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Ghosts of subterranean waters: two new troglobitic species of *Spelaeometra* D. Polhemus & Ferreira, 2018 (Heteroptera: Hydrometridae) from Brazil, with remarks on the enigmatic species *Cephalometra pallida* D. Polhemus & Ferreira, 2018

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Abstract. *Spelaeometra* D. Polhemus & Ferreira, 2018 is a rare genus within the family Hydrometridae, currently composed exclusively of cave-dwelling species. Herein, we describe two new troglobitic species of this enigmatic genus from southwestern Bahia, Brazil: *Spelaeometra ybykoara* sp. nov. from the municipality of Carinhanha, and *Spelaeometra iuiú* sp. nov. from the municipality of Iuiú. The new species are primarily distinguished by diagnostic differences in the morphology of the male genitalia and, despite extensive sampling in surrounding caves, are currently known only from their respective type localities. Moreover the taxonomic descriptions, we provide new information on ecology, habitat characteristics, and potential threats affecting both species. Additionally, we present new remarks on *Spelaeometra gruta* Polhemus & Ferreira, 2018, and on the elusive, rarely collected species *Cephalometra pallida* D. Polhemus & Ferreira, 2018, providing new information on their natural history.

Keywords. Troglobitic, cave, new species, semiaquatic, adaptation.

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Introduction

Caves are distinctive ecosystems characterized by long-term environmental stability, consistently high humidity, limited thermal variation, and permanent darkness. Together, these conditions impose strong selective pressures on subterranean organisms, shaping their ecology and evolution (Barr 1968; Culver

& Pipan 2019). Such pressures promote population isolation, lineage diversification and the emergence of highly specialized taxa, making caves natural laboratories for the study of evolutionary processes in extreme but stable environments (Barr & Holsinger 1985; Soares & Niemiller 2020; Santos *et al.* 2023). To classify cave-dwelling fauna, multiple classification frameworks have been proposed based on morphological, behavioral, physiological and ecological criteria (Christiansen 1962; Howarth 1983; Sket 2008; Culver & Pipan 2014; Howarth & Moldovan 2018). Within these frameworks, troglobites are defined as species strictly restricted to subterranean habitats and unable to maintain epigeal populations, often exhibiting morphological specializations that reflect their obligate association with cave environments (Sket 2008).

Within the order Heteroptera, the family Hydrometridae is predominantly composed of epigeal species associated with freshwater margins and riparian habitats (Grazia *et al.* 2024). In Brazil, 19 species have been recorded, nine of which are endemic (Jardim Botânico do Rio de Janeiro 2025). Troglobitic representatives of Hydrometridae are exceptionally rare, with only three species described to date, all assigned to the genera *Spelaeometra* D. Polhemus & Ferreira, 2018 and *Cephalometra* D. Polhemus & Ferreira, 2018. *Cephalometra* is currently known from a single species described from a cave in the state of Tocantins, whereas *Spelaeometra* previously comprised two species recorded from caves in Minas Gerais and Bahia, *S. gruta* D. Polhemus & Ferreira 2018, and *S. hypogea* Cordeiro *et al.* 2023 respectively.

In this study, we describe two new troglobitic species of *Spelaeometra* from caves in Bahia based on detailed morphological evidence. In addition, we provide ecological data, habitat characterization, and assessments of potential threats. We also provide additional notes on *Spelaeometra gruta*, along with new observations on the poorly known *Cephalometra pallida* Polhemus & Ferreira, 2018.

Material and methods

Study area

The species described in this study were collected in the Serra do Ramalho and Serra de Iuiú karst regions, located in southwestern Bahia State, Brazil (Fig. 1). Both areas are part of the São Francisco Carbonate Supergroup, particularly the Bambuí Group (Auler *et al.* 2001), and are characterized by extensive limestone outcrops and highly developed subterranean systems.

The Serra do Ramalho karst covers approximately 12 000 km² between the Carinhanha and Corrente Rivers, major tributaries of the São Francisco River. The Sete Lagoas and Lagoa do Jacaré formations, composed primarily of calcilutites, calcarenites, calcirudites, and dolomites, dominate the landscape (Ferreira *et al.* 2023). The Serra de Iuiú region, situated within Brazil's Caatinga domain, lies in a semi-arid biome interspersed with ecotonal zones transitioning into Cerrado savanna, resulting in a mosaic of dry forest and savanna vegetation (Cole 1960).

The climate of both karst regions is tropical savanna (Aw) (Köppen classification), characterized by a marked dry season from March to October, with an annual rainfall average of ~640 mm, and mean temperatures of around 26°C (Alvares *et al.* 2013). Specific habitat characteristics and ecological associations of each species are presented in the corresponding “Habitat and threats” section below.

Collection, preservation and permanent storage

Sampling in the caves followed a Directed Intuitive Search (DIS) protocol (Wynne *et al.* 2019). Specimens were located primarily in humid microhabitats and in proximity to flooded areas at the type localities. Individuals were collected manually, one at a time, using brushes moistened with ethanol, and immediately preserved in vials containing 70% ethanol.

Holotypes and paratypes were deposited in the Invertebrados Subterrâneos de Lavras (ISLA) collection at the Centro de Estudos em Biologia Subterrânea (CEBS), from Departamento de Ecologia e Conservação (DEC), Universidade Federal de Lavras (UFLA), Brazil. The selection of specimens designated as holotypes and paratypes, as well as the choice of individuals for dissection or preservation, was based on their state of preservation and the availability of suitable type material.

Male genitalia preparation and examination

For specimen preparation, when available, a male paratype was selected for dissection of the male genitalia. The genital capsule was removed using entomological pins and subsequently immersed in a pancreatin solution for seven days at room temperature to dissolve soft tissues. For photographic documentation, the cleared capsule was transferred to a dish containing alcohol gel overlaid with a thin layer of 70% ethanol, which helped minimize surface reflections during imaging.

Morphological examination techniques and visualization

Measurements and examinations of external morphology were conducted on the holotype and paratypes while they were immersed in alcohol-based gel submerged in 70% ethanol, without additional manipulation. All measurements provided for the specimens in this study are given in millimeters.

Morphological analyses were conducted using a Zeiss Stemi 2000 stereo microscope. Measurements and digital images of diagnostic characters were obtained with a Zeiss Axio Zoom.V16 microscope coupled with ZEN 2.3 software. When paratypes were available, selected structures of taxonomic relevance were

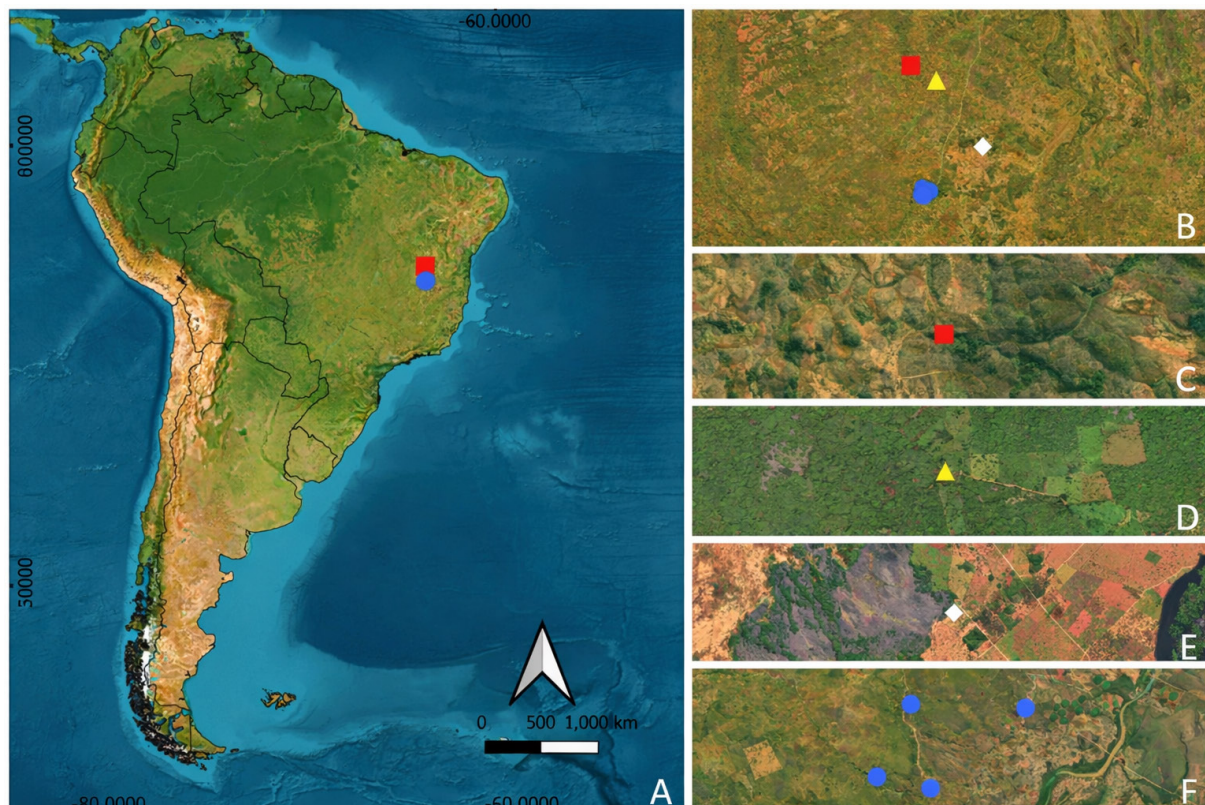


Fig. 1. Distribution map A–B. Species of the genus *Spelaeometra* Polhemus & Ferreira, 2018. C. *Spelaeometra hypogaea* Cordeiro & Moreira, 2023 (Red square) D. *Spelaeometra ybykoara* sp. nov. (yellow triangle) E. *Spelaeometra iuiu* sp. nov. (white diamond) F. *Spelaeometra gruta* Polhemus & Ferreira, 2018 (blue dots).

examined and documented using a Hitachi TM4000 scanning electron microscope (SEM). Image post-processing was carried out in Adobe Photoshop CS6, and illustrations were prepared using Inkscape (<https://inkscape.org>). Color descriptions follow the standard sRGB nomenclature of the ISCC-NBS color system (Centore 2016).

Maps

Distribution maps for species of the genus *Spelaeometra* Polhemus & Ferreira, 2018 (Fig. 1), were prepared using QGIS version 3.44 (<https://qgis.org/download/>).

