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New troglobitic species of *Niambia* from Botswana and Namibia (Crustacea, Isopoda, Oniscidea)

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Abstract

Three new species in the genus *Niambia* are described from southern African caves: *N. botswanaensis* **sp. nov.** from Diviner's Cave (Botswana), *N. ghaubensis* **sp. nov.** from Ghaub Cave and *N. namibiaensis* **sp. nov.** from Märchen Cave (Namibia). All these species show troglomorphic traits such as absence of body pigmentation and eyes. These are the first troglobitic species recorded in the genus. Most of the other species of *Niambia* are epigean and occur in semi-arid environments in the Afrotropical Region.

Keywords

Afrotropical Region, Cave fauna, new species, Platyarthridae

Introduction

The genus *Niambia* Budde-Lund, 1904 is included in the family Platyarthridae, which is probably polyphyletic, thus a revision of its seven genera is needed (see Schmidt 2003, 2008; Javidkar et al. 2015). At present, *Niambia* comprises 22 species from the Afrotropical Region, mainly southern Africa (Schmalfuss 2003; Taiti and Ferrara 2004), with two species introduced into the Americas and New Zealand, i.e., *N. squamata* (Budde-Lund, 1885) into Brazil (Araujo and Taiti 2007) and *N. capensis* (Dollfus, 1895) in California, Chile, and New Zealand (Brusca et al. 2007; Javidkar et al. 2015; Pérez-Schultheiss et al. 2018). Most species are epigean, although *Niambia termitophila* Kensley, 1971 occurs in termite nests, and *Niambia formicarum* Barnard, 1932 and *N. eburnea* (Vandel, 1953) are myrmecophilous (Kensley 1971).

In the present contribution, three new troglobitic species of *Niambia* collected in caves of Botswana and Namibia are described. No species of *Niambia* were previously known from Botswana, while 10 species were recorded from Namibia, i.e., *N. angusta* Budde-Lund, 1909, *N. capensis*, *N. damarensis* (Panning, 1924), *N. flavescens* Barnard, 1924, *N. griseoflava* Barnard, 1924, *N. longicauda* Barnard, 1924, *N. modesta* Budde-Lund, 1909, *N. pallida* Budde-Lund, 1909, *N. squamata*, and *N. truncata* (Brandt, 1833) (Schmalfuss 2003). Furthermore, some ecological remarks are provided for all described species, including a brief discussion of their conservation status and threats to their respective habitats.

Material and methods

The specimens were manually collected and fixed in 70% ethanol for preservation. Measurements and photographs were taken with a ZEISS Axio ZoomV16 stereomicroscope coupled with an Axiocam 506 Color camera at the Center of Studies on Subterranean Biology of the Federal University of Lavras (**CEBS–UFLA**, Lavras, Brazil). Body parts were mounted in micropreparations using Hoyer's medium. Drawings were made with the aid of a camera lucida on Leica DM750. The noduli laterales were measured and illustrated as proposed by Vandel (1962) and the illustrations were prepared using the software GIMP (v. 2.8) with methodology proposed by Montesanto (2015, 2016). For analysis of the dorsal cuticular structures and some body parts, pictures were taken with the scanning electron microscope Hitachi TM4000. Holotype and paratypes of the new species were deposited in the collections of Subterranean Invertebrates of Lavras (**ISLA**) in the Federal University of Lavras, Brazil, and in the Museo di Storia Naturale dell'Università, Sezione di Zoologia "La Specola" (**MZUF**), Florence, Italy.

Taxonomy

Family Platyarthridae Verhoeff, 1949
Genus *Niambia* Budde-Lund, 1904

***Niambia botswanaensis* Cardoso, Taiti & Ferreira, sp. nov.**
http://zoobank.org/C6BBA4C3-24B3-48EB-9FA1-24CF6BB79413
Figs 1–4

Niambia sp. 1; Javidkar et al. 2015: 575, figs 2, 3.

Material examined. ***Holotype.*** • Male; Botswana, North-western District, Gcwihaba region, Diviner's Cave, 20°08'32.2"S, 21°12'36.6"E, 11 January 2016, leg. G. Du Preez (IG12112513lag) (ISLA 78790). ***Paratypes.*** • 1 male, 4 females, same data as holotype (IG12112513lag) (ISLA 78791); 2 males, 2 females, same locality and date (IG12030901-5) (ISLA 78792); 2 males, 1 female, same locality, 20 October 2011 (Parod root) (ISLA 78793); 4 males, 5 females, same locality and date (ISLA 78794); 2 males, 6 females, same locality and date, leg. G. Du Preez (MZUF 9901) (IG120309A-12).

Description. Maximum length: male, 3 mm; female, 3.5 mm. Colorless (Fig. 1A). Dorsal surface of pereon sparsely granulated with scattered triangular scale-setae (Fig. 1E, F); one line of noduli laterales per side on pereonites, close to posterior margins and at certain distance from lateral margins, b/c and d/c co-ordinates as in Fig. 2A; gland pores not visible. Cephalon (Fig. 1B) with suprantennal line visible only at sides, no frontal line, eyes absent. Pleon slightly narrower than pereon, pleonites 3–5 with falciform epimera. Telson (Fig. 2B) triangular with straight sides, obtuse apex. Antennula (Fig. 2C) with three articles, second article shortest, distal article with eight short aesthetascs. Antenna (Figs 1B–D, 2B) reaching distal margin of pereonite 3 when extended backward; fifth article of peduncle and flagellum subequal in length; flagellum with two articles, second article about 3 times as long as first. Mandibles (Fig. 2E, F) with molar penicil consisting of 5–6 setae arising from common stem; left mandible with 2 + 1 penicils, right mandible with 1+1 penicils. Maxillula (Fig. 2G) outer branch with 4 + 5 teeth (three of them slightly cleft) plus one small tooth between outer and inner teeth; inner branch with two short penicils. Maxilla (Fig. 2H) with bilobate apex, inner lobe distinctly smaller than outer lobe. Maxilliped (Fig. 2I) basis rectangular; palp basal article with two stout setae; endite rectangular, medial portion with one long seta, distal margin with one tooth. Pereopod dactylus with inner claw stout, slightly longer than outer one; pereopod 1 (Fig. 3A) carpus with transversal grooming brush. Pleopod exopods without visible respiratory structures. Uropod (Fig. 2B) protopod reaching distal margin of telson, slightly grooved on outer margin; endopod and exopod inserted at same level, endopod distinctly shorter than exopod.

