

EARTHWORMS (ANNELIDA: OLIGOCHAETA, LUMBRICIDAE) OF THE KOPAONIK NATIONAL PARK (SERBIA)

Filip J. Popović¹, Mirjana M. Stojanović-Petrović¹, Tanja B. Trakić¹,
Jovana M. Sekulić^{2*}

¹University of Kragujevac, Faculty of Science, Institute of Biology and Ecology,
Radoja Domanovića 12, 34000 Kragujevac, Serbia

²University of Kragujevac, Institute for Information Technologies Kragujevac,
Department of Science, Jovana Cvijića bb, 34000 Kragujevac, Serbia

*Corresponding author; E-mail: jovanas034@gmail.com

(Received March 06, 2022; Accepted April 04, 2022)

ABSTRACT. This paper presents the first list of earthworm fauna of the Kopaonik National Park, a total of 16 taxa, belonging to eight genera of the family Lumbricidae. The genera with the largest number of the registered taxa are *Dendrobaena* and *Lumbricus*, while the genera *Aporrectodea*, *Bimastos*, *Eisenia*, *Eiseniella*, *Octodrilus* and *Octolasion* are represented by one species each. Also, the review of zoogeographical types and ecological categories of registered species are presented. Half of the species are peregrine, while the rest are autochthonous. Regarding ecological categories, anecic (2) and endogeic (4) species are more sensitive to high mountain environmental conditions than epigeic (12) species, which are more adapted to such conditions. Overall, our results highlight how little was previously known about the earthworm fauna in this area and emphasize the need for further collecting to better understand the hidden earthworm diversity in Kopaonik NP.

Keywords: earthworms, ecological categories, zoogeographical types, Kopaonik National Park.

INTRODUCTION

Kopaonik Mountain is located in the central part of the Republic of Serbia and extends in the form of an 82 km long and 40 to 60 km wide branched ridge. It is the largest mountain in central Serbia, with a total area of 2758 km² (GAVRILOVIĆ, 1979; BOJOVIĆ, 2012). The larger southeastern part is located on the territory of the Autonomous Province of Kosovo and Metohija, while the smaller northwestern part occupies the southern part of central Serbia. Relatively isolated from other mountains in the central part of the Balkan Peninsula, diverse geological composition, size and very rich wildlife indicate that Kopaonik Mt. is one of the most important centers of biodiversity, not only in Serbia but in the Balkans. Such diversity

led to the proclamation of a part of this area in 1981 as a National Park (NP) (Fig. 1). The lowest point in the area of the NP is about 640 m a.s.l., and the highest is Pančičev vrh with 2017 m a.s.l. Favorable natural conditions of this mountain massif have enabled the development of rich and diverse flora and fauna. Under the special protection of the NP are 698 hectares, separated into 11 nature reserves (Kozje stene, Vučak, Mrkonja, Jankova bara, Gobelja, Barska reka, Samokovska reka, Metode, Jelak, Suvo rudište and Duboka) and 26 natural monuments (12 geomorphological, six geological and eight hydrological). The concept of protection is focused on the preservation of autochthonous natural values and monitoring of conditions and changes, especially on populations of rare and endangered plant and animal species, as well as sensitive ecosystems (OSTOJIĆ *et al.*, 2018).

