A new cave-dwelling centipede species from Croatia (Chilopoda: Lithobiomorpha: Lithobiidae)

Dalibor Z. Stojanović*, Dragan Ž. Antić & Slobodan E. Makarov

University of Belgrade, Faculty of Biology, Institute of Zoology, Studentski Trg 16, 11000 Belgrade, Serbia
Serbian Biospeleological Society, Trg Dositeja Obradovića 2, 21000 Novi Sad, Serbia
* Corresponding author: dstojanovic@bio.bg.ac.rs

Abstract: A new species of minute cave-dwelling centipedes, Lithobius radjai sp. nov., is described and illustrated based on specimens collected from a cave in Croatia (Balkan Peninsula). A detailed account of the morphology of specimens of both sexes is provided. Furthermore, a brief comparison with other morphologically similar species is presented, and the type locality of the new species is mapped.

Keywords: “Monotarsobius” - troglomorphic - endemic - Dinaric karst - Dalmatia - Balkan Peninsula.

INTRODUCTION

As the largest limestone region in Europe, the Dinaric karst is one of the world’s richest hotspots of subterranean biodiversity, inhabited by more than 900 troglobitic species (Skeč et al., 2004). This extraordinary number of troglobites increases every year, mostly as a result of cooperation between biologists and speleologists (Simićević, 2017). A large number of these taxa show a high degree of endemism, some of them having been recorded only from a single cave, pit and/or mountain massif. Even today, two and a half centuries after the description of the famous cave olm Proteus anguinus Laurenti, 1768, nearly 330 years after its first find (Valvasor, 1689), and almost 190 years after the description of the first cave-adapted blind arthropod (Leptodirus hochenwartii Schmidt, 1832), there still are new “major” discoveries from the Dinarides. Such are, e.g. the recent discovery and description of the first troglobitic scorpion in Europe (Karaman, 2020), a new millipede family (Antić et al., 2018), etc. “Large” troglobitic and stygobitic species in different animal groups are still being discovered from Dinaric subterranean habitats, while the number of tiny arthropods, like the new species described here, is even higher (e.g. Antić et al., 2016; Akkari et al., 2017; Bedek et al., 2019a, b; Lukić et al., 2018; Pavlichević et al., 2020; Stoev et al., 2015; Švara et al., 2015).

In this study, we describe a tiny new cave-dwelling species of Lithobius Leach, 1814 on the basis of specimens collected from the cave Velika Ćulumova Pećina on the Kijevo karst plateau (part of the central Dinarides, southern Croatia, Balkan Peninsula).

MATERIAL AND METHODS

The type series of the new species includes 10 specimens (five females, four males and one larva III; labeled as L1-L10). Each analysed specimen is preserved in a single labeled vial with 70% ethanol. The material is deposited in the collection of the Natural History Museum, Split, Croatia (NHMSC), and in the collection of the Institute of Zoology, University of Belgrade, Faculty of Biology, Serbia (IZB).

After preparation of temporary microscope slides with glycerin, photos of body parts and whole specimens were made with a Canon PowerShot A80 digital camera connected to a Carl Zeiss Axioskop 40 compound microscope, as well as with a Nikon DS-Fi2 camera with a Nikon SMZ 1270 binocular stereo microscope. For processing of the final images we used the Zerene Stacker software (for focal stacking) and Adobe Photoshop CS6. The drawings were created from photos using tracing paper and a computer monitor. The specimens were measured using a Carl Zeiss Stemi 2000-C dissecting stereomicroscope with an AxioCam MRc camera and integrated Axio Vs40 software packages. The distribution map was created using the blank simple map of Croatia (downloaded from

Manuscript accepted 30.06.2021
DOI: 10.35929/RSZ.0054
the terminology of external morphology used in the description follows Bonato et al. (2011). Finally, we used the ChiloBase electronic database (Bonato et al., 2016) to make a list of European species of the “subgenus Monotarsobius Verhoeff, 1905” [see the recommendations for selected Lithobius subgenera given by Ganske et al. (2021)] for the purpose of comparison with other morphologically similar species.

Abbreviations following Eason (1964) are used in the text and in the tables: a = anterior, C = coxa, D = dorsal, F = femur, m = median, p = posterior, Pf = prefemur, T, TT = tergite, tergites, Ti = tibia, Tr = trochanter, V = ventral. Other abbreviations in the figures used to mark some of the morphological structures are explained directly in the figure legends.

**TAXONOMY**

*Lithobius radjai* Stojanović, Antić & Makarov, sp. nov.

**Holotype:** NHMSC L10; female; Croatia, Šibenik-Knin County, Municipality of Kijevo, the cave Velika Ćulumova Pećina, under stones in dark part of the cave, 43.98925°N, 16.37227°E, 451 m a.s.l.; 15.04.2006; leg. T. Rada.

**Paratypes:** NHMSC; 1 male, 1 female (NHMSC L1 and L4); same data as for holotype. – IZB; 3 males, 3 females, 1 larva III (IZB ChL027-L3, -L6 and -L7; IZB ChL027-L2, -L5 and -L8; and IZB ChL027-L9, respectively); same data as for holotype.