Results

Key to species of *Spelaeometra* D. Polhemus & Ferreira, 2018

1. Body length approximately 2.56 mm (median); eyes with 16 ommatidia; antennae not exceeding body length; paramere with a long ventroapical process, hook-shaped, extending to about half the length of the distal arm *Spelaeometra ybykoara* Serafim & Ferreira sp. nov.
 - Eyes with fewer than 16 ommatidia; antennae usually exceeding body length; paramere with ventroapical process short or not strongly elongate 2
2. Body length approx. 2.85 mm; eyes with about 7 ommatidia; antennal segments I and II subequal in length; gular lobe reduced, not covering any labial segment; paramere with a narrower hook-like apex *Spelaeometra hypogea* Cordeiro & Moreira, 2018
 - Eyes with 8–12 ommatidia; antennal segments variable; gular lobe covering labial segment I or not evident; paramere with subtriangular apex or short hook 3
3. Body length approx. 2.39 mm; eyes with 10–12 ommatidia; paramere with short ventroapical process, hook-shaped; ventrolateral margin strongly angled
 - *Spelaeometra iuiu* Serafim & Ferreira sp. nov.
 - Body length approx. 2.50 mm; eyes with about 8 ommatidia; gular lobe covering labial segment I; paramere with subtriangular apex, not forming an elongate hook; dorsal margin of distal arm straight *Spelaeometra gruta* D. Polhemus & Ferreira, 2018

Taxonomy

Class Insecta Linnaeus, 1758
Order Hemiptera Linnaeus, 1758
Suborder Heteroptera Latreille, 1810
Family Hydrometridae Billberg, 1820
Subfamily Hydrometrinae Billberg, 1820
Genus *Spelaeometra* D. Polhemus & Ferreira, 2018

Spelaeometra ybykoara Serafim & Ferreira sp. nov.

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Figs 1D, 2–7, 15C

Diagnosis

Spelaeometra ybykoara sp. nov. can be distinguished from all other species of the genus by the following combination of characters: antennae not exceeding body length, compound eyes with 16 ommatidia; and parameres tripartite, with well-developed subtriangular apical process ventrad, almost reaching the middle of the distal arm.

Etymology

The specific epithet is a noun in apposition derived from the Tupi word *yby-koara*, meaning “cave inhabitant.” This term originates from the Tupi language, spoken by indigenous peoples of Brazil, and is used here to honor the region’s cultural heritage and its deep connection to the land. As a noun in apposition, the epithet is indeclinable and does not change to agree in gender with the genus name.

Type material

Holotype

BRAZIL • ♂; Bahia state, Carinhanha municipality, Lapa dos Peixes I cave; 13°50'16.750" S, 43°58'29.060" W; 4 Jun. 2024; Ferreira R.L. leg.; preserved; ISLA 126339.

Paratypes

BRAZIL • 1 ♂; same collection data as for holotype; dissected; ISLA 126340 • 2 ♀♀; same collection data as for holotype; ISLA 126342–43 • 2 juvs; same collection data as for holotype; ISLA 126345 • 1 ♂, 2 ♀♀; same collection data as for holotype; 17 Jul. 2024; ISLA 126346–48 • 2 ♀♀; same collection data as for holotype; 7 May 2023; ISLA 126349–50.

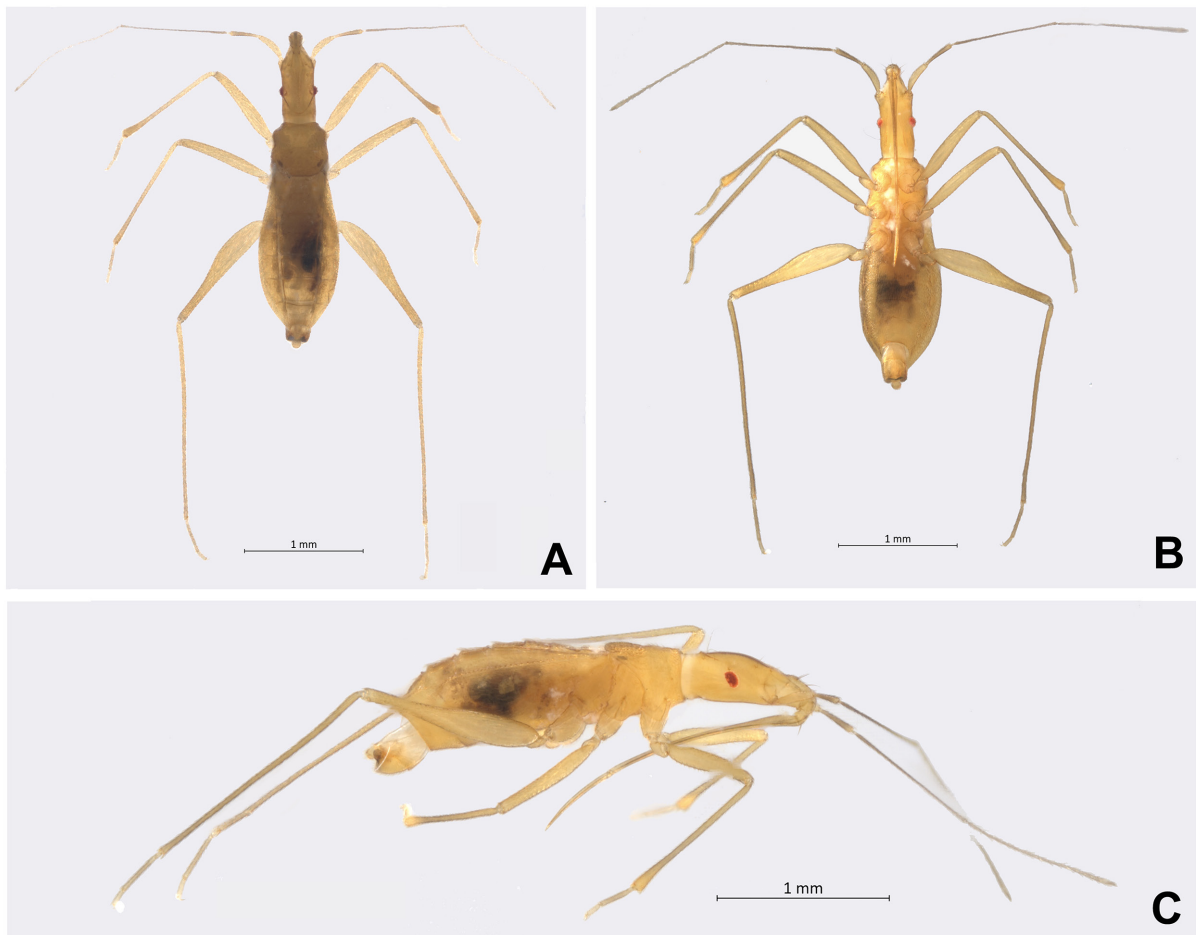


Fig. 2. *Spelaeometra ybykoara* Serafim & Ferreira sp. nov., paratype, ♂ (ISLA 126340), habitus. A. Dorsal view. B. Ventral view. C. Lateral view.

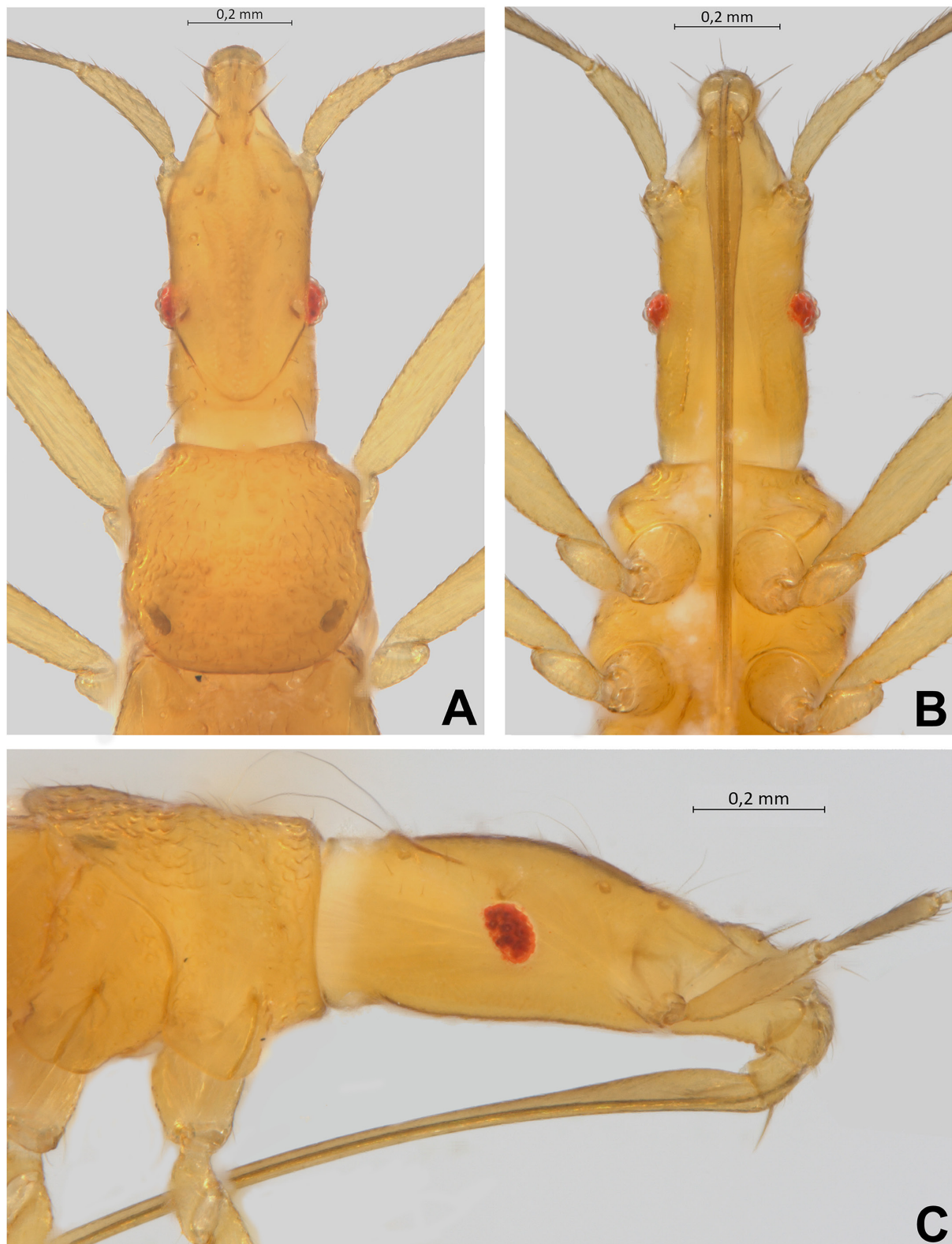


Fig. 3. *Spelaeometra ybykoara* Serafim & Ferreira sp. nov., paratype, ♂ (ISLA 126340), head and thorax. A. Dorsal view. B. Ventral view. C. Lateral view.

Description

Male apterous

BODY LENGTH. 2.48–2.60 mm ($n = 3$; including one small, one medium, and one large specimen), maximum width (at abdomen) 1.19–1.26 mm ($n = 3$).

Structural characters holotype

HEAD. Length 0.77, width 0.26; length interocular 0.25, transocular 0.33, ocular width 0.06, ocular length 0.09; eyes with 16 ommatidia present. Antennal segments I–IV = 0.27, 0.24, 0.93, 1.09. Rostrum length 1.67, lip segment length I–IV = 0.10, 0.06, 1.11, 0.40, respectively.