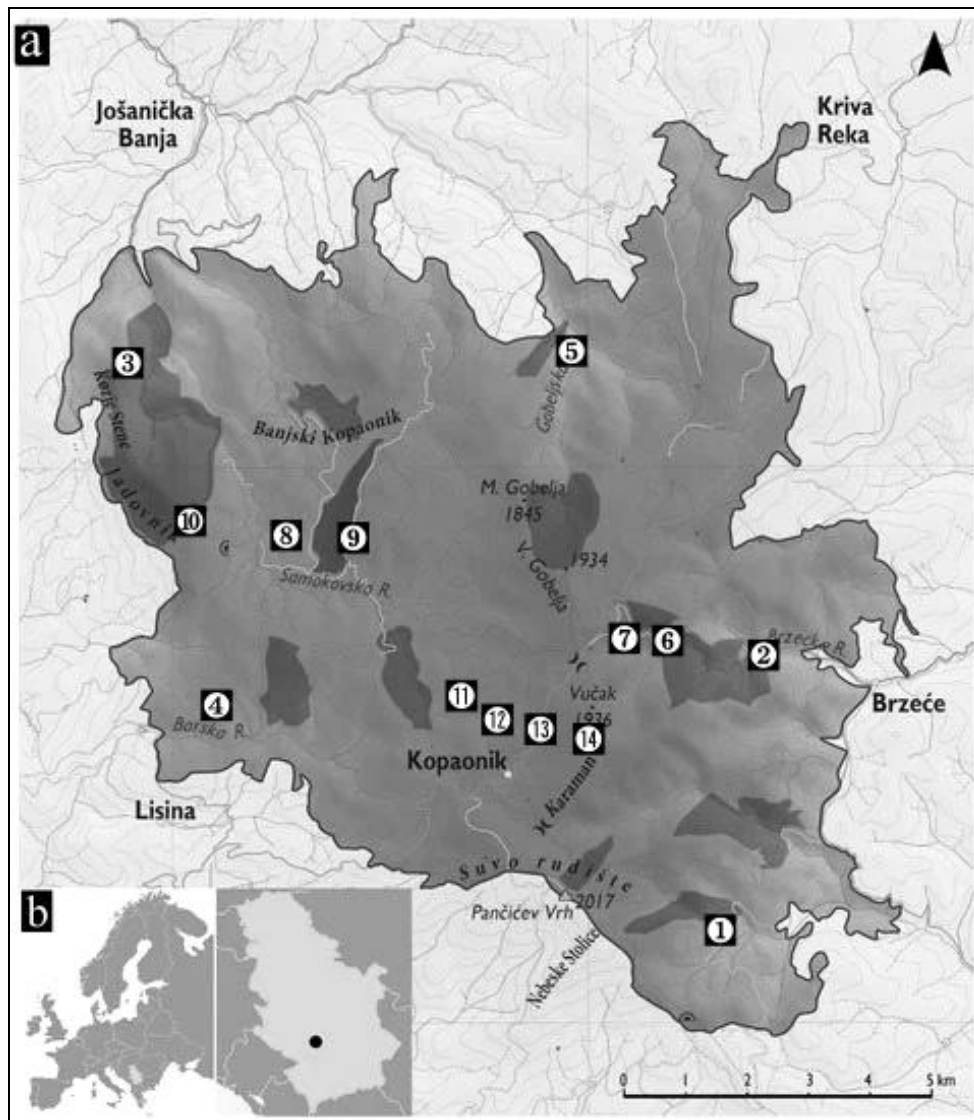


Figure 1. Location of the study area: (a) Kopaonik National Park (numbers denote sampled localities see Table 1); (b) geographic position of the Kopaonik Mountain in Serbia and Europe.

The earthworm fauna of Serbia is quite well-known. STOJANOVIĆ-PETROVIĆ *et al.* (2020) recorded the presence of 77 lumbricid taxa in the country. Regarding the fauna of earthworms in national parks in Serbia, it is worth mentioning that was researched only in the Đerdap National Park (SEKULIĆ *et al.*, 2021). The earthworm fauna of Kopaonik Mt. was quite unknown due to the scarce pioneering reports of ŠAPKAREV (1972, 1980) and STOJA-

NOVIĆ (1996). Recently, POPOVIĆ *et al.* (2020, 2022a, 2022b) recorded new earthworm data on the western slopes of Kopaonik Mt. with 27 species belonging to 10 genera of the family Lumbricidae. On the other hand, the stunning relief of Kopaonik NP with many deep valleys and impassable mountain barriers has promoted an astonishing diversification in many groups of organisms including plants, amphibians, reptiles, birds and mammals (AMIDŽIĆ, 2007).

The purpose of this paper is to present the list of the earthworm species until now registered for the Kopaonik NP, with the zoogeographical types and ecological categories where these species belong.

MATERIALS AND METHODS

Specimens treated in this work were collected as a total of 124 samples taken in sporadic samplings between 2018 and 2021 (from May to September), in the protected areas of Kopaonik NP. As the collecting methods, we have used digging up eight soil samples 50 x 50 x 40 cm from each of the 14 sampling units (plots) (ZICSI, 1958), positioned as on Fig. 1, described in Table 1, as well as turning over rocks, debris and logs. The earthworms were killed in 70% ethanol, immediately fixed in 4% formalin solution, and later transferred and stored in 90% ethanol. Species identification was made to species level according to the complex features provided in MRŠIĆ (1991) and CSUZDI and ZICSI (2003) keys. Based on taxonomic characteristics only mature earthworms were counted. The material is deposited in the Earthworm Collection of the University of Kragujevac, Serbia (CEKUS) and is publicly accessible.

Table 1. List and description of studied localities in Kopaonik National Park.

Loc. Nr.	Locality / Altitude (m)	Latitude	Longitude	Date	Habitat / Plant association
1.	Jelovarnik, 1126	43.26	20.85	10.06.2021.	Near the Jelovarnik Stream
2.	Jelak, 1192	43.30	20.85	04.05.2021. 10.06.2021.	Beech fir forest (<i>Abieti-Fagetum moesiacaе</i>)
3.	Kozje stene, 1281	43.33	20.73	05.05.2018.	Beech forest (<i>Fagetum moesiacaе submontanum</i>), the right bank of Samokovska River
4.	Barska reka, 1321	43.30	20.74	31.05.2019.	the right bank of Barska River
5.	Mrkonja, 1533	43.35	20.83	30.05.2020.	Pasture
6.	Metode, 1540	43.30	20.84	04.05.2021. 10.06.2021.	Beech fir forest (<i>Fagetum moesiacaе submontanum</i>), near the Gvozdački Stream
7.	Gvozdac, 1550	43.30	20.83	14.05.2018.	Meadow
8.	Kadijevac, 1595	43.32	20.75	25.09.2021.	Meadow, spruce forest (<i>Piceetum abietis</i>)
9.	Jankova bara, 1620	43.32	20.77	16.08.2020.	Blueberry bushes
10.	Kukavica, 1729	43.32	20.74	31.05.2020.	Meadow
11.	Markov kamen, 1740	43.29	20.80	25.09.2021.	Spruce forest (<i>Oxali acetosella-Piceetum abietis</i>)
12.	Rtanj, 1786	43.28	20.82	16.07.2019.	Spruce forests (<i>Oxali acetosella-Piceetum abietis</i>)
13.	Jaram, 1800	43.30	20.82	16.07.2019.	Spruce forest (<i>Piceo-subalpinae-Vacinio-Juniperetum</i>), near the Karamanski Stream
14.	Vučak, 1936	43.31	20.83	25.09.2021.	Spruce forest (<i>Piceo-subalpinae-Vacinio-Juniperetum</i>)

The zoogeographic categorization of registered earthworm species is based on their distribution as proposed by CSUZDI and ZICSI (2003), POP *et al.* (2010) and CSUZDI *et al.* (2011). Based on their ecological behavior (BOUCHÉ, 1972) earthworm species were classified into three ecological categories, epigeic, anecic and endogeic. In the species list given below, we use the following abbreviations: D = distribution in the Kopaonik NP (number of exemplars (exp.), locality, habitat, date of sampling); Z = zoogeographical types; E = ecological category.

