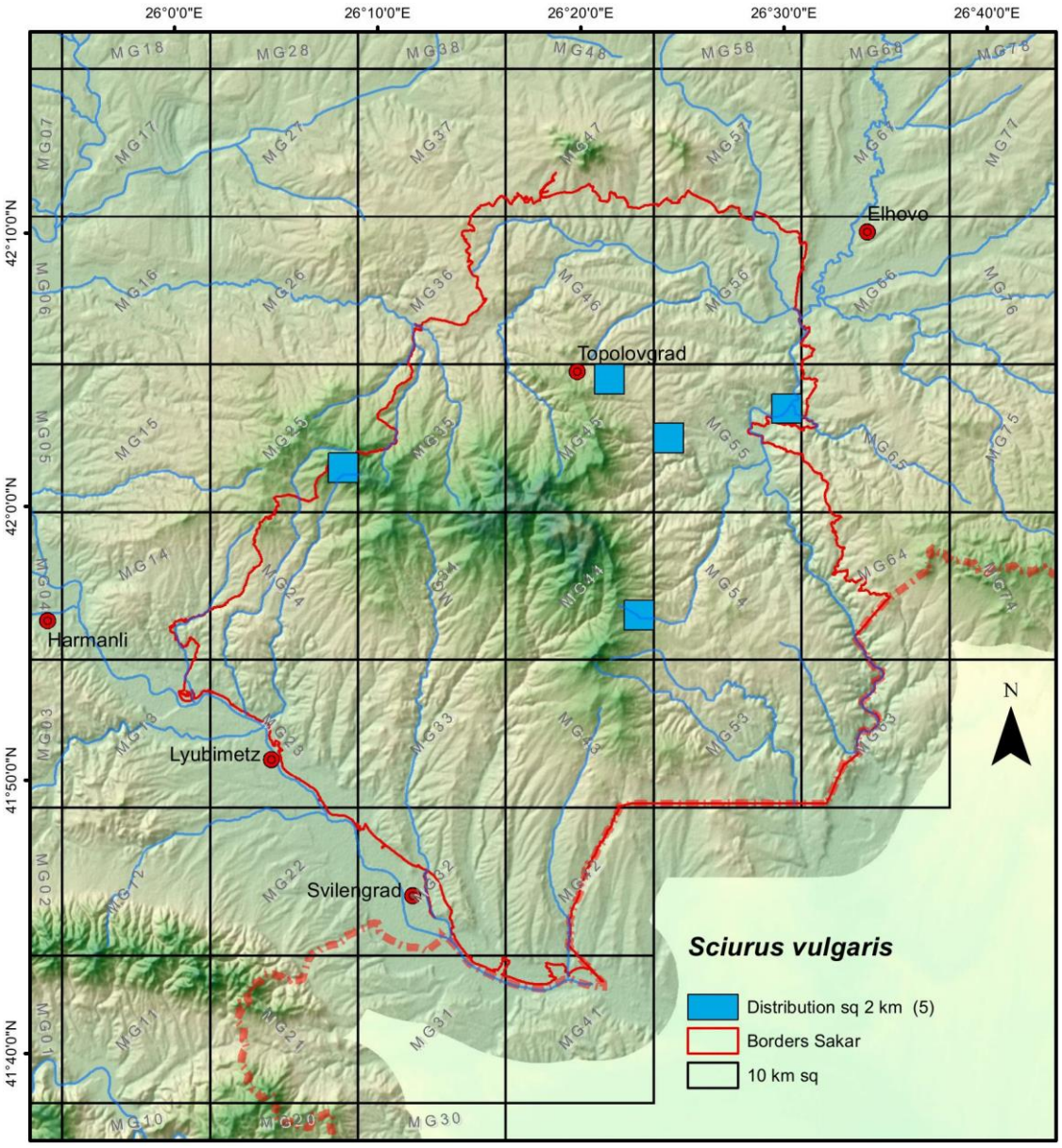
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Lepus europaeus
Distribution sq 2 km (131)
Borders Sakar
10 km sq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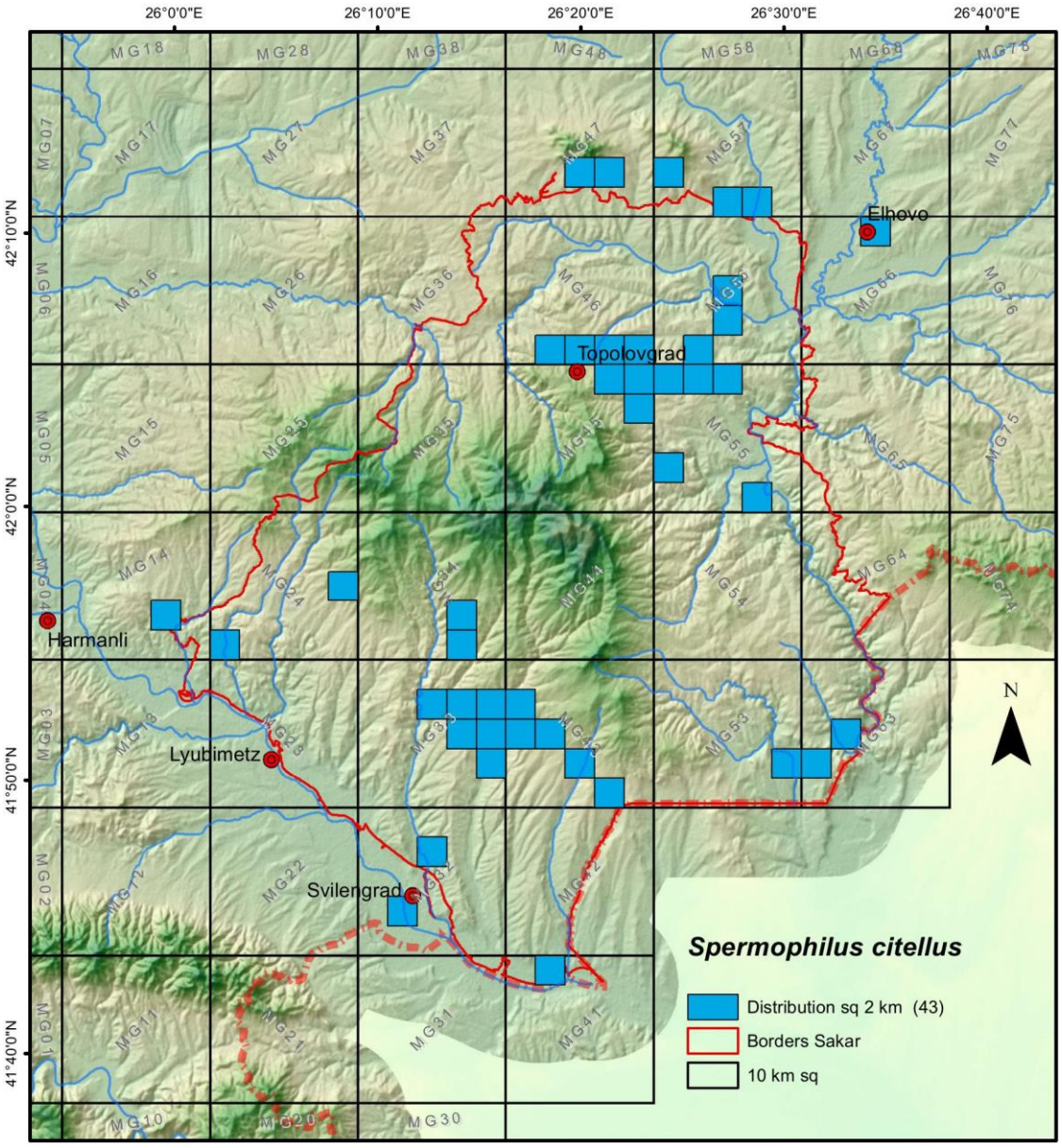
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Sciurus vulgaris
Distribution sq 2 km (5)
Borders Sakar
10 km sq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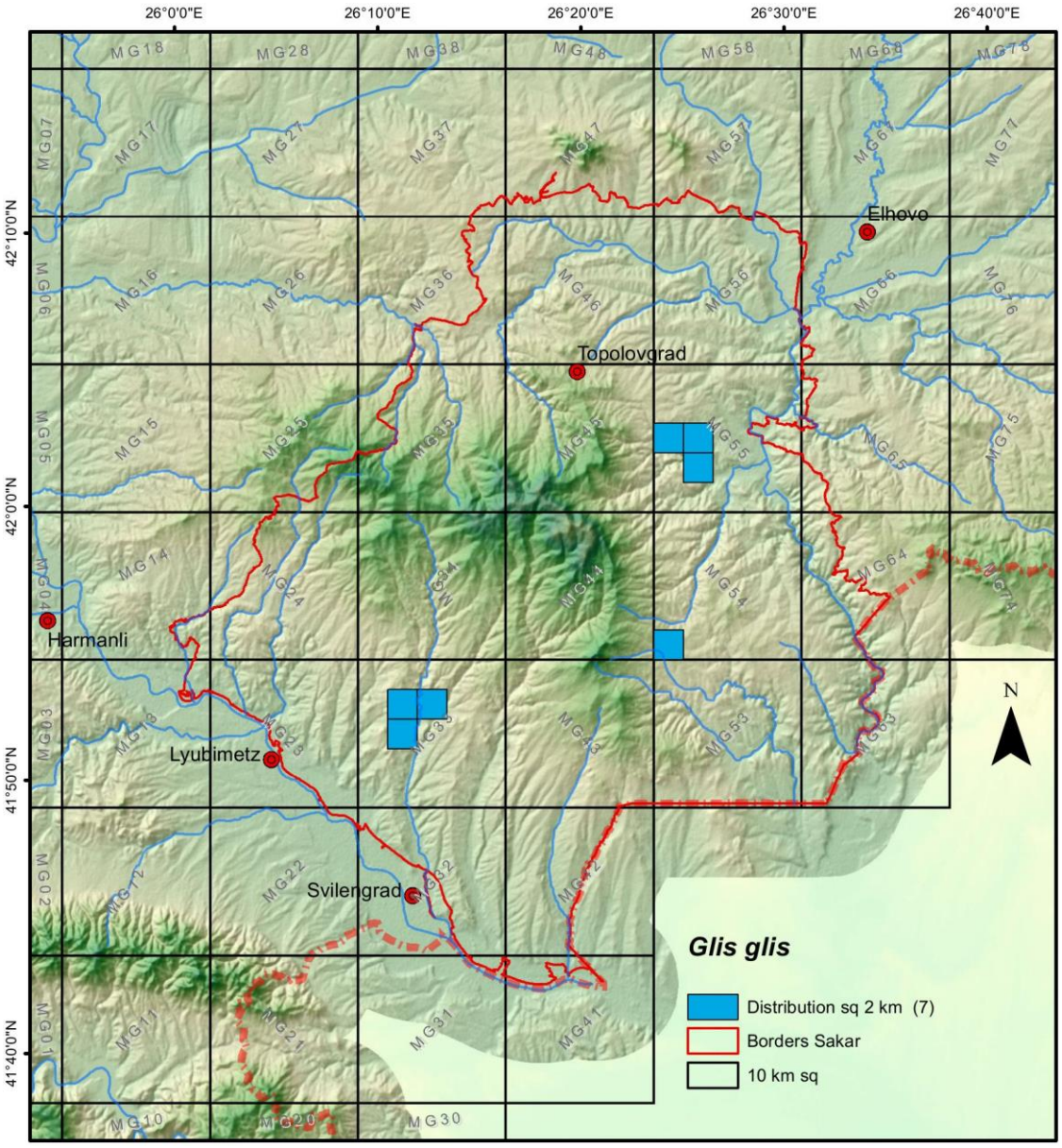
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Spermophilus citellus
Distribution sq 2 km (43)