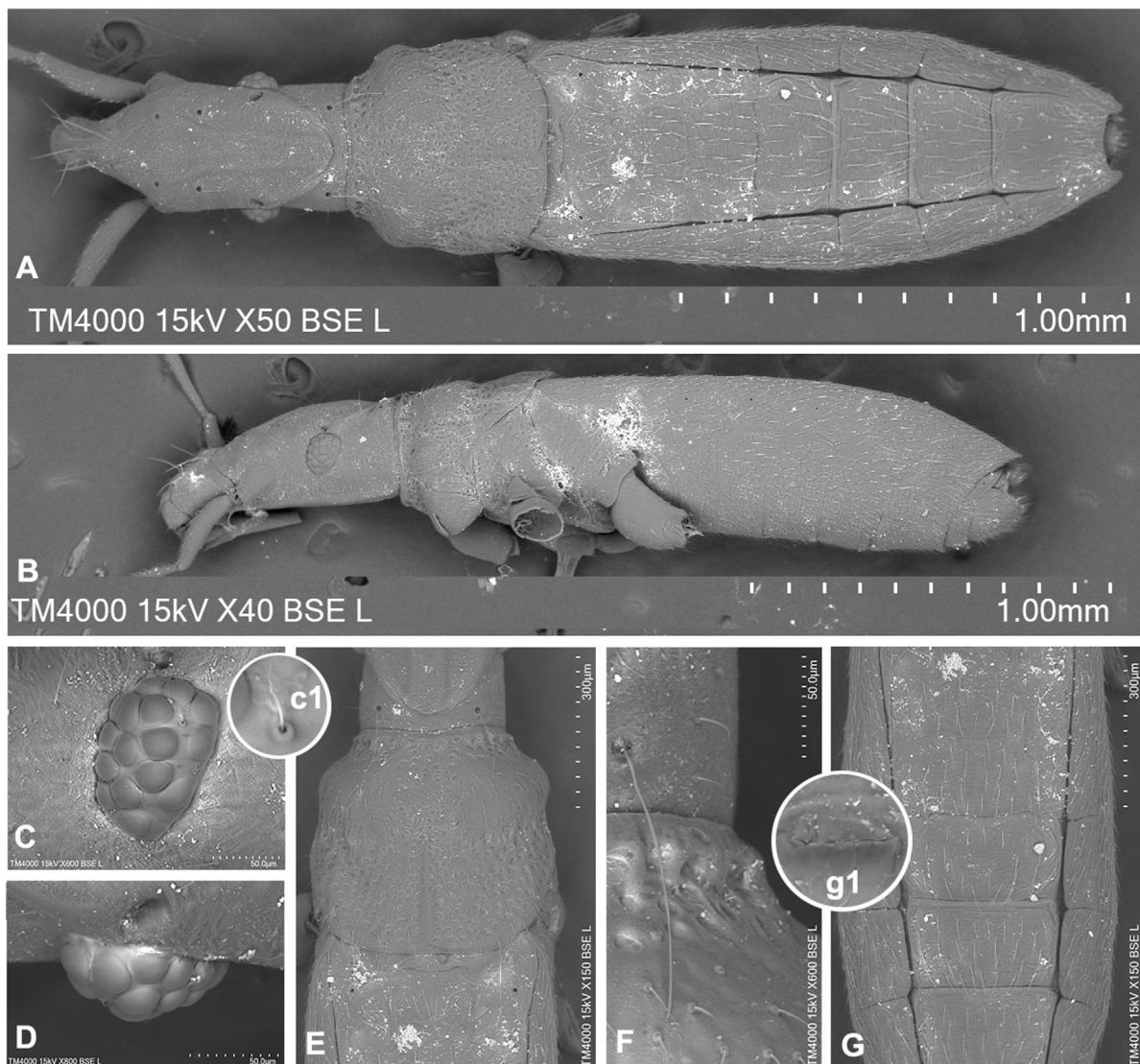


Fig. 4. *Spelaeometra ybykoara* Serafim & Ferreira sp. nov., paratype, ♂ (ISLA 126346), electron microscopy plate. **A.** Body, dorsal view. **B.** Body, lateral view. **C.** Ocellus, dorsal view; c1 = ocular bristle. **D.** Ocellus, lateral view. **E.** Thorax, dorsal view. **F.** Bristle. **G.** Abdomen, dorsal view; g1 = odoriferous orifice located in the IV mediotergite abdominis.

THORAX. Length 0.43, width 0.47, with only the pronotum visible, covering the mesonotum and metanotum.

LEGS. Segment lengths: anterior femur, tibia, tarsus I, tarsus II, tarsus III = 0.74, 0.88, 0.04, 0.16, 0.11; middle femur, tibia, tarsus I, tarsus II, tarsus III = 0.83, 1.04, 0.03, 0.19, 0.10; posterior femur, tibia, tarsus I, tarsus II, tarsus III = 1.12, 1.67, 0.03, 0.3, 0.12.

ABDOMEN. Length 1.23, maximum width 0.68, minimum width 0.48. Length of abdominal tergites I–VII = 0.14, 0.17, 0.15, 0.19, 0.18, 0.19, 0.19; maximum width of abdominal tergites I–VII = 0.41, 0.37, 0.32, 0.31, 0.29, 0.27, 0.22. (Table 1).

General description (paratype, ♂, ISLA 126340)

COLORATION (preserved specimen) (Figs 2A–C, 3A–C). head and thorax, brilliant orange-yellow (67, sRGB Centroids for ISCC-NBS Level 3 Categories), basally on the thorax and apically on the abdomen, strong orange-brownish (68). Appendage insertions light yellow (86), bringing dark to moderate yellow (87) along their length. Abdomen and male genitalia strong yellowish-brown (74).

HEAD. In dorsal view (Fig. 3A), lateral margin slightly concave, carinae behind the eyes totally elevated. In lateral view (Fig. 3C), dorsal margin convex, ventral margin sinuous with two small convexities and two small concavities. In ventral view (Fig. 3B), longitudinal carinae weakly elevated. Rostrum (Fig. 2B), long and slender, surpassing the third abdominal segment. Cephalic trichobothria (Figs 3A, C, 4F) present, as described for the genus. Compound eyes (Fig. 4C–D) reduced, bearing 16 ommatidia with ocular setae present; ocelli absent. Antennae (Fig. 2A–C), not exceeding body length; antennal segments as described for the genus.

THORAX. In dorsal view (Fig. 3A) with pronotum slightly bilobed laterally, almost linear distally. Wings (Fig. 3A) completely absent, with interior wing buds visible. In lateral view (Fig. 3C), thoracic pleurae as described for the genus. In ventral view (Fig. 3B), sternum bearing paired, sinuous, slightly raised longitudinal carinae.

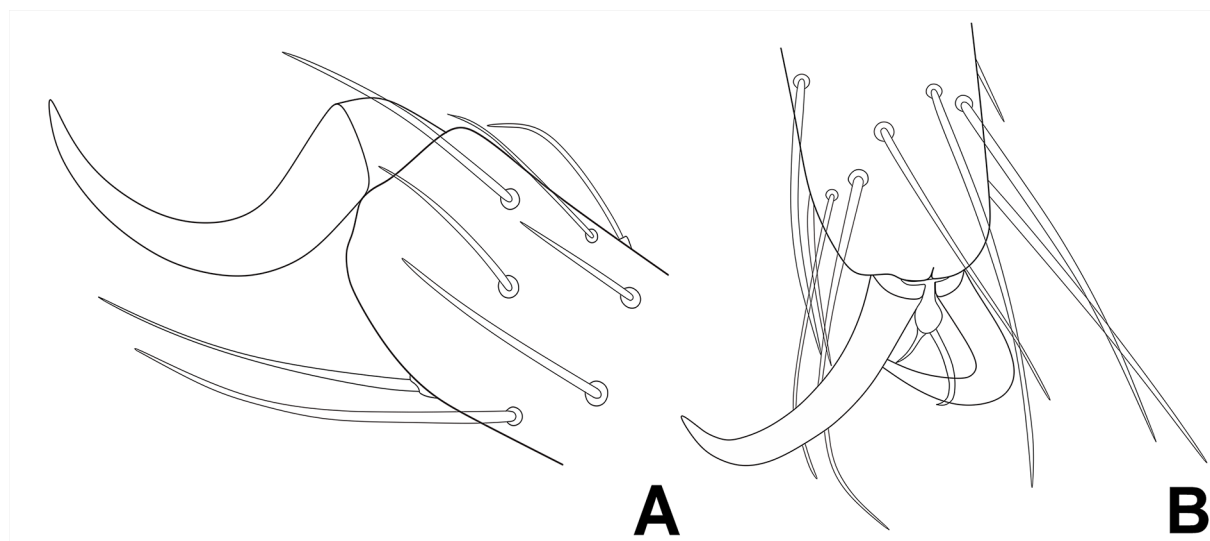


Fig. 5. *Spelaometra ybykoara* Serafim & Ferreira sp. nov., paratype, ♂ (ISLA 126340), drawings of the claws of the middle and hind legs. **A.** Claw of the middle leg. **B.** Claw of the posterior leg.

Table 1 (continued on next page). Overview of measurements of *Spelaeometra* species presented for the holotype. N-dash (-) indicate missing data.

Male lengths	<i>S. gruta</i>	<i>S. hypogea</i>	<i>S. ybykoara</i>	<i>S. iuiu</i>
Body length	2.5	2.85	2.68	2.39
Head length	0.75	0.85	0.77	0.69
Maximum width (across eyes)	0.35	0.31	0.33	0.29
Anteocular width	-	0.3	0.26	0.24
Interocular width	0.25	0.28	0.25	0.21
Clypeal length	-	0.18	0.16	0.13
Basal clypeal width	-	0.06	0.05	0.05
Maximum clypeal width	-	0.1	0.08	0.07
Ocular length	-	0.06	0.09	0.06
Ocular width	0.05	0.01	0.06	0.04
Length of antennal segment I	0.3	0.35	0.27	0.24
Length of antennal segment II	0.2	0.34	0.24	0.24
Length of antennal segment III	0.95	1.24	0.93	0.74
Length of antennal segment IV	1.2	1.6	1.09	1.3
Comprimento do rostro	1.7	-	1.79	1.54
Length labial segment I	-	0.12	0.1	0.1
Length labial segment II	-	0.08	0.06	0.05
Length labial segments III	1.05	1.54	1.11	1.07
Length labial segments IV	0.45	0.5	0.4	0.32
Thorax length	0.5	-	0.44	0.4
Maximum thorax width	0.4	-	0.47	0.47
Anterior femur	0.8	1	0.74	0.67
Tibia length	1	1.3	0.88	0.91
Tarsus I	0.05	0.04	0.04	0.02
Tarsus II	0.2	0.28	0.16	0.18
Tarsus III	0.1	0.12	0.11	0.09
Middle femur	0.95	1.2	0.83	0.85
Tibia length	1.1	1.44	1.04	1.03
Tarsus I	0.05	0.04	0.03	0.03
Tarsus II	0.2	0.28	0.19	0.18
Tarsus III	0.15	0.12	0.1	0.09
Posterior femur	1.2	-	1.12	1.04
Tibia length	1.75	-	1.67	1.54
Tarsus I	0.05	-	0.03	0.04
Tarsus II	0.35	-	0.3	0.28
Tarsus III	0.18	-	0.12	0.11
Abdominal length	1.5	1.6	1.24	1.19
Minimum abdominal width	-	0.28	0.48	0.48

Table 1 (continued). Overview of measurements of *Spelaeometra* species presented for the holotype. N-dash (-) indicate missing data.