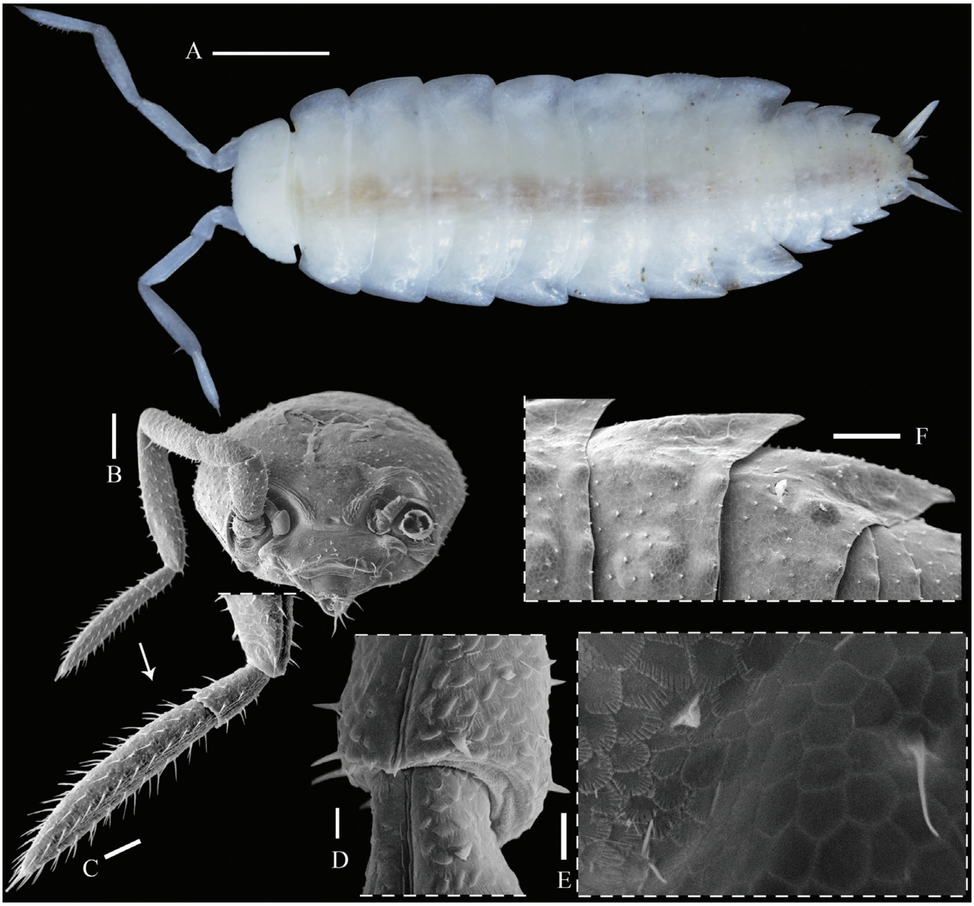

Figure 1. *Niambia botswanaensis* sp. nov. Male paratype **A** habitus, dorsal view **B** cephalon, frontal view **C** antennal flagellum **D** antennal peduncle, water conducting system **E** nodulus lateralis and scale-seta on pereonite 3 **F** noduli laterales on pereonites 5–7. Scale bar: 0.5 mm (**A**); 100 μm (**B, F**); 20 μm (**C**); 10 μm (**D, E**).

Male. Pereopods with sternal margin bearing some apically trifid setae; pereopod 7 (Fig. 3B) with no distinct sexual modifications. Pleopod 1 (Fig. 3C) exopod round; endopod longer than exopod, distal portion tapering. Pleopod 2 (Fig. 3D) exopod triangular, bearing one subapical seta, outer margin concave; endopod longer than exopod. Pleopod 3–5 exopods as in Fig. 3E–G.

Etymology. The new species is named after Botswana, where the specimens were collected.

Taxonomic remarks. This and the following new species are included in the genus *Niambia* since they show all the characters of the genus, except for lacking respiratory areas in the pleopod exopods. This condition may be due to a secondary reduction due to the humid environment of the caves where they occur. Most of the species of *Niambia* are epigean and inhabit semi-arid habitats in South West Africa (Barnard 1932).

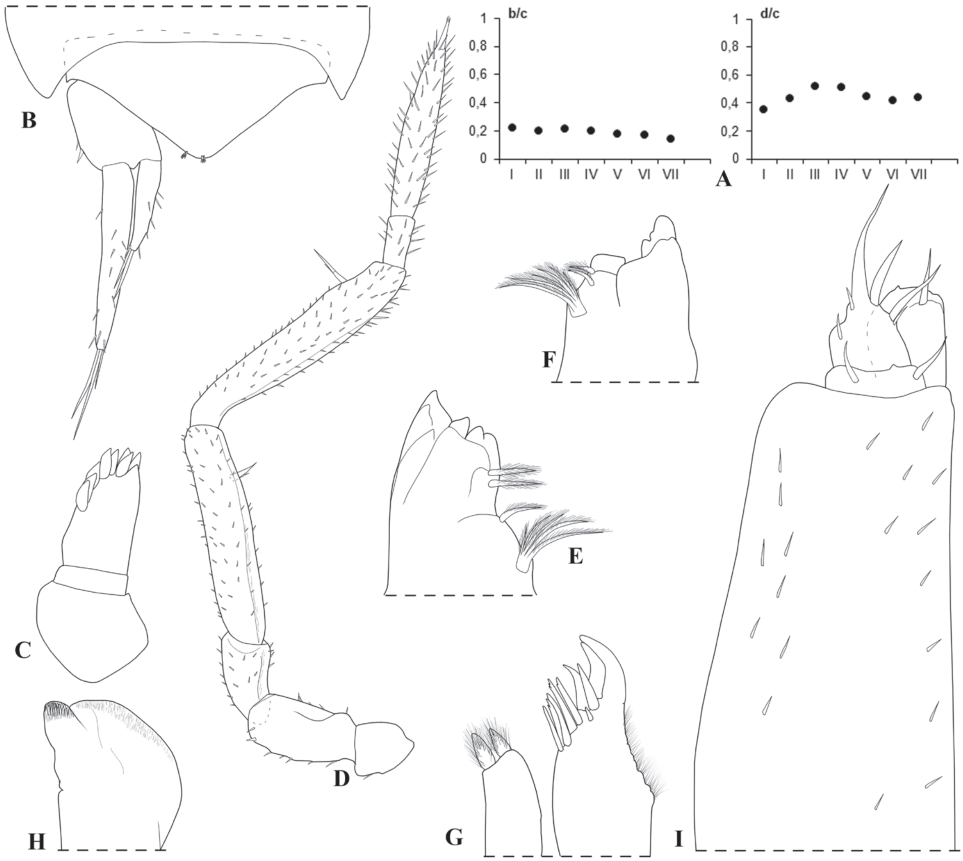

Figure 2. *Niambia botswanaensis* sp. nov. Male paratype **A** co-ordinates of noduli laterales **B** pleonite 5, telson and left uropod, dorsal view **C** antennula **D** antenna **E** left mandible **F** right mandible **G** maxillula **H** maxilla **I** maxilliped.

In lacking the frontal line on cephalon, *N. botswanaensis* sp. nov. resembles *N. duffeyi* Ferrara & Taiti, 1981 and *N. longiantennata* Taiti & Ferrara, 1991 from Ascension Island, as well as *N. septentrionalis* Taiti & Ferrara, 2004 from Socotra Island (Yemen). However, it is distinct in lacking pigmentation and eyes, and in the shape of the male pleopod 1 exopod without posterior point (compare fig. 11 in Ferrara and Taiti 1981; fig. 30 in Taiti and Ferrara 1991; and fig. 33D in Taiti and Ferrara 2004).