Borders Sakar
10 km sq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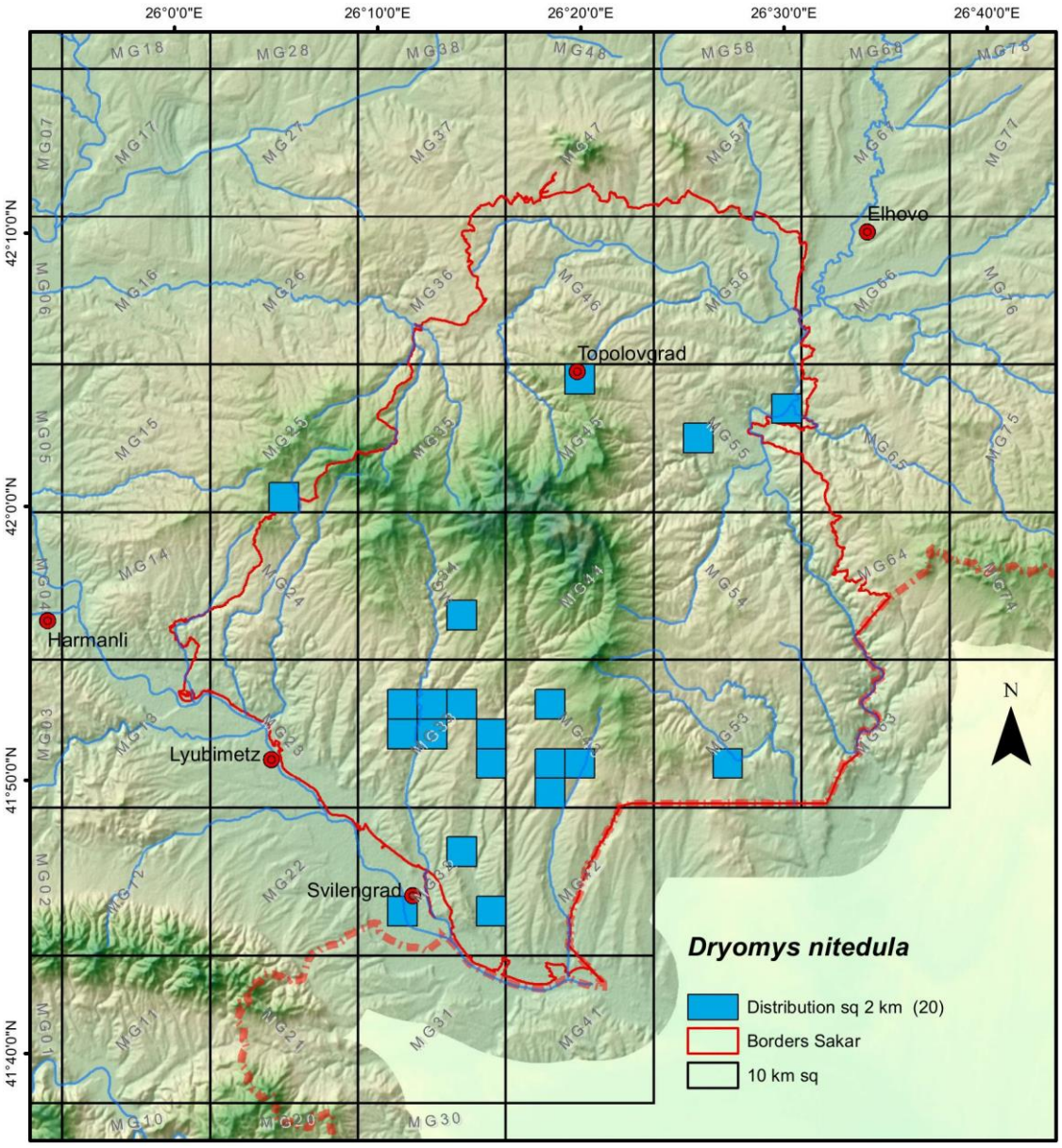
41°40'0"N
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Glis glis
Distribution sq 2 km (7)
Borders Sakar
10 km sq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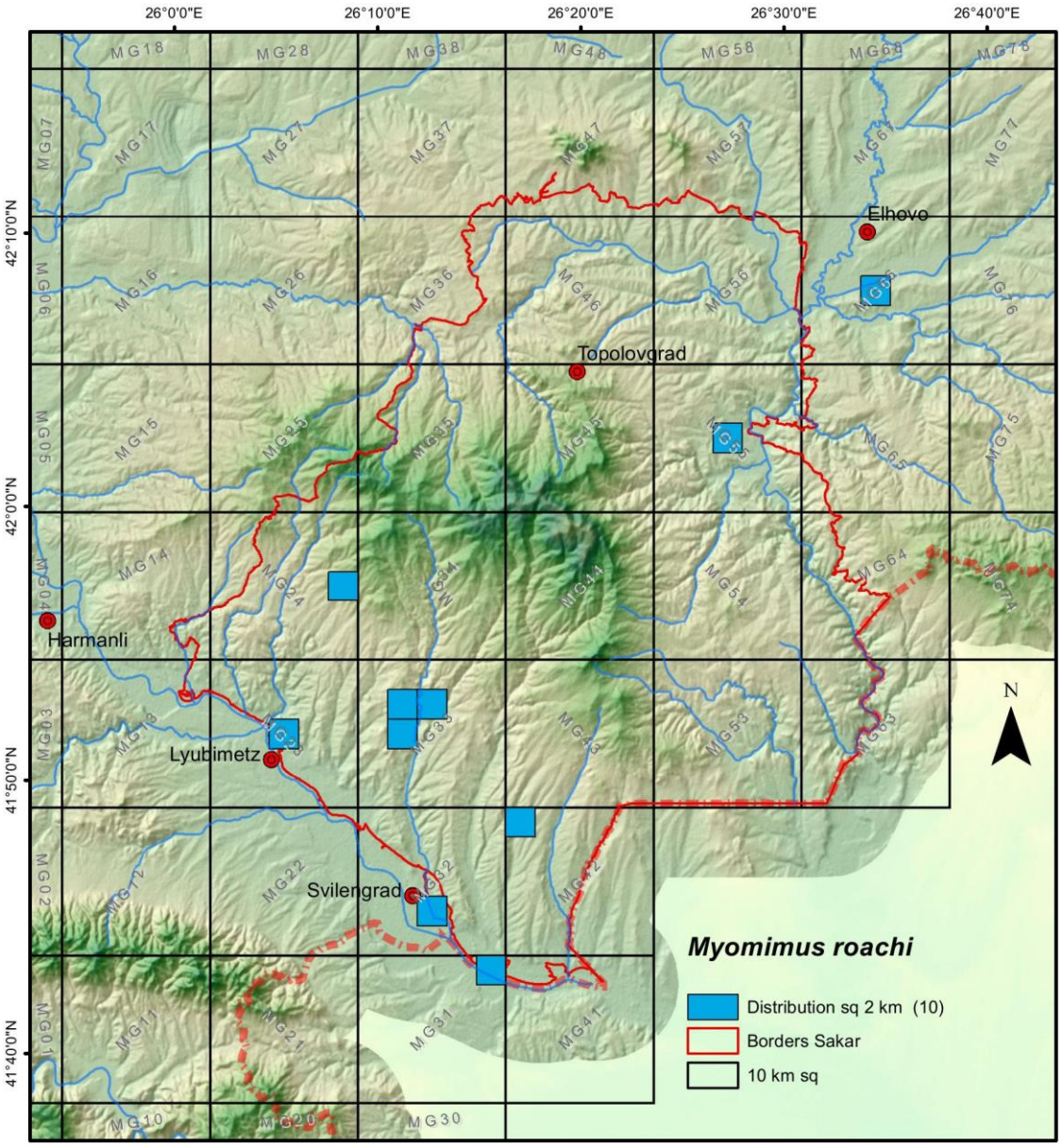
41°50'0"N
41°40'0"N
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Dryomys nitedula
Distribution sq 2 km (20)
Borders Sakar
10 km sq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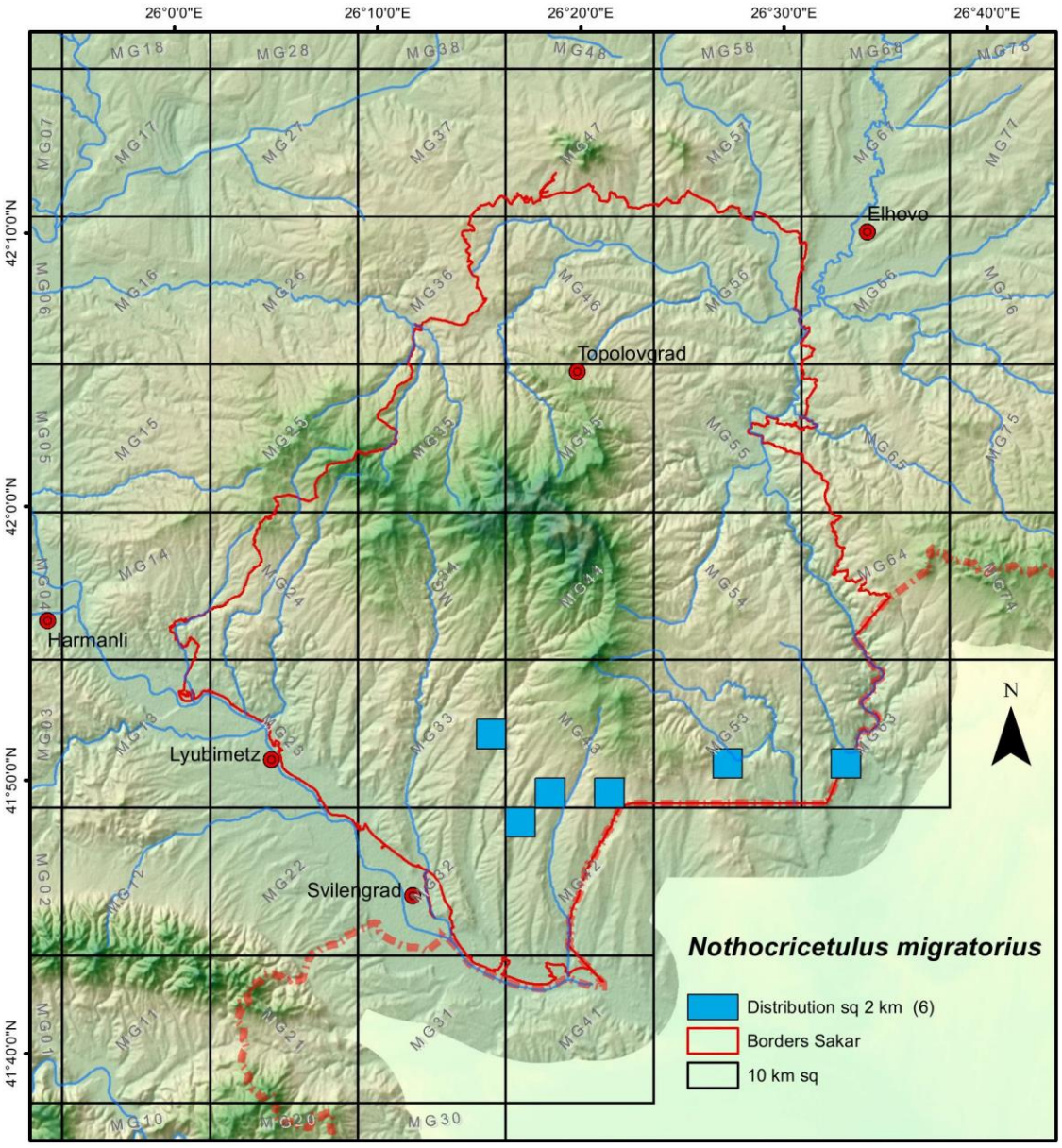
41°40'0"N
