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Article

Neocarus kayapo, a new species of Opilioacaridae (Parasitiformes) from Brazilian caves

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ABSTRACT
Neocarus comprises a genus with a wide range of distribution in the Americas, having occurrences from the southern United States to Argentina. In this context, Brazil is a region with great biodiversity where 17 species of this genus have been described up to now. The present description emphasizes the great biodiversity of Opilioacarida found in Brazil, and the new species, *Neocarus kayapo* **sp. nov.** that differs from the others by presenting multiple setae *cht* (2–4) at the base of both male and female chelicera, and also by the presence of two lateral opposite projections on the ovipositor, clearly a set of features that are unique among the species of the genus *Neocarus*.

KEYWORDS: Cerrado, free-living, hypogean, Neotropical region, Opilioacarida, Parasitiformes.

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INTRODUCTION

In recent years, the Brazilian caves have been the target of massive research and one of the results of these studies is the number of new species found and described. These include a great diversity of vertebrate and invertebrate parasitic mites, some free-living and others that present characteristics that may have evolved in response to pressures from the subterranean environment (e.g. Nava *et al.* 2010; Bernardi *et al.* 2012; Narita *et al.* 2013; Costa *et al.* 2019; Gomes-Almeida and Pepato 2021; Bassini-Silva *et al.* 2022; Noei *et al.* 2022). Among the mite groups enjoying increased information obtained by cave inventories, including many of the species described in the most recent studies, is the Opilioacarida (Araújo *et al.* 2020). Currently, three genera and 17 species of Opilioacaridae are known to be present in Brazil (one *Brasilacarus*, one *Caribeacarus*, two *Amazonacarus*, and 14 *Neocarus*), nine of which were described from specimens collected in caves. However, this number of species is only a small fragment of the diversity that is potentially present in the Brazilian territory (Bernardi *et al.* 2020; Araújo *et al.* 2021).

It is expected that with the continuous collection of cave invertebrates, new species of Opilioacaridae will be revealed and described. In this paper, a new species of *Neocarus* Chamberlin and Mulaik, 1942 found in caves in the southeast region of Brazil is described.

MATERIAL AND METHODS

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Study area

The specimens were collected through inventories of the cave fauna in the Araxá, state of Minas Gerais, Brazil (Fig. 6). The invertebrate inventories in Brazilian underground environments have involved a complete cave investigation with detailed visual collections, which is an attempt to make as detailed a sampling of the community as possible (Pellegrini and Ferreira 2012; Simões *et al.* 2015; Wynne *et al.* 2018). In these inventories some *Neocarus* specimens were found, collected with brushes, and stored in 100% alcohol for further studies.

The specimens were collected in the caves designated as CBMM_0001 (19° 41' 60.00" S, 46° 52' 55.92" W, DATUM WGS84) and SB-0009 (19° 40' 54.14" S ,47° 02' 55.88" W), located in the Serra da Bocaina rock formation, represented by an extensive elevated region, sustained by quartzite and mica schists of the Canastra Group (Fig. 1). In addition, the region is part of the Cerrado Biome, and harbors a humid subtropical climate, with cold winters and hot, humid summers, average temperature of 21.1 ℃. The warmest months are September and October (maximun of 28.8 °C), and the coldest months are June and July (minimum of 13.8° C). The rainfall pattern in the area presents an annual average of 1774 mm, June being the driest month, with an average precipitation of 17 mm, while January has an average of 297 mm (INMET 2022).