RESULTS

A total of 16 taxa, belonging to eight genera of the family Lumbricidae Rafinesque, 1815 were registered in 124 samples collected between 2018 and 2021 (from May to September), on the 14 localities in protected areas of Kopaonik NP.

Genus *Aporrectodea* Örley, 1885

Aporrectodea rosea (Savigny, 1826)

Enterion roseum Savigny, 1826: 182.

Aporrectodea rosea Csuzdi, 2012: 97; Stojanović *et al.*, 2018: 134; Popović *et al.*, 2020: 63.

D. 2 exp., Kozje stene, the right bank of Samokovska River, 05.05.2018; 4 exp., Gvozdac, meadow, 14.5.2018; 4 exp., Mrkonja, pasture, 30.05.2020; 2 exp., Kukavica, meadow, 31.05.2020; 3 exp., Metode, near the Gvozdački Stream, 10.06.2021; 4 exp., Kadijevac, meadow, 25.09.2021. **Z.** Peregrine. This peregrine species is broadly distributed in Serbia (STOJANOVIĆ *et al.*, 2018), and is one of the most represented species in the western part of Kopaonik Mt. (POPOVIĆ *et al.*, 2022a). **E.** Endogeic.

Genus *Bimastos* Moore, 1893

Bimastos rubidus (Savigny, 1826)

Enterion rubidum Savigny, 1826: 182.

Bimastos rubidus Csuzdi, 2012: 97; Csuzdi *et al.*, 2017: 9; Popović *et al.*, 2020: 64.

D. 4 exp., Kozje stene, the right bank of Samokovska River, 05.05.2018; 4 exp., Kozje stene, beech forest, 05.05.2018; 2 exp., beech fir forest, Jelak, 10.6.2021. **Z.** Peregrine. **E.** Epigeic. This species was found mostly in leaf litter, in fallen trunks and under barks of decaying logs.

Genus *Dendrobaena* Eisen, 1873

Dendrobaena alpina alpina (Rosa, 1884)

Allolobophora alpina Rosa, 1884: 28.

Dendrobaena alpina alpina Csuzdi, 2012: 97; Popović *et al.*, 2020: 64.

D. 2 exp., Jelak, beech fir forest, 04.05.2021; 3 exp., Jankova bara, blueberry bushes, 16.08.2020. **Z.** Balkanic-Alpine. **E.** Epigeic. This subspecies is better adapted to the mountains' conditions, with maximal presence above 1500 m (POPOVIĆ *et al.*, 2022).

Remarks. The specimens we found on the Kopaonik Mountain are taxonomically more similar to the subspecies *D. alpina popi*, described by ŠAPKAREV (1971) from the Macedonian part of the Šara Mountain. MRŠIĆ (1991) confirmed the validity of the *D. alpina popi*, finding it in Bosnia and Herzegovina. CSUZDI *et al.* (2005) indicated that the *D. alpina* species group contains some 15 nominal species, pointing to several synonyms. The similarity of these

species can be characterized by a clitellar position on segments from 26, 27 to 33, 34, and tubercles around 30–32. According to the earthworm database given by CSUZDI (2012), subspecies *D. alpina popi* is considered a younger synonym of subspecies *D. alpina alpina*. Unfortunately, the subspecies attributed to Balkan origin had not been studied during the last revision (CSUZDI *et al.*, 2005). We consider the taxonomic status of this subspecies will most likely be clarified by molecular phylogenetic analysis. The two above-mentioned subspecies have some different taxonomic characteristics (Table 2).

Table 2. A comparison of some taxonomical characteristics of the subspecies *Dendrobaena alpina alpina* and *D. alpina popi*.

Characteristic	<i>D. alpina alpina</i> (Author's data)	<i>D. alpina popi</i> (Acc. to Šapkarev, 1971)	<i>D. alpina alpina</i> (Acc. to Mršić, 1991)
Body size / Number of segments	78–143 mm / 127–167	88–136 mm / 135–160	38–121 mm / 64–138
Color body	unpigmented/greyish	unpigmented/greyish	purple-red
Prostomium	epilobous	epilobous/tanylobous	epilobous
Seminal vesicles	11,12	11,12	11,12
Spermatheca	9/10, 10/11	9/10, 10/11	9/10, 10/11
Clitellum	27–33,34	25–27–33,1/234	26–28–33,34
Tubercula pubertatis	30–32	27–30–32	29,30–32

Dendrobarena attemsi (Michaelsen, 1902)

Helodrilus (Dendrobaena) attemsi Michaelsen, 1902: 47.

Dendrobarena attemsi Csuzdi, 2012: 97; Stojanović *et al.*, 2018: 149.

