

Cladistic analysis of the Brazilian troglobitic harvestmen genus *Iandumoema* Pinto-da-Rocha (Opiliones: Gonyleptidae) with the description of three new species: a brief exercise over the use of troglomorphisms in cladistic analysis

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Abstract. From an ecological and evolutionary standpoint, troglobitic organisms are of special interest because they have evolved in, and are restricted to, the subterranean environment. *Iandumoema* Pinto-da-Rocha, 1997 stands out for being the only Brazilian harvestmen genus with more than one troglobitic species, with three species described from caves in Minas Gerais state. Traditionally, testing the monophyly of troglobitic groups is more challenging than testing groups that do not include troglobites. Many of their shared features might be the result of convergence or parallelism imposed by the cave environment, such as the absence of light, limited and infrequent availability of food resources and low population density, among others. In the case of *Iandumoema*, this becomes even more difficult because the genus is currently included in the species-rich and polyphyletic subfamily Pachylinae. This study tested the monophyly of this troglobitic genus and proposed the first phylogenetic hypothesis for *Iandumoema* based on cladistic analysis using morphological data. The analysis included all described species of *Iandumoema* and three new troglobitic species: *I. cuca*, sp. nov. (type locality: Itacarambi, Gruta da Água do João Ferreira); *I. gollum*, sp. nov. (type locality: Presidente Juscelino, Lapa D'Água); and *I. stygia*, sp. nov. (type locality: Montes Claros, Gruta do Cedro). The matrix comprises 79 characters and 28 terminal taxa: six species of *Iandumoema*; 14 of Pachylinae; six from other Gonyleptidae subfamilies; one species of Cosmetidae; and one of Metasarcidae. The cladistic analysis resulted in one parsimonious tree (339 steps, consistency index = 0.35, retention index = 0.56). *Iandumoema* is a monophyletic and well supported genus, nestled among Brazilian 'Pachylinae'. Three new species are described and an identification key and ecological remarks for all six species of the genus *Iandumoema* is provided.

Additional keywords: Arachnida, caves, Neotropical fauna, taxonomy.

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Introduction

Gonyleptidae Sundevall, 1833 is the largest family of harvestman in the Neotropical region, with 16 subfamilies and 830 species in 272 genera (Kury 2013, 2016). Pachylinae is the richest subfamily, including ~400 species (Kury 2016) with four scutal areas and lacking the diagnostic characters of the other subfamilies (Hara *et al.* 2018). It is polyphyletic, and most of the genera are poorly described for modern standards (Pinto-da-Rocha *et al.* 2014), which hinders comparative studies, including phylogenetic ones.

Pachylinae also includes most of the Brazilian cave-dwelling species (more than 50 from 155 recorded species; de Ázara and Ferreira 2018).

The only non-monotypic cave-restricted Pachylinae genus is *Iandumoema* Pinto-da-Rocha, 1997, which is restricted to limestone caves in Minas Gerais state, Brazil. It was proposed by Pinto-da-Rocha (1997) to include *I. uai* from Gruta Olhos D'Água Cave, Itacarambi, Minas Gerais, and was the third-known troglobitic harvestmen species from Brazil (the first being *Spaeleoptes spaeleus* H. Soares, 1966, and the second,

Pachylospeleus strinatii Šilhavý, 1974). Pinto-da-Rocha (1997) tentatively placed it in the Pachylinae based on a classification proposed by Roewer (1913). However, he refrained from proposing further phylogenetic relationships owing to the lack of data on the genital features of other Pachylinae genera and the unarmed nature of the dorsal scutum and free tergites. Twelve years later, Hara and Pinto-da-Rocha (2008) described *I. setimapocu* from Lapa do Zú Cave, São João da Lagoa (erroneously cited as Coração de Jesus in the original description), Minas Gerais. In that article, the authors proposed that the distribution of the genus was restricted to northern Minas Gerais. In 2015, Pinto-da-Rocha *et al.* described the first eyeless species of the genus, *I. smeagol*, from Toca do Geraldo Cave and Lapa do Santo Antônio Cave, both in Monjolos, Minas Gerais. They suggested that *I. smeagol* and *I. setimapocu* might be closely related, but stressed the need for a proper cladistic analysis to corroborate this relationship. Later papers related to *Iandumoema* focused mainly on ecological and conservation aspects, highlighting their vulnerability to anthropogenic actions.

Currently, *Iandumoema* is composed of three species (Pinto-da-Rocha *et al.* 2015), all of them troglobitic, that is, restricted to subterranean environments. Despite the small number of species, the phylogenetic relationships and monophyly of *Iandumoema* remain untested.

One difficulty in including troglobitic taxa in cladistic analysis might be related to the apparent controversy about using troglomorphisms (or troglobiomorphisms, i.e. apomorphic character states related to the hypogean life; Trajano 2012) as characters. According to Marques and Gnaspini (2001), the inclusion of characters subject to parallel evolution would result in error and should be treated in a different manner analytically. Desutter-Grandcolas *et al.* (2003), as well as other researchers, heavily criticised the approach of Marques and Gnaspini (2001). The criticism was based on the different treatment of those characters before analysis, as well as some technical flaws (Harris *et al.* 2003). Desutter-Grandcolas *et al.* (2003) recommended evaluating the outcome of analysis including *v.* excluding the characters associated with troglomorphism.

The few examples of cladistic analysis including troglobitic Neotropical harvestmen using morphological data are Pinto-da-Rocha (2002) (with *Pachylospeleus strinatii* Šilhavý, 1974) and, recently, Acosta (2019) (with *Otilioleptes marcelae* Acosta, 2019). Unfortunately, Pinto-da-Rocha (2002) did not provide the matrix or the tree search routine; hence, his treatment of troglomorphisms is unknown. Acosta (2019), on the other hand, included a matrix that is a different version of that made by Kury and Villarreal (2015). Nevertheless, no character related to troglomorphism was explicitly included or received special concern, since his focus was to elucidate the placement of the new taxon in Gonyleptoidea. In the present study, we used the Desutter-Grandcolas *et al.* (2003) approach to test the monophyly of *Iandumoema* and proposed a phylogeny using the cladistic methodology for the first time. Herein, we provide a diagnosis and ecological remarks for all *Iandumoema* species and describe three new species.

Materials and methods

Abbreviations of the repositories cited include the following.

ISLA, Coleção de Invertebrados Subterrâneos de Lavras, Universidade Federal de Lavras, Lavras, Minas Gerais

ISNB, Institut Royal des Sciences Naturelles de Belgique

MNRJ, Museu Nacional da Universidade Federal do Rio de Janeiro, Rio de Janeiro

MZSP, Museu de Zoologia, Universidade de São Paulo, São Paulo

SMF, Naturmuseum Senckenberg Sektion Arachnologie, Frankfurt am Main.

Abbreviations used in tables include: Fe, femur; Mt, metatarsus; Pa, patella; Ta, tarsus; Ti, tibia; and Tr, trochanter. The following abbreviations are used in synonymies: cat, catalogue; cit, citation; dis, notes on geographical distribution; and sys, systematic note. We use the notation #X(Y) in results, where #X means the number of the character, and (Y), the character state.

All types designated here as destroyed were lost in a fire on 2 September 2018 along with the bulk of the arachnological collection of MNRJ (Kury *et al.* 2018). There is no formal impediment according to International Commission on Zoological Nomenclature rules to describing a species for which the holotype was lost before publication. Article 73.1.4. (International Commission on Zoological Nomenclature 1999) states that 'Designation of an illustration of a single specimen as a holotype is to be treated as designation of the specimen illustrated; the fact that the specimen no longer exists or cannot be traced does not of itself invalidate the designation'. The International Commission on Zoological Nomenclature (2017) provides more recommendations and explanation regarding this matter. For further discussion on this topic, see Marshall and Evenhuis (2015), Krell and Marshall (2017) and references therein.

We used the standard names and numbers of the 267 colour centroids of the National Bureau of Standards Inter-Society Colour Council Colour System (see <http://people.csail.mit.edu/jaffer/Color/Dictionaries#nbs-isc>, accessed 2 November 2018) in the (re)descriptions as described in Kury and Orrico (2006). Scanning electron microscopy was carried out with a JSM-6390LV (JEOL, Tokyo) at the Center for Scanning Electron Microscopy of Museu Nacional, Universidade Federal do Rio de Janeiro, with an accelerating voltage of 10 kV after sputter-coating with gold-palladium.

Topological nomenclature and integumentary ornamentation follows Acosta *et al.* (2007). Terminology for the outline of the dorsal scutum follows Kury and Medrano (2016) and for the macrosetae and microsetae of the penis ventral plate follows Kury and Villarreal (2015) and Kury (2016). Only characteristics different from those of males are mentioned in the female descriptions. Tarsal segmentation: order is given from left to right when individual counts are provided for the numbers of tarsomeres in tarsus I to IV. All measurements are in millimetres (except for penis). Setiferous tubercles (i, small; I large) on pedipalps are given from proximal to distal order.

Geographic coordinates from our localities are in decimal degrees (datum: World Geodetic System WGS84), whereas those from literature are provided verbatim.

Photographs were taken with a Cybershot DSC-V1 camera (Sony, Tokyo, Japan) attached to the stereomicroscope. The software package CombineZP (see <http://www.hadleyweb.pwp.blueyonder.co.uk/CZP/News.htm>, accessed 1 November 2018) by Alan Hadley was used to create composite images with extended depth of field by combining several images taken at different focal planes. The resulting images were edited with Adobe Photoshop CS5 (Adobe, San Jose, CA). The plates were prepared in CorelDraw X7 for photographs (see <https://www.coreldraw.com>).

Taxon sampling

The ingroup is composed of the three described species of *Iandumoema* plus the three new species described herein. The outgroup is composed of 20 species representing eight subfamilies of Gonyleptidae, one species of Cosmetidae and one species of Metasarcidae, both families close to Gonyleptidae (Pinto-da-Rocha *et al.* 2014). The list of species used as outgroup in the analysis is shown in Table 1. The outgroup selection is based on Pinto-da-Rocha *et al.* (2014) as well as taking into account (1) morphological resemblance to *Iandumoema* and (2) morphological diversity of the revised and unrevised subfamilies.

Cladistic analysis

The character matrix is composed of 79 characters (Appendix 1) for 28 taxa. It was constructed in MESQUITE (ver. 3.5, W. P. Maddison and D. R. Maddison, see <http://www.mesquiteproject.org>, accessed 10 December 2018). Winclada

(ver. 1.00.08, K. C. Nixon, see <http://www.cladistics.com>, accessed 30 January 2019) was used for characters state optimisations and CorelDraw X7 (M. Bouillon and P. Beirne, Corel Corporation, Canada; see <https://www.coreldraw.com>) for tree editing. The annotated list of characters is shown in Box 1. Characters in the matrix correspond to males except where otherwise stated, because females are morphologically more homogeneous than males, frequently lacking the diagnostic dimorphic features present in males, such as leg IV armature (Mendes 2011). Character statements follow the logic of neomorphic and transformational structure proposed by Sereno (2007). The characters were treated as unordered, and the polarisation was indicated upon rooting the diagrams from the outcome of the parsimony analysis including all taxa (Nixon and Carpenter 1993).

Trees were searched in TNT (ver. 1.5, see <http://www.lillo.org.ar/phylogeny/tnt/>, accessed 30 January 2019; Goloboff *et al.* 2008) using parsimony under equal and implied weights (Goloboff 1993) with the traditional search option. Heuristic searches consisted of 1000 replicates of random addition sequences followed by tree bisection–reconnection branch swapping holding 100 trees per iteration. Two measures of group support were calculated: Goodman–Bremer support (GBS) (Goodman *et al.* 1982; Bremer 1988; Grant and Kluge 2008) and symmetric resampling (1000 replicates, cut = 50, change probability = 33) (Goloboff *et al.* 2003). We used space plots ('Navajo rugs') to summarise the monophyly (or not) of a given clade in the trees retrieved from the analysis under implied weight with different concavity values ($k = 1, 3, 6, 9, 11, 15$ and 20). These plots work similarly to sensitivity analysis, aiding to evaluate the stability of the results (see Mendes 2011 and references therein).

Table 1. List of the species and their respective vouchers used as outgroups in the cladistic analysis

Family	Subfamily	Species	Depository
Cosmetidae	Cosmetinae	<i>Cynorta conspersa</i>	MNRJ 6098
Gonyleptidae	Caelopyginae	<i>Ampheres leucopheus</i>	MZSP 751
Gonyleptidae	Goniosomatinae	<i>Goniosoma varium</i>	MNRJ 27174
Gonyleptidae	Gonyleptinae	<i>Gonyleptes horridus</i>	MNRJ 4438
Gonyleptidae	Hernandariinae	<i>Acrogonyleptes spinifrons</i>	MZSP 1035
Gonyleptidae	Pachylinae	<i>Carlotta serratipes</i>	MNRJ 6394
Gonyleptidae	Pachylinae	<i>Daguerreia inermis</i>	MZSP 10564
Gonyleptidae	Pachylinae	<i>Discocyrtus invalidus</i>	MZSP 1060
Gonyleptidae	Pachylinae	<i>Discocyrtus prospicius</i>	MNRJ 5517
Gonyleptidae	Pachylinae	<i>Eusarcus catharinensis</i>	MZSP 431
Gonyleptidae	Pachylinae	<i>Giupponia chagasi</i>	MNRJ 4640
Gonyleptidae	Pachylinae	<i>Guaraniticus lesserti</i>	MNRJ 27174
Gonyleptidae	Pachylinae	<i>Hypophyllonomus longipes</i>	ISNB
Gonyleptidae	Pachylinae	<i>Metagyndes martensii</i>	MNRJ 4328
Gonyleptidae	Pachylinae	<i>Neopachylus bellicosus</i>	SMF RI 786
Gonyleptidae	Pachylinae	<i>Pachylus chilensis</i>	MNRJ 2132
Gonyleptidae	Pachylinae	<i>Paradisococyrtus trochanteralis</i>	SMF RII 997/54
Gonyleptidae	Pachylinae	<i>Pseudogyndesoides latus</i>	MZSP 707
Gonyleptidae	Pachylinae	<i>Triglochynura curvispina</i>	MZSP 16336
Gonyleptidae	Progonyleptoidellinae	<i>Progonyleptoidellus striatus</i>	MNRJ 6809
Gonyleptidae	Sodreaninae	<i>Sodreana sodreana</i>	MZSP 416
Metasarcidae	–	<i>Incasarcus ochoai</i>	MZSP

