

# First record of a specialized hygropetricolous cave beetle, genus *Croatodirus* (Coleoptera: Leiodidae), in Slovenia

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**Abstract.** The cave hygropetric, an inaccessible subterranean habitat defined by films of water flowing down the cave walls, is renowned for its specialized filter feeding cave beetles. To date, no data on cave hygropetricolous beetles have been known for Slovenia, despite the existence of suitable karst areas. This paper reports on the first finding of a hygropetricolous cave beetle in Slovenia. A single female of a species belonging to the genus *Croatodirus* was discovered in the cave »Brezno treh src« on the Snežnik Plateau. The geomorphology and climate of the sampling site as well as the biology of hygropetricolous cave beetles are briefly described.

Key words: hygropetricolous beetles, cave hygropetric, *Croatodirus*, Mt Snežnik, Brezno treh src, Dinaric Karst, troglobiont

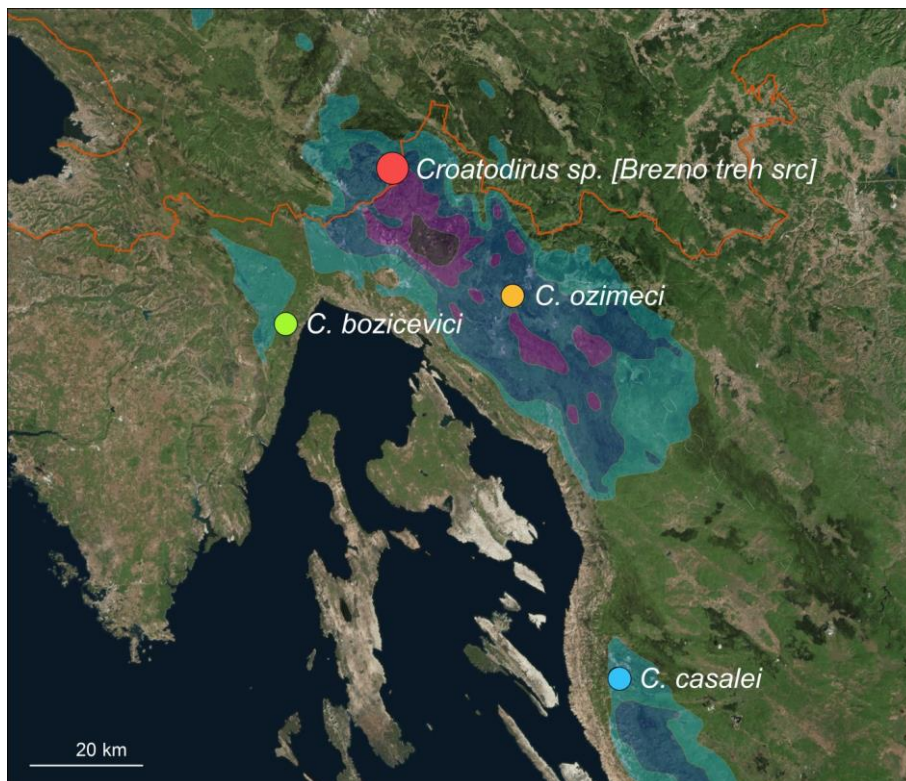
**Izvleček.** Prva najdba specializiranega hrošča iz rodu *Croatodirus* (Coleoptera: Leiodidae) v jamskem higropetrikumu v Sloveniji – Teško dostopne podzemeljske habitate, katerih značilnost je čez stene v obliki filma mezeča voda, imenujemo jamski higropetrik. Ta je znan po jamskih hroščih, ki se prehranjujejo s filtriranjem vode. Doslej o pojavljanju specializiranih higropetričnih hroščev, kljub obstoju primernih območij, v Sloveniji ni bilo podatkov. V prispevku je podan opis prve najdbe higropetričnega hrošča iz rodu *Croatodirus* za Slovenijo, iz »Brezna treh src« na Snežniku. Opisani so tudi geomorfologija, klimatske lastnosti najdišča ter kratek pregled biologije higropetričnih hroščev.