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Myomimus roachi
Distribution sq 2 km (10)
Borders Sakar
10 km sq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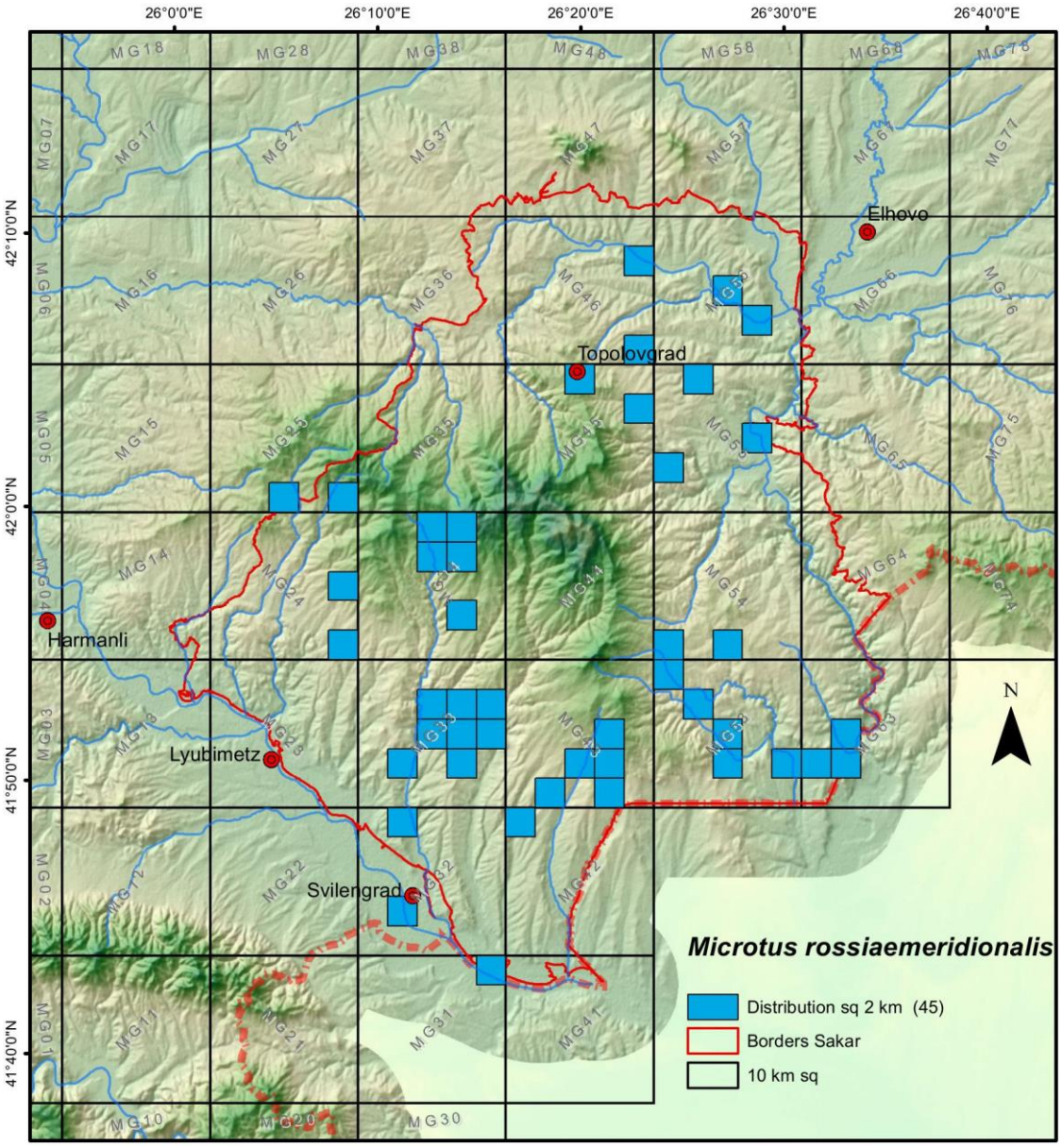
41°50'0"N
41°40'0"N
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Nothocricetulus migratorius
Distribution sq 2 km (6)
Borders Sakar
10 km sq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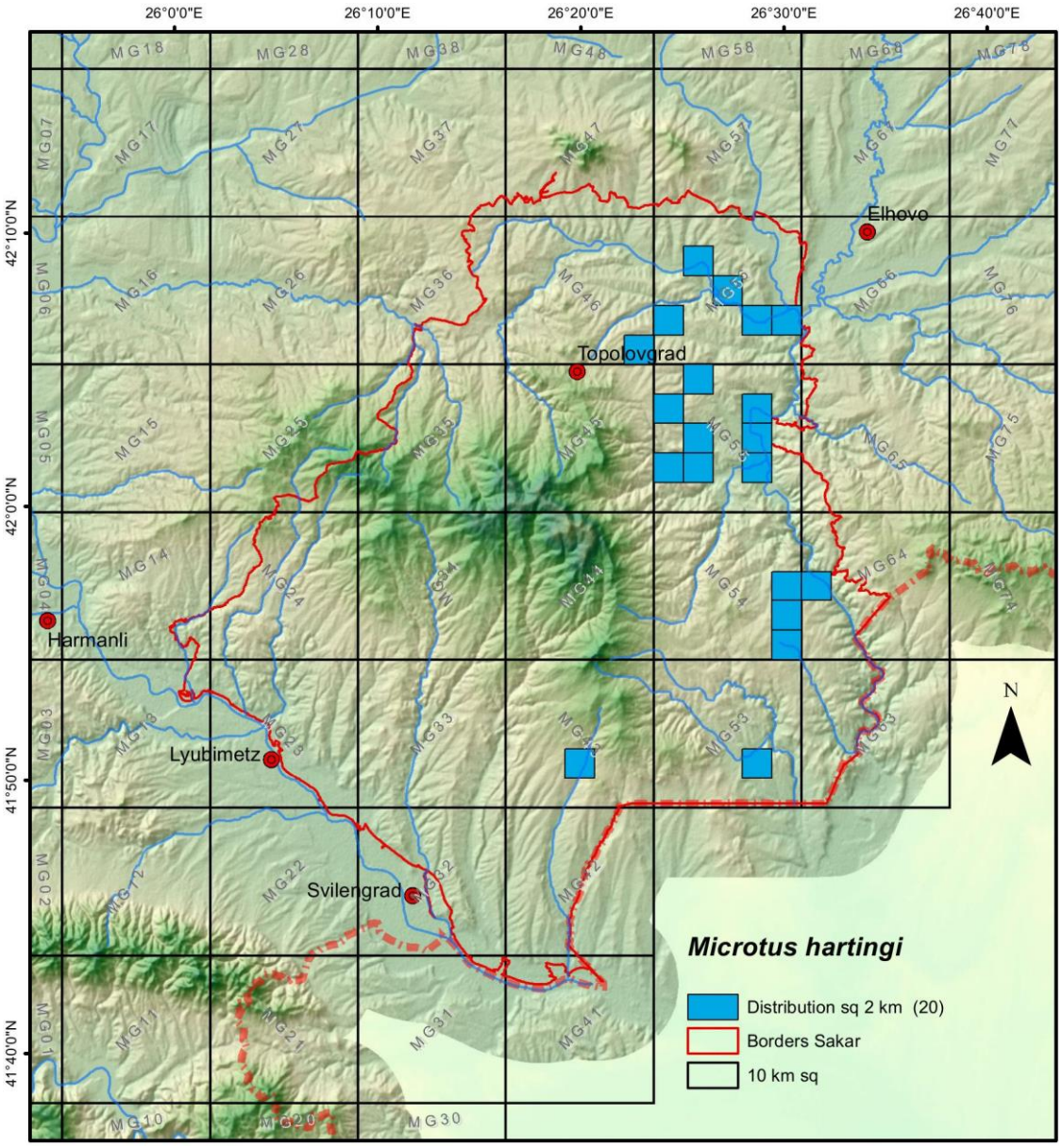
41°40'0"N
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Microtus rossiaemeridionalis
Distribution sq 2 km (45)