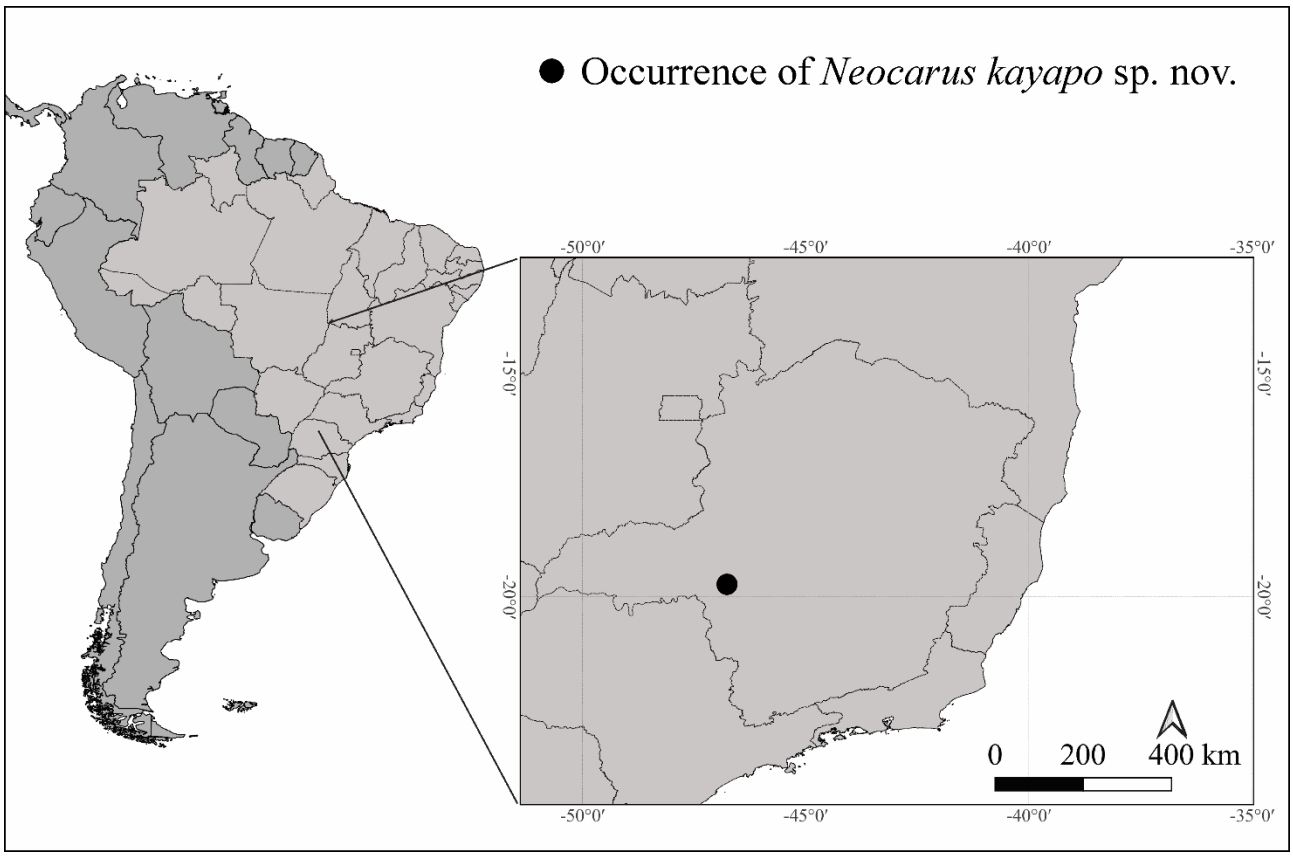

Figure 1. Map with distribution records of the new species, *Neocarus kayapo* **sp. nov.**, found in one cave in Serra da Bocaina, Estado de Minas Gerais, Brazil.

Morphological studies

Due to the large body size the *Neocarus* species, the collected individuals were dissected, cleared with lactic acid (50%) and mounted on permanent slides using Hoyer medium (Walter and Krantz 2009). The slides were kept in a drying oven at 50 ℃ for 12 days and after the drying procedure, morphological study and drawings were prepared using a Leica MDLS phase-contrast microscope (Leica Microsystems, Wetzlar, Germany) connected to a light chamber (drawing tube). The measure-

ments were taken on adult mites using an ocular micrometer device and presented in micrometers (μm).

The nomenclature (terminology) used in the paper follows different authors who have studied the characteristics present in the group in detail: palp and legs (Grandjean 1936; Vázquez and Klompen 2002; Bernardi *et al*. 2014; Araújo *et al*. 2018), subcapitulum and chelicera (van der Hammen 1966), idiosoma and sternal area (Klompen *et al*. 2015). Used abbreviations: F = female; M = male. All specimens are deposited in the following collections: **ISLA** Collection of Subterranean Invertebrates from Lavras, Federal University of Lavras, Biology Department, Zoology Sector, Lavras, Minas Gerais, Brazil; **MZLQ** Acarological Reference Collection, University of São Paulo, Escola Superior de Agricultura 'Luiz de Queiroz', Entomology and Acarology Department, Piracicaba, São Paulo, Brazil.

RESULTS

Family Opilioacaridae With, 1902
Genus: *Neocarus* Chamberlin and Mulaik, 1942

Type species: *Neocarus texanus* Chamberlin & Mulaik, 1942, by original designation.

Neocarus kayapo sp. nov. (Figs. 2–8)

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Diagnosis

Palp tarsus with 5 foliate setae, each of which with 4 or 5 lobes; *st1*, *st2*, *st3* and *st5* tapering and ribbed; female pregenital and genital area with barbed and stout setae, ovipositor without setae, but with two pairs of smooth projections, placed apically and laterally. Male pregenital area with smooth and tapering setae and/or barbed and tapering setae and/or stout and ribbed setae, genital area with barbed and tapering setae. Male and female present multiple setae on basal portion of chelicera (*cht*). Sexual dimorphim presents in male palpal genu with 13–15 smooth setae, and female carrying only 1–3 smooth setae.

Description

Chelicera (Fig. 2) – Basal segment with multiple setae 2–4 (cht_1) (in the same specimen, the number of setae varies, the left chelicera may have more or fewer setae than the base of the right chelicera), fixed digit with 3 setae (ch_1", ch_2' and ch_2"). Dorsal (*id*) and antiaxial lyrifissure (*ia*) well-developed. Fixed digit with 2 teeth, and movable digit with 1 large tooth and a well-developed terminal hook. Movable digit with one small ventral denticles, *ogc* present.