Ključne besede: higropetrični hrošči, jamski higropetrik, *Croatodirus*, Snežnik, Brezno treh src, Dinarski kras, troglobiont

## Introduction

In their study, Giachino & Vailati (2006) stated that specialized hygropetricolous beetles (referred to also as hygropetric) are bound to geographical areas receiving more than 2000 mm total annual precipitation. This conclusion was based on the overview of the localities where hygropetricolous beetles were known to exist (Fig. 1). The areas exceeding this limit were hypothesized to enable the functioning of a special subterranean habitat, the

cave hygropetric (Sket 2004, Giachino & Vailati 2006). Defined by a constant influx of percolating waters derived from the surface, the cave hygropetric enables the formation of rich microbial communities that serve as nutrients to hygropetricolous beetles (Engel et al. 2013, Paoletti et al. 2013).



**Figure 1.** Distribution of the hygropetricolous beetles from the genus *Croatodirus*. The areas exceeding 2,000 mm annual precipitation, enabling existence of the cave hygropetric, are indicated in light blue = 2,000 to 2,500 mm, dark blue = 2,500 to 3,000 mm, violet = 3,000 to 3,500 mm and purple = 3,500 to 4,000 mm annual precipitation. Data sources: Subbio Database ([www.subbio.net/db](http://www.subbio.net/db)), ESRI World Imagery ([www.esri.com](http://www.esri.com)), Ranković et al. 1961.

**Slika 1.** Razširjenost higropetričnih hroščev iz rodu *Croatodirus*. Označena so območja z več kot 2000 mm letne količine padavin, meje, ki omogoča obstoj jamskega higropetrika (svetlo modra = 2000 do 2500 mm, temno modra = 2500 do 3000 mm, svetlo vijolična = 3000 do 3500 mm in temno vijolična 3500 do 4000 mm letne količine padavin). Viri: podatkovna baza Subbio Database ([www.subbio.net/db](http://www.subbio.net/db)), ESRI World Imagery ([www.esri.com](http://www.esri.com)), Ranković et al. 1961.

All known genera of hygropetricolous beetles, i. e. the Dinaric genera *Hadesia* Müller 1911, *Radziella* Casale & Jalžić 1988, *Tartariella* Nonveiller & Pavičević 1999, *Croatodirus* Casale, Giachino & Jalžić 2000, *Nauticiella* Moravec & Mlejnek 2002, *Velebitodromus* Casale, Giachino & Jalžić 2004 and *Kircheria* Giachino & Vailati 2006, as well as the sole Alpine genus *Cansiliella* Paoletti 1972, share similar morphological adaptations (Perreau & Pavičević 2008). The most conspicuous include a highly hydrophobic pubescence of exoskeleton, an elongated and specifically shaped head, increased size of mandibles and feeding apparatus, densely covered with thickened filtering setae, and specialized claws that enable them holding on to the