**Diagnosis:** The new species is distinguished from its congeners by a unique combination of characters: the translucent cuticle of its whitish body; small size as compared to its congeners; two roundish ocelli on each side in a horizontal line; Tömösvéry’s organ slightly smaller or equal to adjoining ocellus; 2+2 coxosternal teeth; porodonts moderately slender; no triangular projections on posterior angles of all tergites; tarsi of legs 1-3 undivided; 1-2 (usually 2) roundish coxal pores; female gonopods with 2+2 coniform spurs and a tridentate apical claw; male gonopods short, with one long seta; no sexual dimorphism in terminal legs; posterior accessory spines on penultimate and ultimate legs present, without anterior accessory spines.

*Lithobius radjai* sp. nov. can be clearly distinguished from morphologically similar European *Lithobius* species by the combination of characters presented in Table 1.

**Etymology:** The new species is named in honour of our friend and colleague Tonći Rađa (Split, Croatia), a well-known biospeleologist and the collector of the type material of the new species. The epithet, a name in the genitive case, is a patronym.

**Description:**

**Measurements:** Female holotype 4.8 mm long, ca 0.5 mm in widest part of the trunk. Body length of female paratypes (n = 4), male paratypes (n = 4), and larva III (n = 1): 4.7-6 mm, 4.9-5.3 mm and 2.4 mm, respectively.

**Colouration** (Figs 1C, 4C): Whitish, with pale yellowish, slightly sclerotized parts (cephalic capsule, forcipular coxosternite, tergites, leg claws and antennae), translucent over entire surface, especially on legs and trunk; possible slight discoloration after nearly 15 years in ethanol.

**Antennae:** -1/3 of body length in adults, and 1/4 of body length in larval specimen; ca 2.5 times longer than cephalic capsule, narrowing distad (Figs 1C-D, 2A). Mostly 20-22 antennal articles in adults (in holotype 22+20), larva III with 14 articles in both antennae. Terminal article ca 2.5 times as long as broad (Fig. 2A). In female holotype total length of left and right antenna 1.3 mm and 1.1 mm. Length of the antennae in male paratypes 1.2-1.4 mm; in female paratypes 1.0-1.2 mm; in larva III specimen each antennae ca 0.9 mm. All antennal articles with numerous sensilla trichodea. Additionally, last antennal article with sensilla microtrichodea distally and with two long sensilla basiconica laterally, one each on opposite sides of article (present also in larva III) (Fig. 2B).

**Cephalic plate:** Generally smooth, with few setae mostly scattered on plate margin. Posterior margin almost straight; cephalic plate slightly narrowing anteriad (Fig. 2A). Plate length and width in holotype 0.47 mm and 0.49 mm, respectively; in male paratypes length 0.46-0.52 mm, width 0.45-0.51 mm; in female paratypes length 0.47-0.52 mm, width 0.47-0.51 mm; in larva III length 0.29 mm, width 0.34 mm (length/width ratio: holotype 0.96:1; male paratypes 1.02:1; female paratypes 1:1 to 1.04:1; larva III 0.85:1).

**Ocelli:** Two roundish ocelli on each side in a horizontal line (Fig. 1A-B); anterior ocellus almost twice as large as posterior one; both depigmented in the centre, with pale brown to chestnut brown pigmented ring around them. Tömösvéry’s organ: Oval; slightly smaller or of same size as anterior ocellus; lying anteroventral to ocelli on anterolateral margin of cephalic capsule (Fig. 1A-B).

**Forcipular segment** (Fig. 2C): Coxosternite sub-trapezoidal; its anterior margin narrow, with external sides slightly higher than internal sides; dental margin with 2+2 small teeth of same size; medial diastema moderately deep, U-shaped, with approximately same width and depth; porodont moderately slender, positioned posterolateral to lateral tooth; no shoulders of forcipular coxosternite lateral to teeth; a few setae scattered in anterior part of coxosternite.

**Tergites** (Fig. 1C-D): All transparent, smooth; setae...
Fig. 1. *Lithobius radjai* sp. nov., ♀ paratype IZB ChL027-L5 (A), ♂ paratype IZB ChL027-L7 (B), ♀ holotype NHMSC L10 (C-D). (A) Head, ventrolateral view. (B) Ocelli and Tömösváry’s organ on right side of cephalic capsule, ventrolateral view. (C) Habitus, dorsal view. (D) Habitus, dorsal view. Abbreviation: to = Tömösváry’s organ. Scale bars: 1 mm (C-D); 0.5 mm (A); 0.1 mm (B).
Fig. 2. Lithobius radjai sp. nov., ♀ holotype NHMSC L10 (A), larva III paratype IZB ChL027-L9 (B), ♂ paratype NHMSC L1 (C-D). (A) Head, dorsal view. (B) Distal part of right antenna, ventral view. (C) Head, ventral view. (D) Right leg 1, anteroventral view. Abbreviation: sb = sensilla basiconica. Scale bars: 0.2 mm (A, C); 0.1 mm (B, D).
A new centipede from Croatia

429

scarce and irregularly scattered; posterior angles of all tergites rounded, without triangular projections; T1 rectangular in shape, with narrower posteralateral side; posterior margins of TT 1, 2, 4, 6, 8, 11 and 13 straight, in TT 5, 7, 9, 11 and 12 slightly convex, and in TT 3 and 10 slightly concave; anterior margin of TT 1, 5, 7, 8, 9, 11 and 13 straight, slightly convex in TT 3, 6, 10, 12 and 14, and slightly concave in TT 2 and 4; T9 widest of all tergites; intermediate tergites in both sexes with straight posterior margin.