Box 1. List of characters and their states used in the cladistic analysis

Italic formatting indicates the character proposition

- (1) *Dorsal scutum, anterior margin, frontal hump, armature*: (0) granules; (1) a main pair of paramedian tubercles.
- (2) *Dorsal scutum, anterior margin, frontal hump, shape*: (0) conspicuous, normally build, oval shaped in dorsal view; (1) conspicuous, height comparable to ocularium, anterior part projected anteriorly, approximately bell shaped in dorsal view; (2) conspicuous, as a high protuberance comparable to ocularium, not projected anteriorly, oval shaped in dorsal view.
- (3) *Dorsal scutum, ocularium, eye*: (0) absent; (1) present
- (4) *Dorsal scutum, ocularium, eye, pigmentation*: (0) absent; (1) present
- (5) *Dorsal scutum, ocularium, height (Hara & Pinto-da-Rocha 2010)*: (0) low; (1) medium; (2) high.
- (6) *Dorsal scutum, ocularium, unpaired armature*: (0) unarmed; (1) as a large spiniform tubercle (approximately twice or three times larger than the surrounding tubercles); (2) as a large spiniform apophysis, its height more than half of carapace length).
- (7) *Dorsal scutum, ocularium, unpaired armature, apex, shape*: (0) straight; (1) curved backward.
- (8) *Dorsal scutum, ocularium, unpaired armature, spine, shape*: (0) most of the spine straight; (1) uniformly curved backwards; (2) uniformly curved frontwards.
- (9) *Dorsal scutum, ocularium, paired armature*: (0) absent; (1) present.
- (10) *Dorsal scutum, ocularium, paired armature, type*: (0) one pair of tubercles; (1) one pair of large tubercles (larger than the eye); (2) one pair of spiniform apophysis.
- (11) *Mesotergal areas, type of granules*: (0) blunt granules; (1) pointed granules.
- (12) *Mesotergal area I, state of fusion*: (0) undivided; (1) divided in right and left halves.
- (13) *Mesotergal area I, paired armature*: (0) unarmed (i.e. without any remarkable integumentary ornamentation standing out among the tubercles); (1) with a pair of tubercles.
- (14) *Mesotergal area II, paired armature*: (0) unarmed (i.e. without any remarkable integumentary ornamentation standing out among the tubercles); (1) with a pair of tubercles.
- (15) *Mesotergal area III, paired armature*: (0) unarmed (i.e. without any remarkable integumentary ornamentation standing out among the tubercles); (1) with a pair of tubercles; (2) with a pair of blunt, ovoid, large tubercles; (3) with a pair of high apophysis.
- (16) *Mesotergal area III, unpaired armature*: (0) unarmed (i.e. without any remarkable integumentary ornamentation standing out among the tubercles); (1) with a spiniform apophysis.
- (17) *Mesotergal area III-IV, state of fusion*: (0) undivided; (1) divided.
- (18) *Mesotergal area IV, paired armature*: (0) unarmed (i.e. without any remarkable integumentary ornamentation standing out among the tubercles); (1) with a pair of tubercles.
- (19) *Posterior margin of DS, curvature*: (0) approximately straight; (1) concave.
- (20) *Free tergites I-III, row of granules*: (0) similar sized granules; (1) pointed tubercles becoming conspicuously enlarged centrally.
- (21) *Free tergite I, paired armature*: (0) absent; (1) present.
- (22) *Free tergite II, paired armature*: (0) absent; (1) present.
- (23) *Free tergite III, paired armature*: (0) absent; (1) present.
- (24) *Free tergite I, unpaired armature*: (0) absent; (1) present.
- (25) *Free tergite II, unpaired armature*: (0) absent; (1) present.
- (26) *Free tergite II, type of unpaired armature*: (0) a central blunt tubercle; (1) a central pointed tubercle; (2) a central apophysis.
- (27) *Free tergite III, unpaired armature*: (0) absent; (1) present.
- (28) *Free tergite III, type of unpaired armature*: (0) a central blunt tubercle; (1) a central pointed tubercle; (2) a central apophysis.
- (29) *Pedipalp, femur, mesal subapical tubercle*: (0) absent; (1) present.
- (30) *Pedipalp, patella-tibia, articulation placement*: (0) obliquely articulated (distal ventral part of patella connected in an oblique way on basal part of tibia); (1) dorsally articulated (distal ventral part of patella connected with dorso-basal part of tibia).
- (31) *Coxa IV, proapical apophysis*: (0) absent; (1) present.
- (32) *Coxa IV, proapical apophysis, size in relation to apical width of coxa IV*: (0) length of the apophysis shorter than the coxa IV apical width; (1) length of the apophysis similar to the coxa IV apical width; (2) length of the apophysis longer than the coxa IV apical width.
- (33) *Coxa IV, proapical apophysis, curvature in dorsal view*: (0) approximately straight; (1) smoothly curved; (2) with abrupt curvature in the same plane; (3) with abrupt curvature in different plane (dorsally).
- (34) *Coxa IV, proapical apophysis, branching pattern*: (0) uniramous; (1) bifid with ventral branch very short; (2) bifid with dorsal and ventral branches approximately similar sized.
- (35) *Coxa IV, retro-apical apophysis*: (0) absent; (1) present.
- (36) *Coxa IV, apical width, relative to apical width of coxa III*: (0) similar; (1) large (at least 1.5 times wider than apical width of coxa III).
- (37) *Coxa IV, length in relation to stigmatic sternite posterior margin (SEPM) in situ*: (0) shorter than SEPM; (1) reaching as far as SEPM; (2) conspicuously longer than SEPM; (3) slightly longer than SEPM.
- (38) *Coxa IV, closeness of the retro-lateral margin of coxa IV to stigmatic sternite*: (0) adjacent to each other; (1) afar from each other, rendering angle between them.

(continued next page)

Box 1. (continued)

- (39) *Trochanter IV, probasal apophysis*: (0) absent; (1) present.
- (40) *Trochanter IV, procentral armature*: (0) absent; (1) present.
- (41) *Trochanter IV, proapical armature*: (0) absent; (1) present.
- (42) *Trochanter IV, dorso-ventral diagonal (in lateral view) keel on prolateral face*: (0) absent; (1) present.
- (43) *Trochanter IV, retro-apical armature*: (0) absent; (1) present.
- (44) *Trochanter IV, retro-apical armature, shape*: (0) as a pointed tubercle (its length $\sim 1/4$ to less of the podomere middle width); (1) as a large pointed tubercle (its length $1/3$ to $2/3$ of the podomere middle width); (2) as a robust spiniform apophysis (its length at least longer than the podomere middle width).
- (45) *Trochanter IV, basal-central retro-lateral face, armature*: (0) granules irregularly distributed; (1) 2–4 tubercles roughly organised in a row.
- (46) *Trochanter IV, basal-central retro-lateral face, apophysis*: (0) absent; (1) present.
- (47) *Trochanter IV, length*: (0) similar as the width of trochanter IV; (1) at least 1.5 times longer than wide trochanter IV.
- (48) *Femur IV, retro-lateral curvature, pattern (in dorsal view)*: (0) strongly curved on basal $1/4$ on; (1) slightly curved in the entire femur IV; (2) sub-straight or straight.
- (49) *Femur IV, dorso-basal, ornamentation*: (0) absent; (1) present.
- (50) *Femur IV, dorso-basal, type of ornamentation*: (0) as a large tubercle; (1) as a robust apophysis.
- (51) *Femur IV, retro-dorsal row, armature*: (0) row of similar sized granules; (1) row of granules with tubercles on the basal third and scattered along the row; (2) row of granules with tubercles and apophysis.
- (52) *Femur IV, retro-lateral subapical, armature*: (0) unarmed; (1) as a spiniform robust apophysis; (2) as a blunt apophysis.
- (53) *Femur IV, proventral row, armature*: (0) row of similar sized granules; (1) row of granules becoming tubercles (approximately twice the size of the granule) apically; (2) row of granules becoming spiniform tubercles (more than three times the size of the granule, conspicuously high tubercles) apically; (3) row of similar sized high tubercles.
- (54) *Femur IV, retro-ventral row, armature*: (0) row of similar sized granules; (1) row of granules becoming tubercles (approximately twice the size of the granule) apically; (2) row of granules becoming spiniform tubercles (more than three times the size of the granule, conspicuously high tubercles) apically; (3) row of similar sized high tubercles; (4) row of tubercles becoming granules (tubercle approximately one third the width of the podomere) apically.
- (55) *Femur IV, proventral apical face, armature*: (0) as a granule; (1) as a tubercle; (2) as a spiniform apophysis.
- (56) *Femur IV, retro-ventral apical face, armature*: (0) as a granule; (1) as a tubercle; (2) as a spiniform apophysis; (3) as a robust sigmoid apophysis.
- (57) *Femur IV, retro-dorsal apical face, armature*: (0) as a granule or tubercle; (1) as a large spiniform tubercle (its length $\sim 1/4$ of the podomere apical width); (2) as robust apophysis.
- (58) *Patella IV, ventral armature*: (0) approximately similar sized granules covering the podomere; (1) with elevated tubercles; (2) with pointed apophyses.
- (59) *Tibia IV, proventral row*: (0) granules of similar size or slightly larger; (1) granules increasing in size apically, becoming high tubercles.
- (60) *Tibia IV, retro-ventral row*: (0) granules of similar size or slightly larger; (1) granules increasing in size apically, becoming high tubercles; (2) row of similar sized high tubercles.
- (61) *Tibia IV, proventral apex*: (0) tubercle; (1) spiniform apophysis.
- (62) *Tibia IV, retro-ventral apex*: (0) tubercle; (1) spiniform apophysis.
- (63) *Tarsus IV, tarsal process*: (0) absent; (1) present.
- (64) *Female, coxa IV, proapical apophysis*: (0) absent; (1) present.
- (65) *Female, coxa IV, proapical apophysis, size in relation to apical width of coxa IV*: (0) length of the apophysis approximately or less than half of the coxa IV apical width; (1) length of the apophysis similar to the coxa IV apical width; (2) apophysis longer than coxa IV apical width.
- (66) *Penis, ventral plate, shape*: (0) basal and apical portion approximately of same width, approximately rectangular; (1) basal portion wider than apical one, approximately pyriform.
- (67) *Penis, ventral plate, distal margin*: (0) approximately straight; (1) with a cleft; (2) concave (as in *Cynorta*); (3) convex.
- (68) *Penis, ventral plate, basal lobes, developmental degree*: (0) inconspicuous; (1) conspicuous, not strongly projected sideways or dorsally; (2) conspicuous, strongly projected dorsad/laterally, globose.
- (69) *Penis, stylus, ventral trichomes*: (0) absent; (1) present.
- (70) *Penis, ventral process*: (0) absent; (1) present.
- (71) *Penis, ventral process, apex, shape*: (0) as a ventrally curved large flabellum (its width at least three times the stylus width); (1) as a small flabellum (its width approximately twice the stylus width); (2) spatula-like with serrate distal margin; (3) hook-like apex directed ventrally with serrate narrow lateral projections; (4) rectangular shaped; (5) with small lateral projections, rendering a mushroom shape; (6) sub-conical, serrate margin; (7) as a bifid large flabellum with serrated margins; (8) truncate, with lateral small projections; (9) narrowing apically, without lateral projections.
- (72) *Penis, ventral process, stem*: (0) absent; (1) present.
- (73) *Penis, ventral process, stem length*: (0) short (less than a quarter of stylus length); (1) long (more than half of the stylus length); (2) medium (approximately one third of stylus length).
- (74) *Penis, ventral process, stem width*: (0) as wide as stylus; (1) conspicuously narrower than stylus width; (2) wider than stylus.
- (75) *Penis, dorsal process, presence*: (0) absent; (1) present.
- (76) *Penis, macrosetae A, number of pairs*: (0) 1 pair; (1) 3 pairs; (2) 4 pairs; (3) 5 pairs; (4) 2 pairs.
- (77) *Penis, macrosetae C, number of pairs*: (0) 2 pairs; (1) 3 pairs; (2) 4 pairs.
- (78) *Penis, macrosetae C, shape*: (0) straight; (1) apically curved.
- (79) *Penis, macrosetae E, presence*: (0) absent; (1) present.

Results

Cladistic analysis

The cladistic analysis using all the characters under equal weights retrieved one most parsimonious tree (length (L) = 339 steps, consistency index (CI) = 35, retention index (RI) = 56) (Fig. 1). *Iandumoema* is recovered as a monophyletic genus with high support values (resampling measures = 82, Goodman–Bremer support = 8) (Fig. 2). The genus is supported by 12 unambiguous synapomorphies; five of them being non-homoplastic synapomorphies, namely: frontal hump on anterior margin of dorsal scutum as an oval shaped (in dorsal view) high protuberance (comparable to ocularium height) [#2(2)]; absence of eye pigmentation [#4(0)]; ocularium unpaired armature apex curved backwards [#7(1)]; trochanter IV with basal–central retro-lateral row of tubercles roughly organised in a row [#45(1)]; and apex of ventral process of penis spatula-like, with serrate distal margin [#71(2)]. Of the five non homoplastic synapomorphies, four

are not related to modification to hypogean life style, thus corroborating that *Iandumoema* monophyly does not rely on putative troglomorphy in this study. Indeed, the analysis excluding characters that might be related to troglomorphy (#3 and #4) resulted in the same tree as the one retrieved under equal weights (Fig. 1). The single most parsimonious tree recovered excluding characters #3 and #4 has the same CI and RI values and fewer steps (L = 335; CI = 35; RI = 56).