Male lengths	<i>S. gruta</i>	<i>S. hypogea</i>	<i>S. ybykoara</i>	<i>S. iuiu</i>
Maximum abdominal width	0.75	0.44	0.68	0.55
Length of abdominal mediotergite I	0.15	0.2	0.14	0.17
Length of abdominal mediotergite II	0.15	0.2	0.17	0.11
Length of abdominal mediotergite III	0.15	0.2	0.15	0.17
Length of abdominal mediotergite IV	0.18	0.2	0.19	0.18
Length of abdominal mediotergite V	0.2	0.22	0.18	0.16
Length of abdominal mediotergite VI	0.2	0.24	0.19	0.19
Length of abdominal mediotergite VII	0.2	0.26	0.19	0.18
Maximum width of abdominal mediotergite I	-	0.36	0.41	0.35
Maximum width of abdominal mediotergite II	-	0.32	0.37	0.33
Maximum width of abdominal mediotergite III	-	0.3	0.32	0.31
Maximum width of abdominal mediotergite IV	-	0.3	0.31	0.28
Maximum width of abdominal mediotergite V	-	0.26	0.29	0.25
Maximum width of abdominal mediotergite VI	-	0.24	0.27	0.21
Maximum width of abdominal mediotergite VII	-	0.2	0.22	0.17

ABDOMEN. In dorsal view, mediotergites almost equal in length (Fig. 4A, G). Scent orifice on mediotergite IV obscure (Fig. 4, g1). In ventral view, some regions brownish.

LEGS (Fig. 2A–C). Anterior and posterior legs with few distinct setae. Femur slender proximally. Tibiae long and robust (Fig. 2A–C). Tarsi as in other species of the genus, except for tarsus II: long on the anterior and middle legs, short on the hind leg. Middle leg with one claw on tarsus III (Fig. 5A), fore and hind legs with two claws on the apex of tarsus III (Fig. 5B).

MALE GENITALIA (Fig. 6A–F). Parameres, bilaterally symmetrical, relatively large and broad, tripartite, with a short basal stem, distal arm with concave dorsal margin, convex ventral margin, with well-developed subtriangular apical process ventrad, almost reaching the middle of the distal arm.

Female apterous

BODY LENGTH. 2.53–2.68 ($n = 3$; including one small, one medium, and one large specimen), maximum width (at abdomen) 1.30–1.32 ($n = 3$). Structural characters as in males, elongated.

Habitat and threats

Spelaeometra ybykoara sp. nov. is currently known only from a single locality within the Água Clara Cave System (ACCS), a complex linear network of four major subterranean conduits formed in calcarenitic strata of the Sete Lagoas Formation, which forms striking carbonate outcrops in the region. From upstream to downstream, these caves include Gruna da Água Clara (13 880 m), Gruna dos Índios (510 m), Lapa dos Peixes I (9320 m; Figs 6A–C, 13A, E), and Lapa dos Peixes II (2100 m). The species was recorded exclusively in Lapa dos Peixes I, a cave characterized by a pronounced seasonal microclimatic gradient created by airflow between entrances located at opposite ends of the conduit. While much of the main gallery becomes markedly dry during the austral winter, the section where

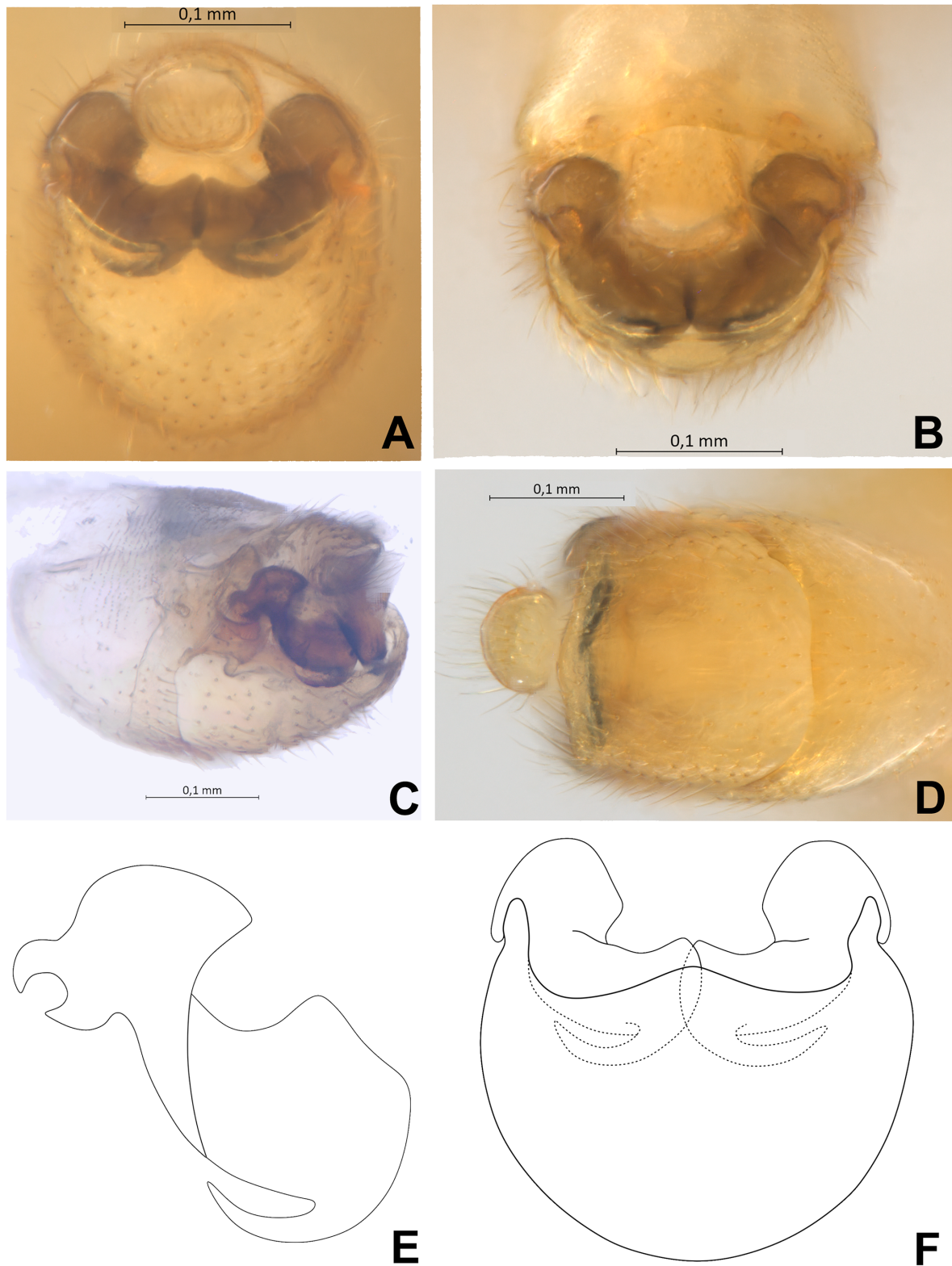


Fig. 6. *Spelaeometra ybykoara* Serafim & Ferreira sp. nov., paratype, ♂ (ISLA 126340), male terminalia. **A.** Ventrocaudal view. **B.** Dorsocaudal view. **C.** Laterocaudal view. **D.** Ventral view. **E.** Drawing of the left paramere in left lateral view. **F.** Drawing of the male terminalia in ventrocaudal view.

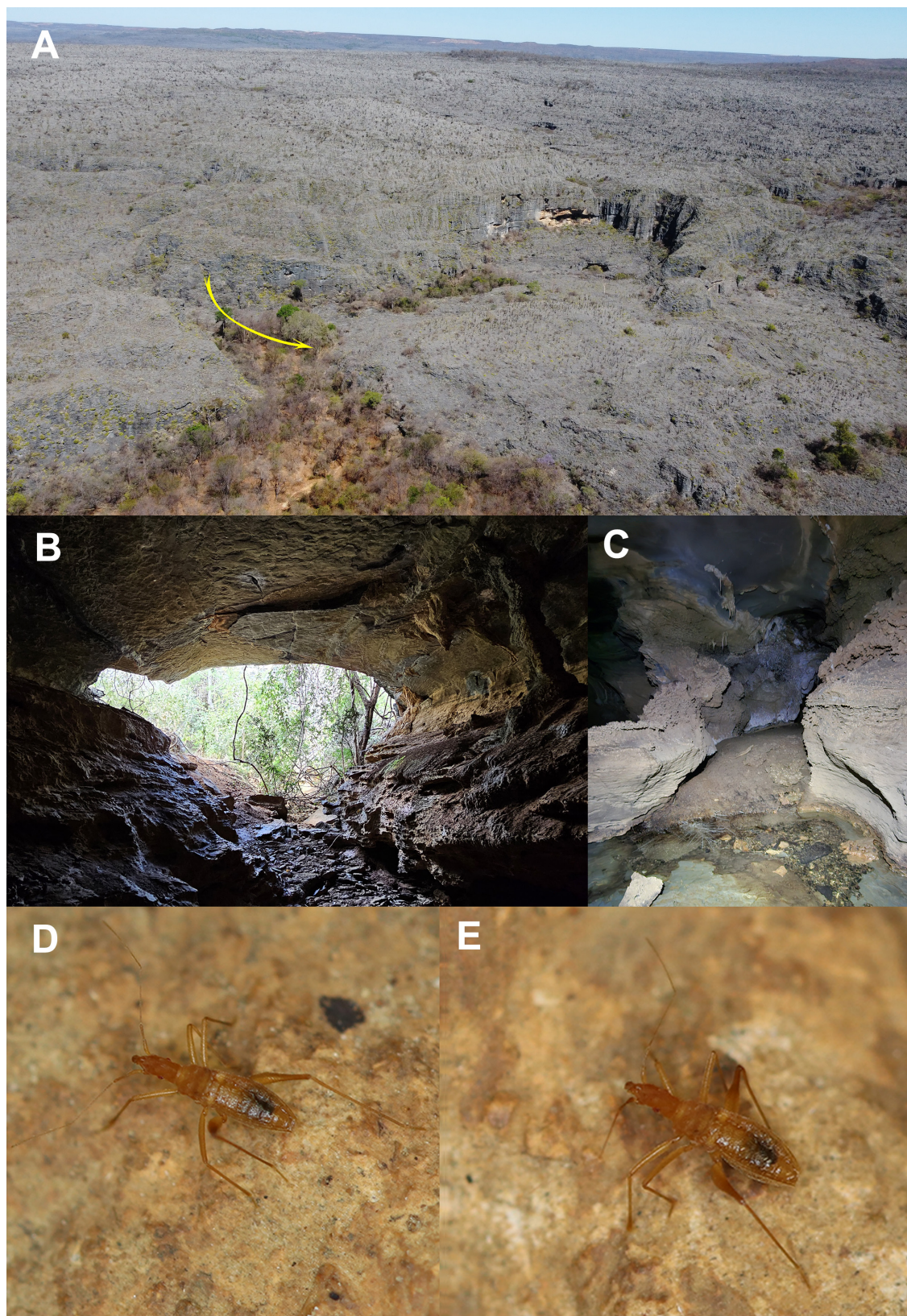


Fig. 7. **A.** Entrance to Lapa dos Peixes I. **B.** Lapa dos Peixes I, entrance seen from the inside out. **C.** Habitat of *Spelaeometra ybykoara* Serafim & Ferreira sp. nov. **D–E.** *S. ybykoara* in dorsal view.

specimens were collected retains consistently high humidity throughout the year due to the presence of a perennial water body.