Sternites: Smooth, translucent, with few setae mostly scattered on margins. Generally trapeziform, from more elongate (longer than wide in anterior part of the body) to more stockily trapezoidal (equal in length and width to wider than long in posterior part of body).

Legs: Moderately short and robust; their size progressively increasing toward posterior part, terminal legs noticeably larger than leg-pair 13 (Fig. 1D). Tarsi of legs 1-13 undivided (Fig. 2D). Tarsal articulation well defined in leg-pairs 14 and 15 (Figs 3A, C; 4A).

---

Table 1. Comparison between Lithobius radjai sp. nov. and morphologically most similar species of European "Monotarsobius" [(?)* = type of accessory spines (anterior or posterior) on leg-pairs 14 and/or 15 not specified in species description].

| Species | Lithobius radjai sp. nov. | L. aeruginosus L. Koch, 1862 | L. anacanthinus (Matic, 1976) | L. beshkovi (Matic & Stavropoulos, 1988) | L. biunguiculatus Loksa, 1947 |
|---------|--------------------------|-----------------------------|-----------------------------|---------------------------------|-------------------------------|
| Body length (in mm) | 4.7-6 | 6-11 | 5-6 | 9 | 6 |
| Body colouration | whitish, translucent | orange-yellow | uniformly yellow | light brown | uniformly light yellow |
| Number of antennal articles | 20-22 | 19-21 | 19-21 | 20 | 20 |
| Cephalic plate length/width (ratio) | ≈ 1:1 | slightly longer than wide | 1:1 | 1:1 | wider than long |
| Ocelli | 1-2 (in one row); partly depigmented | 3-6 (usually in one row) | 2 (in one row); black | 2 (in one row); poorly visible | 3-4 (in one row) |
| Tömösváry’s organ | slightly smaller or of same size as terminal ocellus | of same size as terminal ocellus | significantly smaller than ocelli | significantly larger than ocelli | no data |
| Coxal pores | 1-2 (usually 2) | 2-4 (usually 3) | 1-2 (usually 1) | 2-3 (usually 2) | 2-4 |
| Plectrotaxy of 14th leg pair | V: -, m, m, m, m; D: -, m, m, m, m | V: -, m, m, m, m, m; D: a, -m, m, m, m, m | without spines | without spines | V: -, m, m, m, m, m; D: m, m, m, m, m, m |
| Plectrotaxy of 15th leg pair | V: -, m, m, m, m, m; D: a, -m, m, m, m, m | V: -, m, m, m, m, m, m; D: a, -m, m, m, m, m, m | without spines | without spines | V: -, m, m, m, m, m, m; D: m, m, m, m, m, m, m |
| Accessory spines (anterior/posterior) of 14th leg pair | one (p) | one (p) | one (?)* | one (?)* | no data |
| Accessory spines (anterior/posterior) of 15th leg pair | one (p) | absent | one (?)* | absent | one (?)* |
| Gonopodal spurs (in female) | 2+2 | 2+2 | unknown | unknown | 2+2 |
| Number of gonopodal claws (in female) | 3 | 3 | unknown | unknown | 3 |
| Distribution | Croatia | widespread throughout Europe | Greece | Greece | Hungary, Poland, Romania, Slovakia |
| Habitat | Cave (troglobiont) | Epigeic; several records from caves (troglophile) | thermophilous forests; epigeic | caves and mesophilous forests | mesophilous forests; epigeic |
| Sources | this study | Loksa, 1947; Koch, 1862; Koren, 1992 | Matic, 1976 | Matic & Stavropoulos, 1988; Zapparoli, 1994, 2002 | Loksa, 1947; Matic, 1966 |
All legs with moderately long and curved claws. Long and slender anterior accessory spines present on claws of leg-pairs 1-13 (Fig. 2D). Anterior accessory spines absent on penultimate and ultimate legs. Posterior accessory claw present on all legs, relatively smaller on leg-pairs 14 and 15 (Fig. 3D-E). Glandular pores on inner side in penultimate and ultimate legs absent in both sexes. Plectrotaxy of female holotype and its variation in paratypes are summarized in Tables 2-8.

**Coxal pore**: Small, rounded, in a shallow gutter-like depression; poorly visible due to translucent cuticle of coxae; usually 2222, otherwise 1222 and 1221.

**Male sexual characters** (Fig. 3A-B): Sternite of ultimate leg-bearing segment trapeziform, with narrower posterior side; first genital sternite wider than long, with scattered short setae, posterior margin convex between the gonopods, without a medial bulge. Gonopods short, developed as small hemispheres, bulge-like, distally with a long seta. Penis moderately long, bilobed, with two long setae on each side. Telson wider than long, with several long setae on posterior margin. Leg-pairs 14 and 15 without any modifications.