Subcapitulum (Fig. 3) – Males and females with all 4 pairs of paralabial setae present: *pl1* small, conical; With's organ (*pl2*) discoid, membranous; rutella (*pl3*) inserted dorso-laterally, with 5 distinct teeth; *pl4* very small, conical, inserted dorsally on subcapitulum. All 4 pairs of circumbuccal setae (*cb*) with bifurcate tips; and 9–11 median and subcapitular (*vm* (in part), *lvm*, *ldm*, *vp*, *lvp*) setae, in female one pair of circumbuccal setae with a rounded tip (*vp*). Setae *vm1* robust with a rounded tip. Lateral lips with distinct canals (*dl1*, *dl2*) and their orifices (*ogl1*, *ogl2*).

Palp (Figs. 4–5) – Trochanter with 4 ribbed setae (= *r*-type). Femur with 12–15 *r*-type, 7–13 *p*-type setae and 1–2 smooth setae. Genu with dimorphism, male carrying 46–49 *r*-type, 0–1 *p*-type setae and 12–15 smooth (*s*-type) setae, and female carrying 39 *r*-type, 1 *p*-type setae and just 1 smooth (*s*-type) setae (fewer setae than male). Tibia with 35–42 *r*-type and 21–26 *s*-type (smooth or lightly barbed) setae. Tibia and tarsus partially fused.

In both sexes, tarsus setation including 4–5 *d* (leaf-like), and approximately 14–16 *ch*, 9–11 *sm* (one smooth and straight), 3–5 *v1*, and 1–2 *v2* setae plus 3 solenidia (= *s*-type sensilla). Leaf-like setae

(*d*-type) with 3–4 large and distinct foliated lobs (the basal lob is smaller and triangular in shape). Modified *sm3*-type sensilla on male palp tarsus absent. Lyrifissures *iπ* and *iα* distinct. Pretarsus with a pair of well-developed sessile claws.

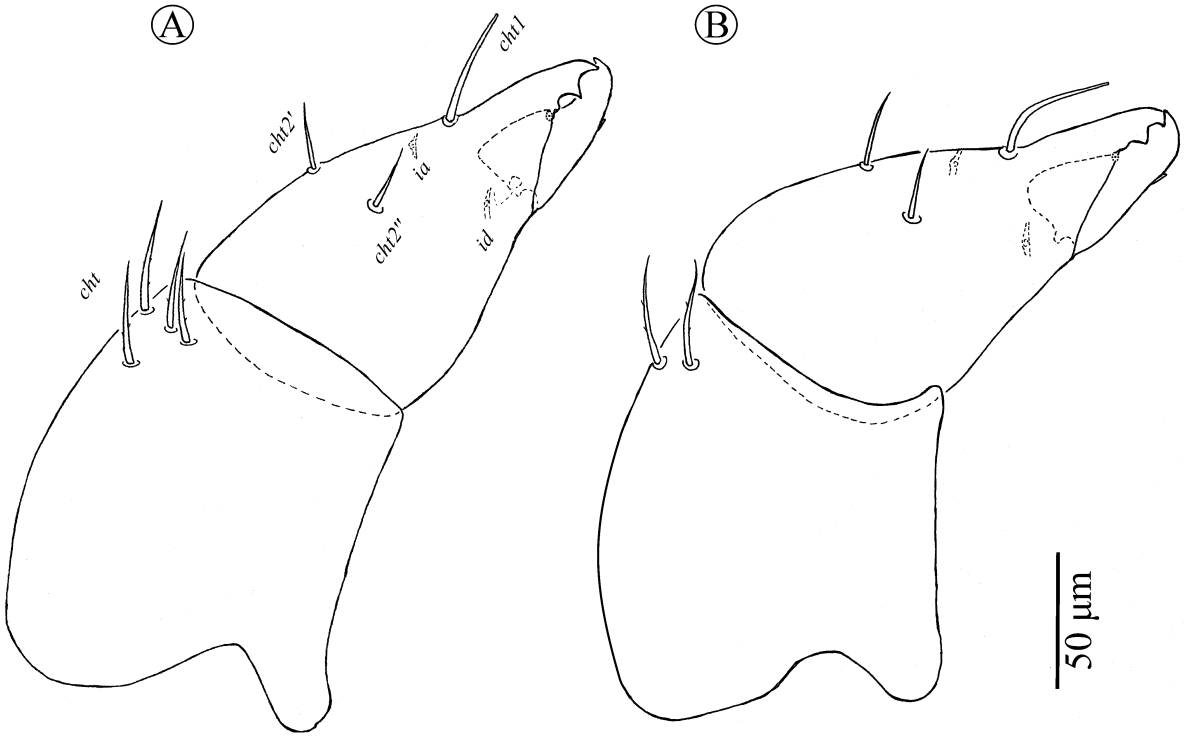

Figure 2. *Neocarus kayapo* **sp. nov.** – Chelicera: **A.** Male; **B.** female. Abbreviations: *cht* = basal segment seta, *ch* = cheliceral setae, *id* = dorsal lyrifissure, *iα* = antiaxial lyrifissure.