The analyses using implied weights resulted in five different trees with different topologies, but all of them corroborate the monophyly of *Iandumoema*. Table 2 summarises those results, including their respective length, CI and RI as well as their fit. The retrieved clades resulting from the analysis under different concavities are summarised in sensitivity plots in Fig. 1. *Iandumoema* is nested among the Brazilian ‘Pachylinae’ and it is a sister-group of a clade including Pachylinae (except for *G. chagasi*, *E. catharinensis* and *D. inermis*) + K92. Pachylinae *sensu stricto* that includes the type genus *Pachylus* Koch, 1839 (type

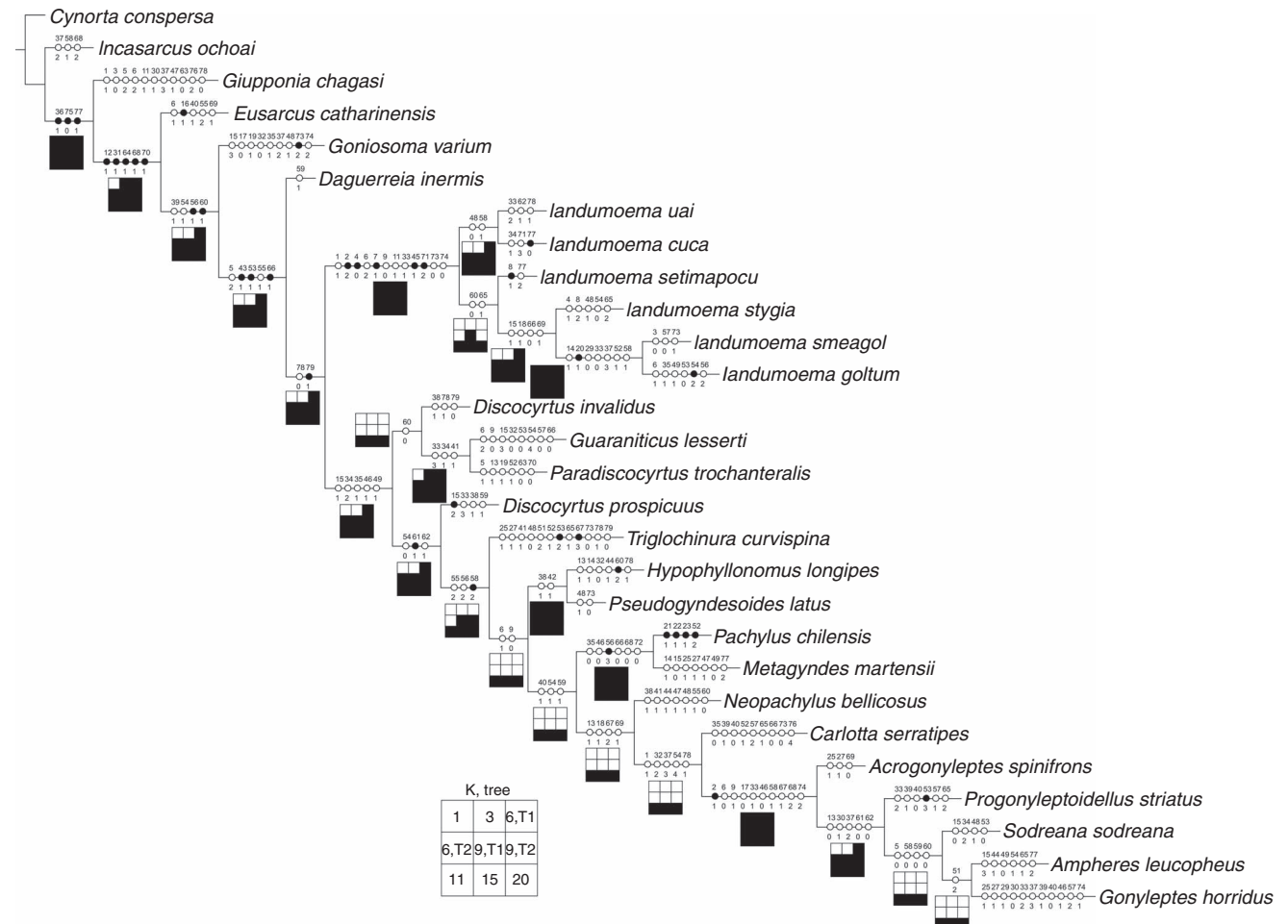


Fig. 1. Cladogram depicting external and internal relationships of *Iandumoema*, with unambiguous synapomorphies mapped. This is the single most parsimonious tree retrieved in the analysis under equal weights (length (L) = 339 steps, consistency index (CI) = 35, retention index (RI) = 56). The character number is above each circle and the character state is below. Black circles indicate non-homoplastic synapomorphies, and white circles indicate homoplastic synapomorphies. Sensitivity plots near the nodes indicates their monophyly (black squares) or not (white squares) in the analyses under implied weights using different concavities values.

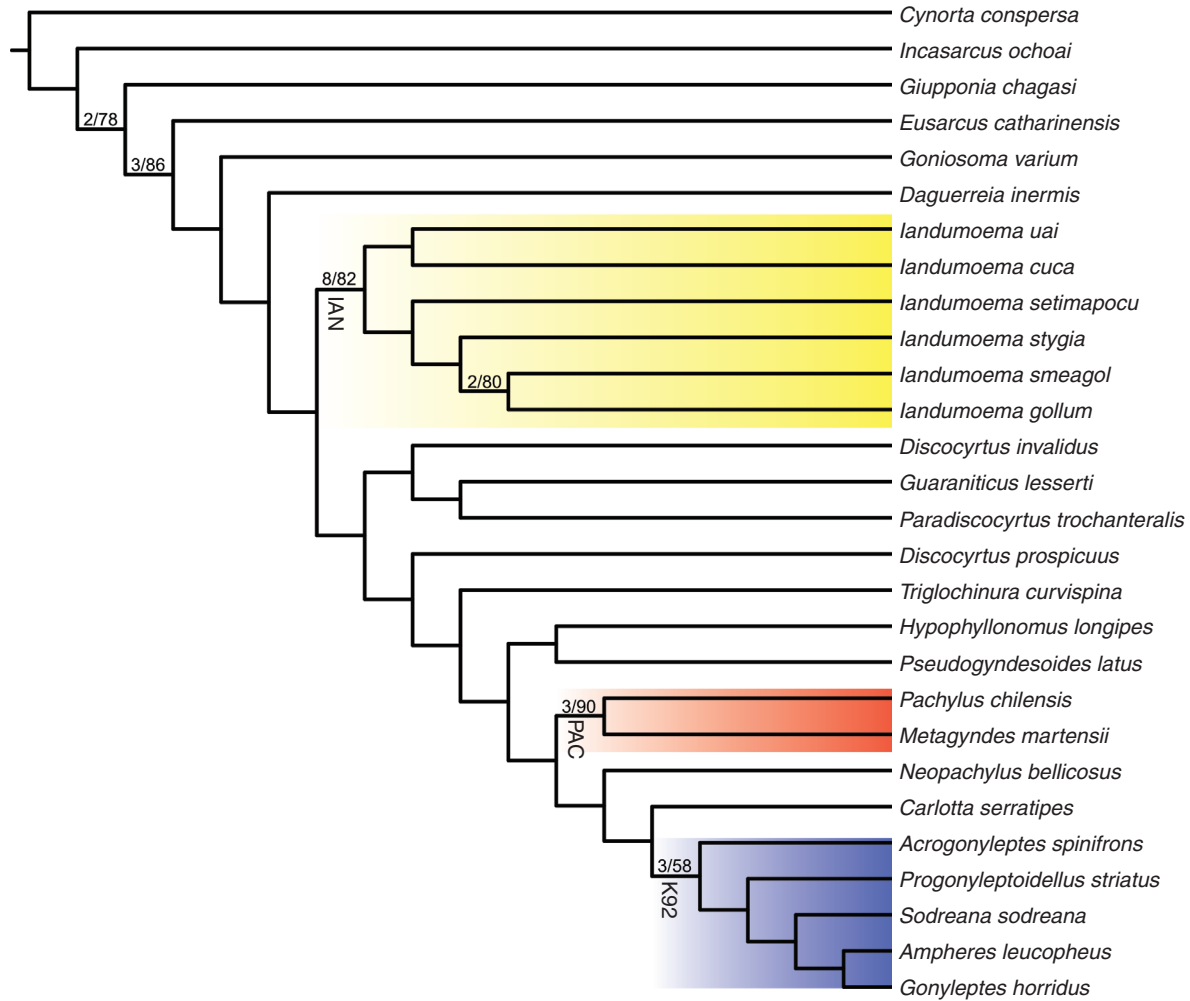


Fig. 2. The single most parsimonious tree retrieved in the analysis under equal weights. Numbers at branches are Goodman–Bremer support metric/symmetric resampling (cut = 50). Abbreviations are IAN, *landumoema*; PAC, Pachylinae *sensu stricto*; K92, clade K92.

Table 2. Number of most parsimonious trees (MPTs), length (number of steps), consistency index (CI), retention index (RI) and fit (fi) from trees found in the analyses

Analysis	MPT	Length	CI/RI	Fit
Equal weights	1	339	0.35/0.56	
Implicit weighting $k = 1$	1	361	0.33/0.52	43.672
Implicit weighting $k = 3$	1	347	0.34/0.55	30.611
Implicit weighting $k = 6$	2	341	0.35/0.56	21.270
Implicit weighting $k = 9$	2	341	0.35/0.56	16.379
Implicit weighting $k = 11$	1	339	0.35/0.56	14.215
Implicit weighting $k = 15$	1	339	0.35/0.56	11.247
Implicit weighting $k = 20$	1	339	0.35/0.56	8.927

species *P. granulatus* Kollar in Koch, 1839) (Pinto-da-Rocha *et al.* 2014) (represented by two species) and clade K92 (represented by one species of each of the five subfamilies) are also recovered as monophyletic in all analyses.

Systematics

Genus *landumoema* Pinto-da-Rocha

landumoema Pinto-da-Rocha, 1997: 844. – Hara & Pinto-da-Rocha, 2008: 55; Kury & Alonso-Zarazaga, 2011: 56 (correct date); Pinto-da-Rocha, Fonseca-Ferreira & Bichuette, 2015: 90, 91.

Type species: landumoema uai Pinto-da-Rocha, 1997, by monotypy.

Diagnosis

Gonyleptid with scutum length of ~3–5 mm; slender and elongated legs. Dorsal scutum (DS) type α (Fig. 3A, C, 6A, C, 9A, C); anterior margin of DS bearing a prominent frontal hump, its height comparable to the ocularium (Fig. 3E, F, 6E, F, 9E, F) and not projected anteriorly (elyptical in dorsal view). Frontal hump bearing a main pair of paramedian tubercles. Ocularium roughly placed in the centre of carapace, with a large spiniform apophysis, its apex curved

backward. Eyes depigmented (except *I. stygia*, sp. nov. and *I. smeagol*). Four unarmed scutal areas or each with a paramedian pair of tubercles. Scutal area I divided into right and left halves. Dorsal scutum with pointed granules. Cheliceral segment I as long as the carapace maximum length, with bulla. Pedipalpal patella connected obliquely to tibia in lateral view. Coxae I–III each with one prodorsal and one retro-dorsal apophyses; the apex of retro-dorsal apophysis of coxa II fused to the apex of prodorsal apophysis of coxa III. Male coxa IV hypertelic, bearing a robust prolateral apophysis smoothly curved in dorsal view (except *I. uai*, with abrupt curvature) (Fig. 3A, B, E, 6A, B, E, 9A, B, E) and as a shorter spiniform apophysis in females (Fig. 3C, D, F, 6C, D, F, 9C, D, F). Male trochanter IV longer than wide, with a short, blunt prolateral apophysis on basal third and 2–4 pointed tubercles roughly organised in a row on basal–central retro-lateral face (unarmed on prolateral face in females) (Fig. 4K–M, 7K–M, 10K–M). Male femur IV approximately twice the DS length, with variable armature and curvature in dorsal view; pointed tubercles on distal quarter of proventral row.

Male genitalia. Ventral plate subrectangular (Fig. 8A, B, 11A, C) to pyriform (Fig. 5A, C), distal border straight, with 3–5 pairs of macrosetae (MS) A, 1 pair of MS B, 2–4 pairs of distal MS C, 1 pair of MS D, 0–3 pairs of MS E. Glans with ventral process, stem short and as thick as stylus and apex spatula-like with serrate distal margin (in *I. smeagol*, narrowing apically, without lateral projections, and in *I. cuca*, sp. nov. and *I. gollum*, sp. nov., hook-like apex directed ventrally with serrate narrow lateral projections). Stylus with ventral median trichomes (Fig. 8C, D, 11B) (except *I. uai*, *I. setimapocu* and *I. cuca*, sp. nov.).

Included species

Iandumoema uai Pinto-da-Rocha, 1997 (type species), *I. setimapocu* Hara & Pinto-da-Rocha, 2008, *I. smeagol* Pinto-da-Rocha *et al.*, 2015, *I. cuca*, sp. nov., *I. gollum*, sp. nov. and *I. stygia*, sp. nov.

Geographical distribution

Brazil: Minas Gerais State: caves in the municipalities of Itacarambi, Monjolos, Montes Claros, Presidente Juscelino and São João da Lagoa.

Key to males of *Iandumoema* (modified from Pinto-da-Rocha *et al.* 2015)

- Ocularium with eyes (Fig. 3A, E).....2
Ocularium without eyes (Fig. 15C, D).....*I. smeagol*
- Ocularium with a large spiniform apophysis (its height more than half of carapace length) (Fig. 3E); and coxa IV with unarmed retro-lateral face (Fig. 3A, B, 4K, M).....3
Ocularium with a spiniform tubercle (approximately twice or three times larger than the surrounding tubercles) (Fig. 6E); and coxa IV with retro-lateral apical apophysis (Fig. 6A, B, 7K, M).....
.....*I. gollum*, sp. nov.
- Proapical apophysis on coxa IV straight or smoothly curved (Fig. 6A, E, 7K, L, 9A, E, 10K, L).....4
Proapical apophysis on coxa IV with abrupt curvature (Fig. 17C)*I. uai*

- Trochanter IV with a retro-apical pointed tubercle (length $\leq 1/4$ of the podomere middle width) (Fig. 3A, B, 4K, M).....5
Trochanter IV with a retro-apical robust spiniform apophysis (length longer than the podomere middle width) (Fig. 9A, B, E, 10K, M).....
.....*I. stygia*, sp. nov.
- Trochanter IV unarmed on dorsal face, prolateral face with dorso-ventral keel on central–apical region; and femur IV approximately straight.....*I. setimapocu*
Trochanter IV dorsal face with median central intumescence (Fig. 3A, E, 4K, L), without prolateral keel; and femur IV strongly curved on basal 1/4 (Fig. 4A–D).....*I. cuca*, sp. nov.

Iandumoema cuca, sp. nov.

(Fig. 3–5, 12D, E, 18)

<http://zoobank.org/urn:lsid:zoobank.org:act:08AF6042-AF17-44F4-854C-F381AB446CBD>

Iandumoema und. sp. 1 de Ázara & Ferreira, 2018: 79 (cat), fig. 27B, C, 43A, B.

Material examined

Holotype. BRAZIL. Minas Gerais: Iracarambi, Gruta da Água do João Ferreira (15°00'35.0"S, 44°07'55.5"W), 29.xi.2016, L.M. Rabelo *et al.* leg. (ISLA 59444, destroyed).

Paratypes. BRAZIL. Minas Gerais: Iracarambi, same locality as holotype, 2♀, 29.xi.2016, L.M. Rabelo *et al.* leg. (ISLA 59445, destroyed); same locality, 1♂, 25.i.2015, R.L. L.M. Rabelo leg. (ISLA 13147, destroyed); same data, 2♀ (ISLA 44197, destroyed).

Diagnosis

Iandumoema cuca, sp. nov. can be distinguished from other species of the genus by the combination of the following characters: ocularium with reduced and depigmented eyes, bearing a high, straight spiniform apophysis subapically curved backwards; scutal areas unarmed; male coxa IV with smoothly curved and subapically bifid (ventral branch shortest), very long (length longer than the coxa IV apical width) proapical apophysis and unarmed on retro-lateral face; trochanter IV with dorso-central subapical bulge.