**Female sexual characters** (Fig. 4): Ultimate sternite of same shape as in males; first genital sternite deeply concave in middle part of posterior margin between condyles of gonopods, with a well sclerotized small medial bulge within this incision. Gonopods: first gonopodal articles broad, each with 5-6 long setae on
A new centipede from Croatia

Located on the flattened Kijevo karst plateau in the municipality of Kijevo, Šibenik-Knin County, Croatia (Fig. 5A), it is a well-known tourist attraction. Due to the presence of a reproductive colony of a protected bat species, this cave is protected by the “Natura 2000” ecological network (Natura code HR2000020) (Barišić, 2010). The cave is also known as the locality of *Alpioniscus* (*Illyrionethes*) *balthasari* (Frankenberger, 1937), an endemic Dinaric species of troglobitic trichoniscid woodlice (Bedek et al., 2019b). The type material of *Lithobius radjai* sp. nov. was collected under stones in the dark part of the cave (Rada, pers. comm.).

**DISCUSSION**

Due to the presence of more than 9000 registered caves and pits in Croatia, with some estimates that there are at least twice as many, the discovery of new species

| Table 1. (Continued) |
|----------------------|
| Species | *L. pasquinii* Matic, 1967 | *L. paucispinus* (Matic, 1976) | *L. sivasiensis* (Matic, 1983) | *L. zveri* (Matic & Stentzer, 1977) |
|---|---|---|---|---|
| **Body length (in mm)** | 5 | 6 | 7-9 | 3 |
| **Body colouration** | yellowish white | fawn-yellow to fawn-brown | light yellow | whitish yellow |
| **Number of antennal articles** | 20-21 | 20 | 20 | 20 |
| **Cephalic plate length/width (ratio)** | no data | no data | ≈ 1:1 | ≈ 1:1 |
| **Ocelli** | 1-2 (in one row); clearly pigmented | 4 (in 2 rows); more than twice as large as ocelli | 5 (in 2 rows); clearly pigmented | absent |
| **Tömösváry’s organ** | no data | no data | smaller than ocelli | extraordinarily large |
| **Coxal pores** | 2 | 2 | 1-2 | no data |
| **Plectrotaxy of 14th leg pair** | V: -, mp, m, m; D: -, mp, mp, m, m | V: -, m, m, m, m; D: -, m, m, m, m | V: -, -; D: -, m, m, m, m | V: -, m, m, m, m; D: -, m, m, m, m |
| **Plectrotaxy of 15th leg pair** | V: -, -; p, p, - | V: -, p, - | V: -, -; p, p, -; D: -, m, m, m, m | V: -, -; p, p, -; D: -, m, m, m, m |
| **Accessory spines (anterior/posterior) of 14th leg pair** | one (?)* | one (?)* | one (?)* | one (?)* |
| **Accessory spines (anterior/posterior) of 15th leg pair** | absent | one (?)* | absent | one (?)* |
| **Gonopodal spurs (in female)** | unknown | unknown | 2+2 | unknown |
| **Number of gonopodal claws (in female)** | unknown | unknown | 3 | unknown |
| **Distribution** | Italy | Turkey | Turkey | Slovenia |
| **Habitat** | cave (presumed troglobiont) | epigeic | epigeic | cave (troglobiont) |
| **Sources** | Matic, 1967 | Matic, 1976 | Matic, 1983 | Matic & Stentzer, 1977 |

ventral surface arranged in two rows and 1-2 moderately shorter dorsolateral setae; 2+2 sharp coniform spurs, inner spurs slightly smaller than outer ones; second gonopodal articles with 2-3 long ventral setae and 3-4 medium-short to long dorsolateral setae each; third articles with 2-3 medium-short to long dorsolateral setae; gonopodal claws moderately curved, tridentate, inner denticles smaller than outer ones, median and external denticles of approximately same size; without secondary sexual characters on penultimate and ultimate legs.

**Type locality:** The cave Velika Ćulumova Pećina, municipality of Kijevo, Šibenik-Knin County, Croatia (Fig. 5A).

**Remarks:** Jalžić (1974) described the cave Velika Ćulumova Pećina (its entrance shown in Fig. 5B-C) as one of the most beautiful speleological objects in all of Dalmatia, with approximately 360 m of tunnels.

---

*Fig. 5A* A centipede from Croatia.
Fig. 3. *Lithobius radjai* sp. nov., ♂ paratype IZB ChL027-L3 (A), ♂ paratype NHMSC L1 (B, D-E), ♀ paratype NHMSC L4 (C). (A) Posterior part of body, ventrolateral view. (B) Posterior segments and gonopods, ventral view. (C) Right ultimate leg, posteroventral view. (D) Tarsus and pretarsus of right penultimate leg, posteroventral view. (E) Pretarsus of right ultimate leg, posteroventral view. Abbreviation: pac = posterior accessory claw. Scale bars: 0.2 mm (A, C); 0.1 mm (B, D-E).
Fig. 4. *Lithobius radjai* sp. nov., ♀ paratype NHMSC L4 (A-B), ♀ holotype NHMSC L10 (C). (A) Posterior part of body, ventrolateral view. (B) Left gonopod, ventral view. (C) Gonopods, ventral view. Scale bars: 0.2 mm (A, C); 0.1 mm (B).
Table 2. Leg spinulation in *Lithobius radjai* sp. nov., female holotype (NHMSC L10).