Some specimens of this species from the type locality were sent to Dr. M. Javidkar in Adelaide for molecular analysis and were included in a phylogenetic cladogram as *Niambia* sp. 1 (Javidkar et al. 2015).

Ecological remarks. The Koanaka and Gcwihaba hills are located in the North-West District (or Ngamiland) of Botswana. The lithology was described by Williams et al. (2012) as Precambrian dolomites from the Damara Sequence. According to Thies and Lewis (2015) the surrounding environment (known as the Kalahari Thirstland) is semi-arid with shrub savanna vegetation and forms part of the Savanna Biome.

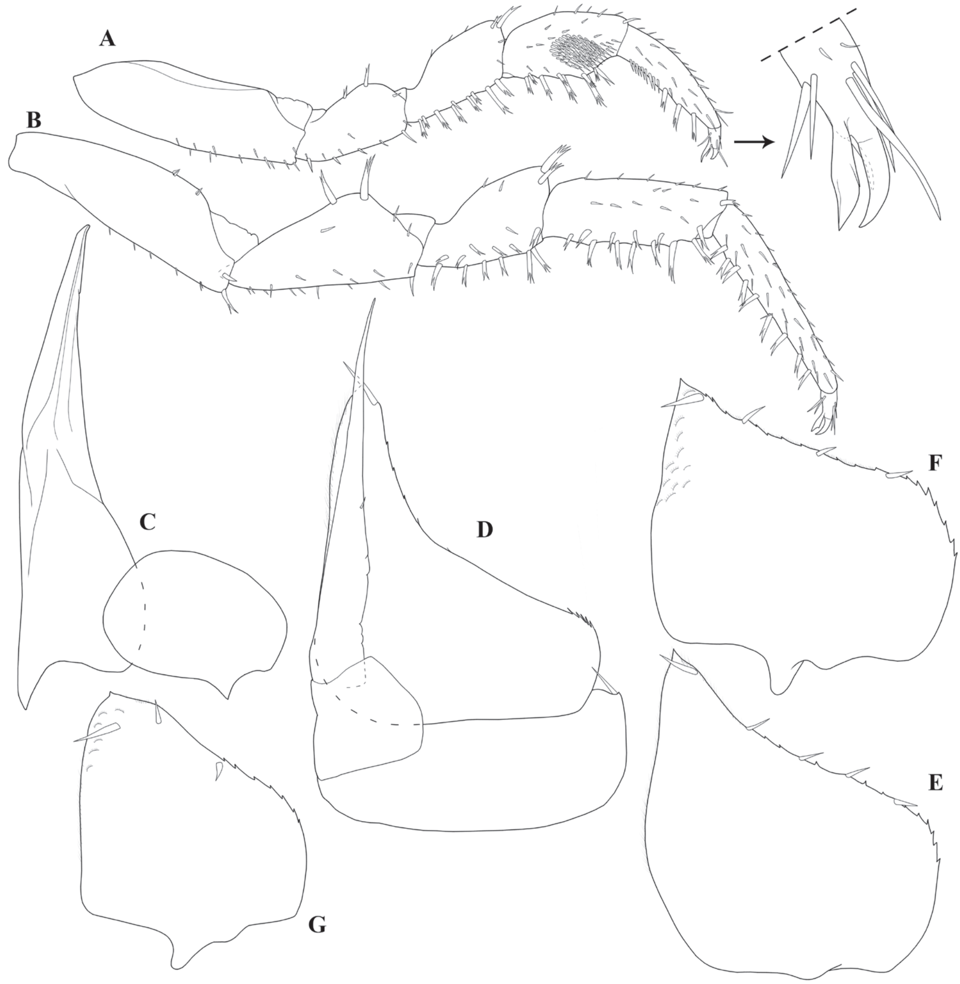

Figure 3. *Niambia botswanaensis* sp. nov. Male paratype. **A** pereopod 1 **B** pereopod 7 **C** pleopod 1 **D** pleopod 2 **E** pleopod 3 exopod **F** pleopod 4 exopod **G** pleopod 5 exopod.

Annual precipitation typically ranges between 400 and 500 mm and temperatures from -8.5 °C to 42.2 °C.

The Koanaka and Gcwihaba hills collectively host four known caves with natural entrances, which include Gcwihaba Cave, a local tourist attraction formerly known as Drotsky's Caverns (Fig. 4A). Furthermore, using gravimetric surveys and exploration drilling, an additional five caves were discovered, opened and explored (Harvey and Du Preez 2014; Du Preez et al. 2015). One of these is Diviner's Cave, the type locality of *Niambia botswanaensis* sp. nov. Initial exploration of Diviner's Cave commenced in 2011 after a 700 mm diameter vertical shaft (borehole) was drilled (Fig. 4B–E). This shaft is 41 m deep and enters the cave in a chamber called 'Entrance Alcove' (Fig. 4C, D). Upon initial exploration of the cave, high CO_2 levels were encountered, especially in areas lower than the general cave development level. However, since the cave was