Description

Male holotype (ISLA 59444)

Dorsum (Fig. 3A, E). Dorsal scutum length, 4.2; dorsal scutum width, 3.2; prosoma length, 1.5; prosoma width, 1.9. Measurements of pedipalps and legs are in Table 3. Dorsal scutum outline type α . Carapace and scutal areas with pointed granules. Anterior margin of carapace with prominent frontal hump bearing a main pair of paramedian tubercles. Eyes reduced and depigmented. Ocularium with a high, straight spiniform apophysis, its apex curved backwards. Scutal areas I–IV unarmed. Scutal area I divided into right and left halves. Lateral margin of DS with an external row of tubercles and an internal irregular row of granules. Posterior margin of DS and free tergites I–III each with a row of tubercles. Anal opercle irregularly tuberculate.

Venter (Fig. 3B). Coxa I with scattered granules plus an irregular row of five setiferous tubercles; II–III with scattered granules; IV and stigmatic area irregularly granulate. Posterior margin of genital sternite and free sternites each with a row of low tubercles.

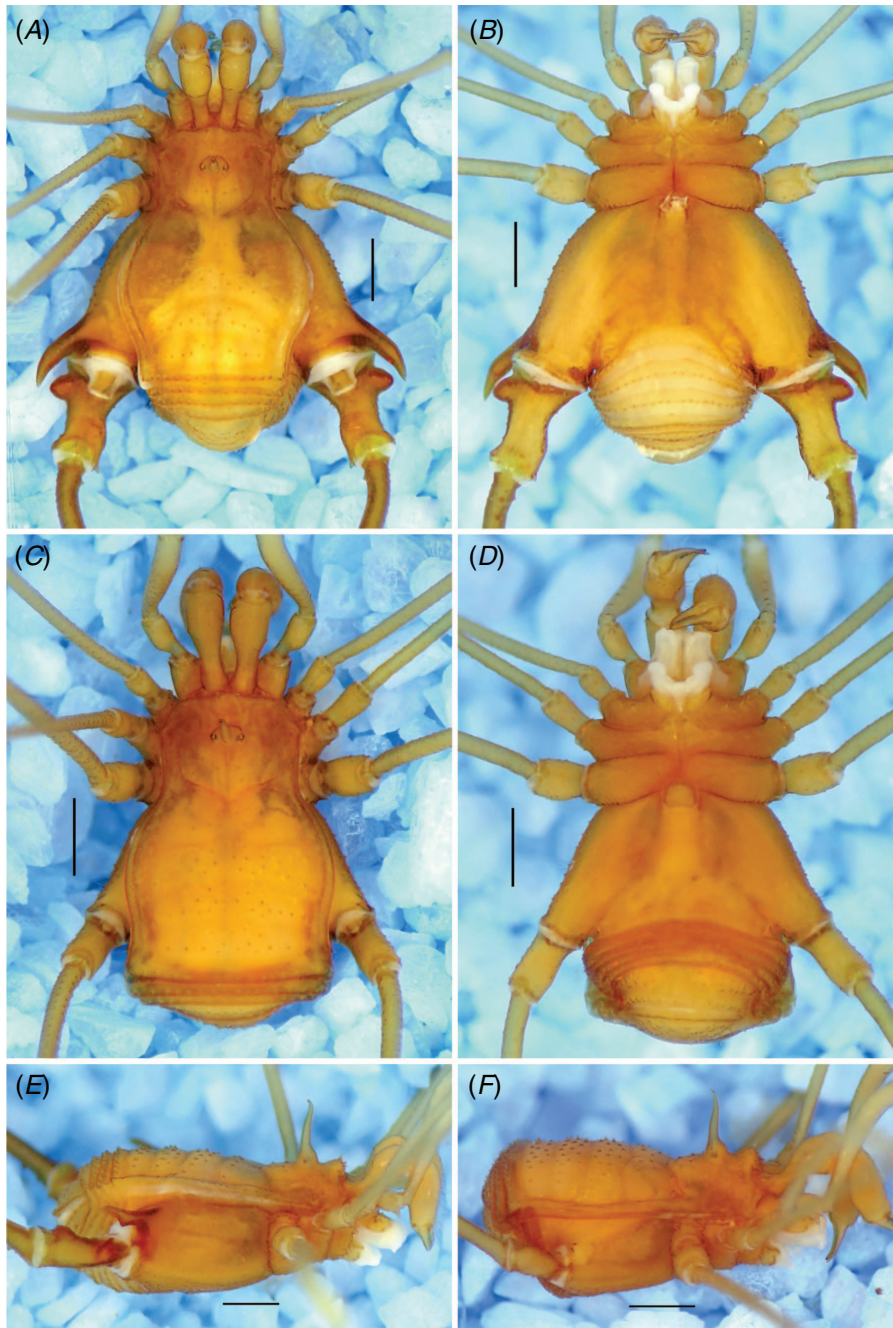


Fig. 3. *Iandumoema cuca*, sp. nov. (A, B, E), male holotype: (A) habitus, dorsal view; (B) same, ventral view; (E) same, right lateral view. (C, D, F) female paratype (ISLA 59445): (C) habitus, dorsal view; (D) same, ventral view; (F) same, right lateral view. Scale bars: 1 mm.

Chelicerae (Fig. 3A). Segment I elongated (three times longer than wide), bulla with scattered granules. Segment II fixed finger and segment III toothed.

Pedipalps (Fig. 4I, J). Slightly elongated (~1.5 times the DS length). Trochanter with two dorsal tubercles and two ventral apical (ventral mesal largest) setiferous tubercles. Femur with one ventro-basal tubercle, median region with a ventral row of five granules and one mesal subapical setiferous tubercle. Patella

smooth. Tibial setation: ectal and mesal IiIi. Tarsal setation: ectal and mesal IiIi.

Legs (Fig. 4A–D, G, H, K–M). Coxae I–III with prodorsal and retro-dorsal apophyses; apex of retro-dorsal apophysis on coxa II fused with prodorsal apophysis on coxa III. Coxa IV granulated, with long, spiniform proapical apophysis (length similar to the coxa IV apical width), this smoothly curved (on dorsal view) and bifid (ventral branch shortest). Trochanters I–III

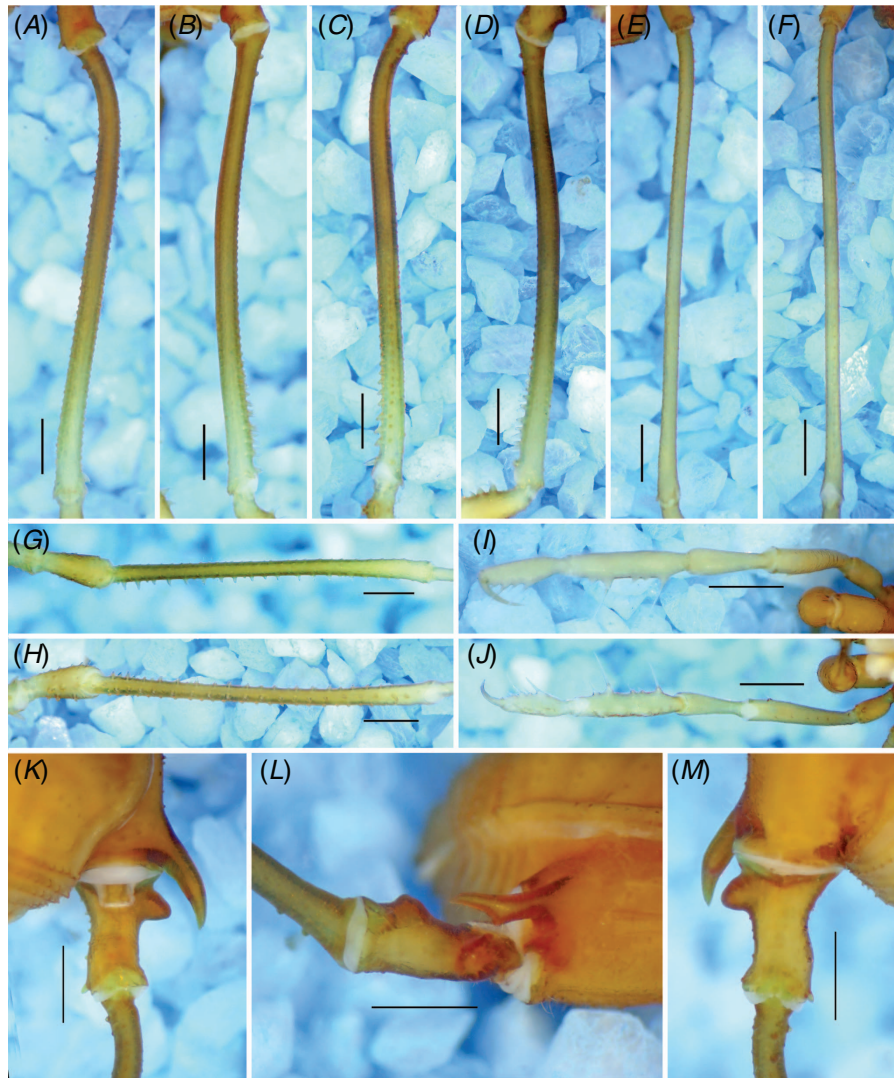


Fig. 4. *Iandumoema cuca*, sp. nov. (A–D, G–M): male holotype. (A) right femur IV, dorsal view; (B) same, prolateral view; (C) same, ventral view; (D) same, retro-lateral view; (G) right patella and tibia IV, dorsal view; (H) same, ventral view; (I) right pedipalp, dorsal view; (J) same, ventral view; (K) coxa–trochanter IV in dorsal view; (L), same, right lateral view; (M) same, ventral view. (E–F), female paratype (ISLA 59445): (E), right femur IV, dorsal view; (F) ventral view. Scale bars: 1 mm.

with scattered granules. Trochanter IV with short, conical, blunt prolateral sub-basal apophysis, this bearing a dorsal intumescence; dorsal face with a dorso-median central intumescence; retro-lateral face with 2–4 basal–central tubercles roughly organised in a row and one apical pointed tubercle (its length approximately one-quarter to less of the podomere middle width). Femora, tibiae–metatarsi I–IV with granules roughly organised in six longitudinal rows (prodorsal, retro-dorsal, pro- and retro-lateral, proventral and retro-ventral rows); femora I–III approximately straight and unarmed. Femur IV strongly curved on basal 1/4, with one retro-basal and two ventro-basal large tubercles; dorso-apical face with two spiniform tubercles, retro-lateral one largest and pointing retro-laterally; two ventral rows of granules becoming tubercles (approximately twice the size of the granule) apically; ventro-apical face with a pair of spiniform large

tubercles. Patella IV with ventral high tubercles. Tibia IV with a retro-lateral row of pointed tubercles; ventral face with two rows of granules increasing in size apically, becoming high, pointed tubercles; ventro-apical face unarmed. Tarsal counts: 7 (3), 16(3), 6, 6.

Penis (Fig. 5). Ventral plate approximately pyriform with basal portion wider than apical one; distal margin approximately straight; basal lobes conspicuous. Ventral plate with four pairs of MS A, one pair of MS B (placed more ventrally), two pairs of straight MS C, one pair of MS D, two pairs of short MS E (placed more ventrally). Microsetae type 1 occupying all of ventral plate, with a lower density in the apical portion. Glans without dorsal process; ventral process stem short (less than a quarter of stylus length) and thick (comparable to that of stylus), apex flabellum-like with tip curved ventrally. Stylus smooth.

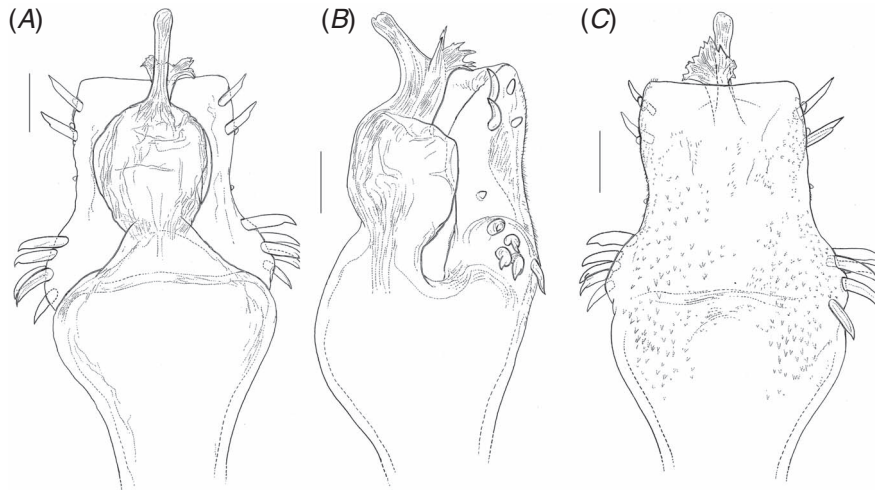


Fig. 5. *Iandumoema cuca*, sp. nov. (ISLA 13147), distal part of penis. (A–C), dorsal, right lateral and ventral views. Scale bars: 0.05 mm.

Table 3. Pedipalp and leg measurements (mm) of *Iandumoema cuca* sp. nov., male holotype (ISLA 59444)

	Tr	Fe	Pa	Ti	Mt	Ta	Total
Pedipalp	0.6	2.5	1.3	1.8	–	1.2	7.4
Leg I	0.6	5.1	1.2	4.2	6.4	3.3	20.8
Leg II	0.7	10.4	1.6	9.3	10.9	10.9	43.8
Leg III	0.9	6.8	1.22	4.4	7.8	3.3	24.42
Leg IV	1.7	8.3	1.7	6.5	10.3	4.6	33.1

Table 4. Pedipalp and leg measurements (mm) of *Iandumoema cuca* sp. nov., female paratype (ISLA 59445)

	Tr	Fe	Pa	Ti	Mt	Ta	Total
Pedipalp	0.5	2.2	1.2	1.6	–	1.2	6.7
Leg I	0.4	4.3	0.9	3.3	6.1	3.1	18.1
Leg II	0.6	9.4	1.1	8.4	9.9	12	41.4
Leg III	0.8	5.9	1.2	3.8	7.4	3.7	22.8
Leg IV	0.9	8.2	1.3	6	9.6	4.7	30.7

Colouration (male, in alcohol) (Fig. 3, 4). Body and appendages background vivid orange yellow (66), prolateral apical apophysis of coxa IV and trochanter IV strong orange (50), median to apical portion of femur IV, patella and pedipalps pale yellow (89).

Female (ISLA 59445; Fig. 3C, D, F, 4E, F)

Dorsal scutum length, 3.9; dorsal scutum width, 2.7; prosoma length, 1.4; prosoma width, 1.8. Measurements of pedipalps and legs are in Table 4. Coxa IV reaching scutal groove IV, with a short proapical apophysis (length $\sim 1/2$ of the coxa IV apical width). Trochanter IV prolateral and retro-lateral faces unarmed. Femur IV basal curvature attenuated, without tubercles except for dorso-apical ones. Tibia IV unarmed.

Etymology

Noun in apposition from the fictional character *Cuca*, created by the Brazilian writer José Bento Renato Monteiro Lobato based on the Brazilian folklore. This character lives in a cave and has the appearance of an alligator. It appears in the book ‘O Saci’ and in the television show called ‘Sítio do Pica-Pau Amarelo’ that is based on Lobato’s series of books.