This microhabitat, notable for its environmental stability, hosts the highest richness of troglitic species in the ACCS (Souza-Silva & Ferreira 2016; Ferreira & Souza-Silva 2023). Despite extensive biological inventories across all caves of the system, *Spelaeometra ybykoara* sp. nov. (Fig. 7D–E) has not been found outside this discrete habitat, strongly suggesting a highly restricted distribution and microendemism. The species' apparent confinement to a single, permanently humid conduit section underscores its potential vulnerability to environmental fluctuations and anthropogenic disturbance.

The broader ACCS is subject to severe external pressures, particularly from agricultural expansion and wood harvesting for charcoal production in the surrounding region (Fig. 7B; Ferreira *et al.* 2023; Ferreira & Souza-Silva 2023). Extensive deforestation near cave entrances (Fig. 8A–B) has reduced organic



Fig. 8. **A.** Deforestation near cave entrance to Lapa dos Peixes I. **B.** Extraction of wood for charcoal production in the surrounding region.

input, simplified habitat structure, and increased soil erosion. These changes accelerate the transport of fine sediments into the cave system, leading to substrate homogenization and the degradation of aquatic and terrestrial microhabitats, processes that disproportionately threaten highly specialized hypogean fauna (Pellegrini *et al.* 2016; Cardoso *et al.* 2022).

Given the exceptional biodiversity of the ACCS, including numerous troglobitic taxa, and the apparent micro-endemism of *S. ybykoara* sp. nov., conservation measures are urgently required. We recommend the establishment of a legally protected conservation unit that encompasses not only the subterranean system but also its contributing catchment microbasins and the surrounding karst landscape. Such a designation, supported by strict environmental regulations, would be essential to safeguard the ecological integrity of this unique subterranean ecosystem and ensure the long-term survival of its highly specialized fauna.

***Spelaeometra iuiu* Serafim & Ferreira sp. nov.**

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Figs 9–12, 15D

Diagnosis

Spelaeometra iuiu sp. nov. can be distinguished from all other species of the genus by the following combination of characters: compound eyes bearing 10–12 ommatidia; paramere tripartite, large and wide, with a strongly angled ventrolateral margin, and with a short ventroapical hook, not exceeding $\frac{1}{3}$ of the length of the anterior region.

Etymology

The specific epithet *iuiu* is a noun in apposition, referring to the municipality of Iuiú, Bahia State, Brazil, where the species was collected. As a noun in apposition, the epithet is indeclinable and does not change to agree in gender with the genus name.

Type material

Holotype

BRAZIL • ♂; Bahia State, Iuiú municipality, Toca Fria cave; 14°32'52.861" S, 43°32'8.992" W; 12 Sep. 2023; Ferreira R.L. leg.; preserved; ISLA 125922.

Description

Male apterous

BODY LENGTH. (n = 1) 2.39, maximum width (at abdomen) 1.19 mm.

Structural characters

HEAD. Length 0.69, width 0.24; length interocular 0.21, transocular 0.29, ocular width 0.04, ocular length 0.06; eyes with 10–12 ommatidia present; Antennal segments I–IV = 0.24, 0.24, 0.74, 1.30. Rostrum length 1.54, lip segment length I–IV = 0.10, 0.05, 1.07, 0.32, respectively.

THORAX. Length 0.40, width 0.47, with only the pronotum visible, covering the mesonotum and metanotum.

LEGS. Segment lengths: anterior femur, tibia, tarsus I, tarsus II, tarsus III = 0.67, 0.91, 0.02, 0.18, 0.09; middle femur, tibia, tarsus I, tarsus II, tarsus III = 0.85, 1.03, 0.03, 0.18, 0.09; posterior femur, tibia, tarsus I, tarsus II, tarsus III = 1.04, 1.54, 0.04, 0.28, 0.11.

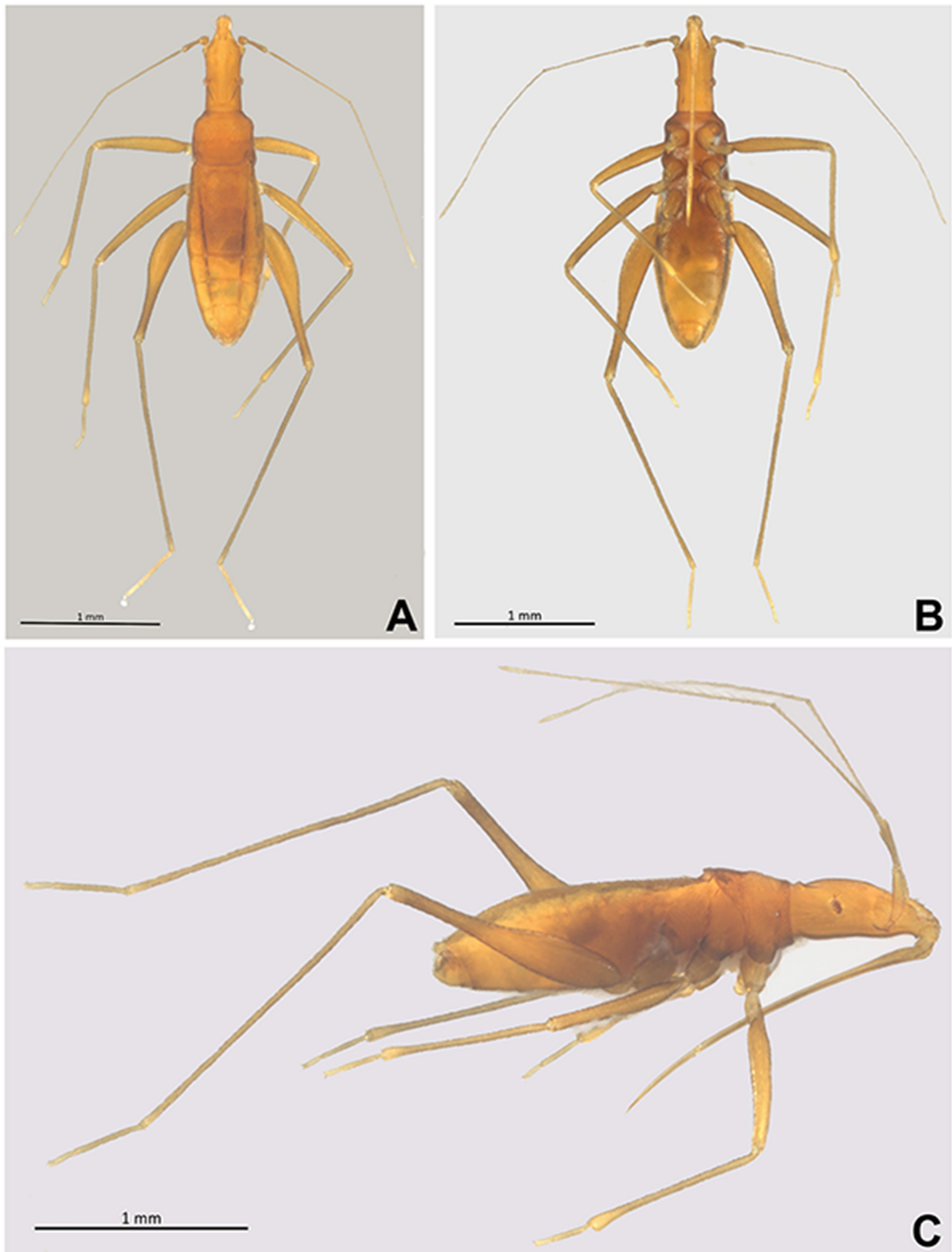


Fig. 9. *Spelaeometra iuiu* Serafim & Ferreira sp. nov., holotype, ♂ (ISLA 125922), habitus. **A.** Dorsal view. **B.** Ventral view. **C.** Lateral view.

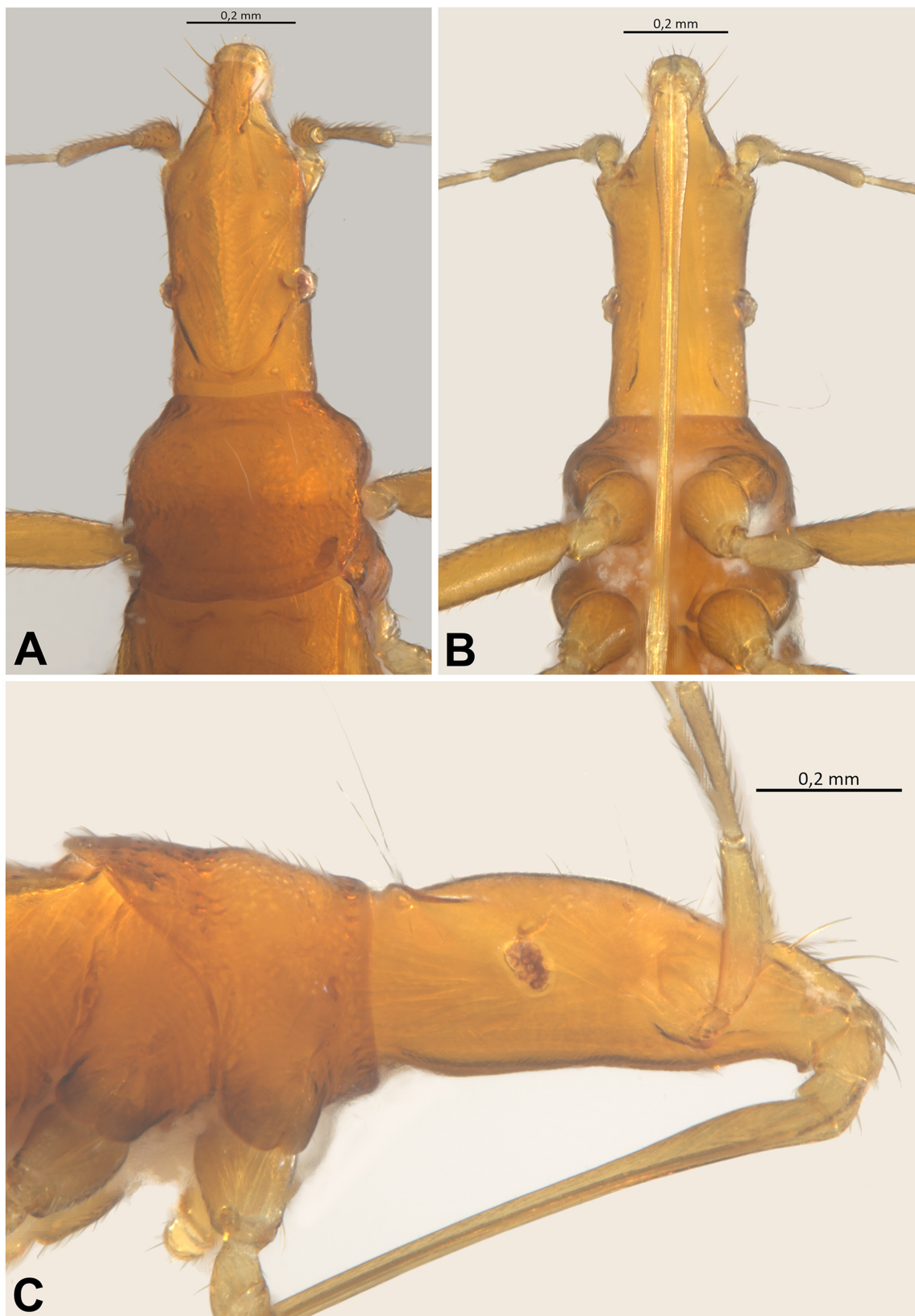


Fig. 10. *Spelaeometra iuiu* Serafim & Ferreira sp. nov., holotype, ♂ (ISLA 125922), head and thorax. A. Dorsal view. B. Ventral view. C. Lateral view.