| Legs | Ventral side | Dorsal side |
|------|--------------|-------------|
|      | C  | Tr | Pf | F  | Ti | C  | Tr | Pf | F  | Ti |
| 1-3  | m  |    |    |    |    | a  |    |    |    |    |
| 4-5  | m  |    |    |    |    | ap |    |    |    |    |
| 6    | (m)| m  |    |    |    | ap |    |    |    |    |
| 7-9  | m  | m  |    |    |    | ap |    |    |    |    |
| 10   | m  | m  |    |    |    | a(p)|    |    |    |    |
| 11   | m  | m  |    |    |    | a  |    |    |    |    |
| 12-13| m  | m  |    |    |    |    |    |    |    |    |
| 14-15| m  | m  | m  |    |    |    |    |    |    | p  |

Table 3. Leg spinulation in *Lithobius radjai* sp. nov., male paratype (NHMSC L1).

| Legs | Ventral side | Dorsal side |
|------|--------------|-------------|
|      | C  | Tr | Pf | F  | Ti | C  | Tr | Pf | F  | Ti |
| 1    | m  |    |    |    |    | a(p)|    |    |    |    |
| 2-3  | m  |    |    |    |    | ap |    |    |    |    |
| 4-9  | m  | m  |    |    |    | ap |    |    |    |    |
| 10-11| m  | m  |    |    |    | a  |    |    |    |    |
| 12   | m  | m  |    |    |    |    |    |    |    |    |
| 13   | (m)| m  | m  |    |    |    |    |    |    |    |
| 14-15| m  | m  | m  |    |    |    |    |    |    | p  |

Table 4. Leg spinulation in *Lithobius radjai* sp. nov., female paratype (IZB ChL27 L2).

| Legs | Ventral side | Dorsal side |
|------|--------------|-------------|
|      | C  | Tr | Pf | F  | Ti | C  | Tr | Pf | F  | Ti |
| 1    | m  |    |    |    |    | (a)|    |    |    |    |
| 2    | m  |    |    |    |    | a  |    |    |    |    |
| 3    | (m)| m  |    |    |    | ap |    |    |    |    |
| 4-11 | m  | m  |    |    |    | ap |    |    |    |    |
| 12   | m  | m  |    |    |    | a(p)|    |    |    |    |
| 13   | m  | m  |    |    |    | a  |    |    |    |    |
| 14-15| m  | m  | m  |    |    |    |    |    |    | p  |

Table 5. Leg spinulation in *Lithobius radjai* sp. nov., male paratype (IZB ChL27 L3).

| Legs | Ventral side | Dorsal side |
|------|--------------|-------------|
|      | C  | Tr | Pf | F  | Ti | C  | Tr | Pf | F  | Ti |
| 1-2  | m  |    |    |    |    | a  |    |    |    |    |
| 3    | (m)| m  |    |    |    | ap |    |    |    |    |
| 4-11 | m  | m  |    |    |    | ap |    |    |    |    |
| 12-13| m  | m  |    |    |    |    |    |    |    |    |
| 14-15| m  | m  | m  |    |    |    |    |    |    | p  |
A new centipede from Croatia

from subterranean habitats of this country is not a rare event (Jalžić et al., 2010). The majority of recorded subterranean species in Croatia are troglobionts, with 70% of them being endemic to Croatia (Gottstein Matočec et al., 2002). The last reported number of subterranean type localities in Croatia is 271, with a total of 427 animal species described from them (Jalžić et al., 2013), but this number increased in the decade after the publication of that paper. The present study adds one more endemic and presumed troglobitic species and one new type locality for Croatia (until now the cave Velika Ćulumova Pećina has not been reported as the type locality of any species). Based on several troglomorphic features such as the depigmented translucent cuticle due to its thinning (a common characteristic in cave species) (see Figs 1C and 4C), a reduced number of partly depigmented ocelli (Fig. 1B), as well as the fact that it is known only from the dark parts of the cave, at places with high humidity (under stones), we consider Lithobius radjai sp. nov. to be a troglobiont.

In light of a large number of morphological characters and existing sets of differing molecular data (both nuclear and mitochondrial markers), a recent study of Lithobiidae phylogeny conspicuously demonstrated the problematic taxonomic status of the subgenera Monotarsobius, Lithobius Leach, 1814 and Sigibius Chamberlin, 1913 (Ganske et al., 2021). The polyphyly of these subgenera was proven in that publication, and it was proposed to avoid using them in taxonomical studies. In other words, the diagnostic features of these Lithobius subgenera are results of homoplasy.

The new species presented here could be classified in the subgenus “Monotarsobius” on the basis of morphology.

