

## New records of Serbian "archaic" and endemic earthworm *Allolobophora (sensu lato) paratuleskovi* (Šapkarev, 1975): geographic range size and biogeographic significance

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**Abstract.** The present study provides new data on the distribution of endemic species *Allolobophora (sensu lato) paratuleskovi* (Šapkarev 1975) in the southwestern and southern parts of Serbia. *Allolobophora (s.l.) paratuleskovi* is an endemic species known to inhabit the Balkan part of Serbia but the knowledge on its distribution is largely based on old literature. Our research indicated that *All. (s.l.) paratuleskovi* is still present in the southwestern part of Serbia, but taking into account new localities, it is evident an extension of the distribution of this species to the south. Based on the identified localities, the new site Leposavić presents the southernmost limit of the species' natural range and first finding in Kosovo. Considering the overall distribution of *All. (s.l.) paratuleskovi*, it is possible to assume that the place of the subduction between Adria and Europe (Vardar zone) is indeed the area of its origin. Our research shows that the major distribution center of this endemic species is located on the southwestern slopes of Kopaonik Mountain. For the first time, based on the extent of occurrence (EOO), it was shown graphically geographic range size of *All. (s.l.) paratuleskovi*.

**Key words:** *Allolobophora (sensu lato) paratuleskovi*, "archaic" species, distribution, extent of occurrence (EOO).

*Allolobophora (s.l.) paratuleskovi* was discovered for the first time in Raška and Novi Pazar (southwestern Serbia) and described as a new species by Šapkarev in 1975. At the end of the 19th and early 20th century, this species was found in the central and eastern parts of Serbia (see references in Stojanović et al. 2019). Based on literature data the northernmost limit of this species has been the central part of Serbia (Kragujevac), while the southernmost limit is the southwest part of Serbia (Novi Pazar) (Stojanović et al. 2018). Our latest researches have divulged new records for *All. (s.l.) paratuleskovi* which has shown that the southern limit expanded.

It seems that the distribution of this species is closely related to the geological history of the Balkan part of Serbia. Concerning the earthworm fauna, the Balkan Peninsula together with the Iberian and Apennine Peninsula makes up the focal points of biodiversity of earthworm fauna in Europe (Csuzdi et al. 2011). A review study conducted by Trakić et al. (2016) recorded 90 endemic taxa on the Balkan Peninsula, of which it is the largest number of the narrow range endemics (57 taxa), while the broad range endemic species take part with 33 taxa. In Serbia has been recorded 26 endemic species, including species of *All. (s.l.) paratuleskovi* which belongs to a broad range Balkan endemic (Stojanović et al. 2018). This study examined the general overview of the distribution of species *All. (s.l.) paratuleskovi* in Serbia.

The specimens for this study were collected during the period from 2015 to 2019., in the southwestern and southern slopes of Kopaonik Mountain (43°16'N, 20°49'E). The samples were collected in meadows on the foothills of the mountain. The specimens were deposited at the Earthworm Collection of the University of Kragujevac, Serbia (CEKUS).

Earthworms were collected by the formalin method, digging (0.4 x 0.4 m<sup>2</sup>) and hand sorting. The earthworms were hand-sorted, then fixed in 96% alcohol, with the label on which the necessary were

marked data. Species identification was done in accordance with the key by Mršić (1991). Also, we established the extent of occurrence (EOO) appearance for species of *All. (s.l.) paratuleskovi* using the GeoCAT tool (Bachman et al. 2011). According to the IUCN threat listing (2011), thresholds for EOO are 100 km<sup>2</sup> (Critically Endangered), 5.000 km<sup>2</sup> (Endangered) and 20.000 km<sup>2</sup> (Vulnerable). The figure with the established EOO was displayed using Google Maps.

*Allolobophora (s.l.) paratuleskovi* (Figure 1).

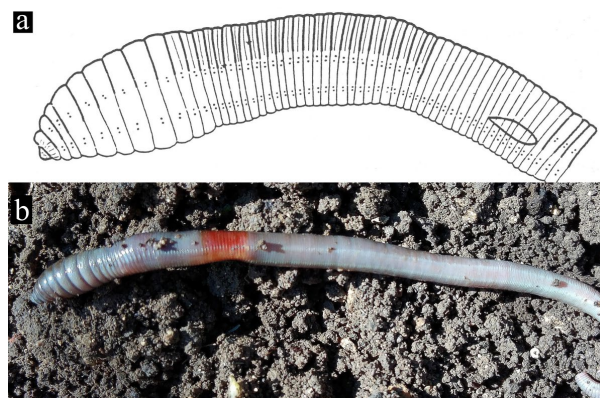
*Allolobophora paratuleskovi* Šapkarev (1975): 55.

*Eophila paratuleskovi* Šapkarev (1987): 82.

