

On the scorpion genus *Trogloorhopalurus* (Arachnida: Buthidae): taxonomy and distribution

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Abstract

This study presents evidence of a previously undescribed species of the scorpion genus *Trogloorhopalurus*, expanding the known diversity of this poorly studied group. Through the morphological analysis of 16 adult specimens, significant differences were identified between *T. lacrau*, a troglophile species, and a new morphospecies, *Trogloorhopalurus* sp.1. Key distinguishing features of the new species include finer carapace granulation, more elongated body and appendages, and a higher number of pectinal teeth. The new species is exclusively associated with caves in the Peruaçu district, while *T. lacrau* is distributed across both cave and epigean environments in the Irecê district and beyond, with some records possibly linked to human-mediated introductions. These findings highlight the need for a reassessment of *T. lacrau*'s conservation status, considering its expanded range and ecological flexibility. In contrast, *T. sp.1* is restricted to a small geographic area (<300 km²), underscoring its vulnerability and the importance of considering it for inclusion in the Brazilian red list of threatened species. This study not only contributes to the taxonomy and biogeography of *Trogloorhopalurus* but also opens opportunities for future research into the evolutionary adaptations and phylogeography of these scorpions, particularly their relationship with cave environments.

1. Introduction

The Brazilian scorpion fauna is the second most species-rich in the world, with about 190 described species, in 28 genera and five families (L.S. Carvalho, in prep.). The most species-rich scorpion fauna in the world is reported from Mexico, where about 300 species are known (Santibáñez-López et al. 2015). However, these two highly diversified faunas differ in a unique characteristic: the number of cave-associated species. For Mexico, more than thirty species in five families have been identified from caves (Sissom and Reddell 2009); while only a handful species are known from Brazil (Moreno-González et al. 2021). Among the Brazilian cave scorpions, the most remarkable taxa are those belonging to the genus *Trogloorhopalurus* Lourenço, Baptista & Giupponi, 2004. This genus is composed by two species, the troglobitic species *Trogloorhopalurus translucidus* Lourenço, Baptista and Giupponi 2004, and the troglophile *Trogloorhopalurus lacrau* (Lourenço and Pinto-da-Rocha 1997)

(Moreno-González et al. 2021). *Trogloorhopalurus translucidus* is known from a few caves in the limestone caves in the Chapada Diamantina region, in the state of Bahia, northeastern Brazil, without any known records outside caves. On the other hand, *T. lacrau* is reported from caves in the same region and one epigean record in the state of Ceará, 700km northwards its type-locality (Esposito et al. 2017).

Recently, numerous new specimens tentatively identified as *T. lacrau* have been collected in limestone caves from other localities, up to 330 km away from its type-locality. These records raise questions on the species limits of *T. lacrau*, and the possibility of the existence of additional related species. In the present study, we provide morphological evidence of an undescribed species of *Trogloorhopalurus*, related to *T. lacrau* and provide an updated distribution of this species.

2. Materials and methods

All examined specimens were deposited in the following Brazilian museums: Centro de Estudos em Biologia Subterrânea (CEZS), Universidade Federal de Lavras, Minas Gerais; Instituto Butantan (IBSP), São Paulo; and Coleção de História Natural (CHNUFPI), Universidade Federal do Piauí, Piauí. A total of 36 measurements of body and appendage structures were taken from all available specimens, using a stereomicroscope equipped with an ocular micrometer. The specimens from two different

Caatinga ecoregions were treated as different operational taxonomic units, due to a previous morphological assessment. Specimens from the Irecê district were considered to represent true *Trogloorhopalurus lacrau*, as this ecoregion encompasses the type-locality of this species. Specimens from the Peruaçu district were tentatively assigned to a different morphospecies. The raw data of each measurement was also compared among morphospecies using appropriate univariate models

(T-tests, Welch's tests, or Mann-Whitney U tests). All analyses were carried out using the R programming language. Besides, the specimens of

both assigned morphospecies were compared based on their general morphology, following standard taxonomic approaches.