Ecological remarks

The cave where *Iandumoema cuca*, sp. nov. was collected (Lapa D’Água do João Ferreira Cave, Itacarambi, Minas Gerais)

(Fig. 12A–C) is in a huge limestone outcrop of the Bambuí formation (Neoproterozoic limestone) surrounded by a well preserved deciduous forest. The cave is located in the transitional area between Cerrado (Brazilian savannah) and Caatinga (Velloso *et al.* 2002) and harbours a single conduit of 150 m of horizontal projection, traversed by a perennial stream in its final portion. Thus, despite the entrance being extremely dry, deeper parts of the cave have a high humidity. A constriction ~ 15 m from the entrance also helps keep the atmosphere more stable from this point on. Local farmers drain the cave water using a hose, gravitationally dragging water for domestic consumption and crop irrigation. Since they do not use pumps, the impact of water drainage seems to be small.

Specimens of *I. cuca*, sp. nov. were observed on the cave walls deep inside the cave. Only six specimens were found during the two visits to the cave (three in each visit), thus indicating an apparently low density of the population. We should point out that there are parts of the cave that are inaccessible to humans, such as the low ceiling at the water entrance and exit. Notwithstanding, the habitat for the harvestmen extends, accompanying the drainage. Other troglotic species found in the cave include the whip-spider *Charinus* sp. (Amblypygi: Charinidae) and the isopod *Xangoniscus* sp. (Styloniscidae). The external environment surrounding the cave is only partially protected because, although the cave itself is located within the Cavernas do Peruaçu National Park, the entrance is not. The entrance is located outside the Park (which coincides

with the limestone outcrop border), in an area where the original vegetation has been replaced by pastures and monocultures.

Finally, it is important to point out that the Lapa D'Água do João Ferreira is located not far from the caves where *Iandumoema uai* occurs, namely the Lapa do Cipó Cave and Olhos D'Água Cave. The distance between the Lapa D'Água do João Ferreira and the latter caves is 8.4 and 12.2 km in a straight line respectively. The regional topography indicates some potential discontinuities in the limestone outcrops between the area of Lapa D'Água do João Ferreira and the areas where *I. uai* occurs (with clear signs of drainages in between both areas). Furthermore, the underground streams flow in the opposite direction in each area: WSW–ENE in the Olhos D'Água Cave, WNW–ESE in the Lapa do Cipó Cave and ENE–WSW in the Lapa D'Água do João Ferreira Cave. This condition could indicate that the systems were formed by distinct drainages, supported (from the trophic point of view) by distinct flows. These conditions might prevent migrations (or at least make it difficult) between both systems. Do Monte *et al.* (2015) suggested that Lapa do Cipó and Olhos D'Água Caves are connected either by a complex system of subterranean microspaces (such as cracks and fissures) or that they were a single system in the past, being currently separated (at least, for humans). However, these hypotheses do not include the Lapa D'Água do João Ferreira owing to the visible discontinuities in the external landscape and the opposite flow direction of the subterranean stream.

***Iandumoema gollum*, sp. nov.**

(Fig. 6–8, 13D, E, 18)

<http://zoobank.org/urn:lsid:zoobank.org:act:8A155660-78EE-41B1-91CE-478C7FE7D0C3>

Iandumoema und. sp. 2 de Ázara & Ferreira, 2018: 79 (cat), fig. 27D, E.

Material examined

Holotype. BRAZIL. Minas Gerais: Presidente Juscelino, Lapa D'Água (18°33'48.1"S, 44°07'41.5"W), ♂, 31.i.2015, R.L. Ferreira *et al.* leg. (ISLA 13150, destroyed).

Paratypes. BRAZIL. Minas Gerais: same data as holotype, 1♀ (ISLA 19114, destroyed); same data, 1♂ (ISLA 59431, destroyed); same data, 1♂ (ISLA 59432, destroyed); same data, 1♂ (ISLA 15637, destroyed); same data, 1♂ (ISLA 59433, destroyed); same data, 2♀ (ISLA 59434, destroyed); same data, 1♀ (ISLA 13143, destroyed); same data, 2♂ paratypes (ISLA 14851, destroyed); same data, 4♀ (ISLA 59435, destroyed); same data, 3♀ and 1 juvenile (ISLA 59436, destroyed); same locality, 11.x.2018, R.L. Ferreira *et al.* leg., 3♂ (ISLA 60382); same data, 2♀ (ISLA 60383).

Diagnosis

Iandumoema gollum, sp. nov. can be distinguished from other species of the genus by the combination of the following characters: ocularium with reduced and depigmented eyes, bearing a moderately high (as high as the ocularium height), straight spiniform apophysis, subapically curved backwards; scutal areas I–IV each with a paramedian pair of pointed tubercles; male coxa IV with straight (in dorsal view), unbranched, very long proapical apophysis and a short, pointed retro-apical spiniform apophysis; male trochanter IV

unarmed on dorso-median face, with retro-apical short, pointed apophysis; male femur IV approximately straight, with large dorso-basal tubercle, retro-ventral and retro-lateral rows of pointed tubercles, and a retro-lateral subapical spiniform apophysis.

Description

Male holotype (ISLA 13150)

Dorsum (Fig. 6A, E). Dorsal scutum length, 3.3; dorsal scutum width, 3.0; prosoma length, 1.9; prosoma width, 1.3. Measurements of pedipalps and legs are in Table 5. Dorsal scutum outline type gamma. Carapace and scutal areas with pointed granules. Anterior margin of carapace with prominent frontal hump bearing a main pair of paramedian tubercles. Eyes reduced and depigmented. Ocularium with a moderately high (as high as ocularium's height), straight spiniform apophysis, its apex curved backwards. Scutal areas I–IV each with a pair of paramedian tubercles. Scutal area I divided into right and left halves. Lateral margin of DS with an external row of tubercles and an internal irregular row of granules. Posterior margin of DS and free tergites I–III each with a row of tubercles; free tergites I–III with tubercles increasing in size to the paramedian region. Anal opercle irregularly tuberculate.

Venter (Fig. 6B). Coxa I with scattered tubercles plus an irregular row of four setiferous tubercles; II–III with scattered granules; IV and stigmatic area irregularly granulate. Posterior margin of genital sternite and free sternites each with a row of low tubercles.

Chelicerae (Fig. 6A). Segment I elongated (three times longer than wide), bulla with scattered granules. Segment II fixed finger and segment III toothed.

Pedipalps (Fig. 7I, J). Slightly elongated (~1.4 times the DS length). Trochanter with two dorsal tubercles and ventral face with two median and two apical tubercles (mesal ones largest). Femur with one ventro-basal tubercle, median region with a row of 3–5 granules, without mesal subapical setiferous tubercle. Patella with one mesal subapical granule. Tibial setation: ectal Iiii, mesal Iiii. Tarsal setation: ectal and mesal Iiii.

Legs (Fig. 7A–D, G, H, K–M). Coxae I–III with prodorsal and retro-dorsal apophyses; apex of retro-dorsal apophysis on coxa II fused with prodorsal apophysis on coxa III. Coxa IV granulated, with very long, spiniform proapical apophysis (longer than the podomere apical width), this straight (in dorsal view) and uniramous; and a short, spiniform retro-apical apophysis. Trochanters I–III with scattered granules. Trochanter IV with short, conical, blunt prolateral sub-basal apophysis; retro-lateral face with 3–4 basal–central tubercles roughly organised in a row and one apical large pointed tubercle (its length 1/3 to 2/3 of the podomere middle width). Femora, tibiae–metatarsi I–IV with granules roughly organised in six longitudinal rows (prodorsal, retro-dorsal, pro- and retro-lateral, proventral and retro-ventral rows); femora I–III approximately straight and unarmed. Femur IV straight, with large dorso-basal tubercle, a subapical retro-lateral spiniform apophysis (longer than podomere middle width); pointed tubercles on basal 1/4 of retro-dorsal row and basal 3/4 of retro-lateral row of granules; dorso-apical face with a pair of spiniform tubercles; ventral face with two

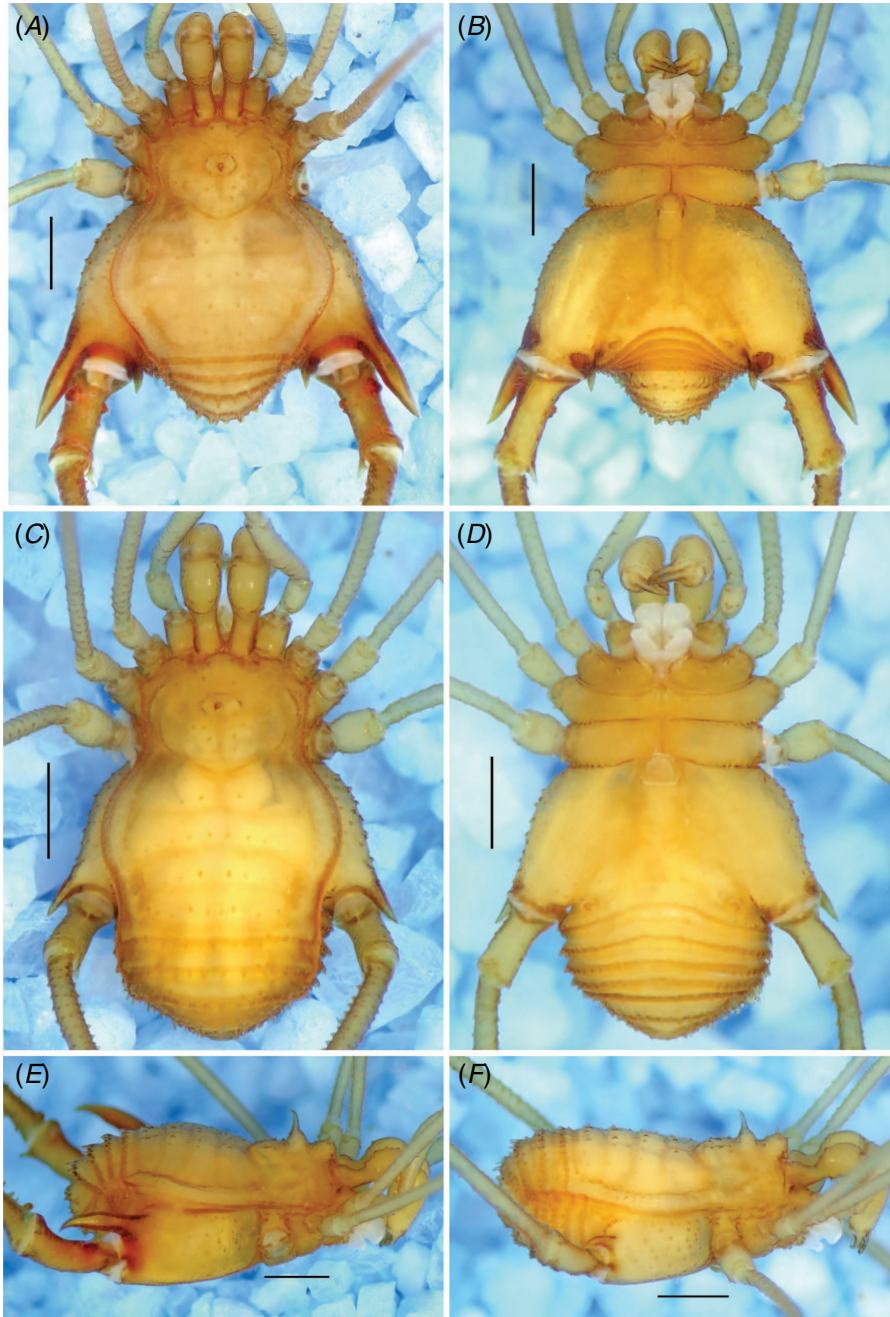


Fig. 6. *Iandumoema gollum*, sp. nov. (A, B, E) male holotype: (A) habitus, dorsal view; (B) same, ventral view; (E) same, right lateral view. (C, D, F) female paratype (ISLA 19114): (C) habitus, dorsal view; (D) same, ventral view; (F) same, right lateral view. Scale bars: 1 mm.

rows, prolateral one with granules becoming tubercles on distal 1/4 and retro-lateral one with large tubercles increasing in size apically; ventro-apical face with a pair of spiniform large tubercles (retro-lateral largest). Patella IV with ventral high tubercles and a ventro-apical pair of spiniform tubercles. Tibia IV with retro-lateral row of spiniform tubercles and two ventral rows of granules slightly

increasing in size apically, ventro-apical face unarmed. Tarsal counts: 7–6(3), 13–14(3), 6, 6–7.

Penis (Fig. 8). Ventral plate approximately rectangular with basal and apical portion approximately of same width; distal margin approximately straight; basal lobes conspicuous. Ventral plate with four pairs of MS A, one MS B (placed more ventrally and on right only), three pairs of MS C apically curved, one pair of

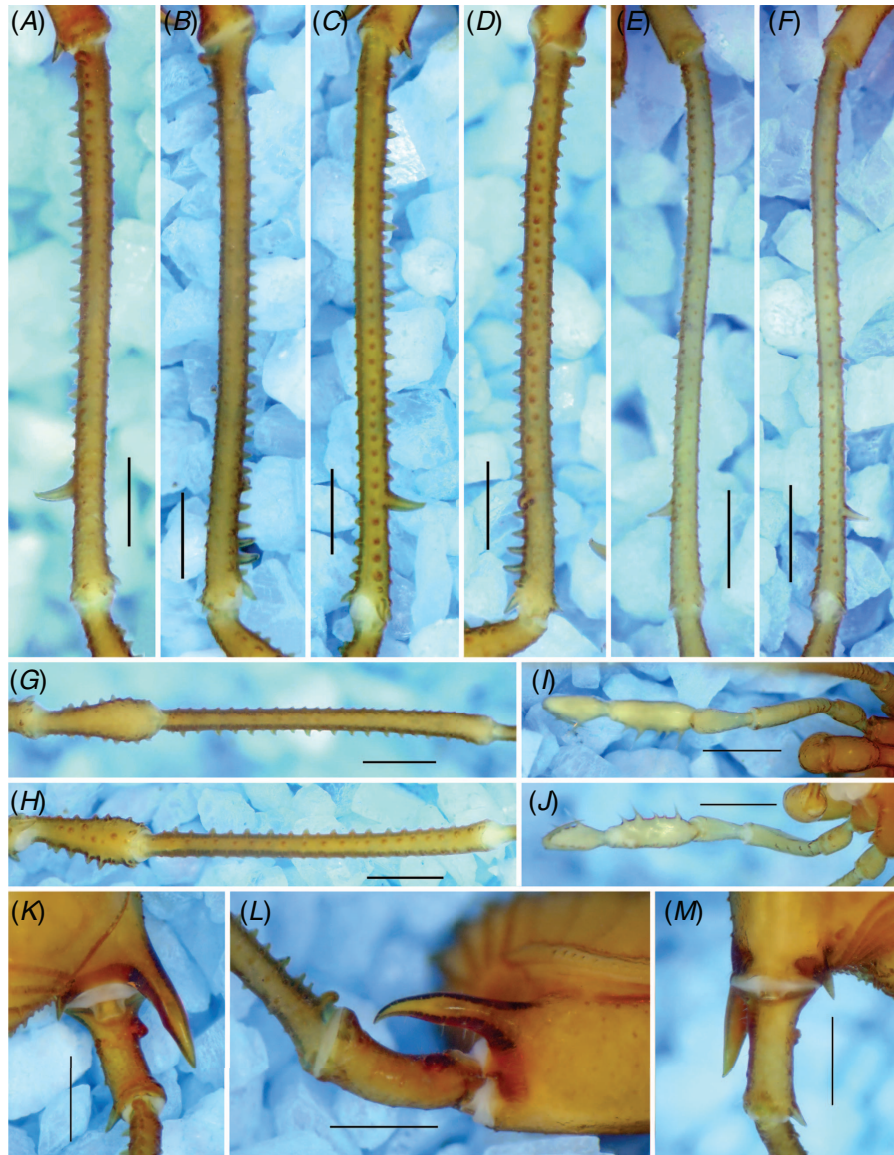


Fig. 7. *Iandumoema gollum*, sp. nov. (A–D, G–M): male holotype. (A) right femur IV, dorsal view; (B) same, prolateral view; (C) same, ventral view; (D) same, retro-lateral view; (G) right patella and tibia IV, dorsal view; (H) same, ventral view; (I) right pedipalp, dorsal view; (J) same, ventral view; (K) coxa–trochanter IV in dorsal view; (L) same, right lateral view; (M) same, ventral view. (E–F) female paratype (ISLA 19114): (E) right femur IV, dorsal view; (F) ventral view. Scale bars: 1 mm.