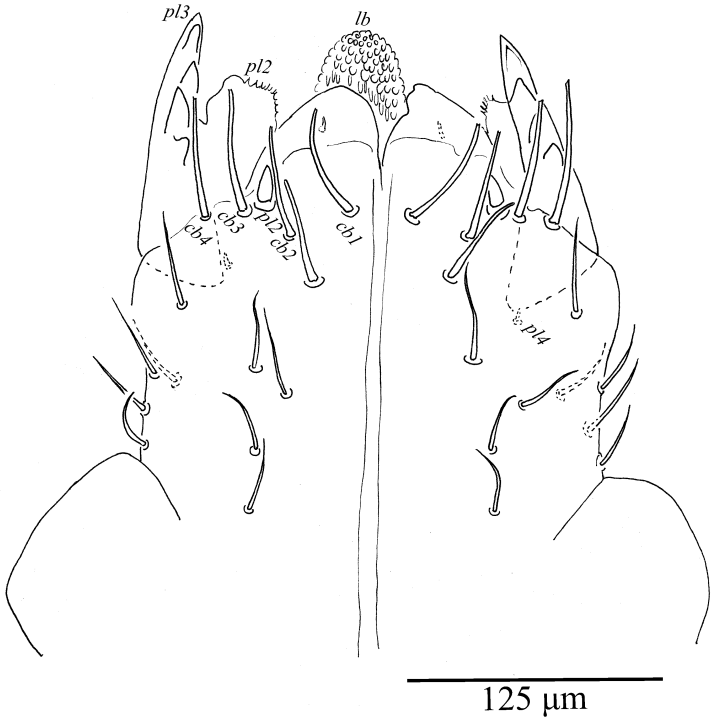

Figure 3. *Neocarus kayapo* **sp. nov.** – Male subcapitulum. Abbreviations: *cb* = circumbuccal setae, *pl* = paralabial setae, *lb* = labrum.

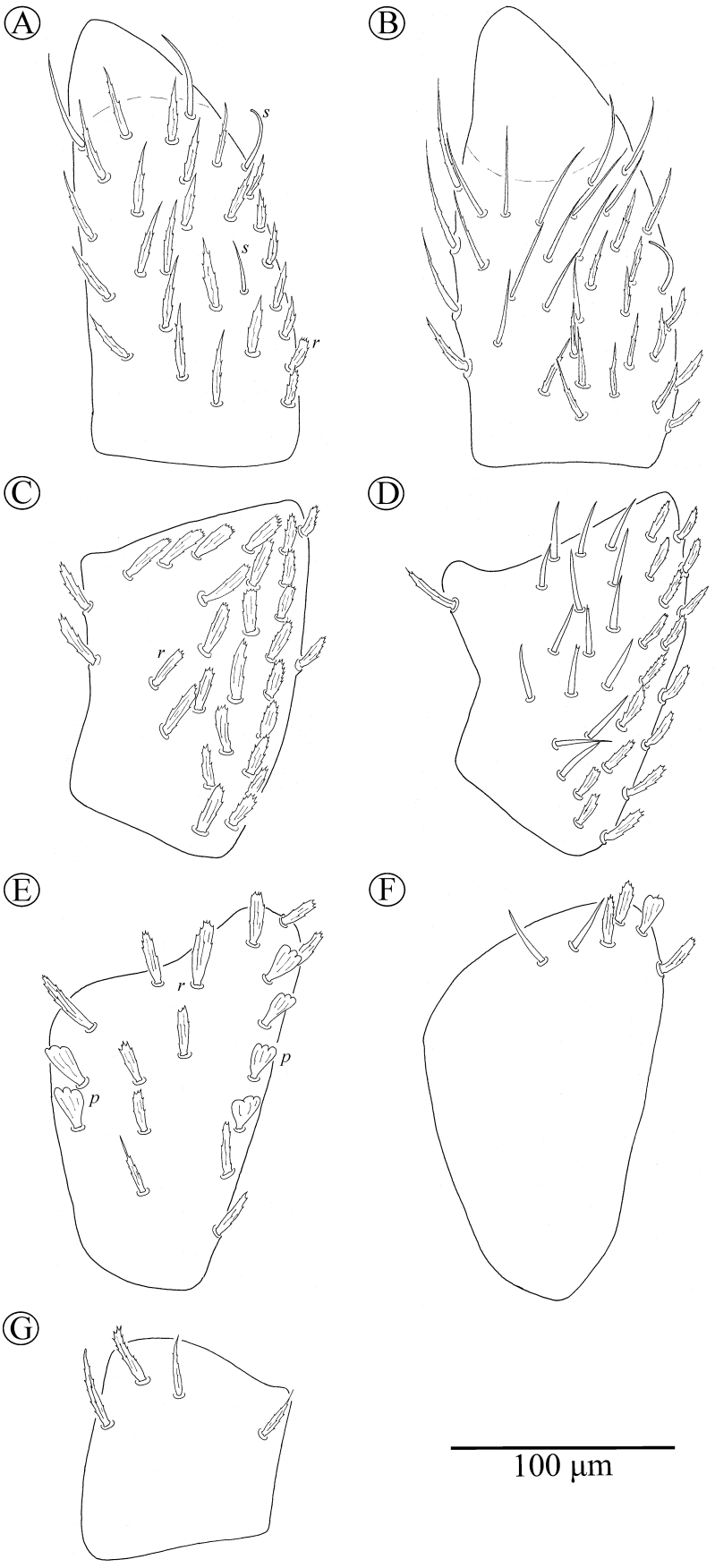

Figure 4. *Neocarus kayapo* **sp. nov.** (male palp) – Palpal tarsus is not represented in detail. **A–B.** Tibia; **C–D.** Genu; **E–F.** Femur; **G.** trochanter. Abbreviations: *p* = papilliform setae, *r* = ribbed setae, *s* = smooth setae.