D. 3 exp., Kozje stene, beech forest, 05.05.2018; 6 exp., Jelak, beech fir forest, 04.05.2021; 4 exp., Metođe, beech spruce forest, 10.06.2021; 2 exp., Markov kamen, spruce forest, 25.09.2021. **Z.** Trans-Aegean. **E.** Epigeic. This small species is usually present in the litter layer of forests.

Dendrobaena byblica (Rosa, 1893)

Allolobophora byblica Rosa, 1893: 4.

Dendrobaena byblica Csuzdi, 2012: 97; Popović *et al.*, 2020: 64.

D. 3 exp., Gvozdac, meadow, 14.5.2018; 2 exp., Barska reka, the right bank of Barska River, 31.05.2019; 4 exp., Metođe, near the Gvozdački Stream, 10.06.2021; 4 exp., Jelovarnik, near the Jelovarnik Stream, 10.06.2021. **Z.** Circum-Mediterranean. **E.** Epigeic. This species shows a preference for damp habitats.

Remarks. *Dendrobaena byblica* is a species group with high morphological variability. POP (1943, 1949) recognized at least seven ‘varieties’ namely: forma *typica*, var. *annectens*, var. *ganglbaueri*, var. *daghestanensis*, *meledaensis*, *olimpiaca* and var. *bulgarica*. ‘Varieties’ differed from the original description by the extension of clitellum and tubercula pubertatis (1–2 segments). Such differences are within the usual intraspecific variation found in species of this group and is unlikely to hold taxonomic relevance. According to SZEDERJESI *et al.* (2017) *Dendrobaena byblica* is a Circum-Mediterranean species group composed of at least 17 nominal taxa. We compared our individuals with the taxonomically most similar species from *Dendrobaena byblica* species group (Table 3).

Table 3. Distinguishing taxonomic characteristics of species of group *Dendrobaena byblica* in the Balkans and the neighbouring territories.

Species	<i>D. byblica</i> (Authors' data)	<i>D. ganglbaueri</i> (Rosa, 1894)	<i>D. feheri</i> (Szederjesi and Csuzdi, 2017)	<i>D. skipetarica</i> (Szederjesi and Csuzdi, 2017)
Characteristic				
Body size	35-73 mm	35-55 mm	40 mm	52 mm
Color body	red violet	red violet	Slight pinkish	dark red violet
Prostomium	epilobous	epilobous	epilobous	epilobous
S. vesicles	9-12	9-12	9-12	9-12
Spermathecae	10,11	10,11	10,11	10,11
Clitellum	25-29,30	23,24-29	23-29	24-28
T. pubertatis	26-28	25-27	25-27	25-27

Dendrobaena illyrica (Černosvitov, 1935)*Helodrilus (Dendrobaena) illyricus* Cognetti, 1906: 1.*Dendrobaena illyrica* Csuzdi, 2012: 97; Popović *et al.*, 2020: 64.

D. 4 exp., Barska reka, the right bank of Barska River, 30.05.2019. **Z.** Illyric. **E.** Epigeic. This species prefers forest soils and humid meadows, formed on acidic magmatites and metamorphites as source rocks (HÖSER, 2020).

Dendrobaena octaedra (Savigny, 1826)*Enterion octaedrum* Savigny, 1826: 183.*Dendrobaena octaedra* Csuzdi, 2012: 97; Popović *et al.*, 2020: 64.

D. 8 exp., Kozje stene, the right bank of Samokovska River, 05.05.2018; 9 exp., Kozje stene, beech forest, 05.05.2018; 9 exp., Rtanj, spruce forest, 16.07.2019; 6 exp., Jaram, spruce forest, 16.07.2019; 5 exp., Jankova bara, blueberry bushes, 16.08.2020; 2 exp., spruce forest, 04.05.2021; 7 exp., Metođe, beech fir forest, 10.06.2021; 9 exp., Metođe, near the Gvozdački Stream, 10.06.2021; 3 exp., Kadijevac, spruce forest, 25.09.2021; 2 exp., Vučak, spruce forest, 25.09.2021; 6 exp., Markov kamen, spruce forest, 25.09.2021. **Z.** Peregrine. **E.** Epigeic. This species is adapted to acidic sandy forest soil, most represented under fallen leaves and trunks, but can be found in meadows soil and near streams.

Remarks. Not surprisingly, the species *D. octaedra* is the most abundant in the studied area. According to POPOVIĆ *et al.* (2022a), this peregrine species was the most abundant earthworm on the western slopes of Kopaonik Mt.

Dendrobaena vej dovskyi (Černosvitov, 1935)*Bimastus vej dovskyi* Černosvitov, 1935: 66.*Dendrobaena vej dovskyi* Csuzdi, 2012: 97; Popović *et al.*, 2020: 64.

D. 5 exp., Kozje stene, the right bank of Samokovska River, 05.05.2018; 6 exp., Kozje stene, beech forest, 05.05.2018. **Z.** Balkanic-Alpine. **E.** Epigeic. This species is living in the uppermost litter layer.

Genus *Eisenia* Malm, 1877***Eisenia lucens*** (Waga, 1857)*Lumbricus lucens* Waga, 1857: 166.

Eisenia lucens Csuzdi, 2012: 97; Popović *et al.*, 2020: 65.