MS D, two pairs of short MS E (placed more ventrally). Microsetae type 1 occupying mostly the central region of ventral plate, with a lower density in the basal portion; microsetae type 3 on the lateral margins of ventral plate. Glans without dorsal process; ventral process stem short (less than a quarter of stylus length) and thick (comparable to that of stylus), apex hook-like curved ventrally, with serrate narrow lateral projections. Stylus with ventral trichomes.

Colouration (male, in alcohol) (Fig. 6, 7). Body and appendages background light orange yellow (70), prolateral apical apophysis of coxa IV and trochanter IV strong orange

(50), median to apical portion of femur IV, patella and pedipalps strong yellow (84).

Female (ISLA 19114; Fig. 6C, D, F, 7E, F)

Dorsal scutum length, 3.2; dorsal scutum width, 2.7; prosoma length, 1.3; prosoma width, 1.8. Measurements of pedipalps and legs are in Table 6. Dorsal scutum outline type α . Coxa IV reaching scutal groove IV, with a long proapical apophysis (length similar to the coxa IV apical width); unarmed on retro-apical face. Trochanter IV with prolateral face unarmed;



Fig. 8. *Iandumoema gollum*, sp. nov. (ISLA 19114), distal part of penis. (A) Dorsal view; (B) ventral view; (C, D) right and left lateral view respectively.

Table 5. Pedipalp and leg measurements (mm) of *Iandumoema gollum*, sp. nov., male holotype (ISLA 13150)

	Tr	Fe	Pa	Ti	Mt	Ta	Total
Pedipalp	0.5	1.3	0.8	1	–	0.8	4.4
Leg I	0.5	3.4	1.1	2.4	4.3	2.1	13.8
Leg II	0.6	7.1	1.6	5.6	8.3	6.6	29.8
Leg III	0.7	4.9	1.1	2.8	4.7	2.1	16.3
Leg IV	1.6	6.9	1.8	4.6	7.2	2.6	24.7

Table 6. Pedipalp and leg measurements (mm) of *Iandumoema gollum*, sp. nov., female paratype (ISLA 19114)

	Tr	Fe	Pa	Ti	Mt	Ta	Total
Pedipalp	0.5	1.3	0.7	1	–	0.7	4.2
Leg I	0.4	2.9	0.9	2	3.6	1.8	11.6
Leg II	0.5	5.9	1.2	4.7	6.4	5.2	23.9
Leg III	0.5	4.3	1	2.5	4.4	1.9	14.6
Leg IV	0.9	6.1	1.4	4	6.7	2.1	21.2

retro-lateral face as in male, but smaller. Femur IV as armed in male, but attenuated.

Etymology

Noun in apposition from the fictional character Gollum created by J. R. R. Tolkien in the novels 'The Hobbit' and 'The Lord of the Rings'. Originally known as Smeagol, he was corrupted by the ring and the name Gollum is derived from the sound of his disgusting gurgling, choking cough. The name is also a reference to the similarity between *I. smeagol* and *I. gollum*, sp. nov.

Ecological remarks

The cave where *I. gollum*, sp. nov. was collected (Lapa D'Água Cave, Presidente Juscelino, Minas Gerais) (Fig. 13A–C) is associated with Neoproterozoic limestones from the Bambuí geological group. The cave comprises a single conduit of 660 m of horizontal projection, which is currently traversed by an intermittent stream. According to Indigenous people, the stream used to flow out of the cave throughout the entire year, but in the past decade, it no longer flows during the dry periods. The constriction, ~50 m from the entrance, also helps keep the atmosphere humid and with comparatively more stable temperature than outside, even during dry and cold periods. We only collected specimens of *I. gollum*, sp. nov. (Fig. 13D, E) beyond this cave constriction, being more abundant in its deeper parts. In the first visit to the cave (31 January 2015), several specimens were observed on different substrates, including cave walls, speleothems and alluvial sediments on the cave floor, and some specimens concentrated near organic materials, such as decaying trunks transported to the cave by floods. The second visit (11 October 2018) revealed fewer specimens compared with the first visit. However, we did not traverse the entire cave. Thus, we cannot be sure that the population density was lower, because specimens might have migrated to deeper parts of the cave. Potential prey of *I. gollum*, sp. nov. are juvenile crickets (*Endecous* sp.), juvenile cockroaches and moths. Other troglobitic species observed in the cave are Escadabiidae harvestmen, millipedes, springtails and the whip-spider *Charinus spelaeus* (Amblypygi: Charinidae). The external area surrounding the cave is quite preserved, and there are no signs of human visitation to the cave, which is also well preserved. At least five other nearby caves in the region were sampled but no additional specimens of *I. gollum*, sp. nov. were found, suggesting that this species is probably restricted to Lapa D'Água Cave.

Iandumoema setimapocu Hara & Pinto-da-Rocha

(Fig. 14C, 18)

Iandumoema setimapocu Hara & Pinto-da-Rocha, 2008: 51, fig. 1–3. – Do Monte, Gallão, von Schimonsky & Bichuette, 2015: 2 (cit), 5 (syst); Pinto-da-Rocha, Fonseca-Ferreira & Bichuette, 2015: 80 (sys), 82 (key), 84–85(sys), 90 (sys); Pérez-González, Ceccarelli, Monte, Proud, DaSilva & Bichuette, 2017: 2 (cit); de Ázara & Ferreira, 2018: 77 (cat), fig. 26D, E, 42B.

Material examined

Holotype. BRAZIL. Minas Gerais: São João da Lagoa, Lapa do Zú, ♂, 3.ix.2004, M.E. Bichuette and E. Trajano leg. (MZSP 28536).

Paratypes. BRAZIL. Minas Gerais: same data as holotype, 1♂ 1♀ (MZSP 28536).

Additional material examined. Minas Gerais: same data as holotype, 1♂, 25.ix.2013, R.L. Ferreira *et al.* (ISLA 14850, destroyed); same data, 1♀, (ISLA 15639, destroyed); same data, 1♀ (ISLA 13145, destroyed).

Diagnosis

Iandumoema setimapocu can be distinguished from other species of the genus by the combination of the following characters: ocularium with reduced and depigmented eyes, bearing a high, straight spiniform apophysis subapically curved backwards; scutal areas unarmed; male coxa IV with slightly sigmoid, unbranched, long spiniform proapical apophysis; male trochanter IV dorso-median face unarmed, with prolateral dorso-ventral keel on central–apical face; male femur IV straight, unarmed on dorso-basal face, and retro-lateral row of granules with spaced pointed tubercles.

Ecological remarks

Hara and Pinto-da-Rocha (2008) did not indicate the coordinates of Lapa do Zú Cave, and mistakenly provided Coração de Jesus as the municipality. Herein, we correct the municipality of the cave as São João da Lagoa. According to Hara and Pinto-da-Rocha (2008), the Lapa do Zú Cave is 3 km long and crossed by a stream that carries considerable amounts of organic debris to the aphotic zone (Fig. 14A, B). RLF could not verify its extension (visit in 25 September 2013). Additional specimens (Fig. 14C) were collected between 200 and 300 m from the cave entrance, on plant debris close to the stream and on the cave walls, in a very humid place (Hara and Pinto-da-Rocha 2008). We further provide a complementary description of Lapa do Zú Cave. It is a limestone cave of considerable volume, with a single sinkhole entrance with intermittent external drainage, receiving organic material from the external environment, especially from floods in the rainy season. Thus, a large amount of plant debris is deposited in different parts of the cave. At its distal part, an abrupt vertical descent leads to a drainage that emerges and sinks amid blocks of rock. The drainage considerably increases the humidity of this part of the cave, even during dry periods. In the visit of 25 September 2013, few specimens were also found with difficulty on the cave sediment and walking freely on the cave walls and speleothems. This might indicate that: (1) the population density is not high; or (2) there are other suitable habitats inaccessible for humans. The external environment around the cave is partially altered, with the original vegetation associated with the limestone outcrops being well preserved, whereas the remaining external area (especially the area crossed by the intermittent stream) is mostly pastures.

Iandumoema smeagol Pinto-da-Rocha *et al.*

(Fig. 15C–E, 18)

Iandumoema smeagol Pinto-da-Rocha, Fonseca-Ferreira & Bichuette, 2015: 83, fig. 2–13. – de Ázara & Ferreira, 2018: 77 (cat), fig. 42C, D.

Material examined

Holotype. BRAZIL. Minas Gerais: Monjolos, Toca do Geraldo cave (18°16'43.31"S, 44°06'10.96"W), 08.vii.2014, R. Fonseca-Ferreira, M.E. Bichuette, I. Arnone and J.E. Gallão leg. (MZSP 67946).

Paratypes. Minas Gerais: same locality of holotype, 1♂, 22.II.2014, Rafael Fonseca-Ferreira and B.G.O. Do Monte leg. (MZUSP 67947); same data, 1♂ (MZSP 67948).

Additional material examined. Minas Gerais: Monjolos, Toca do Geraldo Cave, 15.iv.2017, 1♂ 1♀, R.L. Ferreira *et al.* leg. (ISLA 43363, destroyed); same data, 2♂ (ISLA 43364); same data, 1♂, 14.iv.2017, R.L. Ferreira *et al.* leg. (ISLA 43362); Gruta da Velha Nova cave, 1♂, 11.x.2018 (ISLA 60381).

Diagnosis

Iandumoema smeagol can be distinguished from other species of the genus by the combination of the following characters: ocularium without eyes, bearing a straight spiniform apophysis subapically curved backwards; scutal areas II–IV each with a paramedian pair of pointed tubercles; male coxa IV with an approximately straight (in dorsal view) and unbranched, long proapical apophysis and unarmed on retro-apical face; male trochanter IV unarmed on dorso-central face or prolateral central–apical face; male femur IV straight, unarmed on dorso-basal face and retro-lateral row of granules with spaced pointed tubercles and subapical spiniform apophysis.

Ecological remarks

Pinto-da-Rocha *et al.* (2015) gave a brief description of the habitat of *I. smeagol*. Most specimens were collected in Toca do Geraldo Cave and a single specimen was found in Lapa do Santo Antônio Cave (Fig. 15B). Furthermore, the authors report that, in four visits paid to the Toca do Geraldo, only 14 individuals were found (including adults and juveniles), suggesting a low abundance. Nevertheless, one of the authors (R. L. Ferreira – on 15 April 2017) found at least 15 specimens in a single visit to this cave. All of them were found well distributed throughout the cave (except for the entrance chamber) in the same type of substrates mentioned by Pinto-da-Rocha *et al.* (2015) (Fig. 15C–E). Furthermore, we also observed this species in Toca da Velha Nova Cave, for which the entrance is less than 100 m from that of Toca do Geraldo (Fig. 15A). On 15 April 2017, 17 individuals (including both adults and juveniles) were collected from this cave. Toca da Velha Nova does not have a drainage, and is probably connected (by interstitial spaces) to the Toca do Geraldo Cave. This assumption is based on the fact that the main conduit of the Toca do Geraldo Cave follows towards the direction of Toca da Velha Nova, which is located in an upper topographic level. In a second visit to the Lapa da Velha Nova (11 October 2018), five specimens were collected, including adults and juveniles. In the original description, the authors mentioned that the Toca do Geraldo Cave did not have dry galleries or conduits, but the Toca da Velha Nova Cave might just be those.

Iandumoema stygia, sp. nov.

(Fig. 9–11, 16B–D, 18)

<http://zoobank.org/urn:lsid:zoobank.org:act:0BC55860-605C-4EAD-8408-A3863726F491>

Material examined

Holotype. BRAZIL. Minas Gerais: Montes Claros, Gruta do Cedro cave (16°55'01.9"S, 44°05'01.3"W), 1♂, 14.iv.2017, R.L. Ferreira *et al.* leg. (ISLA 42455, destroyed).

Paratypes. BRAZIL. Minas Gerais: same locality as holotype, 1♂, 09.vi.2015, R.L. Ferreira *et al.* leg. (ISLA 16418, destroyed); same data, 1♂ (ISLA 59437, destroyed); same data, 1♀, (ISLA 59438, destroyed); same data, 1♀ (ISLA 13144, destroyed); same data, 1♀, (ISLA 59439, destroyed); 1♂, same data, 14.iv.2017, R.L. Ferreira *et al.* leg. (ISLA 59440, destroyed); 1♀, same data (ISLA 59441, destroyed); 1♂, same locality, 12.x.2018, R.L. Ferreira *et al.* leg. (ISLA 60384); 1♀, same data (ISLA 60385).

Diagnosis

Iandumoema stygia, sp. nov. can be distinguished from the other species of the genus by the combination of the following characters: ocularium of normal size (larger than granules or tubercles on DS) and pigmented eyes, bearing a high, frontwards curved spiniform apophysis, its apex curved backwards; scutal areas I, III and IV each with a pair of paramedian pointed tubercles; male coxa IV with curved and unbranched, very long (length longer than the coxa IV apical width) spiniform proapical apophysis and retro-lateral face unarmed; male trochanter IV dorso-central face unarmed, with prolateral dorso-ventral keel on central–apical face and one long, robust, retro-lateral apical spiniform apophysis; male femur IV uniformly and smoothly curved inwards in its entire extension, unarmed on dorso-basal face and retro-lateral row of granules with spaced pointed tubercles.