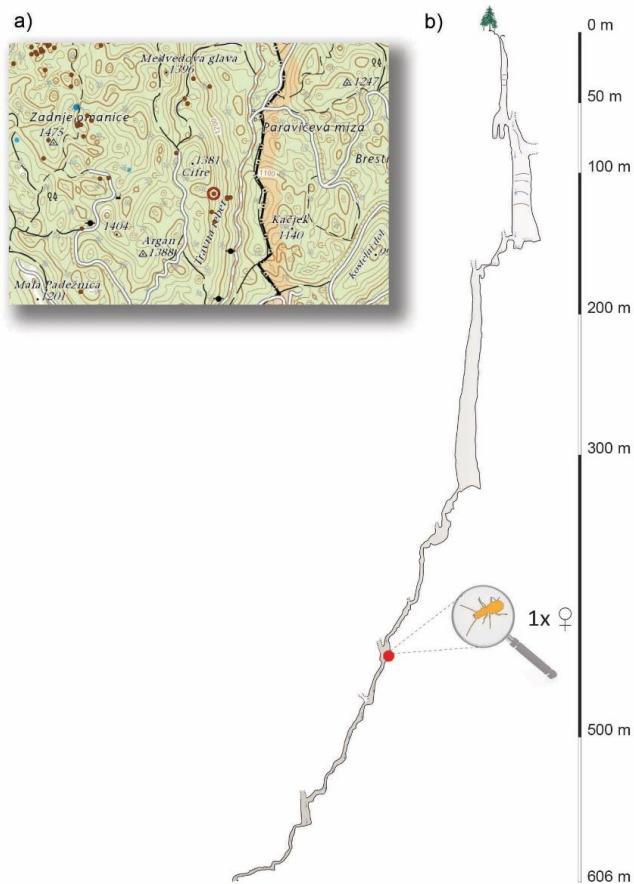
surface despite strong water current (Moldovan et al. 2004, Giachino & Vailati 2006, Perreau & Pavićević 2008). Phylogenetic relations among these genera have not been disentangled up to date, but preliminary data suggest that adaptations to hygropetric habitats evolved convergently in some of the distantly related genera (Polak et al. 2016).

Throughout the Dinaric Karst, several regions with high level of precipitation and harbouring highly endemic hygropetricolous beetles were recognized (Giachino & Vailati 2006, 2010). These areas include mountain plateaus and ridges along the eastern Adriatic coast and in the inner Dinarides – Gorski kotar, Učka, Velebit, Biokovo, Lovćen, Durmitor and Prokletije – all renowned for their rich endemic obligate subterranean fauna. The arc of high-precipitation limestone massifs in the hinterland of the Adriatic Sea extends all the way to the Italian Prealps where hygropetricolous cave beetles are represented by the genus *Cansiliella*. Although karst areas with high annual precipitation, exceeding 2000 mm yearly, are present in the northern most part of the Dinaric Karst (Ranković 1961), no hygropetricolous beetles have been found here to date. Such are the high karst plateaus of Trnovski gozd and Snežnik (Fig. 1). Both areas were thoroughly explored in a speleological and speleobiological sense in the past. Moreover, with 11 troglotic beetles, the cave Ledenica v Dolu on the Trnovski gozd massif represents the richest locality for subterranean beetles in the world (Bognolo 2002, Zagamajster 2007). Despite recent thorough sampling efforts in caves with permanent water flow in the vadose zone of Trnovski gozd (Borko 2016) and Snežnik (own unpublished data), no specialized filter feeding beetles were found. Although areas with potentially suitable habitats had been recognized, Slovenia remained the only country throughout the Dinaric Karst with no records of hygropetricolous cave beetles. Nonetheless, the finding of such a cave animal has remained highly anticipated, as Slovenia represents the only large gap in the »hygropetricolous arc« spanning the carbonate range from Albania in the southeast to the Italian Prealps in the northwest.

## Results and discussion

On Saturday, 9.9.2017, a hygropetricolous beetle from the genus *Croatodirus* was discovered in the cave Brezno treh src (B3S), Cifre, Mt Snežnik, Slovenia (Slovenian cave cadastre number 9834, DK – 48 x, y = 5460733, 5046077, WGS – 84 x, y = 14.4923°, 45.5579°) (Fig. 2). A sole female *Croatodirus* beetle (Fig. 3) was found at the beginning of the cave hygropetric habitat at an approximate depth of 470 m, in a cave section referred to as Ljubljanska borza. It was found walking on a vertical wall, approximately 30 cm from the main water flow. The beetle was photographed in its natural habitat and instantly preserved in 96% ethanol. A representative of another troglotic beetle genus, *Parapropus sericeus*, was spotted nearby. Interestingly, the cave was visited and thoroughly inspected by the author eight times. Despite considerable observation effort, and probably due to the suboptimal habitat characteristics and low population density, this was the first time a hygropetricolous beetle was found in this or any other cave in Slovenia. Other specialized troglotic beetle fauna includes *Anophthalmus spectabilis* and *Typhlotrechus bilimekii* from the subfamily Trechinae (Carabidae), and *Astagobius angustatus*, *Bathysciotes khevenhuelleri*, *Leptodirus hohenwartii*, *Parapropus sericeus* and *Spelaeodromus sneznikensis* from the subfamily

Cholevinae (Leiodidae) (beetles are preserved in Zoological collection of the Department of Biology, Biotechnical Faculty, University of Ljubljana, Slovenia).