D. 6 exp., Kozje stene, beech forest, 05.05.2018; 2 exp., Jelak, beech fir forest, 04.05.2021; 3 exp., Metođe, beech fir forest, 10.06.2021. **Z.** Central European. **E.** Epigeic. This mountain species is found under the bark of decaying logs and under fallen leaves, as well as tree hollows.

Genus *Eiseniella* Michaelsen, 1900

Eiseniella tetraedra (Savigny, 1826)

Enterion tetraedrum Savigny, 1826: 184.

Eiseniella tetraedra Csuzdi, 2012: 97; Popović *et al.*, 2020: 65.

D. 2 exp., Barska reka, the right bank of Barska River, 31.05.2019; 9 exp., Jaram, near the Karamanski Stream, 16.07.2019. **Z.** Peregrine. **E.** Epigeic species inhabits damp habitats, rivers and stream banks.

Genus *Lumbricus* Linnaeus, 1758

Lumbricus castaneus (Savigny, 1826)

Enterion castaneum Savigny, 1826: 180.

Lumbricus castaneus Csuzdi, 2012: 97; Popović *et al.*, 2020: 65.

D. 9 exp., Metođe, near the Gvozdački Stream, 10.06.2021. **Z.** Peregrine. **E.** Epigeic. This species shows a preference for humid soils, rich in organic matter.

Lumbricus polyphemus (Fitzinger, 1833)

Enterion polyphemus Fitzinger, 1833: 551.

Lumbricus polyphemus Csuzdi, 2012: 97; Popović *et al.*, 2020: 65.

D. 2 exp., Kozje stene, beech forest, 05.05.2018. **Z.** Central European. **E.** Anecic. It has a strong preference for clayey brown forest soil.

Lumbricus rubellus Hoffmeister, 1843

Lumbricus rubellus Hoffmeister, 1843: 187.

Lumbricus rubellus Csuzdi, 2012: 97; Popović *et al.*, 2020: 65.

D. 2 exp., Kozje stene, beech forest, 05.05.2018; 3 exp., Kukavica, meadow, 31.05.2020; 2 exp., Metođe, beech fir forest, 10.06.2021; 2 exp., Kadijevac, spruce forest, 25.09.2021. **Z.** Peregrine. **E.** Epigeic. This species shows a broad tolerance of habitat conditions. It can be found in leaf litter, under logs, in woody debris and also recorded in the meadow.

Lumbricus terrestris Linnaeus, 1758

Lumbricus terrestris Linnaeus, 1758: 647.

Lumbricus terrestris Csuzdi, 2012: 97; Popović *et al.*, 2020: 65.

D. 2 exp., Kozje stene, the right bank of Samokovska River, 05.05.2018. **Z.** Peregrine. **E.** Anecic. This species living mostly in meadows, less abundant in deciduous forests.

Genus *Octodrilus* Omodeo, 1956

Octodrilus transpadanus (Rosa, 1884)

Allolobophora transpadana Rosa, 1884: 45.

Octodrilus transpadanus Csuzdi, 2012: 97; Stojanović *et al.*, 2018: 208.

D. 2 exp., Metođe, beech fir forest, 10.06.2021. **Z.** Trans-Aegean. **E.** Endogeic. This species inhabits mostly deciduous (beech) forests, but can be found in grasslands, and moist soils near rivers and streams (KUTUZOVIĆ D.H. and KUTUZOVIĆ B.H., 2013).

Genus *Octolasion* Örley, 1885

Octolasion lacteum (Örley, 1881)

Lumbricus terrestris var. *lacteus* Örley, 1881: 584.

Octolasion lacteum Csuzdi, 2012: 97; Popović *et al.*, 2020: 65.

D. 4 exp., Kozje stene, the right bank of Samokovska River, 05.05.2018; 5 exp., Kozje stene, beech forest, 05.05.2018; 4 exp., Gvozdac, meadow, 14.5.2018; 1 exp., Jaram, near the Karamanski Stream, 16.07.2019; 3 exp., Jelak, beech fir forest, 04.05.2021; 3 exp., Metođe, beech fir forest, 10.06.2021. **Z.** Peregrina. **E.** Endogeic. This is one of the most widely distributed peregrine earthworms, inhabiting almost any habitat.

DISCUSSION

Our study represents new data on the earthworm fauna of an understudied region and, we present the first list of the earthworm species from the Kopaonik NP. The current list of the earthworm fauna recorded for the Kopaonik NP contains 16 species-group taxa (15 species and one subspecies), which belong to eight genera of the family Lumbricidae. The dominant genera *Dendrobaena* and *Lumbricus*, are represented by six and four taxa respectively. Interestingly, the remaining registered genera *Aporrectodea*, *Bimastos*, *Eisenia*, *Eiseniella*, *Octodrilus* and *Octolasion* are represented by one species each.

Dendrobaena attemsi was the first recorded earthworm species registered in the study area by the first author, so the current list of earthworms of Kopaonik Mt. has been increased to 28. The most important distribution center of species *D. attemsi* is situated in Europe (Balkan-Alpine area). Due to this fact, it has long been considered a Balkanic-Alpine species. However, MISIRLIOĞLU and STOJANOVIĆ (2020) provided a general overview of its current distribution and zoogeographical position, but earlier than the above-mentioned data about finding on Kopaonik. *Dendrobaena attemsi* is distributed from the Pyrenees through Central Europe, Balkan Peninsula and Anatolia to the Caucasus. Summarizing all the data reported so far, MISIRLIOĞLU and STOJANOVIĆ (2020) support the assumption that *D. attemsi* in its native range has a Trans-Aegean distribution (CSUZDI *et al.*, 2005).