ABDOMEN. Length 1.19, maximum width 0.55, minimum width 0.48. Length of abdominal tergites I–VII, respectively = 0.17, 0.11, 0.17, 0.18, 0.16, 0.19, 0.18; maximum width of abdominal tergites I–VII = 0.35, 0.33, 0.31, 0.28, 0.25, 0.21, 0.17. (Table 1)

General description

COLORATION (preserved specimen; Fig. 9A–C). head, thorax, and abdomen strong orange yellow (68, sRGB Centroids for ISCC-NBS Level 3 Categories), basally on the thorax and apically on the abdomen, deep orange yellow (69). Appendage insertions light orange yellow (70), changing to moderate orange yellow (71) along their length.

HEAD. In dorsal view (Fig. 10A), lateral margin slightly concave, carinae behind the eyes totally elevated. In lateral view (Fig. 10C), dorsal margin convex, ventral margin straight. In ventral view (Fig. 10B), longitudinal carinae weakly elevated. Rostrum (Figs 9B–C, 10B), long and slender, surpassing the third abdominal segment. Cephalic trichobothria (Fig. 10A, C) present, as described for the genus. Compound eyes (Fig. 10A–C) reduced, bearing 10–12 ommatidia without ocular setae; ocelli absent. Antennae (Fig. 9A–C), longer than body length; antennal segments as described for the genus, except segments I and II of equal size.

THORAX. In dorsal view (Fig. 10A), with pronotum slightly bilobed laterally, almost linear distally. Wings (Fig. 10A) completely absent, with interior wing buds visible. In lateral view (Fig. 10C), thoracic pleurae as described for the genus. In ventral view (Fig. 10B), with sternum bearing paired, sinuous, slightly raised longitudinal carinae.

ABDOMEN. In dorsal view, mediotergites almost equal in length (Fig. 9A). Scent orifice not visible on mediotergite IV.

LEGS (Fig. 9A–C). Anterior and posterior legs with few distinct setae. Femur slender proximally. Tibiae long and robust (Fig. 9A–C). Tarsi, like other species of the genus, with approximately the same size. Middle leg with one claw on tarsus III, fore and hind legs with two claws on the apex of tarsus III as in *Spelaeometra ybykoara* sp. nov.

MALE GENITALIA (Fig. 11A–F). Parameres bilaterally symmetrical, relatively large and long, tripartite, with a short basal stem; distal arm with dorsal margin slightly concave at the end of the joints; ventral margin slightly convex; subtriangular apical process developed ventrally, not reaching the middle of the distal arm.

Habitat and threats

Spelaeometra iuiu sp. nov. is currently known only from Toca Fria Cave, located in the municipality of Iuiú, southwestern Bahia State, Brazil (Fig. 12A–C). Although this is the only confirmed locality, the presence of several other caves in the same limestone outcrop suggests that additional populations may eventually be found in nearby systems. However, it is important to note that numerous caves in the main massif of the Serra de Iuiú karst have been surveyed, and no specimens were found in these systems, suggesting that this species may be restricted to the Serrinha outcrop.

The Serrinha outcrop (Fig. 12A), which hosts Toca Fria Cave, is a relatively small karst formation measuring approximately 2.4 km in length and 1.3 km in width. It lies about 4 km in a straight line from the main massif of the Serra de Iuiú. Toca Fria is a labyrinthine cave system extending roughly 2500 m, with multiple entrances concentrated along the outcrop margins. Permanent water bodies are absent from most of the cave; however, during the rainy season, several conduits become flooded, and moisture persists for several months following rainfall events. By the end of the dry season, the cave's substrates

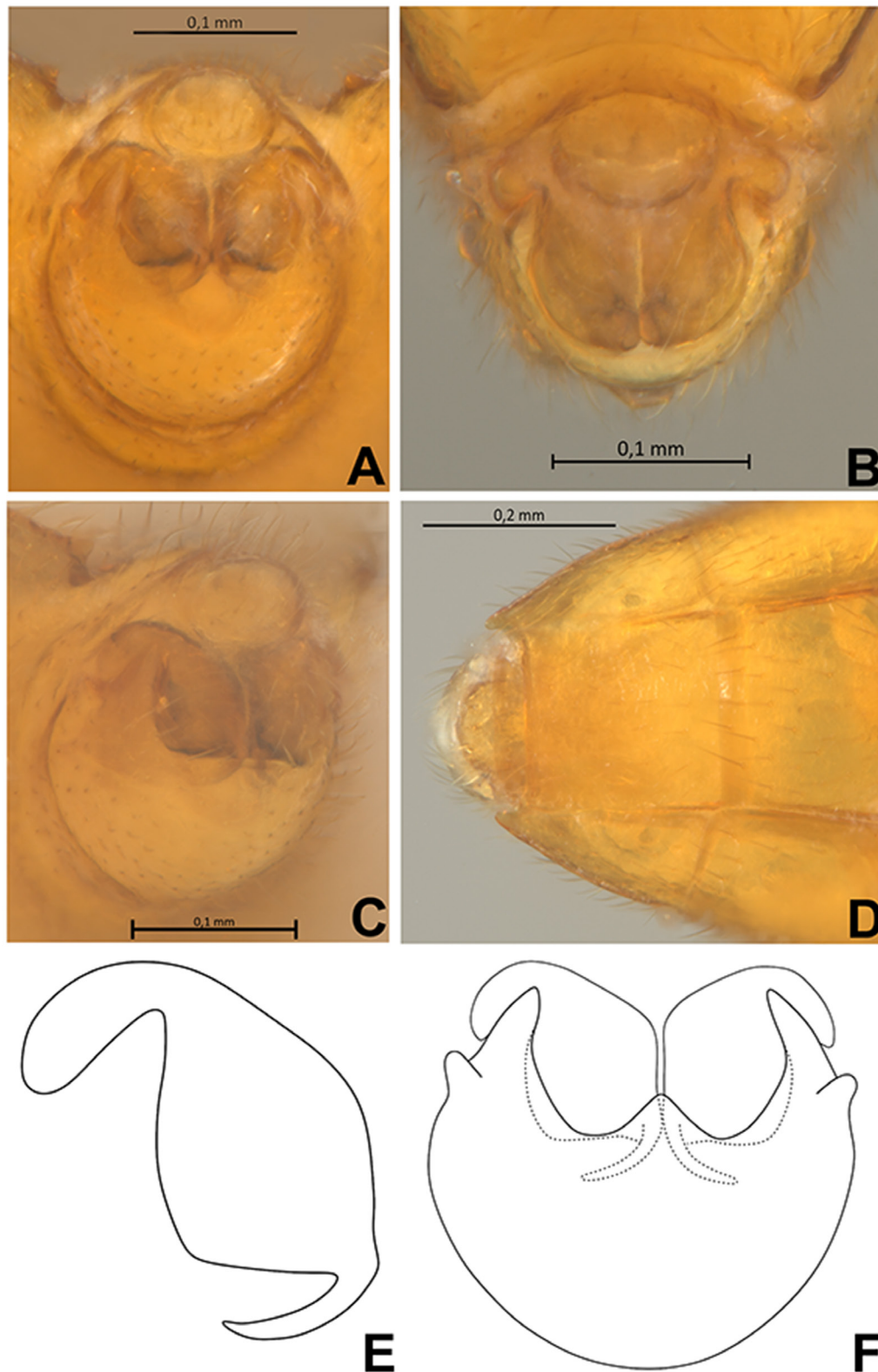


Fig. 11. *Spelaeometra iuiu* sp. nov., Serafim & Ferreira holotype, ♂ (ISLA 125922), male terminalia. **A.** Ventrocaudal view. **B.** Dorsocaudal view. **C.** Laterocaudal view. **D.** Dorsal view. **E.** Drawing of the left paramere in left lateral view. **F.** Drawing of the male terminalia in ventrocaudal view.