Idiosoma – Dark blue Body and violet stripes on legs. Body often with brownish background reflecting ingested food.

Prodorsal shield – Anterior dorsal shield normal, with approximately 95–115 papilliform setae. Sexual dimorphism absent. Both sexes with two pairs of eyes, one pair of lyrifissures (probably *j*) observed. Rostrum rounded.

Opisthosoma – Dorsal idiosomal segments VII to XVI, without setae but with numerous lyrifissures arranged in transverse rows. Preanal segment (XVII) with 1 dorsal seta, plus two lateroventrals. Anal valves (segment XVIII) each with 8–11 setae.

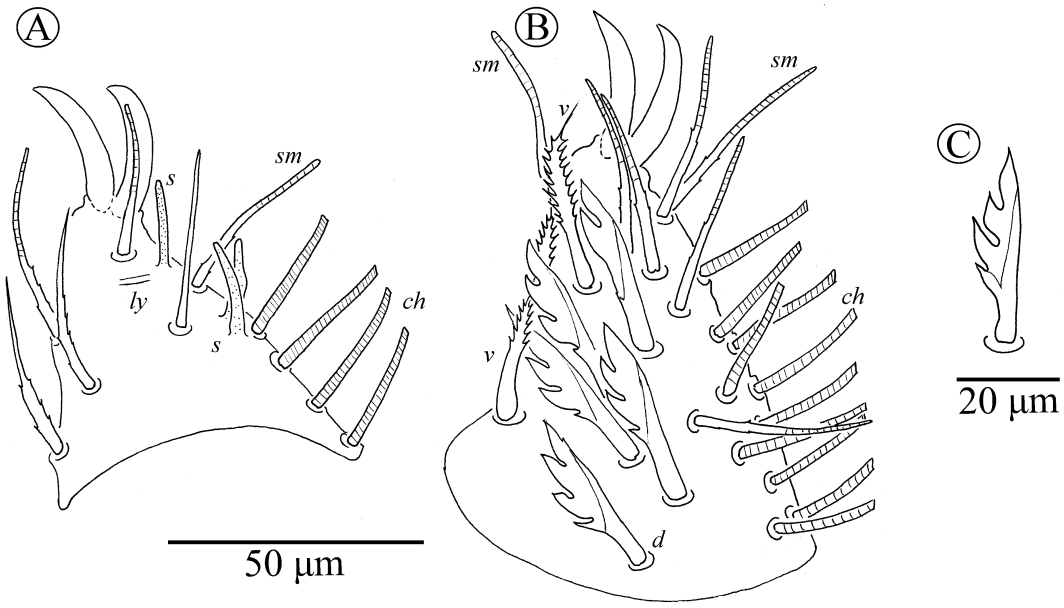

Figure 5. *Neocarus kayapo* **sp. nov.** – Male palp tarsus axial (A), antiaxial (B) view and detail of *d*-type setae (C).

Figure 6. *Neocarus kayapo* **sp. nov.** – specimens alive observed in a hypogean environment, cave CBM-0001, municipality of Araxá, Brazil.

Sternapophyses – Each digitiform structure with 2 pairs of setae, 1 small at tip and 1 long, barbed positioned more basally.

Sternitogenital region (Figs. 7–8) – Sternal verrucae in adults each with 1 long, tapering (*St1*), and 2–3 ribbed and barbed setae. Remaining sternal area with 2 pairs of tapering (*St2* and *St3*) and 4–6 pairs of long, ribbed and barbed setae, and 3 pairs of lyrifissures (two pairs large, the third smaller; all different in shape and size from "standard" opisthosomal lyrifissures). Setae *St2* slightly longer than *St3*. Pregenital capsules each with 1 long tapering seta (*St5*) and 4–6 ribbed setae. Pregenital area in male with, 4–5 ribbed setae with thin or blunt tip, genital area with 5–8 setae variable in shape, some of them smooth and pointed or lightly to strong ribbed and tapering, and blunt and ribbed setae. In females, pregenital with 2 ribbed and blunt setae and genital 6 ribbed and blunt setae. Male genital valves rectangular to rounded in shape. Ovipositor observed evaginated and in good condition, consisting of a tube-like structure with a central opening, with 2 pairs of small finger-like projections positioned laterally at the tip (Fig. 7H). Small gland-like structures present in the median portion. Male glands consist of 2 pairs of ovoid structures, one larger and one smaller, without reel-like structures.