**Figure 2.** Geographic position of the entrance to the cave Brezno treh src, marked with a red circle. Nearby caves are represented with brown dots (a). Section of the cave (modified from Vengar 2010), with the micro location of the *Croatodirus* find at an approximate depth of 470 m (b).

**Slika 2.** Geografska lega vhoda v Brezno treh src, označena z rdečim krogom. Jame v okolici so označene z rjavimi točkami (a). Prerez jame (prilagojeno po Vengar 2010), z označenim mestom ulova osebkov iz rodu *Croatodirus*, na približni globini 470 m (b).



**Figure 3.** A female of *Croatodirus* sp., the first hygropetricolous beetle observed in its natural habitat in Slovenia at a depth of 470 m in Brezno treh src, Cifre, Mt Snežnik (photo: T. Delić).

**Slika 3.** Samica *Croatodirus* sp., prvi higropetrični hrošč, opažen v naravnem okolju v Sloveniji v Breznu treh src, Cifre, Snežnik, na globini 470 m (foto: T. Delić).

The genus *Croatodirus* currently comprises three species: *C. bozicevici* Casale et al. 2000, *C. casalei* Giachino & Jalžić 2004, *C. ozimeci* Casale et al. 2004. The three species are narrowly endemic, each of them bound to a single massif of the Croatian Dinaric Karst; Učka, Velebit and Gorski kotar, respectively (Casale et al. 2004). All species are similar in appearance with only minute details enabling morphological identification of the species. While one of the species, *C. ozimeci*, is known from only one male specimen, the two other species, *C. bozicevici* and *C. casalei*, are known from relatively large populations from Mt Učka and Velebit, respectively (Casale et al. 2000, 2004). Like the other *Croatodirus* species, the beetle from Snežnik was also found in permanent water flows in the deeper sections of the vadose zone. Brezno treh src is more than 30 km apart from the nearest *Croatodirus* localities – Kaverna u tunelu Učka and Lokvarka (syn. Lokvarska špilja), type localities of *C. bozicevici* and *C. ozimeci*, respectively. Because of the limited dispersal within the subterranean realm and highly fragmented subterranean habitats of the Dinaric Karst (Trontelj et al. 2009, Konec et al. 2016), we hypothesize that *Croatodirus* population from Mt Snežnik could belong to an independent lineage, possibly a separate species, despite the relatively small distance from the closest known *Croatodirus* sites. To test this hypothesis, DNA barcoding analysis or comparative morphological examination of additional specimens, especially males, are needed.

Regardless of the outcome of these analyses, the discovery of a novel *Croatodirus* population is an important milestone for several reasons. First, the geographical range of the genus is extended further to the north and its maximal extent now exceeds 100 km (Velebit–Snežnik). Second, *Croatodirus* speciation patterns seem to reflect the speciation patterns described in the southern Dinaric genus *Hadesia* (Polak et al. 2016). Likewise, the most recent common ancestral species probably inhabited the whole area where the genus is present nowadays, but aridification of the climate by the end of Miocene, and the ensuing glaciation

during the Pleistocene (Salzmann et al. 2011, Haywood et al. 2013), triggered vicariant speciation. Third, the discovery of a hygropetricolous cave beetle in Slovenia demonstrated that our knowledge of subterranean fauna is still scarce, despite the long tradition of speleobiology and years of targeted effort aimed at finding this particular type of beetles.

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