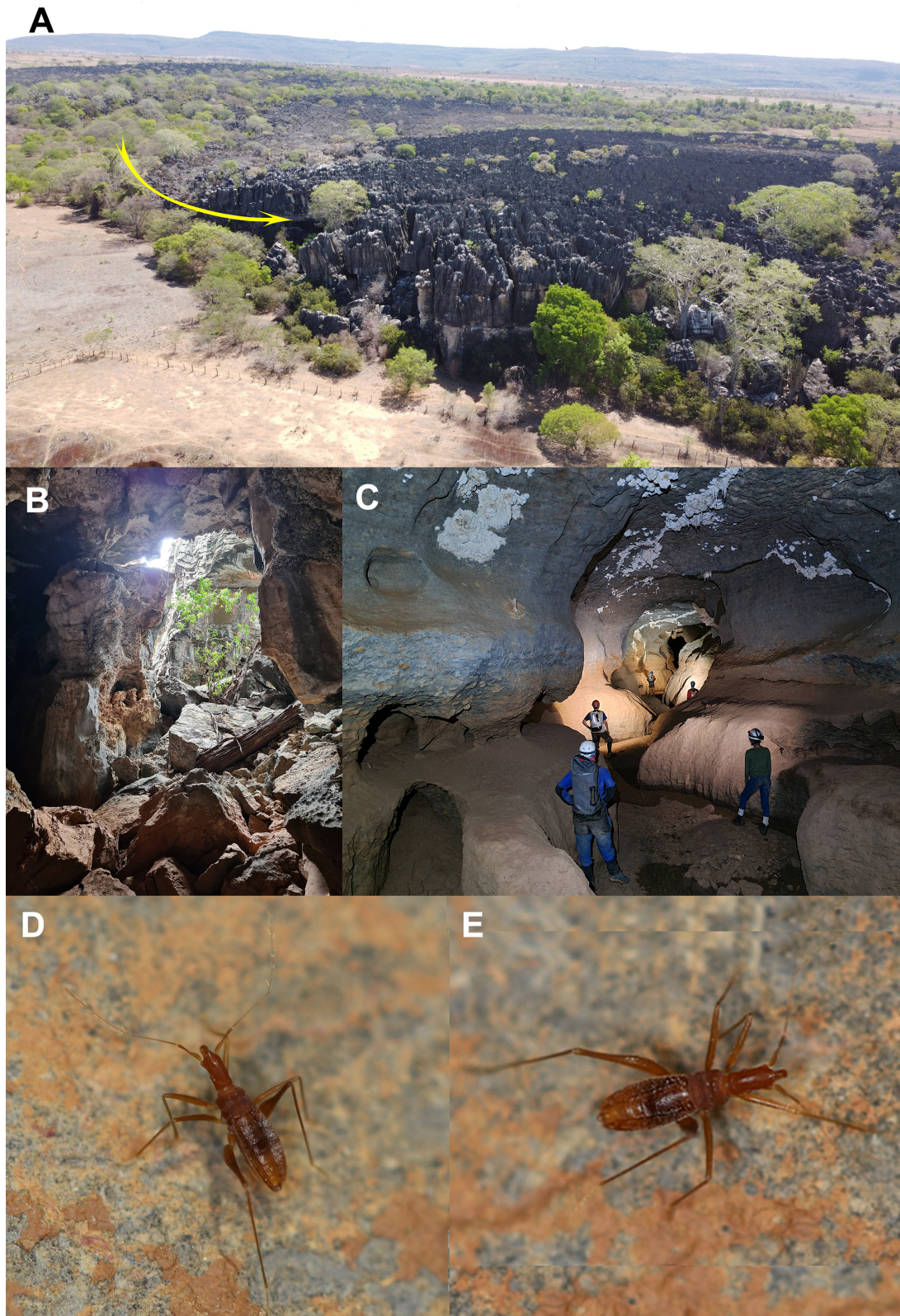


Fig. 12. A. Serrinha outcrop and entrance to Toca Fria. B. Toca Fria cave, entrance seen from the inside out. C. Inside of main conduit of Toca Fria cave. D–E. Specimens of *Spelaeometra iuiu* Serafim & Ferreira sp. nov., in dorsal view.

are predominantly desiccated (Fig. 12C), with residual moisture restricted to sheltered microhabitats beneath rocks in a few interior areas.

Spelaeometra iuiu sp. nov. (Fig. 12D–E) was found under a rock in this moist, secluded area, well beyond the reach of natural light near the entrances. Several conduits also contained partially moistened sediments resulting from surface runoff infiltrating through the entrances. The pronounced seasonal drying of the cave suggests that individuals may retreat to deeper, permanently humid zones inaccessible to humans during the dry season, reappearing in the macrocavern during wetter periods.

Although Toca Fria Cave is occasionally visited by residents, its irregular topography and narrow passages limit visitation primarily to the vicinity of the main entrance, leaving deeper sectors relatively undisturbed. In contrast, the external environment is heavily altered. Most of the native vegetation surrounding the outcrop has been replaced by pasture, except for areas along its upper portion, where patches of xerophytic vegetation persist. Extensive tracts of bare soil now encircle the outcrop (Fig. 12A), promoting soil erosion and sediment deposition within the cave during periods of intense rainfall. Such landscape alterations likely diminish organic matter input and disrupt critical subterranean microhabitats, posing a significant threat to the long-term survival of this species.

***Spelaeometra gruta* D. Polhemus & Ferreira, 2018**
Figs 1F, 13

Type material

Holotype

BRAZIL • ♂ apterous; Minas Gerais, Itacarambi, Lapa D'Água do Zezé; 25 Jan. 2015; Ferreira R.L. leg.; ISLA 10042.

Paratypes

BRAZIL • 2 ♂♂, 5 ♀♀; same data as for holotype; ISLA, BPBM • 2 ♀♀; Minas Gerais, Itacarambi, Cavernas do Peruaçu National Park, Gruta Caboclo; 13 Dec. 2014; Ferreira R.L. leg.; ISLA 10042; ISLA • 2 ♂♂, 2 ♀♀; Minas Gerais, Itacarambi, Gruta do Nestor; 25 Jan. 2015; Ferreira R.L. leg.; ISLA 10042; ISLA • 1 ♀; Minas Gerais, Montalvânia, Gruta do Fóssil; 14°21'37" S, 44°18'55" W; 13 Apr. 2016; Ferreira R.L. leg.; ISLA 15681; ISLA • 1 immature; same data as for preceding; ISLA 15680; ISLA • 4 ♂♂, 3 ♀♀, 1 immature; Minas Gerais, Montalvânia, Lapa Grande; 26 Nov. 2016; Ferreira *et al.* leg.; ISLA 46653; ISLA • 1 ♂; Minas Gerais, Montalvânia, Gruta do Fóssil; 28 Nov. 2016; Ferreira *et al.* leg.; ISLA 46654; ISLA.

Other material examined

BRAZIL • 2 ♂♂; Minas Gerais, Itacarambi Montalvânia, Gruta do Fóssil; 14°21'37" S, 44°18'55" W; 13 Apr. 2016; Ferreira R.L. leg.; ISLA 157015 • 1 ♂; ISLA 157016 (Fig. 13).

Remarks

Spelaeometra gruta D. Polhemus & Ferreira, 2018 (Fig. 13A–D) was the first species described within the genus *Spelaeometra* and represents the first hydrometrid lineage known to exhibit an exclusively cave-dwelling habit. Similar to its congeners, this species possesses an odoriferous orifice located on the fourth mediotergite of the abdomen (Fig. 13D, d1). *Spelaeometra gruta* is relatively widespread in limestone caves situated in the municipalities of Itacarambi, Montalvânia and Juvenília, in northern Minas Gerais State.

Genus *Cephalometra* D. Polhemus & Ferreira, 2018

Cephalometra pallida D. Polhemus & Ferreira, 2018

Fig. 14

Remarks

Cephalometra pallida is evidently a rare and elusive species. It is known exclusively from Natividade cave, and despite extensive sampling efforts in other caves throughout the region, it has never been recorded outside this locality (Fig. 14A–B). Moreover, the population appears to be restricted to a single chamber situated in the innermost portion of the cave, which is connected to the phreatic zone.

The holotype was collected on 15 May 2005, and subsequent surveys failed to detect additional adults for many years (Fig. 14D). Only a single immature specimen was found on 5 May 2013. No individuals were observed on 8 January 2016, and 24 February 2018, only immature specimens were recorded (Fig. 14C). Finally, on 9 June 2025 (after approximately 20 years), adult individuals were detected again.

Given the sporadic nature of these surveys, it is currently not possible to formulate any robust hypotheses regarding the species' life cycle. However, considering that the chamber in which the species is observed

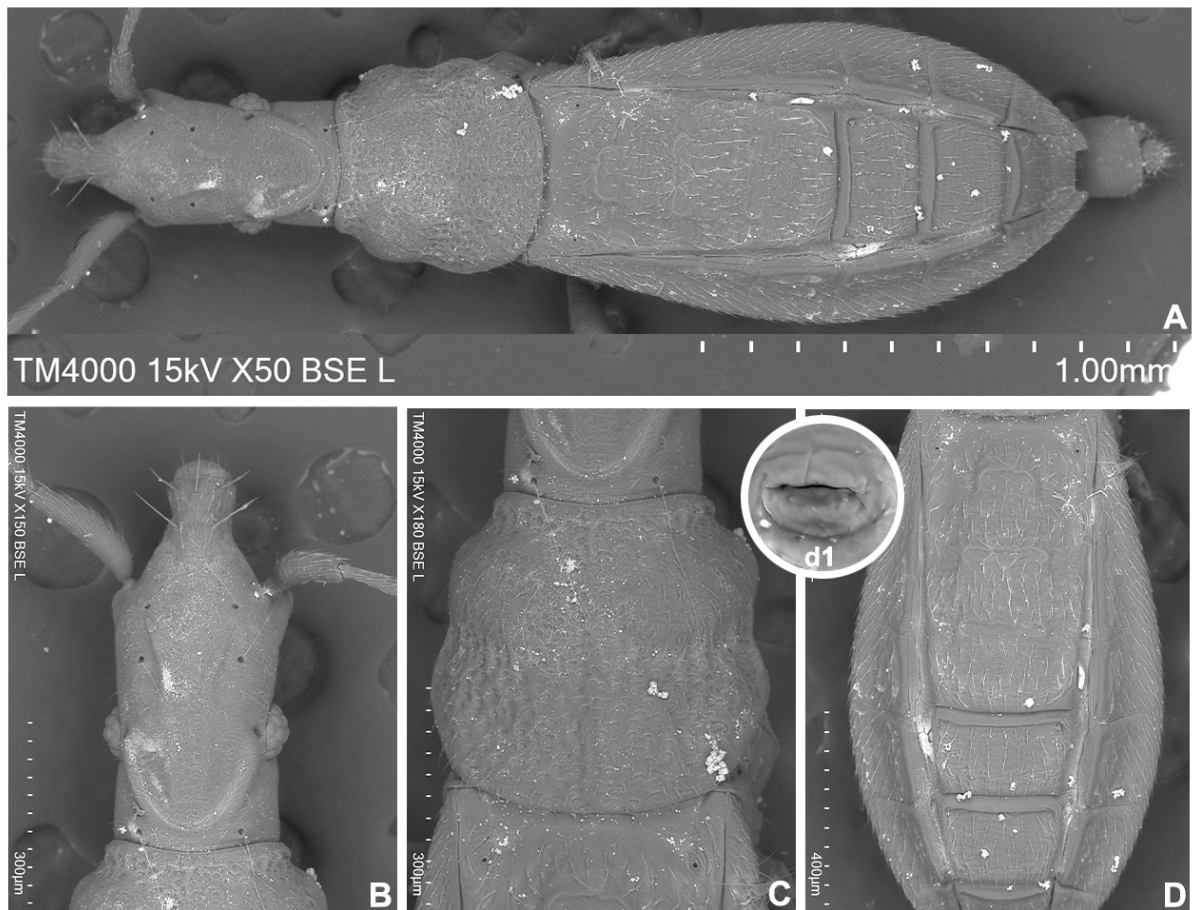


Fig. 13. *Spelaeometra gruta* Polhemus & Ferreira, 2018, paratype ♂ (ISLA 157016), electron microscopy plate. **A.** Body, dorsal view. **B.** Head, dorsal view. **C.** Thorax, dorsal view. **D.** Abdomen, dorsal view; d1 = focus on odoriferous orifice located in the IV mediotergite.



Fig. 14. A. Entrance to Gruta da Natividade. B. Inside of Gruta da Natividade. C. Immature specimen of *Cephalemetra pallida* Polhemus & Ferreira, 2018. D. Adult specimen of *C. pallida*.

is relatively small, it is plausible that individuals may migrate to other subterranean compartments during certain periods of the year, possibly in search of more suitable microhabitats.

As mentioned in the original description of *Cephalometra pallida*, human-induced alterations are clear in the outermost portions of the cave, particularly near the main entrance. Historical accounts from residents indicate that saltpeter extraction for gunpowder production occurred there until at least the 1940s. This activity has left visible traces, including excavated depressions and patches of burned material in the entrance zone and the first chamber. In contrast, the deeper sections of the cave, where *C. pallida* specimens are observed, show no indications of past human presence. These inner compartments appear to have remained untouched, suggesting that historical visitors did not venture beyond the accessible entrance areas. As a result, the deeper environment has been preserved in a largely pristine state.