Borders Sakar
10 km sq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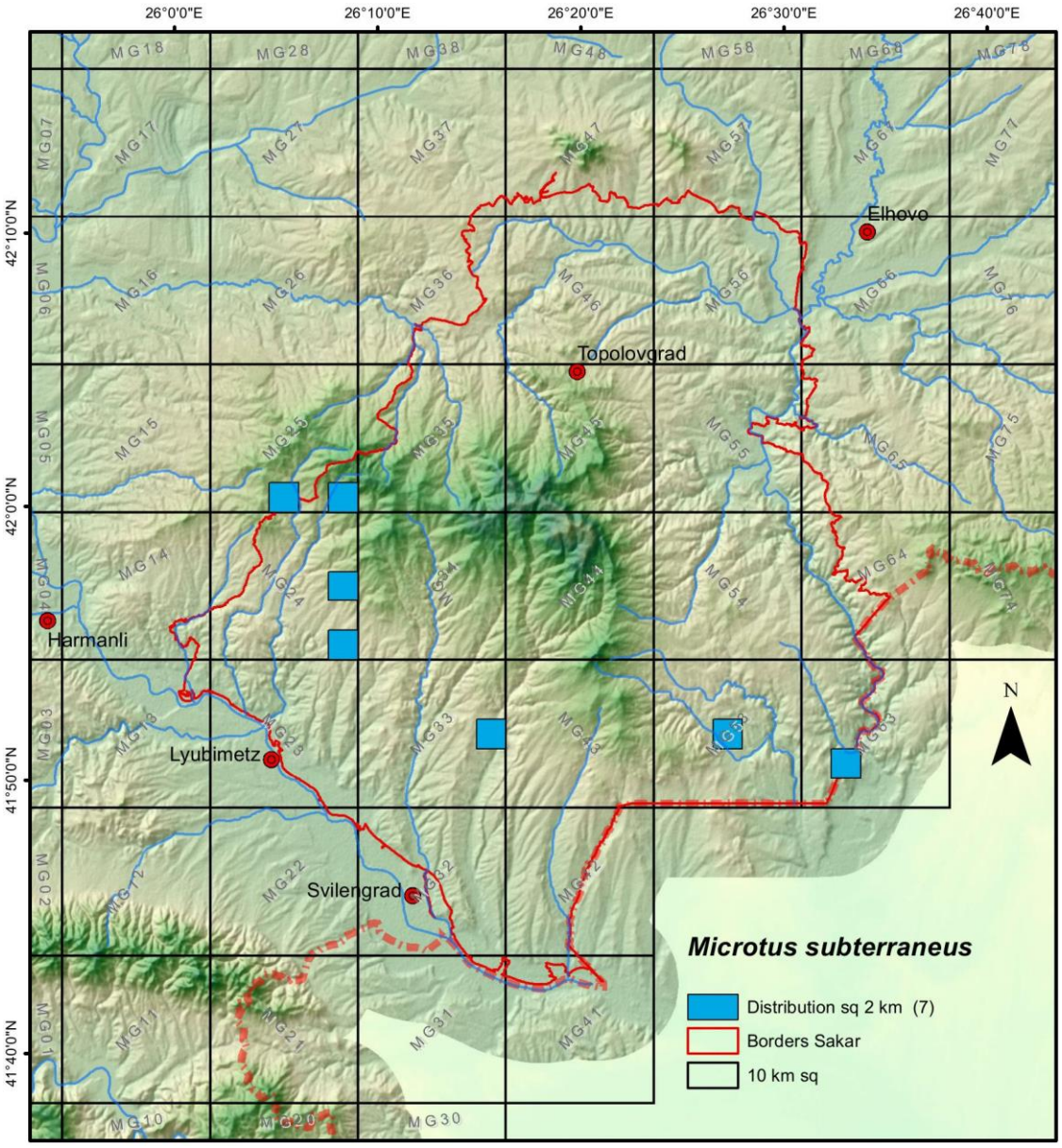
41°40'0"N
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Microtus hartingi
Distribution sq 2 km (20)
Borders Sakar
10 km sq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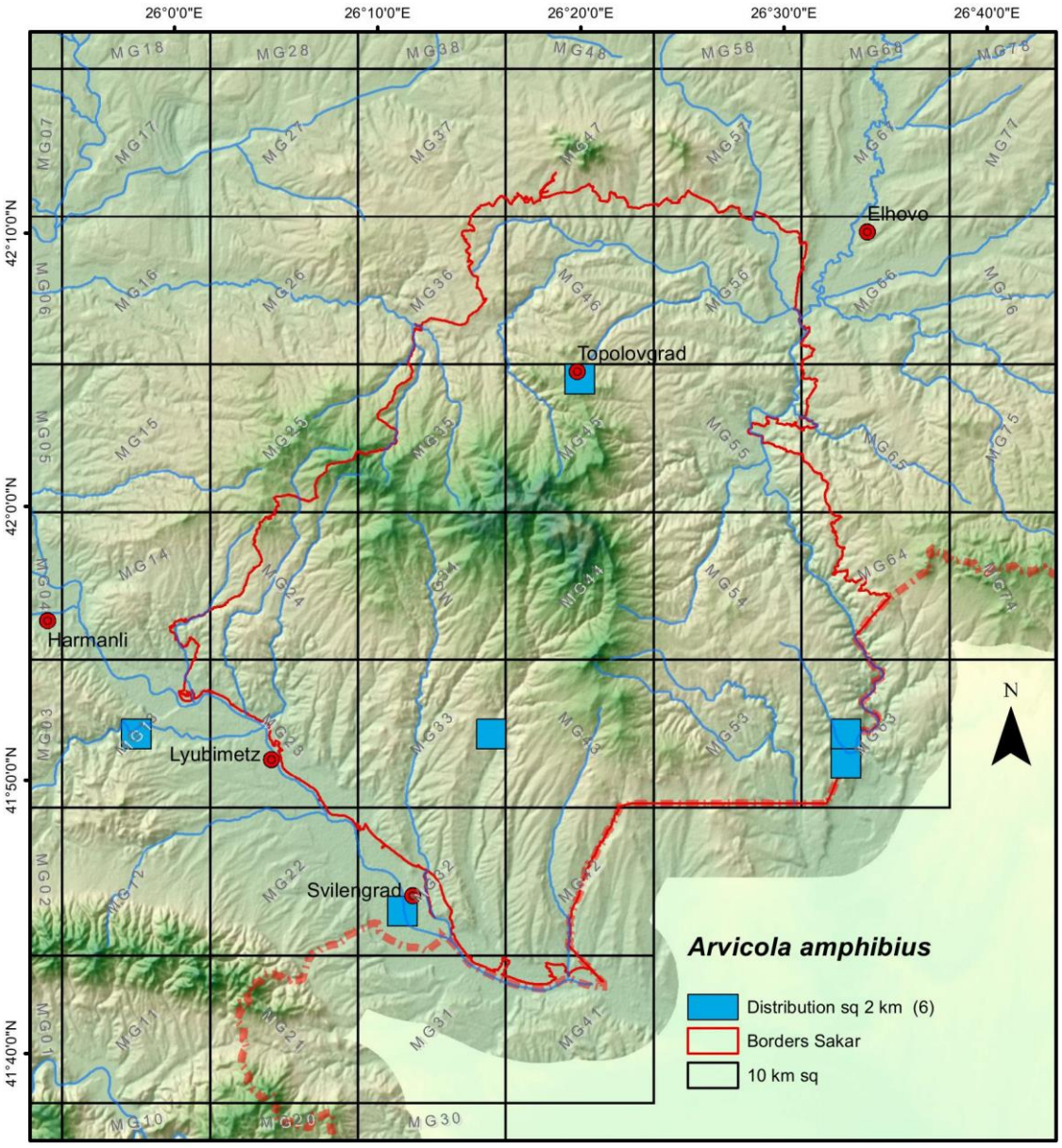
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Microtus subterraneus
Distribution sq 2 km (7)
Borders Sakar
10 km sq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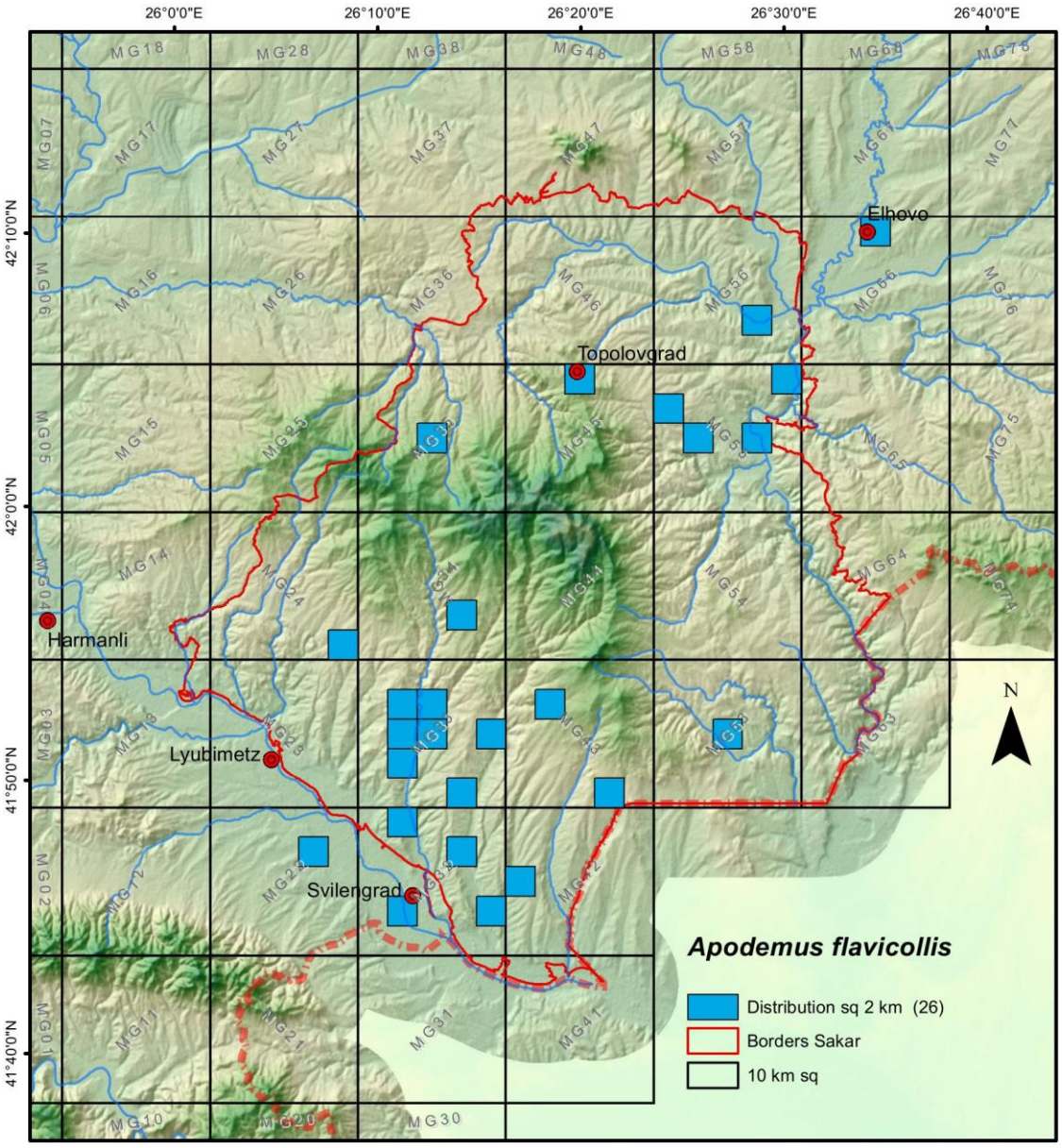