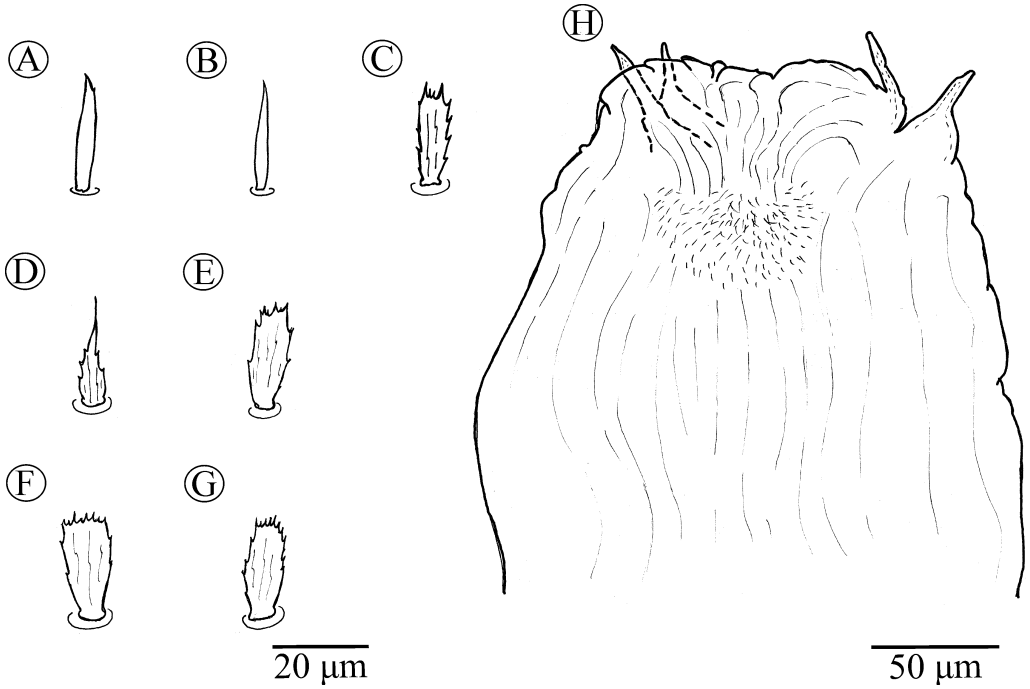

Figure 7. *Neocarus kayapo* **sp. nov.** – **A–D.** Male genital setae; **E.** Male pregenital seta; **F.** Female genital seta; **G.** Female pregenital setae; **H.** Ovipositor.

Legs – Leg I longer than others. Telotarsus I has a highly modified group of dorsal setae located in the apical portion, close to the tarsal claws; *ω1* conical, *ω2* ligulate, *ω3* subulate acuminate, *ω4* acicular; *ζ1* small with crown-like tip inserted close to sensilla group and *ζ2* filiform with bifid tip. Acrotarsus II with a ribbed and bifurcate seta, one small solenidion (w_a), and one long and smooth sensillum (probably also a solenidion) in dorsal portion. Acrotarsus III and IV carry on the dorsal portion only 3 long and barbed setae. Additionally, ventral portion of the acrotarsi II-IV with 3–4 pairs of setae. In addition to the standard set of 1 pair ventro-lateral and 1 dorso-lateral pair of setae, lateral portion of the acrotarsi II-IV with 2 pairs of setae. All pretarsi with one pair of claws and 2 pairs of setae, one pair long and curved, the other smaller and straight. Pretarsal ambulacrum rounded and smooth. Coronidia are present just on basitarsi of legs II to IV. Coronidia are short, smooth and strongly curved mid-dorsally.

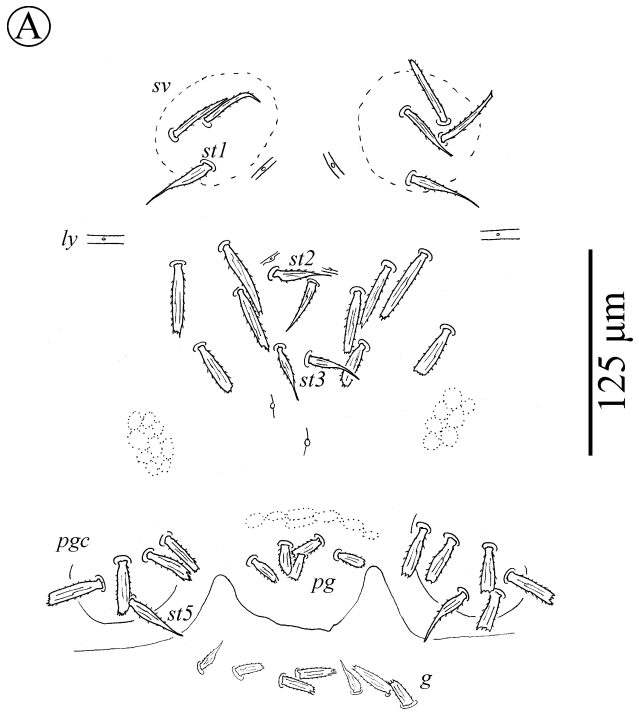

Figure 8. *Neocarus kayapo* **sp. nov.** (male) – Sternitogenittal area. Abbreviations: *ly* = prodorsal lyrifissure, *sv* = sternal verrucae, *pgc* = pregenital capsule, *pg* = pregenital area, *g* = genital area.