*Serbiona paratuleskovi* Mršić & Šapkarev (1988): 27; Mršić (1991): 206; Stojanović & Karaman (2007): 128; Stojanović et al. (2008): 60.

*Allolobophora paratuleskovi* Trakić et al. (2016): 256; Stojanović et al. (2018): 129; Stojanović et al. (2019): 278.

*Allolobophora (s.l.) paratuleskovi* Csuzdi 2012: 97-99; Popović et al. 2020: 66.



**Figure 1.** External characters are shown in diagram a (Šapkarev 1975), as well as the living specimen is shown in photo b (Author's photo)

Examined material:

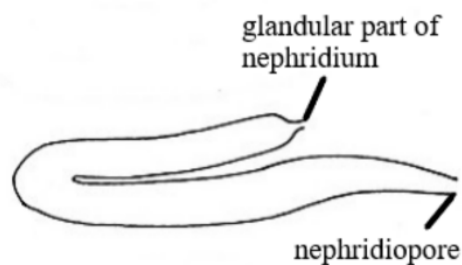
Author's new data: 2 exp., meadow, Lešak 558 m a.s.l. 14.05.2015.; 7 exp., meadow, Leposavić 529 m a.s.l.; 14.05.2015.; 12 exp., meadow, Mure 670 m a.s.l. (Kopaonik Mountain) 06.04.2018.; 1 exp., meadow, Semeteš 1000 m a.s.l. (Kopaonik Mt.) 06.04.2018.; 4 exp., meadow, Rudnica 450 m a.s.l. (Kopaonik Mt.) 10.04.2019.; 2 exp., meadow, Lukovska Banja 681 m a.s.l. 29.04.2020. 5 exp., meadow, Raška 456 m a.s.l. 10.05.2020.

Mršić (1991) transferred several endemic species from the genus *Allolobophora* Eisen 1874 with similar taxonomic characteristics (including *All. (s.l.) paratuleskovi*) in the new genus *Serbiona* Mršić & Šapkarev 1988. However, some species which Mršić (1991) included in the genus *Serbiona* differed significantly taxonomically and even zoogeographically and thus clearly questioned the validity of the newly established genus. During investigating species of genus *Eophila* Rosa 1893, Omodeo (1988) established that they had the same type of nephridial bladder as the species of the genus *Serbiona*. Later, Omodeo et al. (2004) suggested that the genus *Serbiona* should be synonymous with the older genus *Eophila*, specifying the characteristics of the genus that includes all those species that have strictly paired setae, proclinate type of nephridial bladders and calciferous diverticula in 10 segment. However, Mršić (1991) criticized such a division, considering that the position of the spermatheca, shape and orientation of the nephridial bladders, type typhlosoles, as well as the geographical distribution, should be included. According to the recent molecular phylogenetic analysis conducted by De Sosa et al (2019), some species of genus *Eophila* is clearly separated from species of the Balkanic genera *Alpodinaridella* Mršić, 1987, *Italobalkaniona* Mršić & Šapkarev 1988, *Karpatodinariona* Mršić & Šapkarev 1988 and *Serbiona*. Further, some interesting proposals based on narrow sampling molecular phylogenetic research suggested the mentioned Balkanic genera could be joined in a single genus *Cernovitovia* Omodeo 1956 (Domínguez et al. 2015, Szederjesi et al. 2016). Today, this species with unusual taxonomic characteristics is part of the genus *Allolobophora (sensu lato)*, which has an uncertain taxonomic status that will most likely be clarified by molecular research.

*Allolobophora (s.l.) paratuleskovi* belongs to the "archaic" species due to anterior position of spermathecae, shape and orientation of the nephridial bladder, trifold typhlosole and fragmented area. Based on the shape and orientation of the nephridia bladder there are two forms of "archaic" species: "Western forms" (species in which basal part of the nephridial bladder in front of the glandular part) and "Eastern forms" (species in which basal part of the nephridial bladder in behind of the glandular part, including *All. (s.l.) paratuleskovi* (Figure 2). On the other hand, the form typhlosoles indicates ecological adaptation of earthworm fauna in the soil. The "archaic" species have split typhlosoles, while the "modern" species have simple typhlosoles (Mršić 1991).

The distribution area of *All. (s.l.) paratuleskovi* is characterized by a complex geological complexity, which is directly related to its position within the transition zones between the units of the Adriatic and the European plate.