Table 6. Leg spinulation in Lithobius radjai sp. nov., female paratype (NHMSC L4), female paratype (IZB ChL27 L5) and male paratype (IZB ChL27 L7).

| Legs | Ventral side | Dorsal side |
|------|--------------|-------------|
|      | C  Tr Pf F Ti | C  Tr Pf F Ti |
| 1-2  | m            | a           |
| 3    | (m) m       | a(p)        |
| 4-9  | m m         | ap          |
| 10-11| m m         | a           |
| 12-13| m m         |             |
| 14-15| m m m       | p           |

Table 7. Leg spinulation in Lithobius radjai sp. nov., male paratype (IZB ChL27 L6) and female paratype (IZB ChL27 L8).

| Legs | Ventral side | Dorsal side |
|------|--------------|-------------|
|      | C  Tr Pf F Ti | C  Tr Pf F Ti |
| 1-2  | m            | a           |
| 3    | (m) m       | ap          |
| 4-10 | m m         | ap          |
| 11   | m m         | a           |
| 12-13| m m         |             |
| 14-15| m m m       | p           |

Table 8. Leg spinulation in Lithobius radjai sp. nov., larva III (IZB ChL27 L9).

| Legs | Ventral side | Dorsal side |
|------|--------------|-------------|
|      | C  Tr Pf F Ti | C  Tr Pf F Ti |
| 1-4  | m            | a           |
| 3-7  | (m) m       |             |
| 8    | m           |             |
| 9-10 | (m) m       |             |
Regardless of the validity and status of this subgenus, the congeners most similar to *Lithobius radjai* sp. nov. should be sought among species previously described under “*Monotarsobius*”. The diagnostic characters common for all these species are: small size, usually short antennae with around 20 articles, coxosternite with 2+2 forcipular teeth, no posterior triangular projections on tergites, and undivided tarsi in leg-pairs 1-12(13) (summarized in Voigtländer *et al.*, 2017). In total, there are ca 120 species with such features, generally with a Palaearctic distribution (35 species in Europe and more than 80 in Asia (data extracted from Bonato *et al.*, Fig. 5.

Fig. 5. Type locality of *Lithobius radjai* sp. nov. (A) Position on the map of Croatia. (B-C) Entrance to the cave Velika Ćulumova Pećina (photos by T. Rada).
2016). For the purpose of this paper, the new species is compared with all European “Monotarsobius” species, and a detailed comparison with the 13 most similar ones from southeastern Europe, the Apennine Peninsula and western Turkey is provided. 

Lithobius radjai sp. nov. shares many similarities with the compared species, but there are also certain differences to each of them. Unquestionably, the most interesting for comparison are species from the Dinarides, viz., L. hadzii Matic & Dărăbanţu, 1968 (an epigeic species endemic to Croatia) and L. zveri Matic & Stentzer, 1977 (a subterranean species endemic to Slovenia). For a detailed comparison with these two and other similar species, see Table 1.

Finally, one of the significant problems existing in Lithobius taxonomy is visible in Table 1. The descriptions of a large number of Lithobius species are incomplete and/or imprecise in treating some morphological structures of more or less strong taxonomical importance, and sometimes it is even the case that those characters are not included at all. All the mentioned shortcomings have resulted in inadequate descriptions of many taxa today, which leads to many problems in identification and comparison. Fortunately for the present study, this is not so much the case in the descriptions of most European “Monotarsobius” species. There are certain inaccuracies in the descriptions of the species included here that affect their comparability, but these mostly concern characters that are currently not recognized as taxonomically very important. For example, statements on the presence or absence of one or both accessory spines on the penultimate and the ultimate legs are often missing. Furthermore, even when it is provided, in cases where only one accessory spine is present, there is no specification as to whether it is an anterior or a posterior spine (summarized in Table 1). Similar examples, often dealing with much more significant morphological characters (such as the number of antennal articles, the number and/or arrangement of ocelli, the presence of coxosternal teeth and porodonts, features of the genital apparatus, plectrotaxy, etc.), point to the need for a detailed redescription of a significant percentage of Lithobius species.

ACKNOWLEDGEMENTS

This study was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Grant 451-03-9/2021-14/ 200178). We wish to thank our friend and colleague Tonči Rađa (Split, Croatia), who provided us with the material of the new species and photos of the type locality. We are deeply grateful to the reviewer Dr László Dányi (Budapest, Hungary) for useful comments and suggestions, as well as to the subject editor Dr Peter Schwendinger (Geneva, Switzerland). The authors are also grateful to Mr Raymond Dooley (Belgrade, Serbia) for his help in preparing the English version of the manuscript.

REFERENCES

Akkari N., Komerički A., Weigand A.M., Edgecombe G.D., Stoew P. 2017. A new cave centipede from Croatia, Europolybothrus liburnicus sp. nov., with notes on the subgenus Schizopolybothrus Verhoeff, 1934 (Chilopoda, Lithobiomorpha, Lithobiidae). ZooKeys 687: 11-43.

Andersson G. 1979. Taxonomical studies on the post-embryonic development in Lithobius, with a brief comparison with Lamycetes (Chilopoda: Lithobiomorpha). Dissertation, University of Gothenburg, Gothenburg, Sweden, 49 pp.

Antić D.Z., Dražina T., Rada T., Lučić L.R., Makarov S.E. 2016. Taxonomic status of the family Biokovellidae Mršić, 1992 (Diplopoda, Chordeumatida): reconsideration, with a description of one new species. European Journal of Taxonomy 205: 1-23.

Antić D.Z., Rada T., Makarov S.E. 2018. Dalmatosomatidae, a new monotypic family, and Dalmatosoma agaricum gen. et sp. nov. (Diplopoda: Chordeumatida: Craspedosomatidea) from Croatia, Balkan Peninsula. Zootaxa 4403(2): 289-306.

Barišić T. 2010. Speleological research Natura 2000 in County of Šibenik-Knin in 2009 (pp. 1-11). In: Bujjak N., Paar D. (eds). Stručni Seminar o Zaštiti Špilja i Podzemne Faune, Ogulin, Croatia. Zbornik Radova, 85 pp.