Measurements – Female; Idiosoma: length 2307, width 1088; palp 772.8; chelicera length: basal segment 233, fixed digit 266, movel digit 83; leg I (not present); leg II: 2073; leg III: 2187; leg IV: 3078. **Male;** Idiosoma: length 2082–2106; palp: 669–775; chelicera length: basal segment 206–273, fixed digit 256–280, movel digit 86–96; leg I 3382–3700; leg II: 2027–2136; leg III: 2151–2298; leg IV: 3131–3222.

Material examined

Holotype: female, deposited at ISLA/UFLA (nº 79115): Brazil, Minas Gerais State, Araxá city, CBMM_0001 (19° 41' 60.00" S, 46° 52' 55.92" W, DATUM WGS84), 13 Jan. 2021, Alves, JP. Paratypes: three males, deposited at ISLA/UFLA (nº 79115): Brazil, Minas Gerais State, Araxá city, CBMM_0001 (19° 41' 60.00" S, 46° 52' 55.92" W, DATUM WGS84), 15 May 2021, Alves, JP; one male, deposited at MZLQ/ESALQ: Brazil, Minas Gerais State, Araxá city, SB-0009 (19° 40' 54.14" S, 47° 02' 55.88" W), 12 November 2022, Alves, JP.

Etymology

The species was named in honor of the indigenous people Kayapó, originally well distributed in the surrounding areas of the type locality.

Remarks

Neocarus kayapo **sp. nov.** presents a great variation of setal shape in the male genital area, similar to *N. spelaion* Bernardi and Borges-Filho, 2018, *N. simmonsi* Bernardi, Zampaulo & Oliveira, 2020 and *N. missiones* Vázquez, Bernardi & Klompen, 2020, but it differs from them by the presence of setae on the female pregenital area. In addition, *N. kayapo* **sp. nov.** differs from other *Neocarus* species by the presence of multiple setae on the base of the chelicera in male and female.

The ovipositor in this family is a unique a characteristic structure useful to differentiate Opilioacarida species. *Neocarus kayapo* **sp. nov.** presents a unique ovipositor cylindrical shape with 2 pairs of small finger-like projections.

Identifications of *Neocarus* species generally requires consideration of multiple characters simultaneously. Table 1 summarizes the comparative data and is provided to assist in the identification of the newly described species.

Table 1. Comparative setal patterns and shape for the pregenital and genital region, ovipositor and palp of *Neocarus* adults.

Occurence	species/ subspecies	female		male		palp		ovipositor	others
		pregenital region (nº. and type of setae)	genital/ eugenital region (nº. and type of setae)	pregenital region (nº. and type of setae)	genital region (nº. and type of setae)	*ch*-type (nº. of setae)	*d*-type (nº. of setae)	morphology	
North America									
USA	*Neocarus texanus*	2 st/r	nude	4–6 st/r	8–9 sh	10–14 (21*)	5	simple, without setae	–
Mexico	*Neocarus nohbecanus*	nude	nude	4–5 st/r	5–7 st/r	17–19	4	with 7–12 long lightly barbed setae around the ovipore	–
Mexico	*Neocarus siankaanensis*	nude	nude	2 st/r	4 st/r	14–15	5	simple, without seate	–
Mexico	*Neocarus bajacalifornicus bajacalifornicus*	2 st/r	nude	5–8 (13a) st/r	7–8 (11a) st/r	14–18 (21a)	5	with multiple (25) setae around the ovipore	–
Mexico	*Neocarus bajacalifornicus chamelaensis*	2–3 st/r	nude	4–5 st/r	4–6 st/r	16	5	with multiple setae around the ovipore	–
Mexico	*Neocarus calakmulensis*	2–3 st/r	nude	2–6 st/r	3–8 st/r	17	5	simple, without setae	–
Mexico	*Neocarus veracruzensis*	2 st/r	nude	6–8 st/r, 0–1 s	6–8 st/r	13	5	simple, without setae	–
Mexico	*Neocarus comalensis*	3 st/r	nude	5–7 st/r	6–10 st/r	14–18	5	with numerous large and thick terminal setiform sensilla	–
Mexico	*Neocarus chactemalensis*	nude	nude	4–6 st/r	4–6 st/r	11–13	4	with 11 long, serrate, terminal setiform sensilla with bifurcate tips	–
Central America									
Nicaragua	*Neocarus nicaraguensis*	2–5 st/r	nude	2–7 st/r	3–6 st/r	18–22	5–6	with a pair of small setae near to ovipore	–
Cuba	*Neocarus orghidani*	nude	nude	4–5 st/r	5–7 st/r	20–24	4	–	–

* number of setae in super adults. ** The description of *Neocarus ojastii* does not provide sufficient detail for an adequate comparison.
Setae type: sh: smooth setae; st/r: stout and ribbed setae; tp: tapering; tp/b: tapering and barbed setae; wb: weakly barbed setae.

Table 1. Continued.