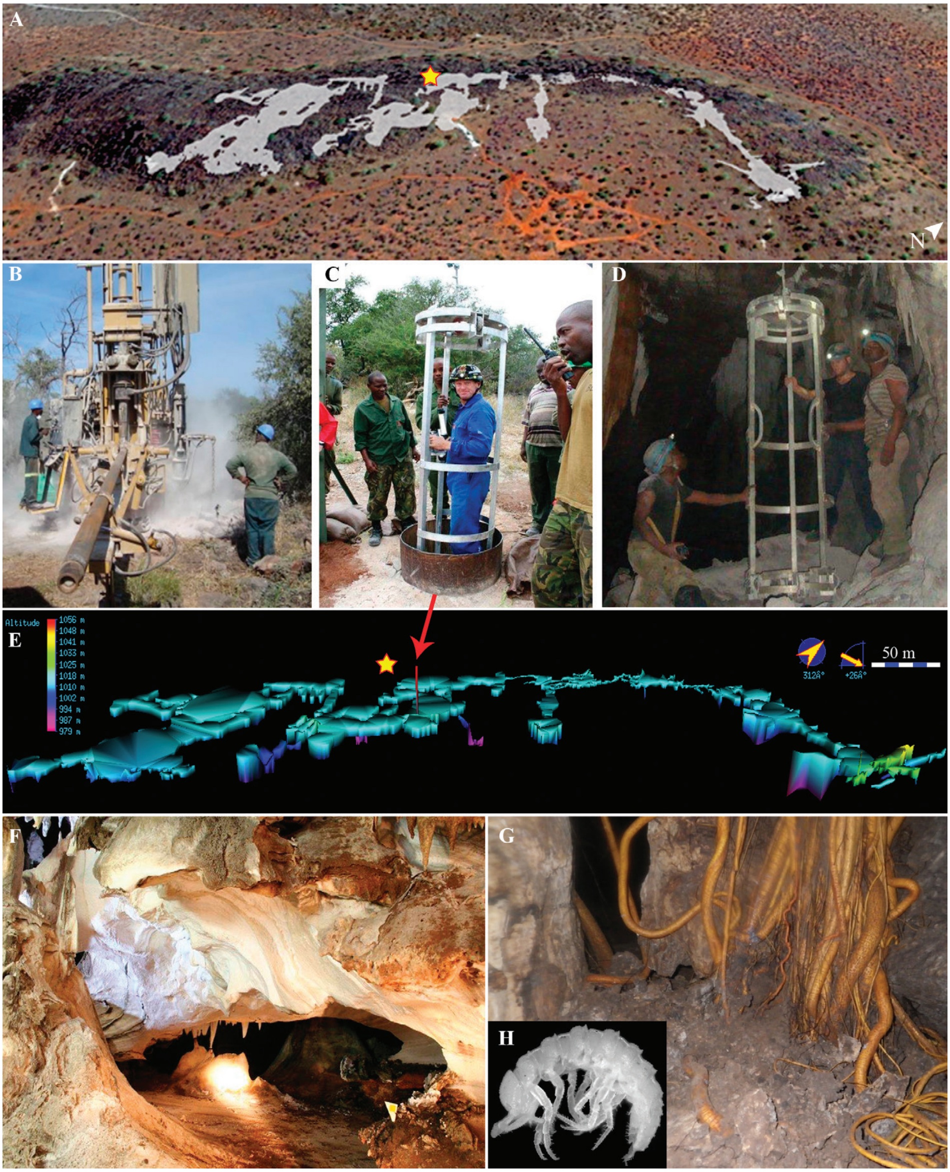

Figure 4. *Niambia botswanaensis* sp. nov. **A** Koanaka and Gcwihaba hills, cave map delimited in gray **B** Diviners Cave vertical shaft (borehole) drilled **C** man-made entrance on the surface **D** entrance chamber inside a cave **E** Diviners Cave map (angled perspective) showing vertical entrance **F** calcite formation in Diviners Cave **G** Roots of the fig tree (*Ficus cordata*) where the specimens were collected **H** specimen of *Niambia botswanaensis* sp. nov.

allowed to vent following the drilling of the borehole, CO_2 levels gradually decreased and facilitated further exploration. As can be expected, atmospheric conditions in Diviner's Cave and those with man-made entrances were quite distinct from the observed in local caves with natural entrances (Du Preez et al. 2015). All the caves associated with the Koanaka and Gcwihaba hills are protected and declared as Botswana National Monuments.

Specimens of *Niambia botswanaensis* sp. nov. were collected by hand in Calcite Baboon Chamber, Diniver's Cave. The collection site is located (Fig. 4F, G) at the one end of this chamber where large *Ficus cordata* roots penetrate the cavity (Du Preez et al. 2015). Associated with this root system is a community of soil invertebrates that include pseudoscorpions (*Botswanoncus ellisi* Harvey & Du Preez, 2014), diplurans (Japygidae), centipedes (*Cryptops* sp.) and termites.

During sampling atmospheric conditions were measured using a Fluke 971 Temperature Humidity Meter. An average temperature of 28.5 ± 0.5 °C and relative humidity of 93 ± 5.4% were recorded in Diviner's Cave.

Niambia ghaubensis Cardoso, Taiti & Ferreira, sp. nov.

http://zoobank.org/86223FA7-AB12-4E95-A8C9-948F89DA6C34

Figs 5–8

Material examined. ***Holotype.*** • Male; Namibia, Tsumed, Ghaub cave, 05 November 2008, leg. R. L. Ferreira (ISLA 78795). ***Paratypes.*** • 1 male (slide), 6 females, same data as holotype (ISLA 78796).

Description. Maximum length: male, 4 mm; female, 5 mm. Colorless (Fig. 5A, B). Dorsal surface smooth with scattered fan-shaped scale-setae (Figs 5E, 6A); one line of noduli laterales per side on pereonites, at certain distance from lateral margin, b/c and d/c co-ordinates as in Fig. 6B; gland pores not visible. Cephalon (Fig. 5C) with no suprantennal and frontal lines; eyes absent. Pleon slightly narrower than pereon, pleonites 3–5 epimera with triangular posterior points. Telson (Fig. 6C) triangular with straight sides, apex right-angled. Antennula (Figs 5D, 6D) with three articles, second article shortest, distal article with ca. 10 aesthetascs. Antenna (Fig. 6E) reaching distal margin of pereonite 3 when extended backward; fifth article of peduncle shorter than flagellum; flagellum with two articles, second article about 3.5 times as long as first. Mandibles (Fig. 6F, G) with molar penicil consisting of 6–7 setae arising from common stem; left mandible with 2+1 penicils, right mandible with 1+1 penicils. Maxillula (Fig. 6H) outer branch with 4 + 5 (four of them cleft) plus one small tooth between inner and outer teeth; inner branch with two penicils. Maxilla (Fig. 6I) with bilobate apex, inner lobe distinctly smaller than outer one. Maxilliped (Fig. 6J) basis rectangular; palp basal article with two stout setae, distal article with apical tuft of setae; endite rectangular, medial portion with one long and one small seta, distal margin with 2 teeth. Pereopod 1 (Fig. 7B) carpus with transversal grooming brush. Pereopods with inner claw of dactylus smaller than outer one (Fig. 7C). Uropod (Fig. 7A) protopod reaching distal margin of telson; endopod inserted proximally, shorter than exopod.

Male. Pereopods 1–2 (Fig. 7B) merus and carpus with sternal margin covered with long apically trifid setae. Pereopod 7 (Fig. 7C) with no distinct sexual modifications. Genital papilla (Fig. 11C) with triangular frontal shield. Pleopod 1 (Fig. 7D) exopod

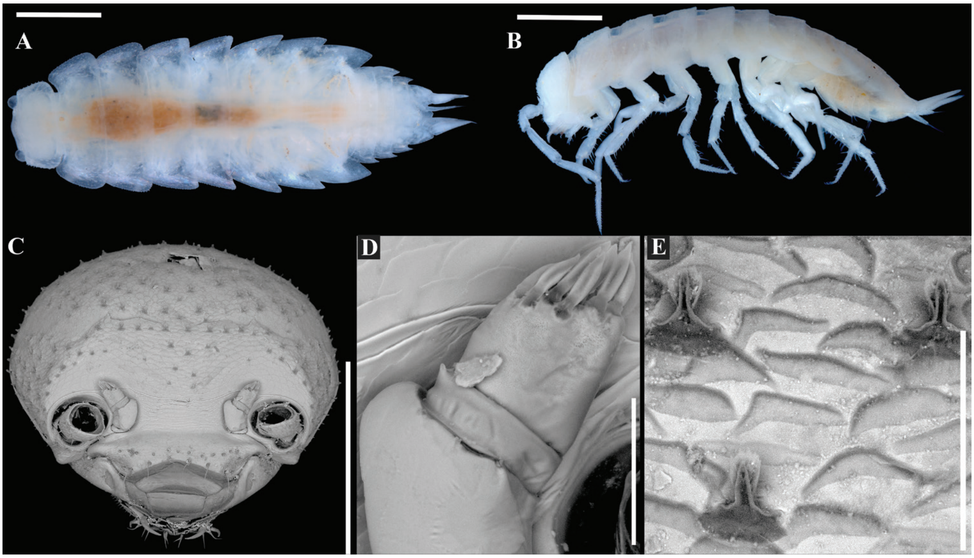

Figure 5. *Niambia ghaubensis* sp. nov. Female paratypes **A** habitus, dorsal view **B** habitus, lateral view **C** cephalon, frontal view **D** antennula **E** scale setae. Scale bars: 1 mm (**A, B**); 500 µm (**C**); 50 µm (**D, E**).