41°50'0"N
41°40'0"N
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Arvicola amphibius
Distribution sq 2 km (6)
Borders Sakar
10 km sq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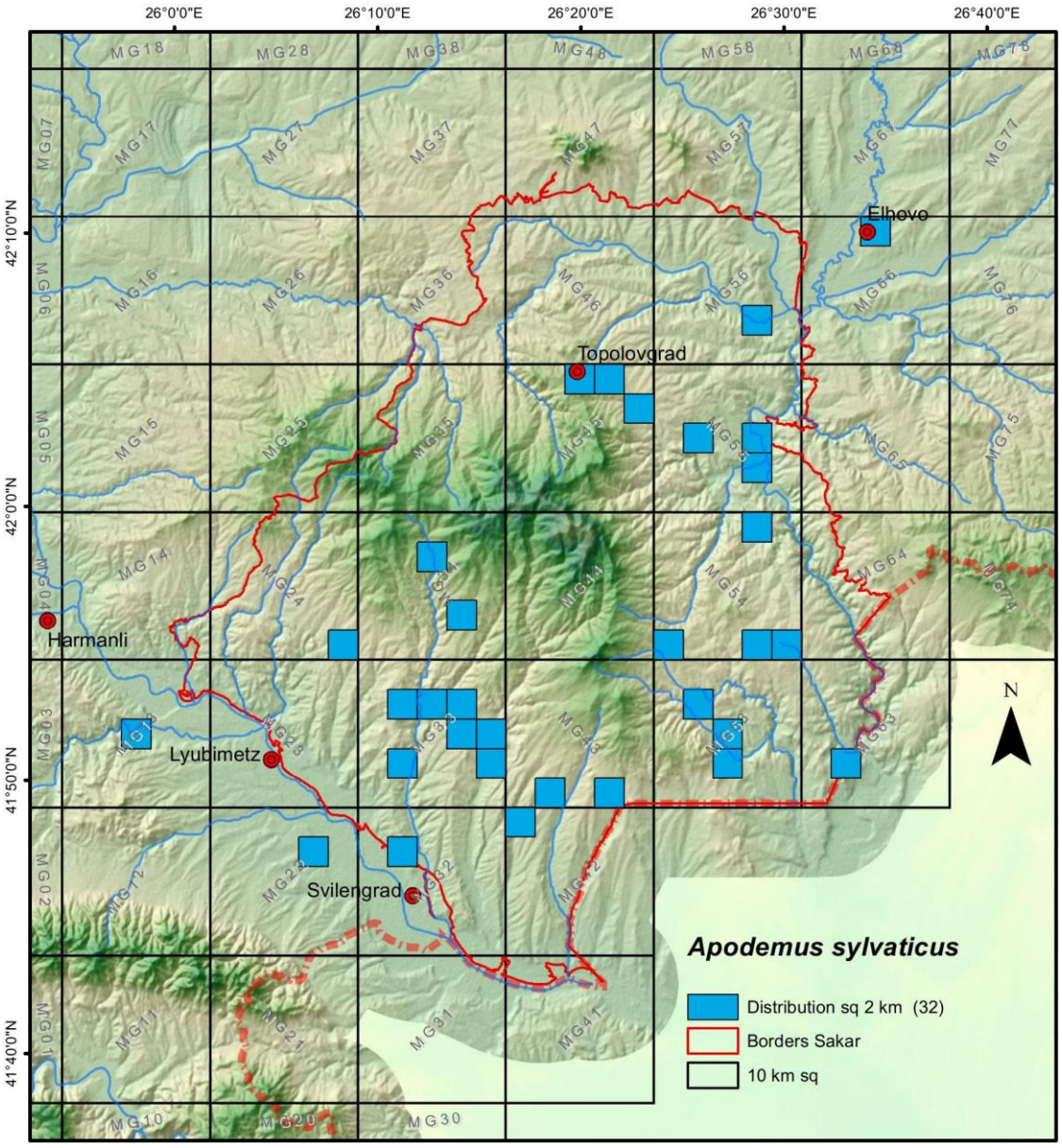
41°40'0"N
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Apodemus flavicollis
Distribution sq 2 km (26)
Borders Sakar
10 km sq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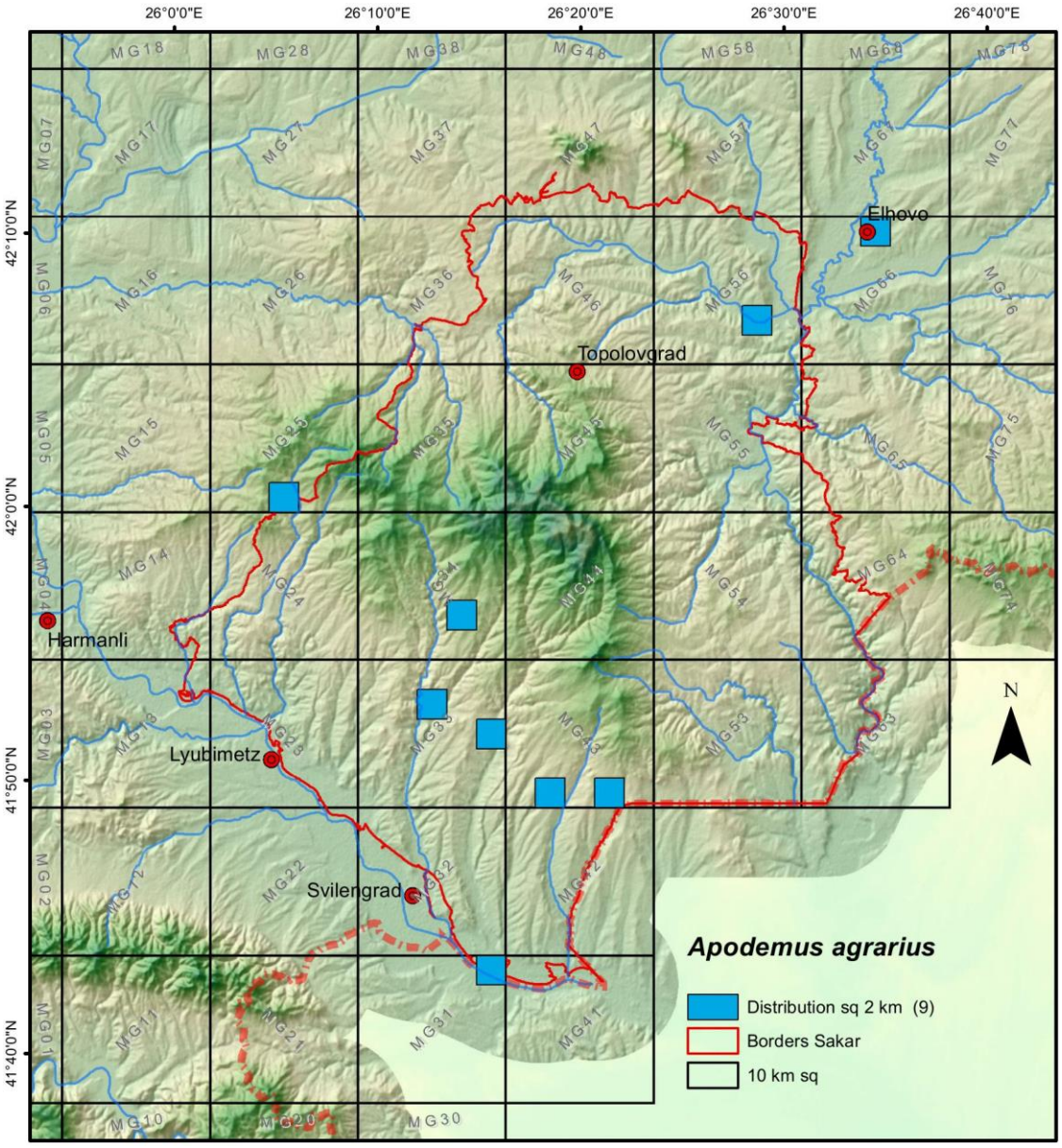
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Apodemus sylvaticus
Distribution sq 2 km (32)
Borders Sakar