Occurence	species/ subspecies	female		male		palp		ovipositor	others
		pregenital region (nº. and type of setae)	genital/ eugenital region (nº. and type of setae)	pregenital region (nº. and type of setae)	genital region (nº. and type of setae)	*ch*-type (nº. of setae)	*d*-type (nº. of setae)	morphology	
Belize	*Neocarus belizensis*	nude	nude	2–3 st/r	4–5 st/r	17–21	5–6	with 3 terminal lobes	–
South America									
Venezuela	*Neocarus ojastii***	nude	nude	6–9?	13 st/r	–	–	no information	–
Brazil	*Neocarus caipora*	nude	8–12 sh	4–8 st/r	5–8 tp/r	15–16	6	simple, without setae	triangular male genital valves
Brazil	*Neocarus chimera*	nude	6–7 sh	6–8 tb/b or 2–5 st/r	5–10 sh	19–20	7–9	simple, without setae	
Brazil	*Neocarus coronatus*	nude	6–8 tp/b	1–7 st/r	5–15 tp/r	18–25	4	with 3 pairs of smooth digitiform projections	anterior dorsal shield with higher setal density
Brazil	*Neocarus jonasi*	nude	14–21 sh	7–12 tb/b or 2 st/r	9–19 sh	14–23	5–7	simple, without setae	–
Brazil	*Neocarus kaiapo*	2 st/r	6 st/r	4–6 tb/b or st/r	5-8 sh or st/r	14-16	4–5	with 2 pairs of small finger-like projections positioned laterally at the tip	basal segment with multiple setae 2-4 (cht_1)
Brazil	*Neocarus marambaia*	nude	6 sh	5–7 st/r	8–11 tb/b	12–16	4	simple, without setae	–
Brazil	*Neocarus peruassu*	nude	8–9 tb/b	2–5 tb/b	6–11 tb/b	19–20	6–7	simple, without setae	Male palpal genu with distinct dimorphic setae
Brazil	*Neocarus potiguar*	1 tp/r	4–8 sh	5 st/r	7–10 st/r	25–27	5–6	simple, without setae	–

* number of setae in super adults. ** The description of *Neocarus ojastii* does not provide sufficient detail for an adequate comparison.
Setae type: sh: smooth setae; st/r: stout and ribbed setae; tp: tapering; tp/b: tapering and barbed setae; wb: weakly barbed setae.

Table 1. Continued.

Occurence	species/ subspecies	female		male		palp		ovipositor	others
		pregenital region (nº. and type of setae)	genital/ eugenital region (nº. and type of setae)	pregenital region (nº. and type of setae)	genital region (nº. and type of setae)	*ch*-type (nº. of setae)	*d*-type (nº. of setae)	morphology	
Brazil	*Neocarus proteus*	2–5 st/r	4–6 wb	2–5 st/r	3–5 sh	12–13	5–6	simple, without setae	Tíbia I without smooth seate
Brazil	*Neocarus setilatus*	nude	13–21 sh	3–6 st/r	4–6 st/r	11–15	5	simple, without setae	–
Brazil	*Neocarus spelaion*	nude	10–12 sh	9–12 sh or tp/r	7–11 sh and/ or tp/r	14–18	5–6	simple, without setae	–
Brazil	*Neocarus simmonsi*	nude	6–12 st/b or tp/b	4–10 sh or tp/r or st/r	4–10 sh or tp/r or st/r	15–17	6	simple, without setae	–
Argentina	*Neocarus platensis*	0	4–10 sh	6 st/r	5 sh	22–25	5–6	simple, without setae	–
Argentina	*Neocarus misiones*	nude	12–13 tp/b	7–9 st/r and/ or tp/b	12–13 tp/b	15	6	with three very distinct rounded terminal lobes and a bilobed membranous	–
Argentina	*Neocarus entrerios*	nude	6–12 sh	6–10 st/r	8–10 tp/r	20	6	with a pair of papillate, retrorse spines connected to a papillate ridge	–
Uruguay	*Neocarus paraplatensi*	nude	13 sh	4–6 st/r	5–7 sh	17–20	5–6	with 4 pairs of smooth forked digitiform projections and a rugose basolateral patch	–

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Neocarus kayapo، گونهٔ جدیدی از Opilioacaridae (Parasitiformes) از غارهای برزیل

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چکیده

Neocarus شامل یک جنس با طیف گسترده‌ای از پراکنش در قاره آمریکا است که از جنوب ایالات متحده تا آرژانتین وجود دارد. در این زمینه، برزیل منطقه‌ای با تنوع زیستی زیاد است که تاکنون ۱۳ گونه از این جنس توصیف شده است. توصیف حاضر بر تنوع زیستی زیاد Opilioacarida یافت شده در برزیل تاکید می‌کند و گونهٔ جدید ***Neocarus kayapo* sp. nov.** با داشتن چند موی *cht* (٤-۲) در پایه کلیسر هر دو کنهٔ نر و ماده، و همچنین با وجود دو برجستگی مقابل پهلویی روی تخمگذار، به وضوح با مجموعه‌ای از ویژگی‌های منحصر به فرد در بین گونه‌های جنس *Neocarus* متفاوت است.

واژگان کلیدی: سرادو، زندگی آزاد، زیرزمینی، ناحیهٔ نوتروپیکال، Opilioacarida، Parasitiformes.

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