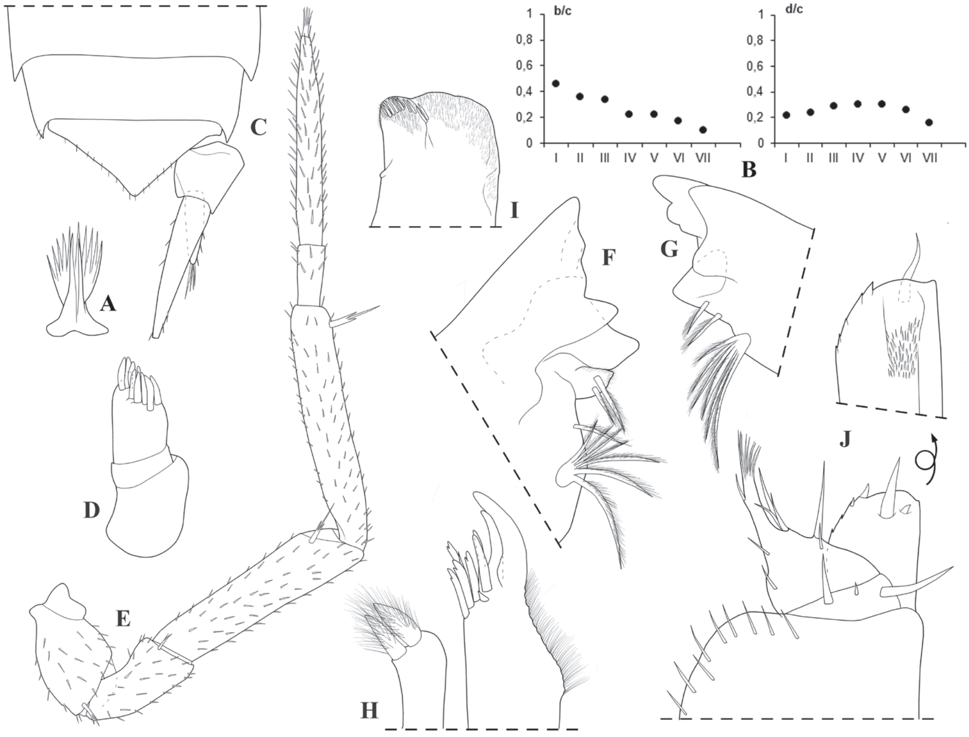

Figure 6. *Niambia ghaubensis* sp. nov. Female paratype **A** scale-seta **B** co-ordinates of noduli laterales **C** pereonites 4 and 5, telson and right uropod, dorsal view **D** antennula **E** antenna **F** left mandible **G** right mandible **H** maxillula **I** maxilla **J** maxilliped.

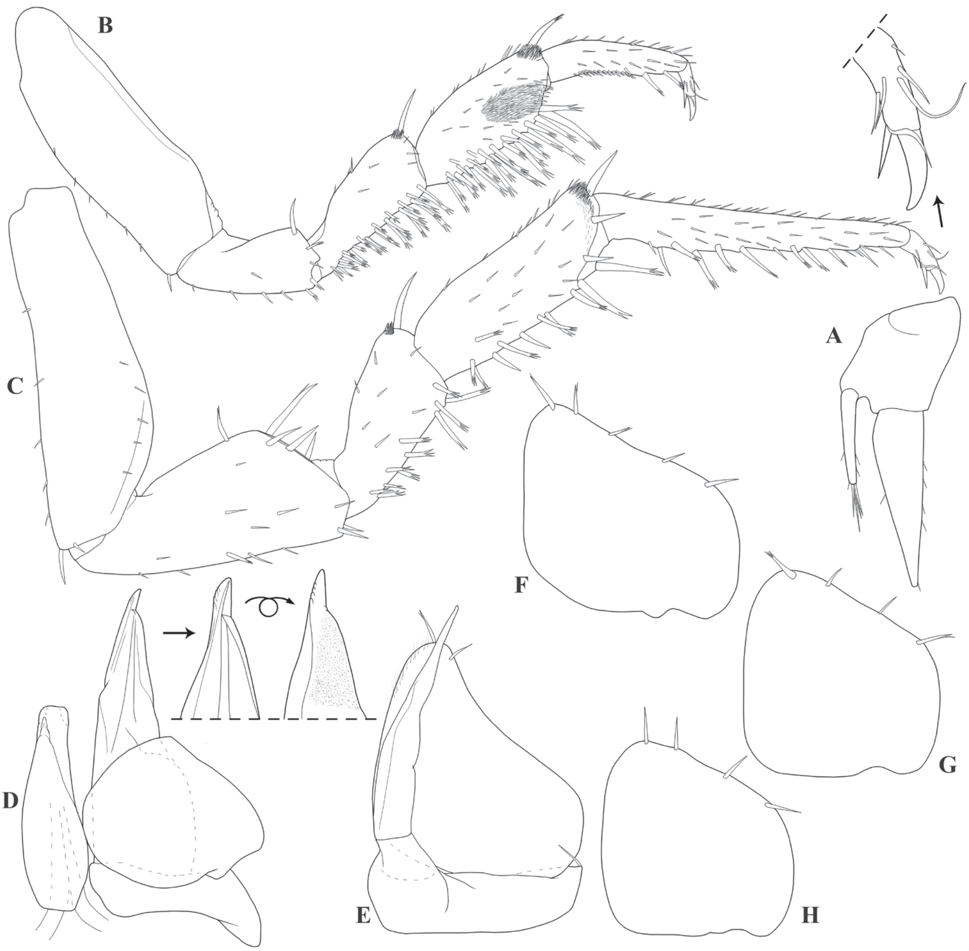

Figure 7. *Niambia ghaubensis* sp. nov. Male paratype **A** uropod **B** pereopod 1 **C** pereopod 7 **D** genital papilla and pleopod 1 **E** pleopod 2 **F** pleopod 3 exopod **G** pleopod 4 exopod **H** pleopod 5 exopod.

cordiform, with very short posterior point; endopod longer than exopod, with triangular distal lobe. Pleopod 2 (Fig. 7E) exopod triangular, bearing two setae; endopod slightly longer than exopod. Pleopods 3–5 exopods as in Fig. 7F–H.

Etymology. The new species is named after Ghaub cave, the type-locality of the species.

Taxonomic remarks. *Niambia ghaubensis* sp. nov. differs from *N. botswanaensis* sp. nov. by the telson with right-angled instead of obtuse apex, male pereopods 1–2 with a brush of setae on carpus and merus sternal margin instead of sparse setae, dactylus of pereopods with a thinner inner claw, and male pleopod 1 exopod cordiform instead of rounded.