Description

Male holotype (ISLA 42455)

Dorsum (Fig. 9A, E). Dorsal scutum length, 3.5; dorsal scutum width, 2.9; prosoma length, 1.3; prosoma width, 1.9. Measurements of pedipalps and legs are in Table 7. Dorsal scutum outline type α . Carapace and scutal areas with pointed granules. Anterior margin of carapace with prominent frontal hump bearing a main pair of paramedian tubercles. Eyes of normal size (larger than the granules or tubercle on DS), pigmented. Ocularium with high, frontwards curved spine, its apex curved backwards. Scutal areas I, III and IV each with a pair of paramedian pointed tubercles; scutal area I divided into right and left halves. Lateral margin of DS with an external row of tubercles and an internal irregular row of granules. Posterior margin of DS and free tergites I–III each with a row of tubercles. Anal opercle irregularly tuberculate.

Venter (Fig. 9B). Coxa I with scattered granules plus an irregular row of four setiferous tubercles; II–III with scattered granules; IV and stigmatic area irregularly granulate. Posterior margin of genital sternite and free sternites each with a row of low tubercles.

Chelicera (Fig. 9A). Segment I elongated (two times longer than wide), bulla with scattered granules. Segment II fixed finger and segment III toothed.

Pedipalps (Fig. 10I, J). Slightly elongated (~1.5 times the DS length). Trochanter with one dorsal apical tubercle and two ventral apical (ventral mesal largest) setiferous tubercles. Femur with one ventro-basal tubercle, median region with a ventral row of four granules and one mesal subapical setiferous tubercle.

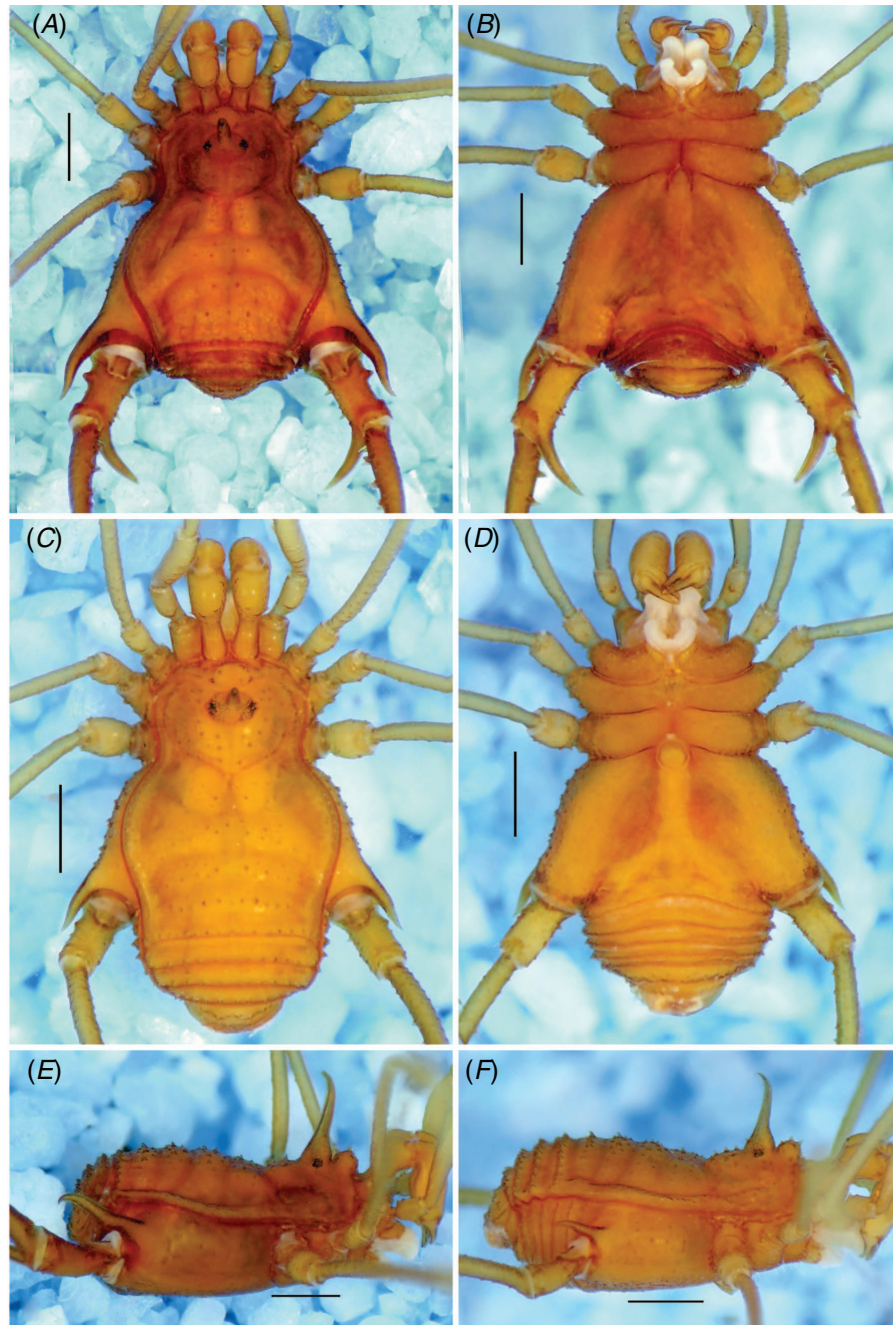


Fig. 9. *Iandumoema stygia*, sp. nov. (A, B, E) male holotype: (A) habitus, dorsal view; (B) same, ventral view; (E) same, right lateral view. (C, D, F) female paratype (ISLA 13144): (C) habitus, dorsal view; (D) same, ventral view; (F) same, right lateral view. Scale bars: 1.0 mm.

Patella smooth. Tibial setation: ectal IIIi, mesal IiIi. Tarsal setation: ectal and mesal IiIi.

Legs (Fig. 10A–D, G, H, K–M). Coxae I–III with prodorsal and retro-dorsal apophyses; apex of retro-dorsal apophysis on coxa II fused with prodorsal apophysis on coxa III. Coxa IV granulated, with long, spiniform proapical apophysis (longer than the coxa IV apical width), which is smoothly curved (on dorsal view) and uniramous. Trochanters I–III with scattered

granules. Trochanter IV prolateral face with short, conical, blunt sub-basal apophysis, and a dorso-ventral keel on central-apical face (in lateral view); retro-lateral face with 2–4 basal-central tubercles roughly organised in a row and one robust, long apical spiniform apophysis (its length at least longer than the podomere middle width). Femora, tibiae–metatarsi I–IV with granules roughly organised in six longitudinal rows (prodorsal, retro-dorsal, pro- and retro-

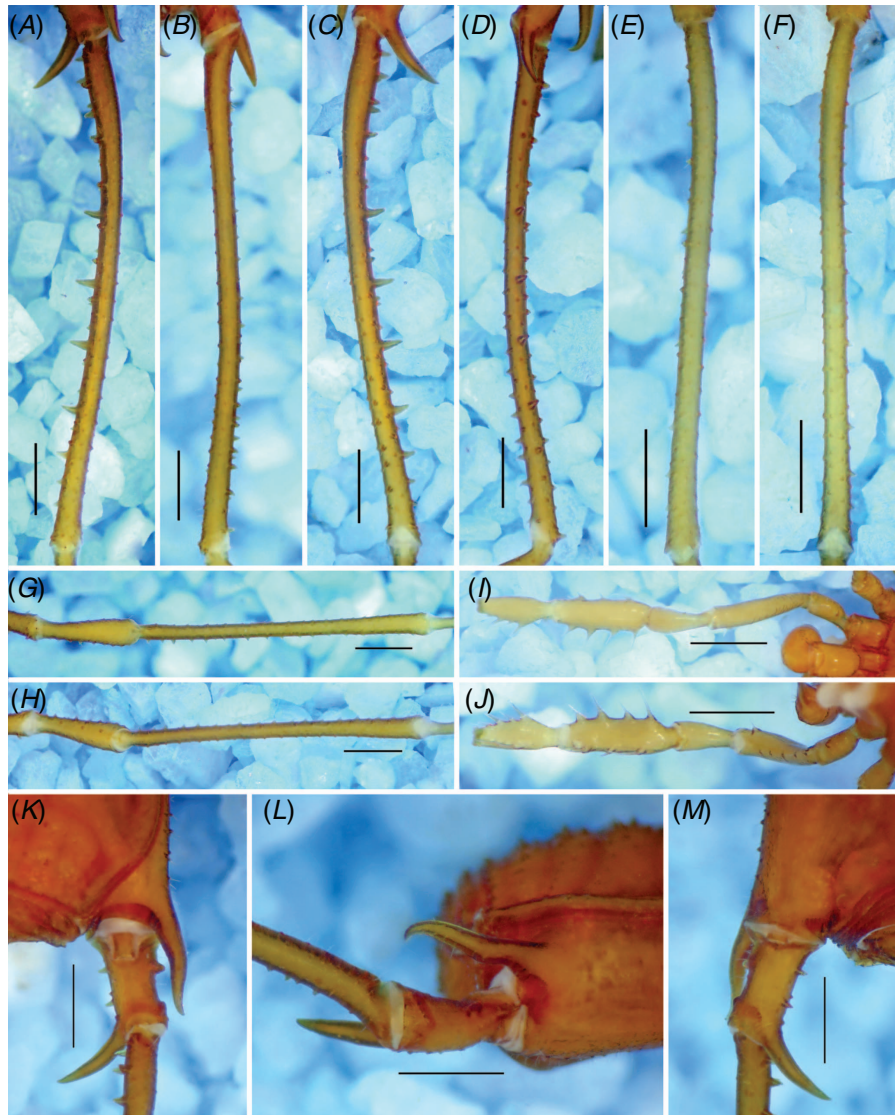


Fig. 10. *Iandumoema stygia*, sp. nov. (A–D, G–M): male holotype. (A) right femur IV, dorsal view; (B) same, prolateral view; (C) same, ventral view; (D) same, retro-lateral view; (G) right patella and tibia IV, dorsal view; (H) same, ventral view; (I) right pedipalp, dorsal view; (J) same, ventral view; (K) coxa–trochanter IV in dorsal view; (L) same, right lateral view; (M) same, ventral view. (E–F), female paratype (ISLA 13144): (E) right femur IV, dorsal view; (F) ventral view. Scale bars: 1.0 mm.

lateral, proventral and retro-ventral rows); femora I–III unarmed; femora I–II approximately straight, femur III slightly curved and unarmed. Femur IV uniformly and smoothly curved in its entire extension, with large dorso-basal tubercle; basal 1/3 of retro-dorsal row of granules with spaced pointed tubercles; dorso-apical face with one retro-lateral, one retro-dorsal and prolateral spiniform tubercles; retro-lateral row of granules with spaced pointed large tubercles (length approximately the same that the podomere middle width); ventral face with two rows of granules becoming tubercles (approximately twice the size of the granule) apically; ventro-apical face with a pair of pointed tubercles. Patella IV granulated, unarmed. Tibia IV

with two ventral rows of granules of approximately similar size, unarmed. Tarsal counts: 6(3), 12–14(3), 6, 6.

Penis (Fig. 11). Ventral plate approximately rectangular with basal and apical portion approximately of same width; distal margin approximately straight; basal lobes conspicuous. Ventral plate with 4–5 pairs of MS A, one pair of MS B (shorter and placed more ventrally), four pairs of MS C, one pair of MS D, 2–3 pairs of MS E (short and placed more ventrally). Microsetae type 1 occupying all ventral plate. Glans without dorsal process; ventral process stem short (less than a quarter of stylus length) and thick (comparable to that of stylus), apex spatula-shaped with serrate margin. Stylus with ventral trichomes.

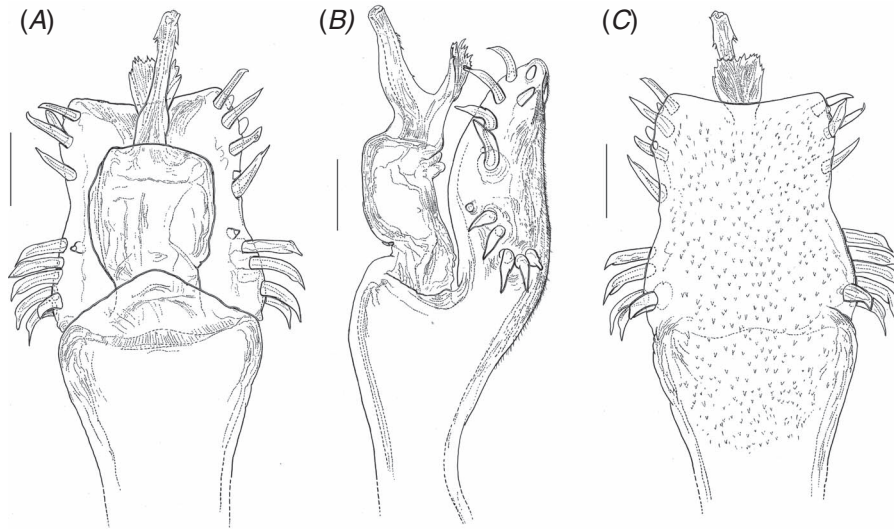


Fig. 11. *Iandumoema stygia*, sp. nov. (ISLA 16418), distal part of penis. (A–C), dorsal, right lateral and ventral views. Scale bars: 0.05 mm.

Table 7. Pedipalp and leg measurements (mm) of *Iandumoema stygia* sp. nov., male holotype (ISLA 42455)

	Tr	Fe	Pa	Ti	Mt	Ta	Total
Pedipalp	0.5	1.8	0.6	1.3	–	0.9	5.1
Leg I	0.5	2.9	1	2.6	4.5	2.2	13.7
Leg II	0.6	8.1	1.7	6.8	8.3	5.5	31
Leg III	0.7	4	1.3	3	5.3	2.2	16.5
Leg IV	1.1	6.9	1.6	5.4	8.2	2.6	25.8

Colouration (male, in alcohol) (Fig. 9, 10). Body and appendages background strong orange (50), median to apical portion of femur IV, patella and pedipalps strong orange yellow (68).

Female (ISLA 13144; Fig. 9C, D, F, 10E, F)

Dorsal scutum length, 3.3; dorsal scutum width, 2.8; prosoma length, 1.3; prosoma width, 1.8. Measurements of pedipalps and legs are in Table 8. Coxa IV reaching scutal groove IV, with a long proapical apophysis (length similar to coxa IV apical width). Trochanter IV prolateral face with a sub-basal tubercle, without dorso-ventral keel, retro-lateral face as in male, but attenuated, with a small retro-apical tubercle. Femur IV with spaced pointed tubercles only in retro-lateral row, dorso and ventro-apical faces each with one pair of pointed tubercles.