3. Results

A total of 16 adult female individuals were analyzed, including 13 assigned to *Troglophopulus lacrau* and three assigned to *Troglophopulus* sp.1. Six topotype specimens from Lapa do Bode, Itaeté, state of Bahia, were measured, along with 10 specimens collected from two previously unrecorded caves. *Troglophopulus* sp.1 specimens were collected at four caves in the Peruaçu district, extending the geographic distribution of the genus *Troglophopulus* westward. Additionally, we examined specimens of *T. lacrau*, collected in epigeal environments in two other municipalities of the state of Bahia

The first main observation is that the carapace of *Troglophopulus* sp.1 specimens presents a finer granulation, when compared to *T. lacrau* specimens. We did not observe intermediate states or polymorphism in this character within the morphospecies, which favors this character as a diagnostic feature distinguishing the two taxa.

The individual comparisons using raw measurements of each measured structure revealed some distinguishing features (Fig. 1). Specimens assigned to *Troglophopulus* sp.1 exhibited a significantly more elongated body, mesosoma, pedipalp (total), pedipalp femur, pedipalp patella, pe-

dipalp chela, movable finger of the pedipalp chelae and telson. Besides, the number of pectinal teeth was greater in *Troglophopulus* sp.1 (Fig. 2).

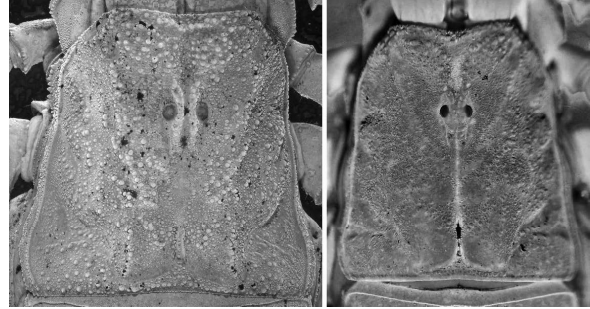


Figure 1: Dorsal view of the carapace of *Troglophopulus lacrau* (left) and *Troglophopulus* sp.1 (right), showing the differences in carapace granulation.

Variable	<i>T. lacrau</i> (♀; n = 13)	<i>Troglophopulus</i> sp.1 (♀; n = 3)	Statistics
Total length	39.14 - 46.50 (42.69 ± 2.74)	44.10 - 46.00 (44.87 ± 1.00)	T = 2.275, p = 0.046
Mesosoma (length)	10.00 - 13.57 (11.62 ± 1.27)	13.29 - 15.71 (14.38 ± 1.23)	T = 3.478, p = 0.039
Pedipalp (total length)	17.14 - 23.00 (20.06 ± 1.77)	22.43 - 24.14 (23.38 ± 0.87)	T = 4.719, p = 0.003
Femur (length)	4.00 - 5.57 (4.59 ± 0.43)	5.43 - 5.43 (5.43)	U = 36.00, p = 0.029
Patella (length)	4.86 - 5.86 (5.37 ± 0.35)	6.14 - 6.43 (6.29 ± 0.14)	T = 7.13, p = 0.000
Chela (length)	7.36 - 10.00 (8.81 ± 0.82)	9.71 - 10.43 (10.10 ± 0.36)	T = 4.188, p = 0.003
Chela (movable finger length)	4.43 - 6.43 (5.53 ± 0.53)	6.14 - 6.57 (6.33 ± 0.22)	T = 4.148, p = 0.003
Telson (length)	4.00 - 4.86 (4.27 ± 0.29)	4.36 - 5.00 (4.74 ± 0.34)	U = 34.50, p = 0.047
Pectinal tooth count	13 - 17 (16)	17 - 19 (17)	U = 34.00, p = 0.049

Figure 1: Summary of significant results of univariate comparisons between measurements of both *Troglophopulus* morphospecies.

Bold highlighted data represent significant comparisons. ¹Raw measurements normalized by the own structure length.

²Raw measurement normalized by the carapace length.