Ecological remarks. The Ghaub cave is the third largest cave in Namibia, with approximate 2.5 km of passages. It consists of an intricate net of labyrinthine conduits with different levels. The lowest level connects to the phreatic level; thus, some ponds are observed inside the cave. The cave is inserted in the dolomites of the Otavi geological group, dating from the upper Precambrian (Goudie and Viles 2015). The cave has a single entrance (Fig. 8A), in which there is currently a gate installed to prevent unauthorized entry. The conduits' morphologies are somewhat variable since they transect an intricate stratigraphy along the almost 40 m vertical gap within the rock (Fig. 8B,

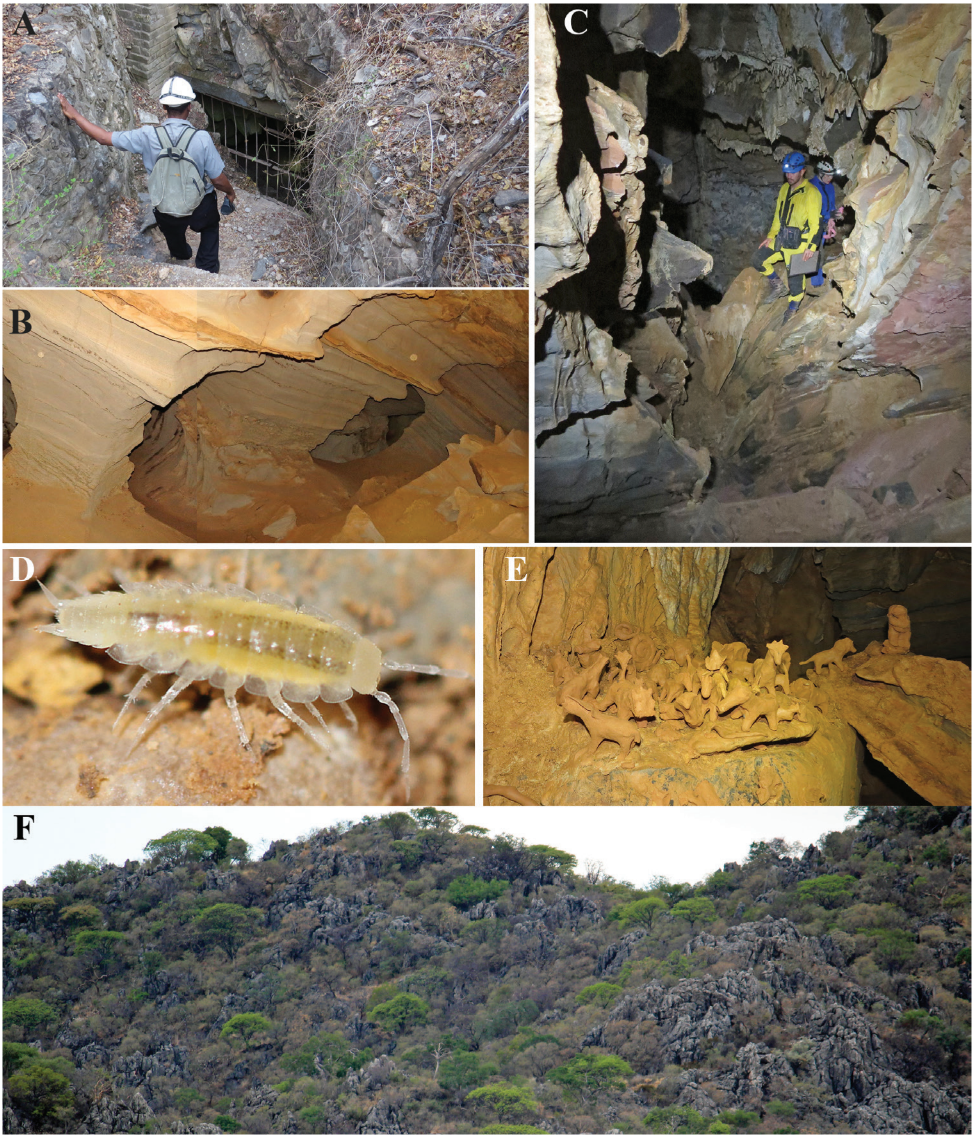

Figure 8. *Niambia ghaubensis* sp. nov. **A** Ghaub cave's entrance **B** cave intricate stratigraphy **C** cave conduits **D** specimen of *Niambia ghaubensis* sp. nov. **E** cave chamber with mud animals **F** external hills surrounding the cave.

C). Although the lower levels of the cave are connected to the phreatic level, most of the cave remains dry. Yet, moist substrates occur in some areas by drip water from speleothems. Organic resources observed are mainly the guano produced by insectivorous bats, where invertebrates are usually concentrated. Specimens of *Niambia ghaubensis* sp. nov. were only found in the deep sections of the cave, associated with moist substrates (Fig. 8D). Curiously, such areas were devoid of other invertebrates, and also of guano. Hence, it seems that this species is highly specialized, avoiding areas richer in organic matter and, thus, other invertebrate species (including predators). Individuals were observed freely walking on the cave floor.

The Ghaub cave is currently used for touristic purposes, receiving visitors regularly. However, apart from the rudimentary stone stairway at the gate entrance in the first conduit, no other man-made structures are present in the cave. The only altered area in the cave due to the tourism is a small chamber at the lower level, which is quite moist with mud. In this chamber, locals used to make mud animals that were left in some parts of the chamber, forming curious sets of mud figures (Fig. 8E). Fortunately, the cave sections where *N. ghaubensis* sp. nov. occurs are difficult to access, which minimizes the threat to this species by visiting tourists. The region's climate is considered as hot semi-arid (BSh), according to the updated Koppen-Geiger classification (Beck et al. 2018). According to historical data from 1982 to 2012, the average annual rainfall in the area ranges from 500 to 600 mm, with the wet season occurring from November to March (Merkel 2019). The cave is located in the "Angolan Mopane Woodlands" ecoregion (Dinerstein et al. 2017). The surface environment surrounding the cave is protected and located in a reserve that hosts tourists also for photographic safaris. The Otavi mountains are, in general, well preserved, with the land cover dominated by natural forests (Fig. 8F).

Niambia namibiaensis **Cardoso, Taiti & Ferreira, sp. nov.**

http://zoobank.org/F7458124-450A-42F0-B597-CA958F245406
Figs 9–11

Material examined. ***Holotype.*** • Male; Namibia, Otavi, Märchen cave, 07 November 2008, leg. R. L. Ferreira (ISLA 78797). ***Paratypes.*** • 1 male (slide), 2 females, same data as holotype (ISLA 78798).