10 km sq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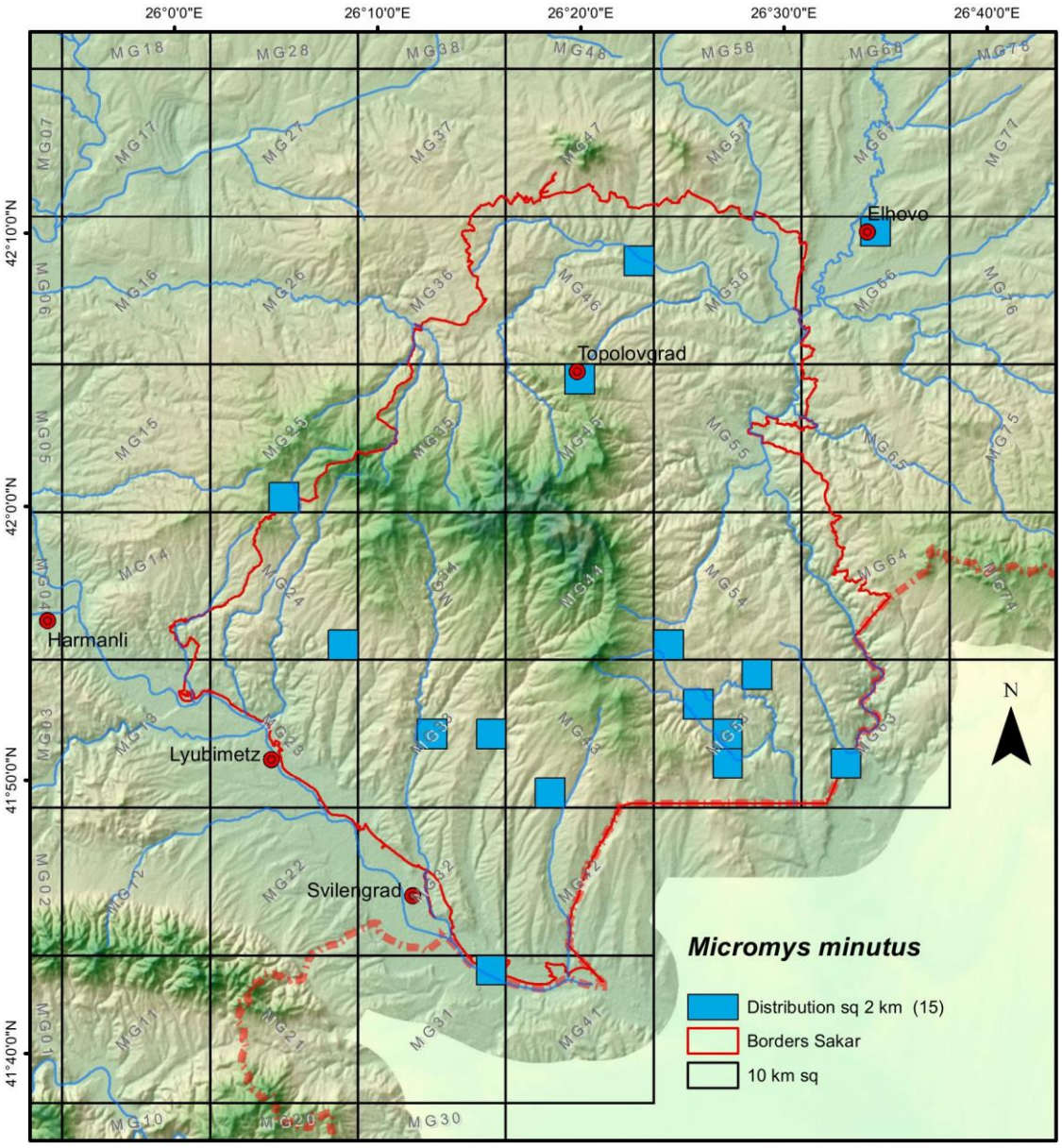
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Apodemus agrarius
Distribution sq 2 km (9)
Borders Sakar
10 km sq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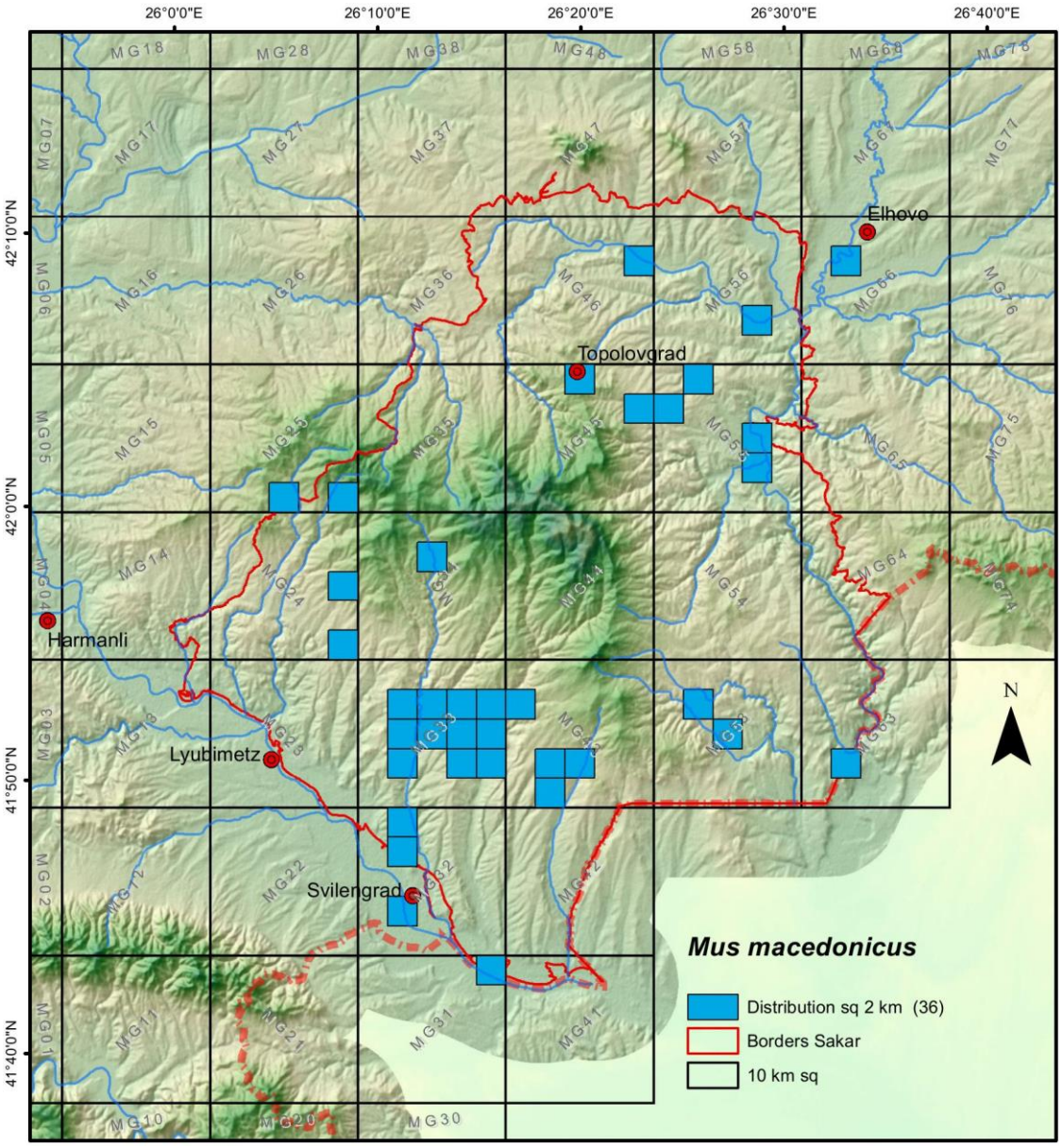
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Micromys minutus
Distribution sq 2 km (15)
Borders Sakar
10 km sq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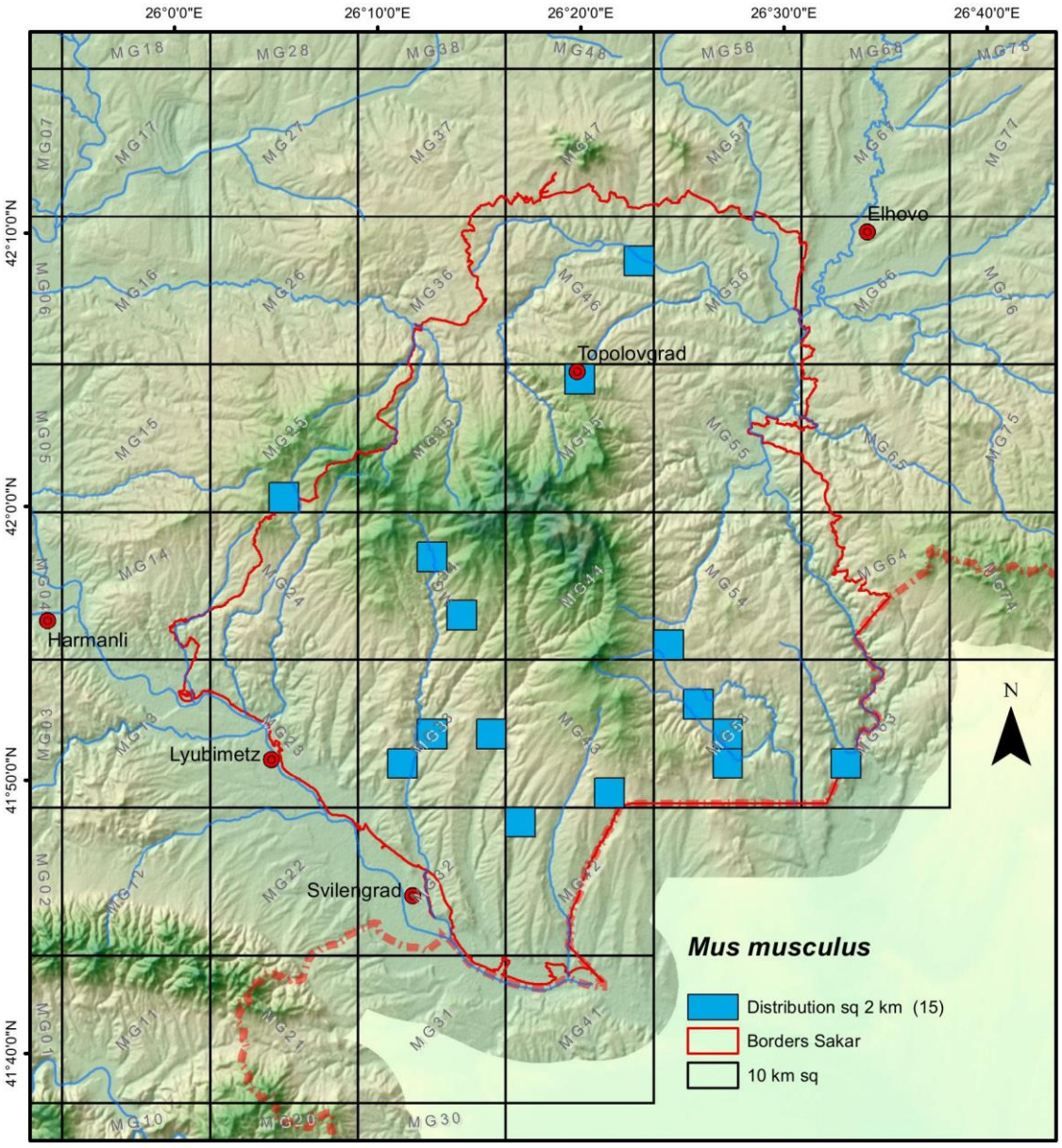
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Mus macedonicus