On the other hand, the genus *Dendrobaena* is heterogeneous to such an extent that it requires urgent revision. *Dendrobaena alpina* and *D. byblica* species groups show great taxonomic variability in pigmentation, the position of male pores, the position of calciferous diverticula, number of vesicles and the position of the spermathecal pores (CSUZDI *et al.*, 2005; SZEDERJESI *et al.*, 2017). MARCHÁN *et al.* (2022) considered that although *D. alpina* and *D. byblica* have been included in molecular phylogenetic analysis, further representatives of their wide taxonomic diversity in Eastern Europe remain to be studied, and the molecular markers must be standardized in order to combine the fragmentary data.

Zoogeographical analysis

Regarding zoogeographic analysis, half of the earthworm species from the Kopaonik NP are peregrine (*Ap. rosea*, *B. rubidus*, *D. octaedra*, *Ei. tetraedra*, *L. castaneus*, *L. rubellus*, *L. terrestris* and *Oc. lacteum*), while the second half belongs to the autochthonous category. Thanks to the wide ecological valence for soil pH, peregrine species are cosmopolitan (TÓTH *et al.*, 2020).

The autochthonous earthworm fauna of Kopaonik NP belongs to five zoogeographic types: Balkanic-Alpine (*D. alpina alpina*, *D. vej dovskyi*), Central European (*E. lucens*, *L. polyphemus*), Circum-Mediterranean (*D. byblica*), Illyric (*D. illyrica*) and Trans-Aegean (*D. attemsi*, *O. transpadanus*). POPOVIĆ *et al.* (2022a) considered that the rich zoogeographic composition of earthworms on the entire territory of Kopaonik Mt. results from the two influences, continental and Mediterranean. The continental elements comprise endemic, Balkanic-Alpine, Illyric and Central-European types.

Mediterranean elements comprise Trans-Aegean and Circum Mediterranean types. Surprisingly, endemic species have not been found in our study area, i.e. on the territory of NP Kopaonik. However, in study POPOVIĆ *et al.* (2022b) in the hilly parts of the mountain, which are not part of the Kopaonik NP, five Vardar endemic species were registered: *Cernosvitovia dofleini* (Ude, 1922), *Cernosvitovia paratuleskovi* (Šapkarev, 1975), *Cernosvitovia serbica* (Šapkarev, 1977), *Cernosvitovia strumicae* (Šapkarev, 1973) and *Cernosvitovia treskavicensis* (Mršić, 1991).

The number of earthworm species number in the nearby national parks is almost identical as well as in Kopaonik NP. Namely, ŠAPKAREV (1977) researched earthworm fauna in three national parks in Macedonia (Pelister NP (18 species), Mavrovo NP (16 species) and Galičica NP (14 species). Also, CSUZDI and ZICSI (2002) recorded 17 species from Fertő-Hanság NP in Hungary. Unfortunately, ŠAPKAREV (1977) and CSUZDI and ZICSI (2002) did not present a zoogeographic analysis in their paper. On the other hand, SEKULIĆ *et al.* (2021) recorded 29 species in Đerdap NP which has an area nearly five times bigger and much more diverse in relief compared to Kopaonik NP.

According to the zoogeographic analysis by SEKULIĆ *et al.* (2021), one-third of registered species were peregrines, while others were autochthones. Also, of the three registered endemic species, two are broad endemic of the Balkans [*Aporrectodea cemernicensis* Mršić, 1991 and *Cernosvitovia getica* (Pop, 1947)] and one is Dacian endemic – *Allolobophora (s.l.) mehadiensis boscaiui* (Pop, 1948).

Ecological analysis

Our study is supporting the attitude that the diversity of earthworms is determined by climatic factors, phylogenetic and biogeographic history, and regional ecological characteristics such as vegetation type, or soil characteristics (LAVELLE and SPAIN, 2001).

The earthworms were collected in Kopaonik NP above 1100 m a.s.l., where are unfavorable environmental conditions for the anecic and endogeic endemic species. These categories are sensitive to acidic soil (SCHELFHOUT *et al.*, 2017), and therefore, dominantly are strongly associated with meadows and deciduous forests at lower altitudes (JÄNSCH *et al.*, 2013; POPOVIĆ *et al.*, 2022a). Besides, finding endemic species may require sampling more plots. We expect to find some epigeic/endemic species from the genus *Dendrobaena* in future field research, for which the Balkans represents one of the main distribution centers (OMODEO and ROTA, 1989).

We found epigeic species in the litter layer of coniferous forests, in fallen trunks and under barks of decaying logs, as well as in damp habitats like river and stream banks, but all above 1100 m a.s.l. An explanation is already given in the literature. According to VAHDER and IRMLER (2018), beech and coniferous forests are responsible for notable acidification of the upper soil layer, allowing domination of epigeic species, and peregrine also (TÓTH *et al.*, 2020).

Acknowledgments

We are grateful to the Public Enterprise „Kopaonik National Park”, which provided logistics support during our field research. This work was supported by the Serbian Ministry of Education, Science and Technological Development (Agreement No. 451-03-68/2022-14/200122 and 451-03-68/2022-14/200378).