The colonization of southeastern Europe took place after the closure of Neotethys ocean, after the collision of Adria and Europe. During the Mesozoic era, the Neotethys ocean was located in present-day Southeastern Europe, while during the Cenozoic era this ocean was destroyed by subduction, colliding with many small plates in Eocene (Van Hinsbergen et al. 2020). In the middle Miocene, a "land bridge" (Vardar zone) was formed between the Adriatic passive margin and the European active margin (Toljić et al. 2019). The distribution of Balkan endemics *Allolobophora (s.l.) (carnelutti, dofleini, paratuleskovi, kosovensis, matjasici, serbica, spasenijakaramani* and *yugoslavica*) is connected with the ancient mainland in Serbia (Mršić 1991), so it can be assumed with high probability that the centre of endemism and diversity of these endemic species is related to this move of the Balkan Peninsula. These endemic species are adapted to live in the deeper layers of the soil, where high humidity and constant temperature allow far more stable conditions compared to the surface layers of the soil. Besides that, anecic and endogeic species to which almost all "archaic" species belong, have a low migration capacity. Most of them are very sensitive to soil drying and have almost no adaptation to survive in the surface layers (Mazaud & Bouche 1980).



**Figure 2.** The diagram the shape and orientation of the nephridia bladder of species *Allolobophora (s.l.) paratuleskovi* (according to Mršić 1991)

According to Gaston & Fuller (2009), geographic range size is one of the fundamental ecological and evolutionary characteristics of species. All available data, from 1975 to 2020 showed that the species *All. (s.l.) paratuleskovi* has a limited geographical range, only in the Balkan part of Serbia (Table 1). Based on all the sites (Figure 3) we graphically depicted the area of EOO for *All. (s.l.) paratuleskovi*.

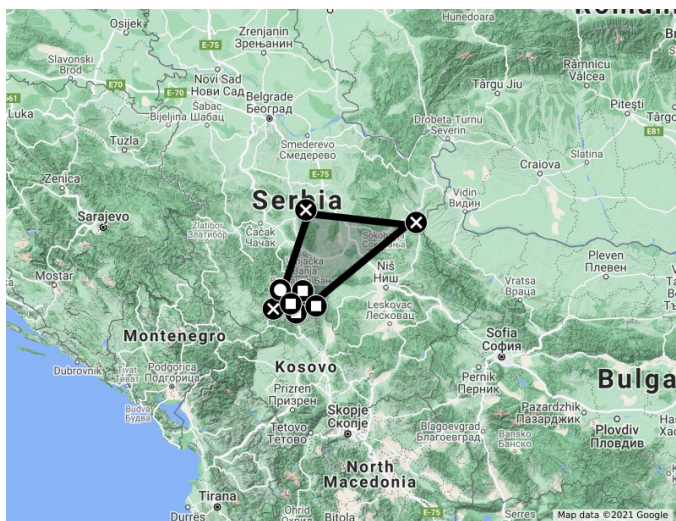
According to IUCN (2011), Red List Categories research carried out by Stojanović et al. (2008) *All. (s.l.) paratuleskovi*, preliminary, belongs to the endangered category. However, our results showed that the total EOO for this species is 7.230 km<sup>2</sup> and, therefore, its current status belongs to the vulnerable category. However, any increase in knowledge of the distribution of *All. (s.l.) paratuleskovi* could result in a change of its status. Unfortunately, anthropogenic impacts were high on the researched area, and that can contribute to endangering this endemic species in the future. Gruttke et al. (2004) propose a method that combines the area component with the distribution center, indicating the responsibility of the population located in the distribution center. Our research has shown that the major distribution centre of this

species is located on the southwestern slopes of Kopaonik Mt., respectively this area is responsible for the existence of this endemic species. Nonetheless, our knowledge of the

distribution of *All. (s.l.) paratuleskovi* is still incomplete. Further research is needed in southern parts of Serbia to explain the real distribution of *All. (s.l.) paratuleskovi*.

**Table 1.** Localities of *Allolobophora (s.l.) paratuleskovi* in Balkan parts of Serbia

Localities	Coordinates	Latitude	Longitude	Sources
Lukovska Banja	43°9'59"N 21°2'12"E	43.16	21.03	Author's data
Lešak	43°10'01"N 20°44'31"E	43.16	20.74	Author's data
Leposavić	43°06'N 20°48'E	43.1	20.8	Author's data
Kopaonik	43°16'09"N 20°49'21"E	43.28	20.81	Author's data
Kragujevac	44°00'36.3"N 20°55'1.9"E	44.01	20.91	Stojanović et al. (2018)
Raška	43°17'31"N 20°36'56"E	43.28	20.61	Šapkarev (1975), Author's data
Novi Pazar	43°08'16"N 20°30'58"E	43.13	20.51	Šapkarev (1975)
Zaječar	43°55'N 22°18'E	43.9	22.27	Stojanović et al. (2018)



**Figure 3.** Geographic range size of *Allolobophora (s.l.) paratuleskovi*, current estimated EOO; square: author's data; circle: author's data and literature data; x: literature data (seen localities in Table 1) (Google Maps 2021)

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