Distribution sq 2 km (36)
Borders Sakar
10 km sq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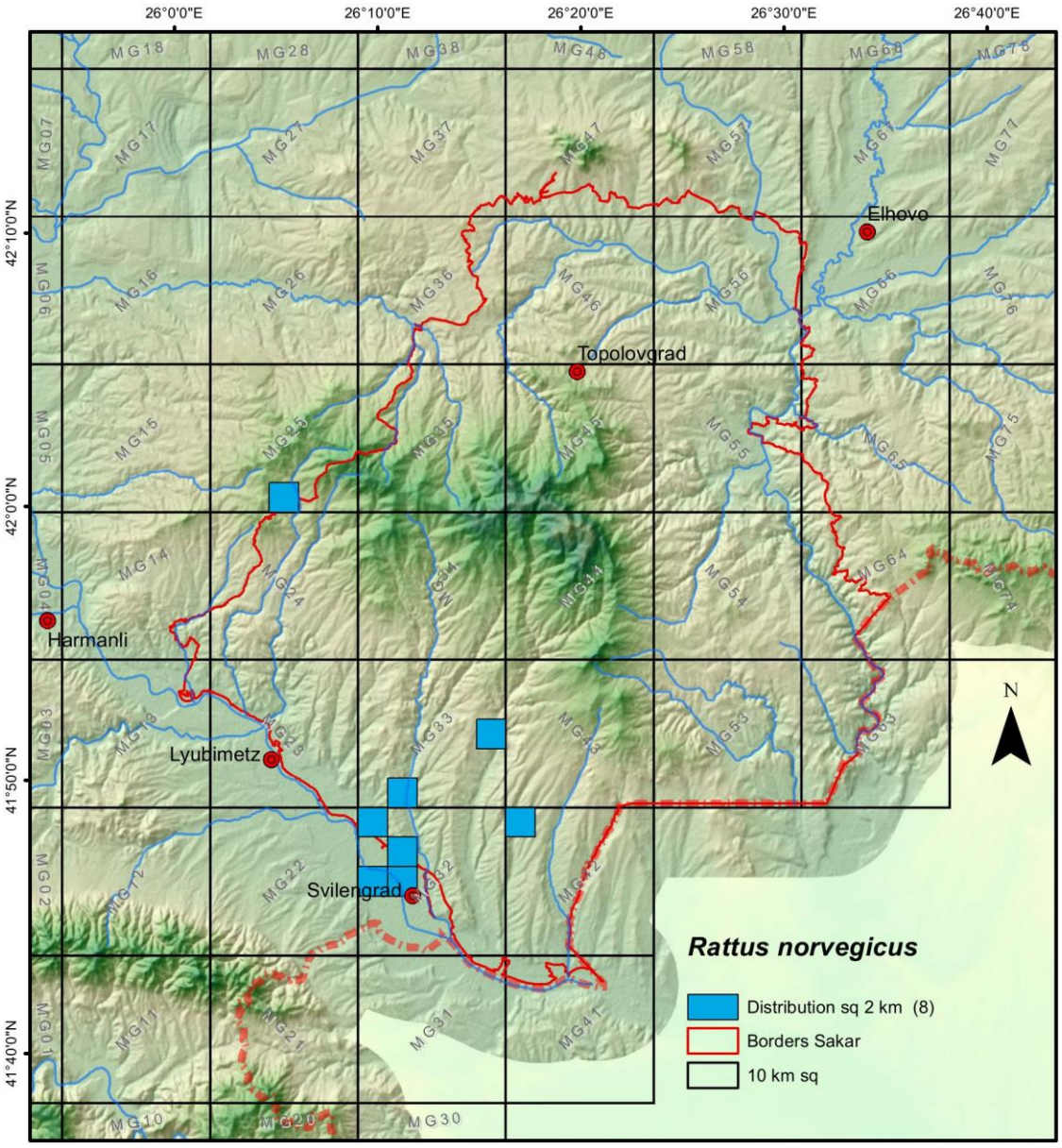
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Mus musculus
Distribution sq 2 km (15)
Borders Sakar
10 km sq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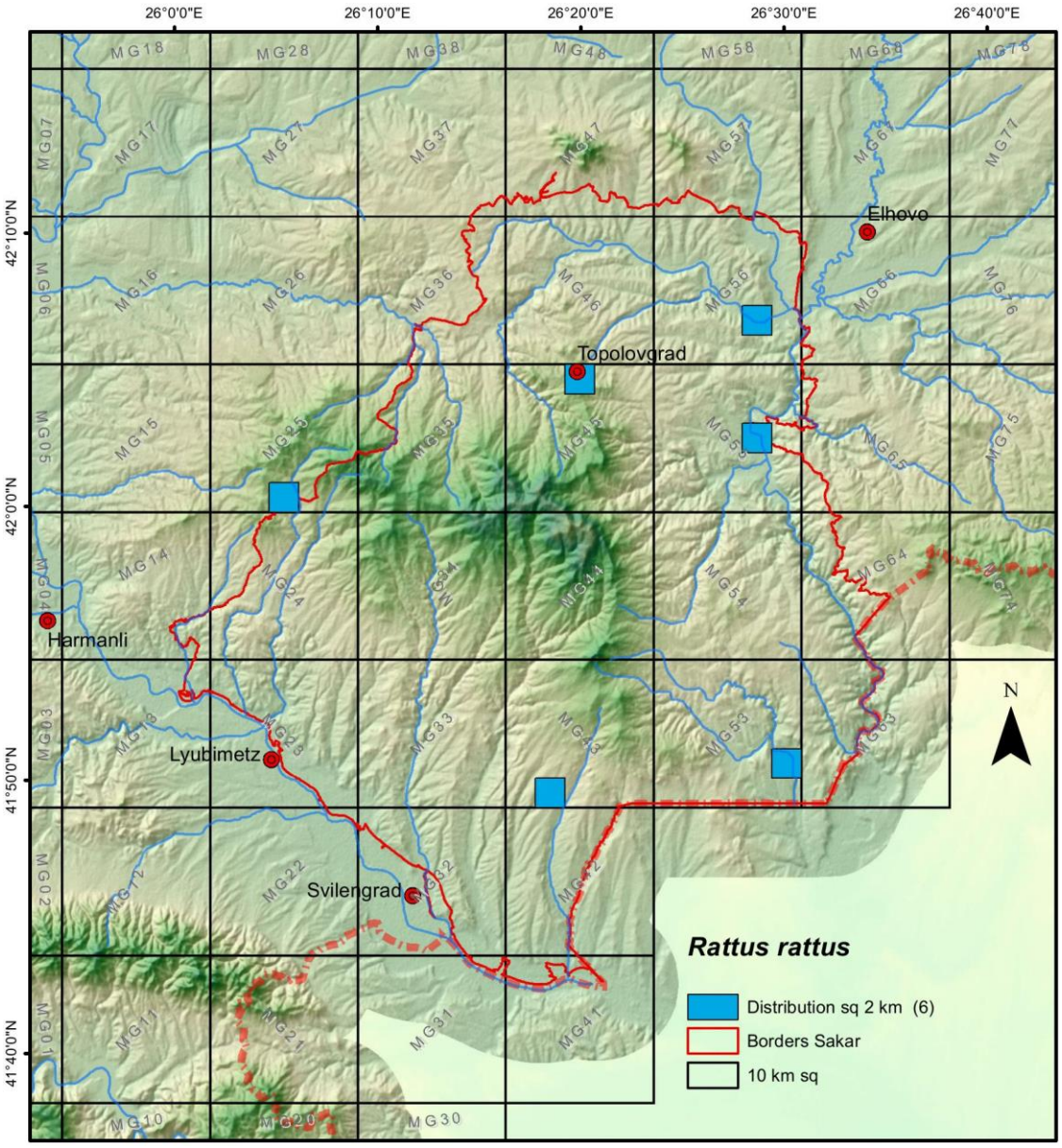
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Rattus norvegicus
Distribution sq 2 km (8)
Borders Sakar
10 km sq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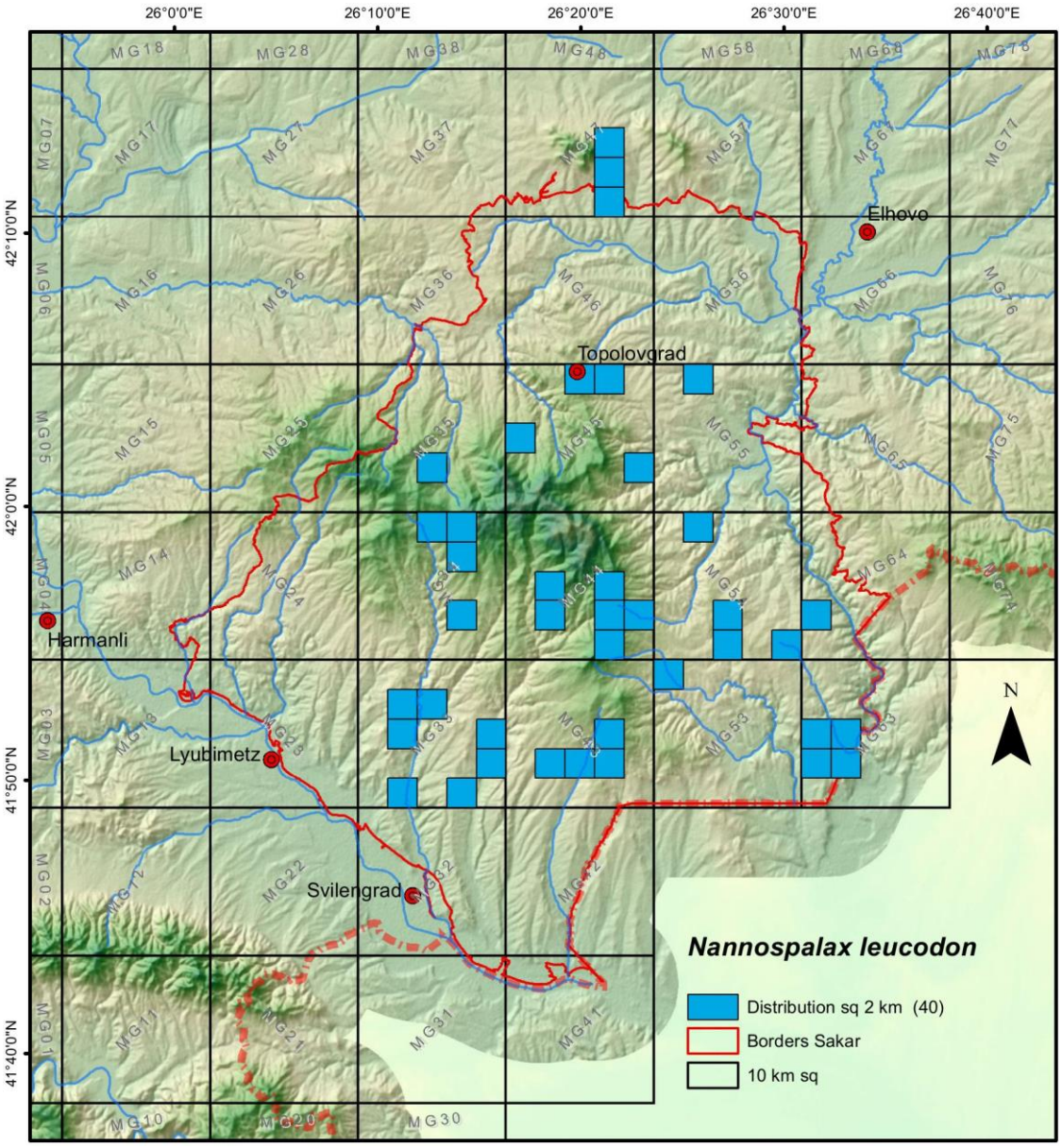
Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Rattus rattus
Distribution sq 2 km (6)
Borders Sakar
10 km sq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Elhovo
Topolovgrad
Harmanli
Lyubimetz
Svilengrad
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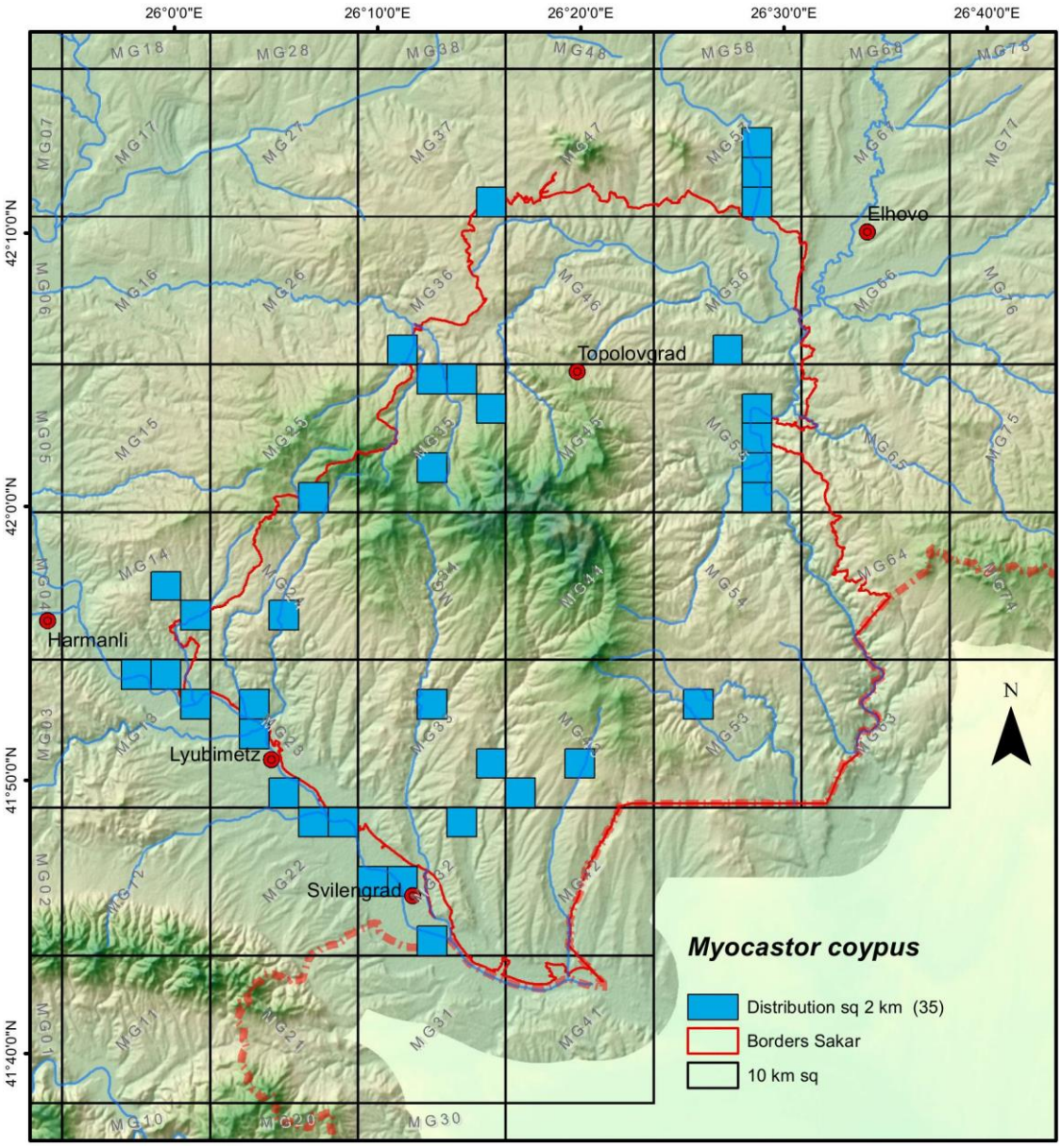
Nannospalax leucodon
Distribution sq 2 km (40)
Borders Sakar
10 km sq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Topolovgrad
Harmanli
Lyubimetz
Svilengrad
N
Myocastor coypus
Distribution sq 2 km (35)
Borders Sakar
10 km sq