References:

- [1] AMIDŽIĆ, L. (2007): National Park Kopaonik. *In: AMIDŽIĆ L., KRASULJA, S., BELIJ S. (eds.): Protected natural resources in Serbia.* Ministry of Environmental Protection and Institute for Nature Conservation, Belgrade, pp. 23–27.
- [2] BOJOVIĆ, G. (2012): *Kopaonik i banje podgorine – turizmološka monografija.* Srpsko geografsko društvo, Beograd.
- [3] BOUCHÉ, M.B. (1972): *Lombriciens de France – Écologie et Systématique.* Institut National de la Recherche Agronomique, Publication 72-2. *Annales de Zoologie-Écologie animale* (Numéro hors-série). 671 pp.
- [4] CSUZDI, C. (2012): Earthworm species, a searchable database. *Opuscula Zoologica Budapest* **43** (1): 97–99. doi: 10.5281/zenodo.1045525
- [5] CSUZDI, C., POP, V.V., POP, A.A. (2011): The earthworm fauna of the Carpathian Basin with new records and description of three new species (Oligochaeta: Lumbricidae). *Zoologischer Anzeiger* **250** (1): 2–18. doi: 10.1016/j.jcz.2010.10.001
- [6] CSUZDI, C., POP, A.A., POP, V.V., WINK, M., ZICSI, A. (2005): Revision of the *Dendrobaena alpina* (Rosa, 1884) species group (Oligochaeta, Lumbricidae) by morphological and molecular methods. *Advances in Earthworm Taxonomy II (Annelida: Oligochaeta).* Cluj University Press: pp. 119–128.
- [7] CSUZDI, C., ZICSI A. (2002): Earthworms (Oligochaeta: Lumbricidae) of the Fertő-Hanság National Park. *In: Mahunka, S. (ed) The Fauna of the Fertő-Hanság national Park.* Hungarian Natural History Museum, Budapest: pp. 165–168.
- [8] CSUZDI, C., ZICSI, A. (2003): Earthworms of Hungary (Annelida: Oligochaeta, Lumbricidae). *Pedozoologica Hungarica – Taxonomic, zoogeographic and faunistic studies on the soil animals*, No1. Hungarian Natural History Museum and Systematic Zoology Research Group of the Hungarian Academy of Sciences, Budapest: 278 pp. doi: 10.5281/zenodo.4309820
- [9] GAVRILOVIĆ, S. (1979): Hipsometrija površine reljefa Kopaonika. *Zbornik radova Geografskog instituta PMF Univerziteta u Beogradu*, knjiga **26**: 93–103.
- [10] HÖSER, N. (2020): Der Regenwurm *Dendrobaena illyrica* (Cognetti, 1906) an der nördlichen und nordwestlichen Grenze seiner Verbreitung (Oligochaeta: Lumbricidae). *Opuscula Zoologica (Budapest)* **51** (1): 55–66. doi: 10.18348/opzool.2020.1.55
- [11] JÄNSCH, S., STEFFENS, L., HÖFER, H., HORAK, F., ROB-NICKOLL, M., RUSSEL, D., TOSCHKI, A., RÖMBKE, J. (2013): State of knowledge of earthworm communities in German soils as a basis for biological soil quality assessment. *Soil Organisms* **85** (3): 215–233.

- [12] KUTUZOVIĆ, D.H., KUTUZOVIĆ, B.H. (2013): Checklist of the earthworm fauna of Croatia (Oligochaeta: Lumbricidae). *Zootaxa* **3710** (1): 1–30. doi: 10.11646/zootaxa.3710.1.1.
- [13] LAVELLE, P., SPAIN, A. (2001): *Soil Ecology*. Dordrecht, Kluwer Academic Publishers, New York: 654 pp. doi: 10.1007/978-94-017-5279-4
- [14] MARCHÁN, D. F., DECAËNS, T., DOMÍNGUEZ, J., NOVO, M. (2022): Perspectives in earthworm molecular phylogeny: recent advances in Lumbricoidea and standing questions. *Diversity* **14** (1): 30. doi: 10.3390/d14010030
- [15] MISIRLIOĞLU, İ.M., STOJANOVIĆ, M. (2020): *Dendrobaena attemsi* (Michaelsen, 1902) (Clitellata, Megadrili) on the Balkan Peninsula and Anatolia: distribution and biogeographical significance. *Opuscula Zoologica (Budapest)* **51** (2): 123–131. doi: 10.18348/opzool.2020.2.123
- [16] MRŠIĆ, N. (1991): *Monograph on earthworms (Lumbricidae) of the Balkans I-II*. Slovenska Akademija Znanosti in Umetnosti, Ljubljana: 755 pp.
- [17] OMODEO, P., ROTA, E. (1989): Earthworms of Turkey. *Bollettino di Zoologia* **56**: 167–199.
- [18] OSTOJIĆ, D., KRSTESKI, B., DINIĆ, A., PETKOVIĆ, A. (2018): Vegetation characteristics of forest ecosystems in `Kopaonik` national park with the reference to the forests with the protection regime level I. *Šumarstvo*, Belgrade **3-4**: 179-194. [in Serbian with English summary]
- [19] POP, V. (1943): Das Verwandtschaftsverhältnis zwischen *Dendrobaena platyura* (Fitzinger) und *Octolasion montanum* Černosvitov (Oligochaeta). *Zoologischer Jahrbücher, Abteilung für Systematik und Geographie der Tiere* **76**: 397–412.
- [20] POP, V. (1949): Lumbricidele din România. *Analele Academiei Republicii Populare Române Secțiunea de Științe Geologice, Geografice și Biologie* **1**: 383–505.
- [21] POP, A.A., POP, V.V., CSUZDI, C. (2010): Significance of the Apuseni Mountains (the Carpathians) in the origin and distribution of Central European earthworm fauna (Oligochaeta: Lumbricidae). *Zoology in Middle East* **51** (sup2): 89–110. doi: 10.1080/09397140.2010.10638462
- [22] POPOVIĆ, F., STOJANOVIĆ, M., TRAKIĆ, T., SEKULIĆ J. (2022a): Earthworms community structure along altitudinal gradients on the western slopes of Kopaonik Mountain in Serbia. *Turkish Journal of Zoology* **46**: 103–114. Doi: 10.3906/zoo-2104-42
- [23] POPOVIĆ, F.J., STOJANOVIĆ, M.M., DOMÍNGUEZ, J., SEKULIĆ, J.M., TRAKIĆ, T.B., MARCHÁN, D.F. (2022b): Molecular analysis of five controversial Balkanic species of *Allolobophora* (*sensu lato*) Eisen, 1873 (Lumbricidae, Clitellata) with emendation of the genus *Cernosvitovia* Omodeo, 1956. *Zootaxa* **5116** (3): 351–372. doi: 10.11646/zootaxa.5116.3.3.
- [24] POPOVIĆ, F., STOJANOVIĆ, M., TRAKIĆ, T., SEKULIĆ J., SEKULIĆ, S., TSEKOVA, R. (2020): New records of earthworms (Annelida: Clitellata) from the Kopaonik Mountain, with the first finding of *Allolobophora treskavicensis* (Mrsic, 1991) in Serbia. *Acta Zoologica Bulgarica* **15**: 61–70.
- [25] SCHELFHOUT, S., MERTENS, J., VERHEYEN, K., VESTERDAL, L., BAETEN, L., MUYS, B., DE SCHRIJVER, A. (2017): Tree species identity shapes earthworm communities. *Forests* **8** (3): 85. doi: 10.3390/f8030085