Description. Maximum length: male, 6 mm. Colorless (Fig. 9A, B). Dorsal surface smooth with fan-shaped scale-setae (Fig. 10C); one line of noduli laterales per side on pereonites, at certain distance from lateral margin, b/c and d/c co-ordinates as in Fig. 10A; some gland pores on pereonites 1 to 7 (Fig. 10C). Cephalon (Figs 9B, 10B) with no suprantennal line; eyes reduced to small dot of pigment (Fig. 9B), absent in some specimens. Pleon slightly narrower than pereon, pleonites 3–5 epimera with triangular posterior points. Telson (Fig. 10D) triangular with slightly concave sides and rounded apex. Antennula (Fig. 10E) with three articles, second article shortest, distal article with ca. seven aesthetascs. Antenna (Fig. 10F) reaching pereonite 2 when extended backward; fifth article of peduncle as long as flagellum;

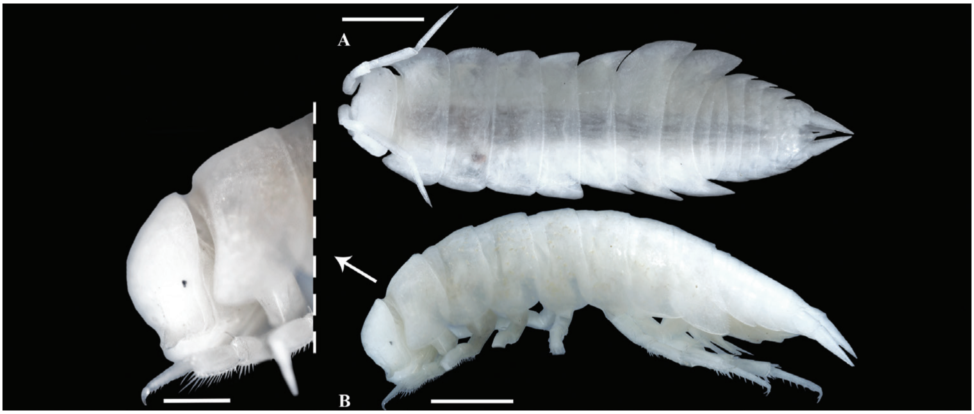

Figure 9. *Niambia namibiaensis* sp. nov. Male paratype **A** habitus, dorsal view **B** habitus, lateral view. Scale bars: 1 mm.

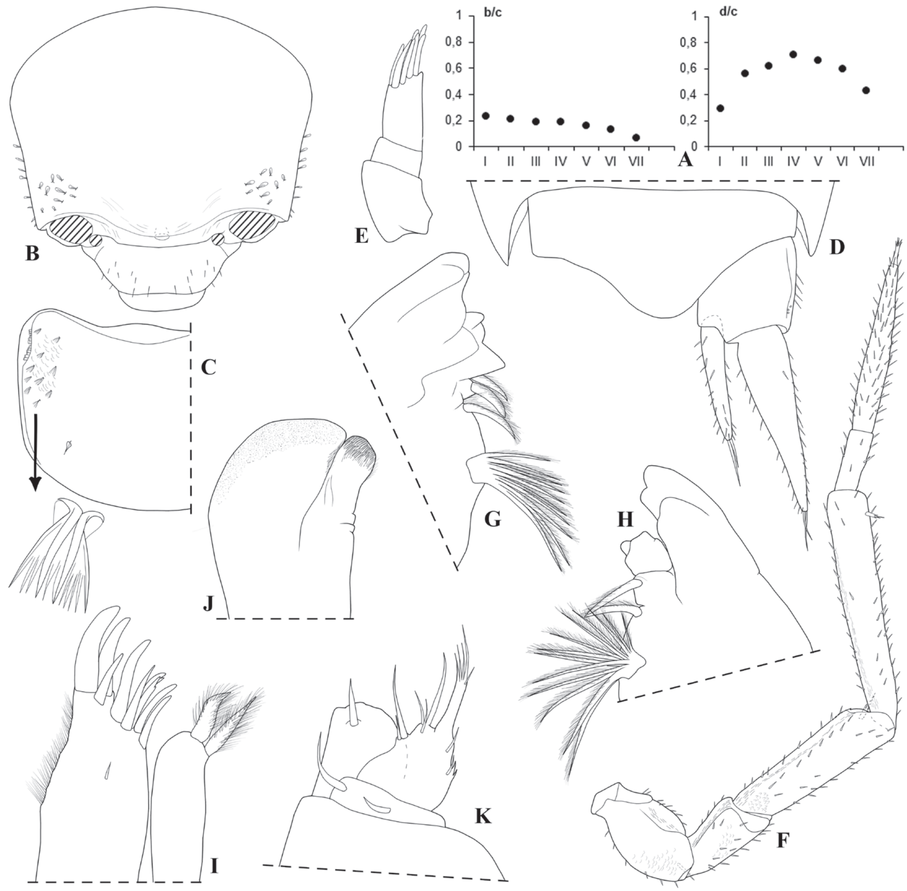

Figure 10. *Niambia namibiaensis* sp. nov. Male paratype **A** co-ordinates of noduli laterales **B** cephalon, frontal view **C** pereonite 1, dorsal view **D** pereonite 5, telson and right uropod, dorsal view **E** antennula **F** antenna **G** left mandible **H** right mandible **I** maxillula **J** maxilla **K** maxilliped.

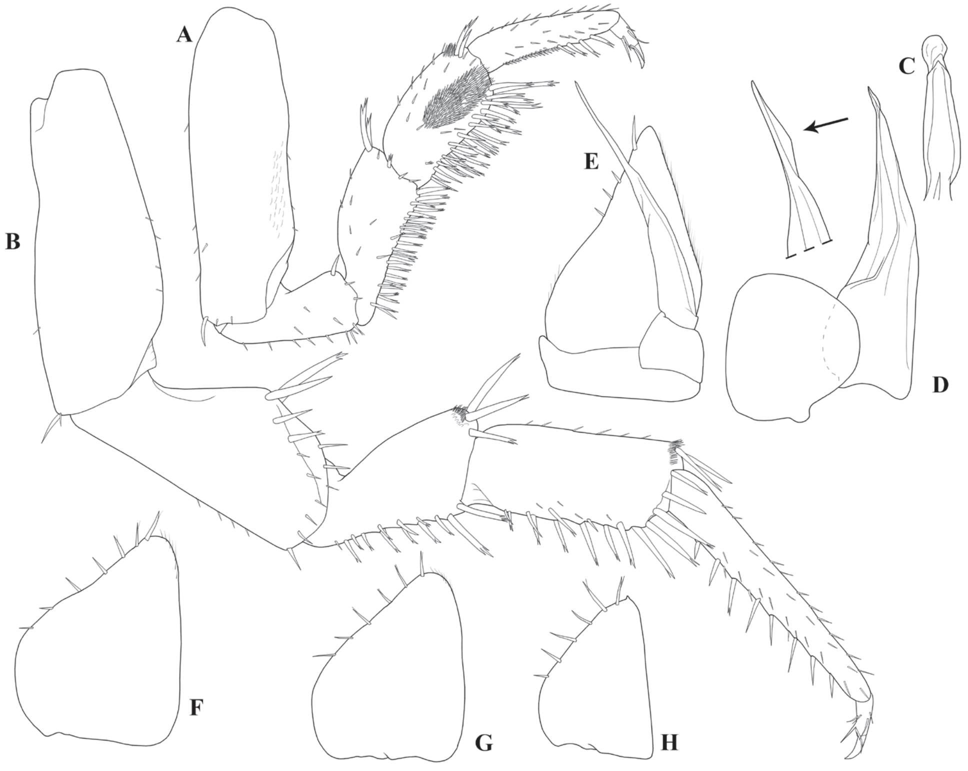

Figure 11. *Niambia namibiaensis* sp. nov. Male paratype **A** pereopod 1 **B** pereopod 7 **C** genital papilla **D** pleopod 1 **E** pleopod 2 **F** pleopod 3 exopod **G** pleopod 4 exopod **H** pleopod 5 exopod.