Bedeck J., Gottstein S., Taiti S. 2019a. Taxonomy of Alpiniscus (Illyriothes): A. magnus and three new species from the Dinaric Karst (Isopoda: Oniscidea: Trichoniscidae). Zootaxa 4657(3): 483-502.

Bedeck J., Taiti S., Bilaldžija H., Ristori E., Baratti M. 2019b. Molecular and taxonomic analyses in troglobiotic Alpiniscus (Illyriothes) species from the Dinaric Karst (Isopoda: Trichoniscidae). Zoological Journal of the Linnean Society 187(3): 539-584.

Bonato L., Edgecombe G.D., Lewis J.G.E., Minelli A., Pereira L.A., Shelley R.M., Zapparoli M. 2016. A new monotypic family, and Dalmatosoma agaricum gen. et sp. nov. (Diplopoda: Chordeumatida: Craspedosomatidea) from Croatia, Balkan Peninsula. Zootaxa 4403(2): 289-306.

Eason E.H. 1964. Centipedes of the British Isles. Frederick Warne, London, 294 pp.

Frankenberger Z. 1937. Über eine neue Illyriothes Art aus Dalmatien. Zoologischer Anzeiger 120: 173-176.

Ganske A.S., Vahtera V., Dányi L., Edgecombe G.D., Akkari N. 2021. Phylogeny of Lithobiidae Newport, 1844, with emphasis on the megadiverse genus Lithobius Leach, 1814 (Myriapoda, Chilopoda). Cladistics 37: 162-184.

Gottstein Matóčec S., Ozimec R., Jalžić B., Kerovec M., Bakran-Petricioli T. 2002. Diversity and vulnerability of groundwater wildlife of Croatia. Ministry of Environment and Physical Planning, Republic of Croatia, Zagreb, Croatia, 82 pp.
Jalžić B. 1974. Ćulumova pećina u Dalmacija [The Ćulumova pećina Cave in Dalmatia]. Naše Planine 5-6: 104-105.

Jalžić B., Bedek J., Bilal’džija H., Cvitanović H., Dražina T., Gottstein S., Klijaković-Gajić F., Lukić M., Oźimec R., Pavlek M., Slapnik R., Štampol V. 2010. Atlas špijških tipskih lokaliteta faune Republike Hrvatske, Svezak 1 [The cave type localities atlas of Croatian fauna, volume 1]. Croatian Biospeleological Society, Zagreb, Croatia, 261 pp.

Jalžić B., Bedek J., Bilal’džija H., Bregović P., Cvitanović H., Ćuković T., Ćuković A., Dražina T., Đud L., Gottstein S., Kljaković-Gašpić F., Lukić M., Malenica M., Miculinčić K., Oźimec R., Pavlek M., Raguž N., Slapnik R., Štampol V. 2013. Atlas špijških tipskih lokaliteta faune Republike Hrvatske, Svezak 2 [The cave type localities atlas of Croatian fauna, volume 2]. Croatian Biospeleological Society, Zagreb, Croatia, 261 pp.

Karaman I. 2020. A new Euscorpius species (Scorpiones: Euscorpiidae) from a Dinaric cave - the first record of troglobitic scorpion in European fauna. Biologija Serbica 42(1): 14-31.

Koch L. 1862. Die Myriapodenfauna von Kärnten und Osttirol. 2. Lithobiomorpha. Nürnberg, 94 pp.

Koren A. 1992. Die Chilopoden-Fauna von Kärnten und Osttirol. 9. Lithobius Hochenwartii, n. g., n. sp. Illyrisches Blatt, Laibach 3: 9-10.

Lukić M., Delić T., Zagmajster M., Deharveng L. 2018. Setting a morphological framework for the genus Verhoeffiella (CollMBOLBA, Entomobryidae) for describing new troglobionic species from the Dinaric karst (Western Balkans). Invertebrate Systematics 32(5): 1118-1170.

Lukić M., Dărăbanţu C. 1968. Contributions à la connaissance des chilopodes de Grecie. Biologia Gallo-Hellenica 14(1): 33-46.

Matic Z. 1979. Stentzer I. 1977. Beitrag zur Kenntnis der Hundertfüßler (Chilopoda) aus Slowenien. Biološki Vestnik 25(1): 55-62.

Müller C.H.G., Sombke A., Hilgen K., Rosenberg J. 2011. Chilopoda - Sense organs (pp. 235-278). In: Menelli A. (ed.), Treatise on zoology - Anatomy, taxonomy, biology. The Myriapoda. Volume 1. Brill, Leiden, 530 pp.

Pavičević D., Dohaj R., Popović M. 2020. A new genus and species of subterranean trechine beetle from Montenegro (Coleoptera: Carabidae: Trechini). Biologia Serbica 42(1): 48-59.

Schmidt F. 1832. Beitrag zu Krain’s Fauna. Leptodirus Hochenwartii, n. g., n. sp. Illyrisches Blatt, Laibach 3: 9-10.

Simićević V. 2017. Poachers threaten Balkans’ underground biodiversity. Science 358(6367): 1116-1117.