- [26] SEKULIĆ, J., STOJANOVIĆ, M., TRAKIĆ, T., POPOVIĆ, F. (2021): Research on the fauna of earthworms (Oligochaeta, Lumbricidae) in Đerdap National Park. *1st International Conference on Chemo and BioInformatics ICCBIKG, Kraragujevac Serbia Book of Proceedings*: 198–201. doi: 10.46793/ICCBI21.202S
- [27] STOJANOVIĆ, M. (1996): *Faunističko ekološka studija Limbricidae (Oligochaeta) uže Srbije - Doktorska disertacija*. Prirodno-matematički fakultet, Univerzitet u Kragujevcu, pp. 236. [in Serbian]
- [28] STOJANOVIĆ, M., SEKULIĆ, J., TRAKIĆ, T. (2018): Checklist of earthworms (Oligochaeta: Lumbricidae) from Serbia – a review. *Zootaxa* **4496** (1): 124–155. doi: 10.11646/zootaxa.4496.1.9
- [29] STOJANOVIĆ-PETROVIĆ, M., TRAKIĆ, T., SEKULIĆ, J. (2020): The earthworms (*Oligochaeta: Lumbricidae*) of Serbia. Novi Sad: Faculty of Science, pp. 278. [in Serbian with English summary]
- [30] SZEDERJESI, T., POP, V.V., PAVLIČEK, T., MARTON, O., KRIZSIK, V., CSUZDI, C. (2018): Integrated taxonomy reveals multiple species in the *Dendrobaena byblica* (Rosa, 1893) complex (Oligochaeta: Lumbricidae). *Zoological Journal of the Linnean Society* **182** (3): 500–516. doi: 10.1093/zoolinnea/zlx049
- [31] ŠAPKAREV, J. (1971): Neue regenwurmer (Oligochaeta: Lumbricidae) aus Mazedonien. *Fragmenta Balcanica* **18**: 150–164.
- [32] ŠAPKAREV, J. (1972): Beitrage zur Kenntnis der Lumbricidenfauna Jugoslawiens. *Archives of Biological Sciences* **24** (1–2): 73–86
- [33] ŠAPKAREV, J. (1977): Earthworms (Oligochaeta: Lumbricidae) from Macedonian National Parks. *Ekologija* **12**: 59–64.
- [34] ŠAPKAREV, J. (1980) Prilog poznavanju kišnih glista (Lumbricidae) SR Srbije. *Zbornik radova faune Srbije* **1**: 165–179. [in Serbian]
- [35] TÓTH, Z., SZLAVECZ, K., SCHMIDT, D.J.E., HORNING, E., SETÄLÄ, H. *et al.* (2020): Earthworm assemblages in urban habitats across biogeographical regions. *Applied Soil Ecology* **151**: 103530. doi: 10.1016/j.apsoil.2020.103530
- [36] VAHDER, S., IRMLER, U. (2018): Effect of pure and multi-species beech (*Fagus sylvatica*) stands on soil characteristics and earthworms in two northern German forests. *European journal of soil Biology* **51**: 45–50. doi: 10.1016/j.ejsobi.2012.03.008
- [37] ZICSI, A. (1958): Einfluss der Trockenheit und der Bodenbearbeitung auf das Leben der Regenwürmer in Ackerböden. *Acta Agronomica Hungarica* **8**: 67–75.