In contrast, the external habitats surrounding it have undergone significant alteration in recent years, primarily due to forest clearing for pastures and agriculture. Although degraded areas were already evident during our first visit in 2005, the extent of deforestation has increased markedly since then. This trend raises concerns regarding the long-term conservation of the species, as deforestation can lead to sedimentation processes that modify subterranean habitats and reduce the influx of organic matter into the cave, both factors capable of compromising the species' viability over time.

Given these threats, systematic monitoring of the population is strongly recommended. Additionally, the creation of a protected area encompassing the limestone outcrop that hosts the cave, together with reforestation of the surrounding landscape, would provide essential safeguards to ensure the persistence of this highly vulnerable species.

Discussion

Small interspecific variation

Species of *Spelaeometra* exhibit remarkably conserved morphology, with limited interspecific variation. Diagnostic differences are subtle and rely primarily on morphometric traits (Table 1) and the shape of the male parameres (Fig. 15A–D). Across the genus, antennal segmentation follows a consistent pattern: segments I and II are short and similar in length; segment III is approximately three times longer than segment II; and segment IV is four to five times as long as segment I. Leg proportions are likewise conserved. The first pair of legs is the shortest and the third pair the longest, with all species bearing hind legs that exceed body length. Only *Spelaeometra hypogea* Cordeiro & Moreira, 2023 shows the middle pair of legs also exceeding body length.

Electron microscopy of *Spelaeometra ybykoara* sp. nov. and *S. gruta* revealed the presence of an odoriferous orifice (Figs 4G: g1, 13D: d1) on the fourth abdominal mediotergite, a condition also observed in *S. hypogea*. Although *S. iuiu* sp. nov. could not be examined because of limited material (only the holotype is known so far), the presence of this structure is presumed. Across species, the pygofer is elongated, bearing a dorsomedian projection and a concave notch, and labial segment III is consistently the longest, exceeding one-third of the body length only in *S. hypogea*. Despite the overall morphological homogeneity within the genus, the combination of these characters supports the distinctiveness and taxonomic validity of the two species described here. Body size varies among species: *S. ybykoara* (2.68 mm, n = 3) is larger than *S. gruta* (2.50 mm, n = 1) and *S. iuiu* sp. nov. (2.39 mm, n = 1), but smaller than *S. hypogea* (2.85 mm, n = 1). Eye reduction is consistent across the genus; however, *S. ybykoara* exhibits the greatest eye length (0.9 mm, n = 1) and the highest number of ommatidia (16, n = 1). It is also the only species in which the antennae do not exceed body length. The rostrum extends beyond two-thirds of the body length, a condition shared with *S. gruta* and *S. hypogea*. The pygofer bears a small medial spine, and the paramere morphology combines features observed in

congeners: basal projections similar to those of *S. gruta*, and an apical hook comparable to that of *S. hypogea*, though proportionally longer and more strongly curved.

Spelaeometra iuiu sp. nov. is readily distinguished by its body size (2.39 mm), which is smaller than that of all known congeners. Eye reduction is comparable to that observed in *S. hypogea* (0.6 mm, $n = 1$), and the number of ommatidia (10–12, $n = 1$) is intermediate among species of the genus. The pygofer bears a more pronounced medial spine than that of *S. ybykoara* sp. nov. The paramere lacks basal projections, as in *S. hypogea*, but differs by possessing a rounded rather than straight base. It is also distinctly broad and asymmetrical, representing a unique morphological configuration within the genus.

With the description of *Spelaeometra ybykoara* sp. nov. and *S. iuiu* sp. nov., the genus now contains four species, all endemic to Brazilian caves. This expansion represents a significant advancement in the understanding of cave-dwelling Hemiptera in Brazil. Nevertheless, the genus displays remarkably low morphological differentiation among species, with the structure of the parameres remains the most reliable diagnostic character (Fig. 15).

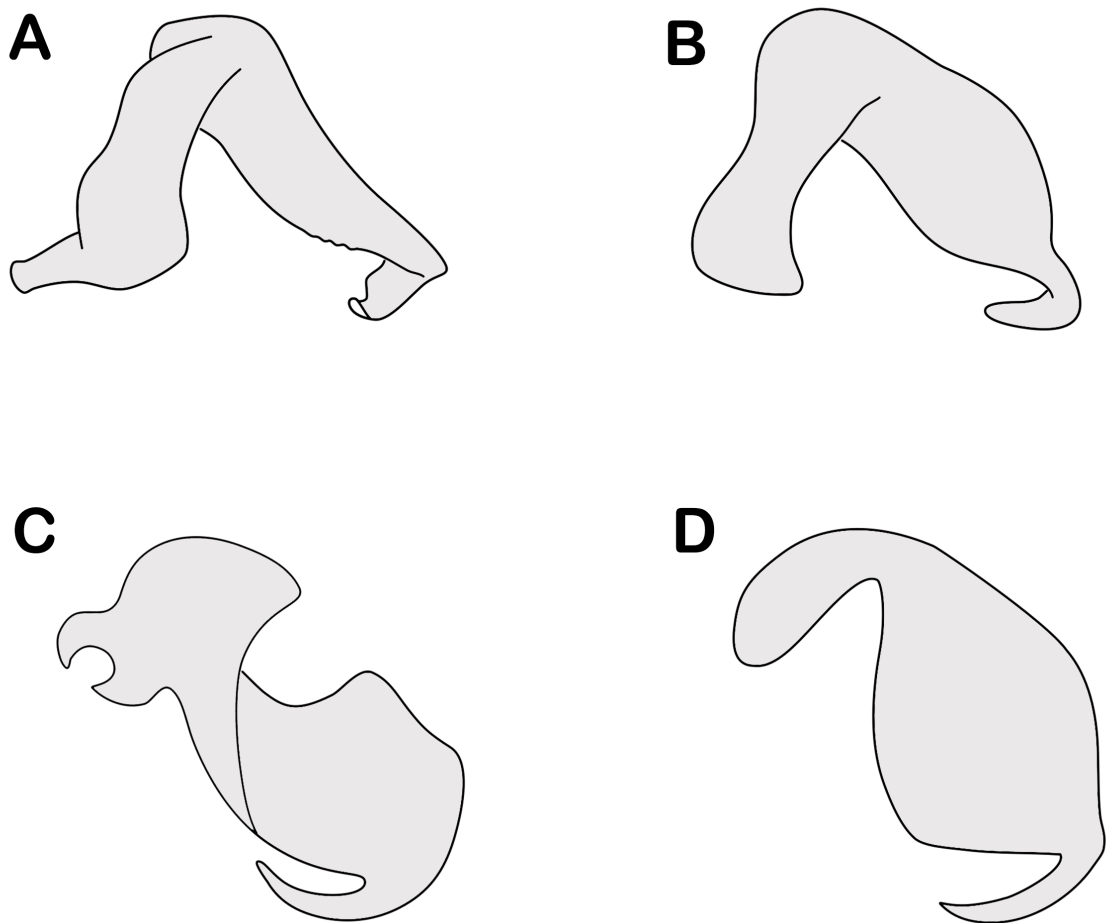


Fig. 15. Parameres of the species of *Spelaeometra*. **A.** *Spelaeometra gruta* D. Polhemus & Ferreira, 2018, paratype ♂ (redrawn from D. Polhemus & Ferreira 2018: fig. 6B). **B.** *Spelaeometra hypogea* Cordeiro & Moreira, 2023 (redrawn from Cordeiro *et al.* 2018: fig. 6B). **C.** *Spelaeometra ybykoara* Serafim & Ferreira sp. nov., paratype, ♂ (ISLA 126340). **D.** *Spelaeometra iuiu* Serafim & Ferreira sp. nov., holotype, ♂ (ISLA 125922).

The high degree of interspecific similarity (also evident in comparisons between *Spelaeometra* and its closely related genus *Cephalometra*) underscores their close evolutionary relationship within tropical subterranean environments. This morphological resemblance supports the hypothesis that *Spelaeometra* may represent a recently diverged species complex, potentially linked to adaptive shifts. In contrast, *Cephalometra pallida*, which likely represents an older lineage that has remained isolated in subterranean habitats for a longer period, exhibits more pronounced troglomorphic traits and a distribution restricted to its type locality.

Generic concepts

Based on a preponderance of shared apomorphic character states, Polhemus & Ferreira (2018) suggested that these genera are most closely allied to *Velimetra schuhi* Andersen, 1977, a Brazilian endemic currently placed in a different subfamily (Heterocleptinae), despite exhibiting notable morphological affinities. *Spelaeometra gruta* and *Cephalometra pallida* share an extensive suite of diagnostic morphological traits, including similar head proportions, absence of ocelli, cephalic trichobothria, elongate antennal segments III–IV with apical invagination, comparable rostral configuration, a fully wingless thorax, and a male genital capsule characterized by a boat-shaped pygofer and tripartite parameres. Together, these features indicate a close phylogenetic relationship between the two nominal genera. Nonetheless, based primarily on morphological (especially morphometric) differences, the two genera have been proposed as distinct taxonomic units.

The differences observed between the type species of the two genera (including degree of eye reduction, coloration, head elongation, number of ommatidia, rostral length, thoracic sternal modifications, and curvature of the parameres) follow a pattern consistent with distinct levels of troglomorphic adaptation. These trends align with the adaptive-shift framework proposed by Howarth (1981, 1983, 2019), which posits that populations colonizing subterranean habitats undergo progressive morphological and physiological transformations driven by selective pressures associated with darkness, nutritional limitation, and environmental stability. Comparable intrageneric gradients of troglomorphy have been documented in the Brazilian cave-dwelling hemipteran *Ferricixius* Hoch & Ferreira, 2012 (e.g., Santos *et al.* 2023), whose species show pronounced variation in eye reduction, wing shortening, and pigmentation, despite exhibiting minimal divergence in genital morphology.

Within *Spelaeometra*, the subtle morphological boundaries, combined with the recurrent expression of traits associated with cave adaptation, support the interpretation of the genus as a set of species undergoing differential troglomorphic modification, as previously noted. From this perspective, the more pronounced eye reduction, paler coloration, and greater appendage elongation observed in *Cephalometra pallida* may eventually represent a more advanced stage of subterranean adaptation rather than evidence of a distinct genus.

The hypothesis that these two cave-dwelling genera of Hydrometridae currently known in Brazil simply represent extremes of a single, continuously variable morphocline is pertinent, although gradual evolution of character states is observed throughout the Hydrometridae family (e.g., Gapud *et al.* 2002; Polhemus 2022; Floriano *et al.* 2025), so such considerations are not limited only to species that live in caves. In this case, it is difficult to determine whether this represents parapatric speciation, as in notable cases reported in the literature for other groups of caves on temperate and tropical regions (Howarth 2019).

Therefore, morphological evidence alone is insufficient to determine whether these differences reflect species-level divergence within a single evolutionary lineage or instead indicate deeper phylogenetic separation. Targeted molecular analyses will be essential to evaluate whether *Spelaeometra* and *Cephalometra* represent independent genera or a single genus comprising a lineage that exhibits adaptive morphological variation, with species expressing different degrees of troglomorphy across a continuous

morphocline. Molecular analyses are strongly recommended for future studies for all described species of *Spelaeometra* to increase confidence in the boundaries between described species, as well as for proposing new species that may be discovered.

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