Sket B., Paragamian K., Trontelj P. 2004. A census of the obligate subterranean fauna in the Balkan Peninsula (pp. 309-322). In: Griffiths H.I., Krystufek B., Reed, J.M. (eds), Balkan biodiversity. Pattern and process in Europe’s biodiversity hotspot. Klwer Academic Publishers, Dordrecht, 358 pp.

Stoev P., Akkari N., Komerciķa A., Edgecombe G.D., Bonato L., Stoev P., Akkari N., Komerciķa A., Edgecombe G.D., Bonato L. 2015. At the end of the rope: Geophilus hadesi sp. n. - the world’s deepest cave-dwelling centipede (Chilopoda, Geophilomorpha, Geophilidae). In: Tuf I.H., Tavukov K. (eds), Proceedings of the 16th International Congress of Myriapodology, Olomouc, Czech Republic. ZooKeys 510: 125-139.

Loksa I. 1947. Beiträge zur Kenntnis der Steinläufer-, Lithobiiden-Fauna des Karpatenbeckens. 1. Fragmenta Faunistica Hungarica 10(3): 73-85.

Lukić M., Delić T., Zagmajster M., Delić T. 2018. Setting a morphological framework for the genus Verhoeffiella (CollMBOLBA, Entomobryidae) for describing new troglobionic species from the Dinaric karst (Western Balkans). Invertebrate Systematics 32(5): 1118-1170.

Matic Z. 1962a. Noi contribuții la cunoașterea subgenului Monotarsobius Verh. (Chilopoda-Lithobiida) din fauna Republicii Populare Romîne. Studii și Cercetări de Biologie (Cluj) 13(1): 75-86.

Matic Z. 1962b. Beiträge zur Kenntnis der Chilopoda aus Sizilien. Bollettino delle Sedute dell’Accademia Gioenia di Scienze Naturali in Catania (Serie 4) 7(2): 51-62.

Matic Z. 1966. Fauna Republicii Socialiste România. Clasa Chilopoda, Subclasa Anamorpha. Volumul VI, Fascicula 1. Academia Republicii Socialiste România, București, România, 267 pp.

Matic Z. 1967. Contribution à la connaissance des Lithobiides, Scutigerides et Cryptopsides des grottes de l’Italie (Myriopoda). Fragmenta Entomologica 5(1): 77-110.

Matic Z. 1976. Sur quelques Myriapodes Chilopodes du Muséum d’Histoire naturelle de Genève. Revue suisse de Zoologie 83(2): 287-306.

Matic Z. 1983. Lisobidi raccolti in Turchia dal Dott. Giuseppe Osella (Chilopoda Lithobiomorpha). Fragmenta Entomologica 17(1): 19-45.

Matic Z., Dărăbanţu C. 1968. Contributions à la connaissance des chilopodes de Yougoslavie. Academia Scientiarum et Artium Slovenica. Classis IV. Historia Naturalis et Medicina. Pars Historiconaturalis 11(5): 201-227.

Matic Z., Stavropoulos G. 1988. Contributions à la connaissance des chilopodes de Grèce. Biologia Gallo-Hellenica 14(1): 33-46.

Matic Z., Stentzer I. 1977. Beitrag zur Kenntnis der Hundertfüßler (Chilopoda) aus Slowenien. Biološki Vestnik 25(1): 55-62.

Müller C.H.G., Sombke A., Hilgen K., Rosenberg J. 2011. Chilopoda - Sense organs (pp. 235-278). In: Menelli A. (ed.), Treatise on zoology - Anatomy, taxonomy, biology. The Myriapoda. Volume 1. Brill, Leiden, 530 pp.

Pavičević D., Dohaj R., Popović M. 2020. A new genus and species of subterranean trechine beetle from Montenegro (Coleoptera: Carabidae: Trechini). Biologia Serbica 42(1): 48-59.

Schmidt F. 1832. Beitrag zu Krain’s Fauna. Leptodirus Hochenwartii, n. g., n. sp. Illyrisches Blatt, Laibach 3: 9-10.

Simićević V. 2017. Poachers threaten Balkans’ underground biodiversity. Science 358(6367): 1116-1117.

Sket B., Paragamian K., Trontelj P. 2004. A census of the obligate subterranean fauna in the Balkan Peninsula (pp. 309-322). In: Griffiths H.I., Krystufek B., Reed, J.M. (eds), Balkan biodiversity. Pattern and process in Europe’s biodiversity hotspot. Klwer Academic Publishers, Dordrecht, 358 pp.

Stoev P., Akkari N., Komerciķa A., Edgecombe G.D., Bonato L. 2015. At the end of the rope: Geophilus hadesi sp. n. - the world’s deepest cave-dwelling centipede (Chilopoda, Geophilomorpha, Geophilidae). In: Tuf I.H., Tavukov K. (eds), Proceedings of the 16th International Congress of Myriapodology, Olomouc, Czech Republic. ZooKeys 510: 95-114.

Švara V., Delić T., Rada T., Fiser C. 2015. Molecular phylogeny of Niphargus boskovici (Crustacea: Amphipoda) reveals a new species from epikarst. Zootaxa 3994(3): 354-376.

Valvasor J.W. 1689. Die Ehre des Herzogthums Krain. Ljubljana, 83(2): 287-306.