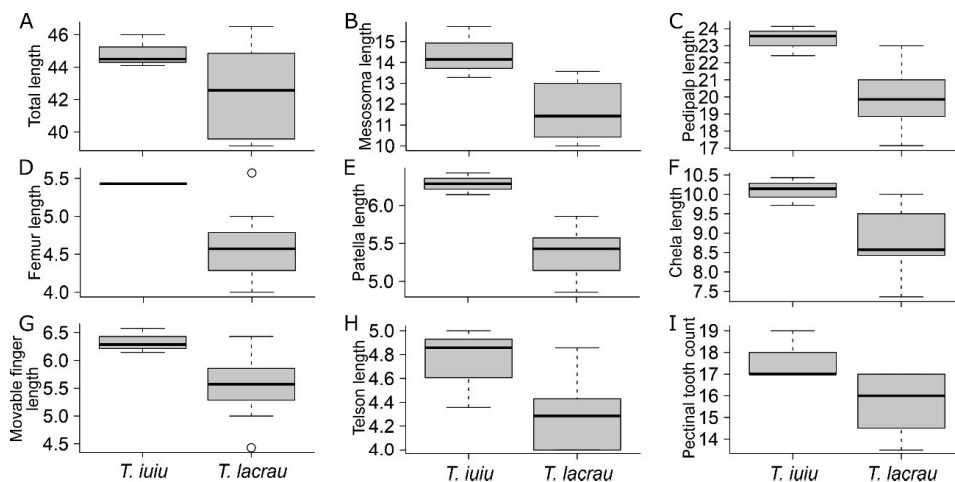


Figure 2: Comparison of morphometric variables between *Troglophopulus lacrau* and *Troglophopulus* sp.1. Only significant comparisons described in Table 1 are displayed. Variables: A) Total length; B) Mesosoma length; C) Pedipalp total length; D) Femur length; E) Patella length; F) Chela length; G) Chela movable finger length; H) Telson total length; I) Pectinal tooth count.

4. Discussion

The data shown herein support the proposition of a new species of the scorpion genus *Troglophopalus*. The new species is endemic to the Peruaçu district, while *T. lacrau* is now reported from both cave and epigeal environments in the Irecê district, in addition to an epigeal record in the state of Ceará. *Troglophopalus* sp.1 can be distinguished from *T. lacrau* by several key features. Its carapace is mostly covered by fine granules with vestigial carinae, whereas *T. lacrau* has coarse granules and well-marked carinae. The dorsomedian carinae of the pedipalp femur and the LIM carinae on metasoma segment II are absent in *T. sp.1* but vestigial in *T. lacrau*. Additionally, the DL carinae on metasoma segments II and III exhibit slightly prominent granules posteriorly in *T. sp.1*, compared to the spinoid and prominent granules on segments I-IV in *T. lacrau*. Other distinctions include the absence of retrolateral secondary and secondary accessory carinae on the pedipalp chela in *T. sp.1*, and differences in the shape of the peg sensillae on the pectinal teeth. Morphometric analyses also reveal significant differences between the two species.

Presently, *Troglophopalus lacrau* is considered “Data Deficient” in the threatened species Brazilian red list, owing to the existence of epigeal records far from its type-locality. The new data provided herein extend its occurrence to additional caves and other epigeal environments. However, it is not possible to rule out the epigeal records as natural records, as they could be related to human-mediated introduction events,

suggesting a species naturally endemic to three caves distributed over a 100 km² straight-line region. The known records encompass three ecoregions of the Caatinga domain: (1) the Irecê district, a very heavily deforested karstic area; (2) the Southern Depressão Sertaneja district, which encompasses deciduous caatinga vegetation and deciduous forests of the crystalline massifs; and (3) the Araripe district, an uplifted sedimentary basin located 700 km northwards of the closest record of *T. lacrau*. Further research is needed to determine whether these potentially introduced populations indeed originated from native cave populations and whether these synanthropic populations will become established or eventually disappear. However, the currently known distribution suggests that this species should be moved from data deficient to least concern in the Brazilian Red List.

The new species, however, is known exclusively from cave environments. The elongated body might be considered evidence of an initial adaptation to cave environments, but this hypothesis should be tested using phylogenetic comparative methods. Regarding its conservation status, *Troglophopalus* sp.1 should be considered for inclusion in the red list, owing to its limited number of locations, restricted to a narrow extent of occurrence (< 300 km²). This assessment is subject to further evaluation, following the International Union for Conservation of Nature procedures adopted by the Brazilian environmental agencies.

5. Conclusion

The present study provides evidence of an undescribed, potentially threatened cave-dwelling species of the poorly known scorpion genus *Troglophopalus*. This represents the third species in the genus. The existence of several known cave populations offers the possibility of

phylogeographic studies using the genus as a model, to estimate the divergence time of species within this genus. Further studies should also focus on the distribution of epigeal populations of *T. lacrau*, to provide data for reassessing the conservation status of this taxon.

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