flagellum with two articles, second article about 3 times as long as first. Mandibles (Fig. 10G, H) with molar penicil consisting of several setae arising from common stem; left mandible with 2+1 penicils, right mandible with 1+1 penicils. Maxillula (Fig. 10I) outer branch with 4 + 5 teeth (two of them cleft); inner branch with two penicils. Maxilla (Fig. 10J) with bilobate apex, inner lobe distinctly smaller than outer lobe. Maxilliped (Fig. 10K) basis rectangular; palp basal article with two stout setae, distal article with apical tuft of setae; endite rectangular, apex with one long seta. Pereopod 1 (Fig. 11A) carpus with longitudinal grooming brush, inner claw of dactylus thin and shorter than outer one. Uropod (Fig. 10D) protopod surpassing distal margin of telson, lateral margin grooved with gland pores; endopod inserted slightly proximally, shorter than exopod.

Male. Pereopods 1–4 (Fig. 11A) merus and carpus with sternal margin covered with long apically trifid setae. Pereopod 7 (Fig. 11B) without distinct sexual modifications. Genital papilla as in Fig. 11C. Pleopod 1 (Fig. 11D) exopod triangular with broadly rounded apex; endopod longer than exopod, distal portion tapering. Pleopod 2 (Fig. 11E) exopod triangular, outer margin slightly concave with four setae on distal part; endopod longer than exopod. Pleopod 3–5 exopods (Fig. 11F–H) triangular, outer margins with 6–7 setae.

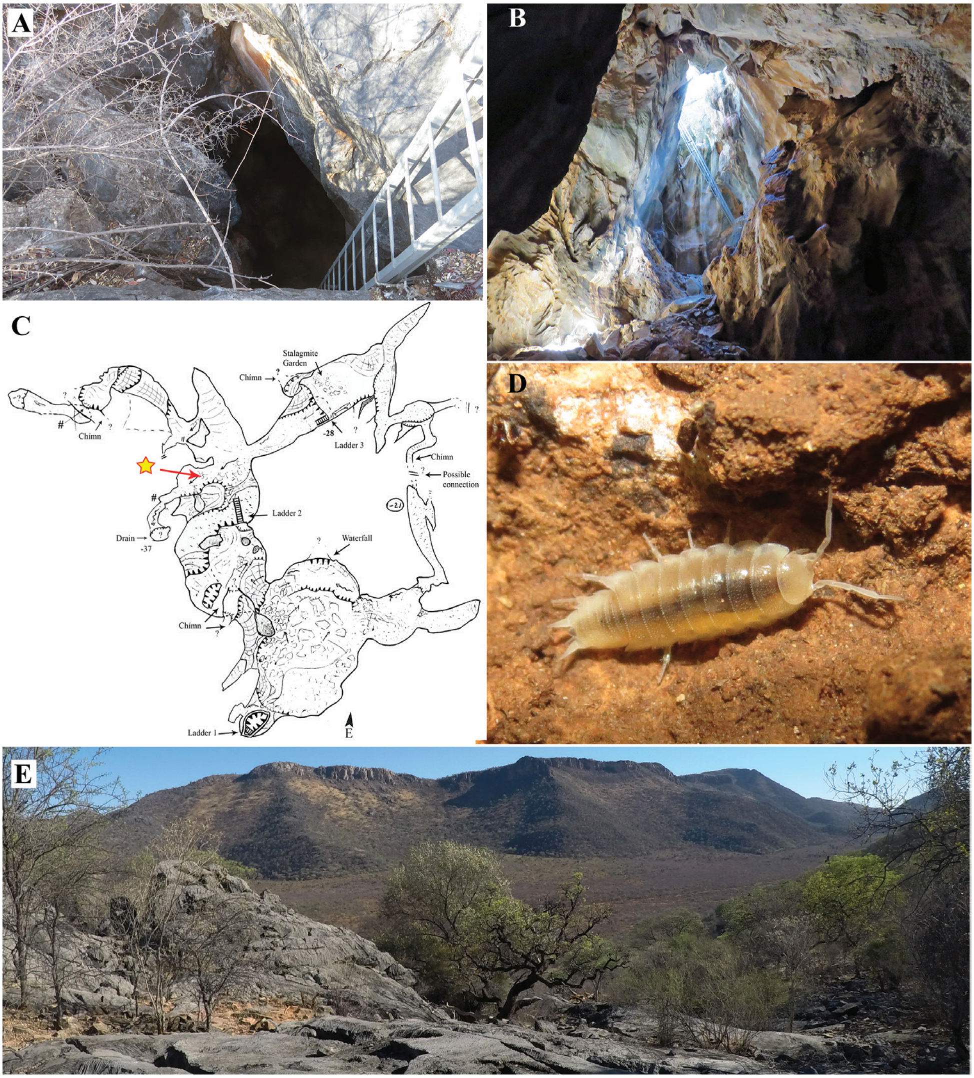

Figure 12. *Niambia namibiaensis* sp. nov. **A** Märchen cave's entrance from outside **B** cave's entrance from inside **C** cave map where the specimens were collected **D** specimen of *Niambia namibiaensis* sp. nov. **E** external environment surrounding the cave.

Etymology. The new species is named after Namibia, where the specimens were collected.

Taxonomic remarks. *Niambia namibiaensis* sp. nov. is easily distinguishable from *N. botswanaensis* sp. nov. and *N. ghaubensis* sp. nov. in having some gland pores on the lateral margins of the pereonites, a rounded apex of telson, a brush of trifid setae on the male pereopods 1–4 merus and carpus, and a different shape of the male pleopod 1. It also differs from *N. botswanaensis* sp. nov. in having the dactylus of pereopods with a thinner inner claw.

Ecological remarks. The Märchen cave and the Ghaub cave are both located in the Otavi Mountains, about 56 km apart. The Märchen cave presents a 12 m vertical shaft at the entrance with the maximum cave depth being 60 m. Farmers installed metal ladders to facilitate access to the cave (Fig. 12A–C). Specimens of *N. namibiaensis* sp. nov. were only found in one of the deepest portions of the cave, under rocks on the floor. This was also the only area with noticeable moisture content (Fig. 12D). Since the visit to the cave occurred in the dry season, most of the cave's substrates were extremely dry. In the humid part of the cave, where the isopods were found, other invertebrates were also observed, including potential predators such as the troglophilic Bothriuridae scorpion *Lisposoma josehermana* Lamoral, 1979 and spiders. The cave was not visited for research purposes during the rainy season and therefore it is not possible to determine if the distribution of this species within the cave is subject to seasonality. However, they may likely present a wider distribution during the wet periods since there are many signs of water drips in the cave. Although other caves were also sampled in the same outcrop, no specimens of *N. namibiaensis* sp. nov. were found. The external environment is well preserved (Fig. 12D) and even with the facilities to access the cave, there are no signs of human impact inside it. This species is not currently considered threatened.

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