Etymology

Name is a noun in apposition, from Styx, one of the five rivers that form the boundary between Earth and the Underworld according to Greek mythology. Styx also refers to the Titan goddess. From Latin *stygius*, from Ancient Greek Στύγιος

Table 8. Pedipalp and leg measurements (mm) of *Iandumoema stygia* sp. nov., female holotype (ISLA 13144)

	Tr	Fe	Pa	Ti	Mt	Ta	Total
Pedipalp	0.5	1.6	0.8	1	–	0.9	4.8
Leg I	0.5	2.8	1.1	2	3.9	1.9	12.2
Leg II	0.6	5.7	1.3	4.5	5.4	5.2	22.7
Leg III	0.7	4	1	2.5	4.4	2.1	14.7
Leg IV	0.7	5.5	1.4	4	6.4	2.1	20.1

(Stúgios, ‘relating to Styx’), from Στύξ (Stúx, ‘Styx, chief river of underworld’).

Ecological remarks

The cave where *I. stygia*, sp. nov. was collected (Lapa do Cedro Cave, Montes Claros, Minas Gerais) (Fig. 16A) is associated with Neoproterozoic limestones from the Bambuí geological group. This dry cave is a single conduit of ~200 m. The constriction, at ~40 m from the cave entrance, makes the inner part comparatively more stable than the entrance area. Furthermore, another constriction (at ~120 m from the entrance) makes the deeper chamber even more isolated from the remaining areas of the cave, resulting in extremely stable temperature and humidity (despite the lack of water bodies in the cave). Specimens of *I. stygia*, sp. nov. were only found in the innermost portions of the cave (Fig. 16B–D), where temperature is constant and humidity is high. They were observed walking freely on speleothems and found with difficulty (see below). During the three visits to the cave, only 11 specimens were collected: five in the first visit (9 June 2015), three in the second visit (14 April 2017) and three in the last visit (12 October 2018). The large number of speleothems

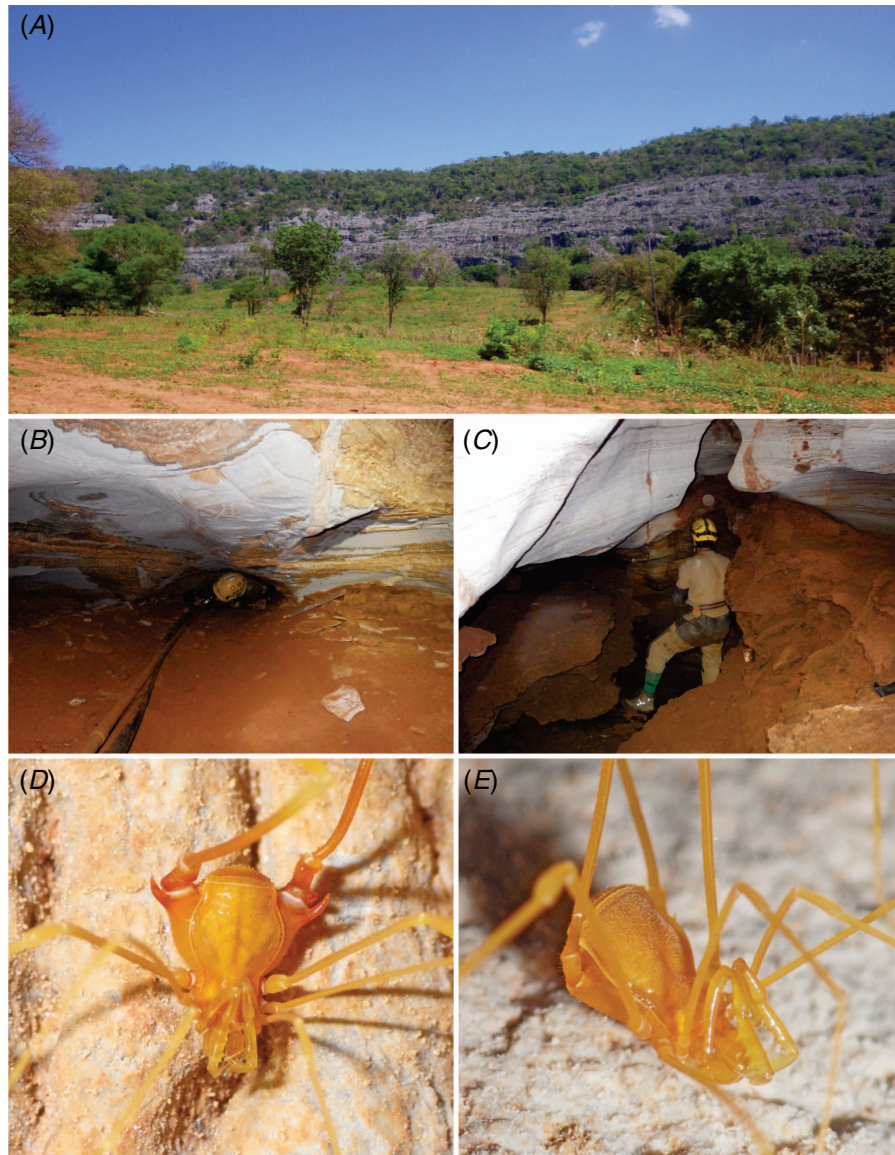


Fig. 12. Habitat and habitus of *Iandumoema cuca*, sp. nov. (A) External area of the Gruta da Água do João Ferreira, Itacarambi, MG, Brazil; (B, C) inner conduit of the cave; (D, E) male and female respectively inside the cave. Photos by L. M. Rabelo.

and the irregular topography (especially in the innermost chambers) makes it hard to estimate the size of the population.

The Lapa do Cedro Cave is visited by humans quite regularly, with many signs of anthropogenic interference (such as broken speleothems, graffiti, among others). However, the difficulty in reaching beyond the second constriction (~120 m from the entrance) due to its size has limited human use, thus preserving the innermost chamber. Considering that this is a dry cave, the main trophic resources are the animals attracted to bat guano piles, such as crickets, cockroaches and isopods. A small patch of forest surrounds the cave entrance, but the remaining external landscape is severely altered, being composed of pastures or monocultures.

Iandumoema uai Pinto-da-Rocha, 1997

(Fig. 17C, D, 18)

Iandumoema uai Pinto-da-Rocha, 1997: 844, fig. 1–9. – Kury, 2003: 173 (cat); Do Monte, Gallão, von Schimonsky & Bichuette, 2015: 2 (cit), 5 (syst), 8–10 (cit), 11 (dist), fig. 3; Pérez-González, Ceccarelli, Monte, Proud, DaSilva & Bichuette, 2017: 2 (cit); de Ázara & Ferreira, 2018: 77 (cat), fig. 26F, 27A, 42E, F.

Material examined

Holotype. BRAZIL, Minas Gerais: Itacarambi, Gruta Olhos D'Água (15°06'47"S, 44°10'11"W), ♂, 10.vii.1993, E. Trajano leg. (MZSP 15029).

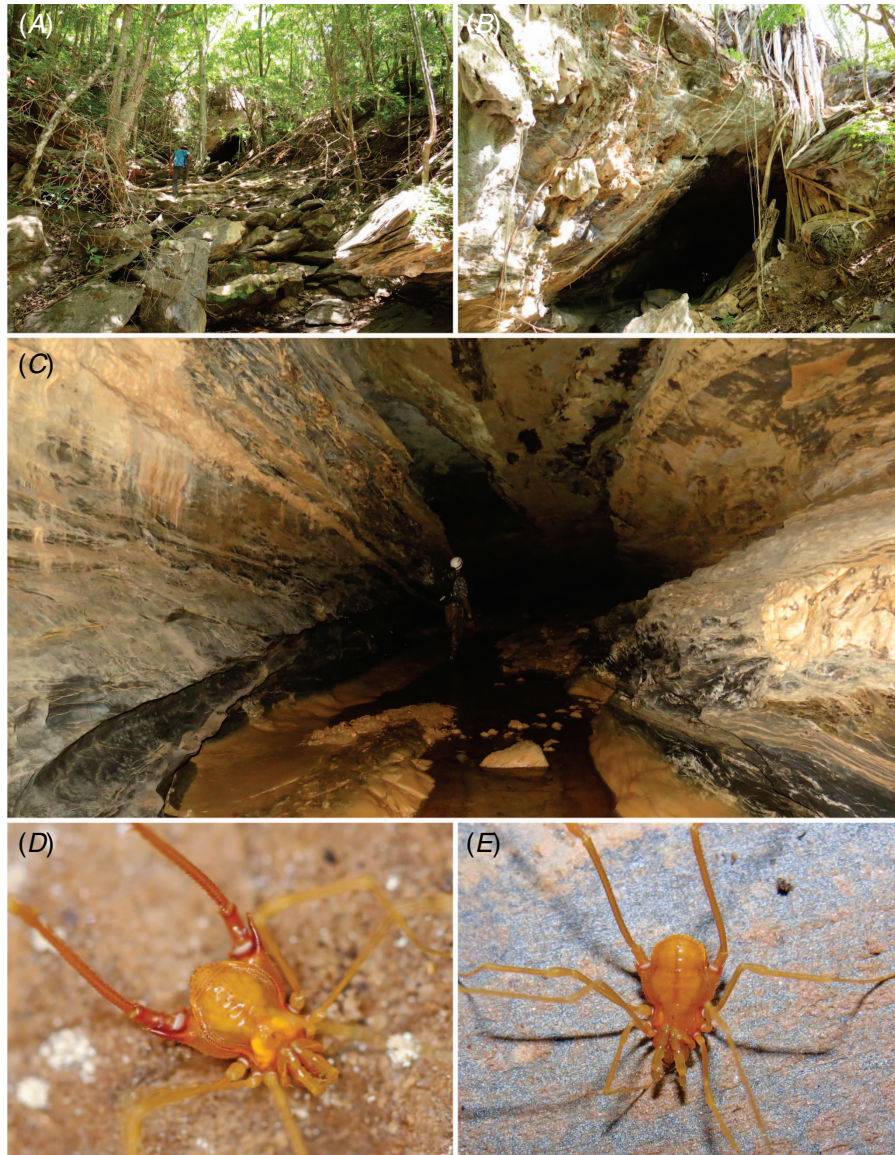


Fig. 13. Habitat and habitus of *Iandumoema gollum*, sp. nov. (A, B) entrance of the Lapa D'Água, Presidente Juscelino, MG, Brazil; (C) inner portion of the cave; (D, E) living male and female specimens inside the cave respectively. Photos by R. L. Ferreira.

Paratypes. BRAZIL, Minas Gerais: same data as holotype, 1♂ 1♀ paratypes (MZSP 15030); same locality, 1♂ 2♀, 15.vi.1995, C. Galán leg. (MZSP 15152); 1♂ 2♀, same locality, vii.1994 (MNRJ, destroyed).

Additional material examined. **Brazil:** Minas Gerais: same locality as holotype, 1♂ 1♀, iv.1985, F. Chaimowicz leg. (MNRJ-HS 858, destroyed); same locality, 1♂, R.L. Ferreira *et al.* leg. (ISLA 13151, destroyed); Lapa do Cipó, 1♂, 26.i.2015, R.L. Ferreira *et al.* leg. (ISLA 59442, destroyed); same data, 1♂ (ISLA 13146, destroyed); same data, 1♂ (ISLA 59443, destroyed); same data, 1♀ (ISLA 14849, destroyed); same data, 3♀ (ISLA 15636, destroyed).

Diagnosis

Iandumoema uai can be distinguished from the other species of the genus by the combination of the following characters: ocularium with normal sized (larger than the granules or tubercle on DS) and depigmented eyes, bearing a high,

straight spiniform apophysis, its apex curved backwards; scutal areas I–IV unarmed; male coxa IV with abruptly curved and unbranched, long spiniform proapical apophysis, retro-lateral face unarmed; male trochanter IV dorso-central face unarmed and with pointed proapical tubercles; male femur IV curved retro-laterally on basal 1/4, unarmed on dorso-basal and retro-lateral faces.

Ecological remarks

Iandumoema uai was previously known only from the Gruta Olhos D'Água Cave, located in Itacarambi, Minas Gerais, with a very small population (by visual estimation; Pinto-da-Rocha 1997). The species seems to prefer the areas near the stream, probably because of the available food sources and substrate diversity (Chaimowicz 1986; Pinto-da-Rocha



Fig. 14. Habitat and habitus of *Iandumoema setimapocu* Hara & Pinto-da-Rocha, 2008. (A) Entrance of the Lapa do Zú, São João da Lagoa, MG, Brazil; (B) inner portion of the cave; (C) living female specimen inside the cave. Photos by R. L. Ferreira.

1997). Furthermore, Pinto-da-Rocha (1997) proposed that floods of the cave stream could control the population fluctuation by carrying away specimens downstream (which probably died).

Do Monte *et al.* (2015) found *I. uai* (Fig. 17C, D), previously considered endemic to Gruta Olhos D'Água, in the Lapa do Cipó Cave, located 6.5 km north-west from the latter cave (Fig. 18). The authors proposed a testable hypothesis of connection between the caves, but unfortunately provided almost no data on the Lapa do Cipó Cave. Thus, we here provide further characterisation for this cave: it has a single and tall entrance located at the base of a limestone outcrop, which receives water from the outside during the rainy season, especially in flash floods. The main conduit (that leads to the entrance) is connected to another, which is perpendicularly orientated in relation to the former. This conduit has many constrictions and is crossed by a drainage (Fig. 17B). Hence, this inner conduit is extremely humid, contrasting with the conditions near the entrance in the cave. RLF visited Lapa do Cipó (28 October 2014) and found eight specimens of *I. uai* only on the cave walls. An Indigenous person indicated that people used to pump the water from the stream inside the cave, and remnants of some of its concrete structures can still be found inside. However, presence of human visitors seems discouraged because of the difficulties in reaching the inner conduits of the cave, especially where

specimens of *I. uai* occur. The pumping activities ceased many years ago, and the cave (as well as its surroundings) can be considered well preserved.

Discussion

The main goal achieved in this article was to test the monophyly of a genus only known from caves. This is important because many genera are still recognised based on the Roewerian system (a classification system that lasted for more than half a century that was based on a limited set of characters that did not take intraspecific variation into account in most cases, obscuring phylogenetic inferences; see Pinto-da-Rocha (2002), Hara and Pinto-da-Rocha 2010 and Mendes 2011, just to name a few), despite the enormous efforts to revert this scenario in the past four decades. The uncertainty of the monophyly of a given group considerably hinders the meaningfulness of comparative, evolutionary studies, as further inferences are not possible or highly doubtful. As *Iandumoema* monophyly is corroborated, it is now possible to tackle other comparative studies (such as ecological, behavioural, chronobiological, just to name a few) in a cave-restricted group under a phylogenetic perspective for the first time in Brazil.

We addressed the issue regarding the use of troglomorphic characters in cladistic analysis using the approach of Desutter-

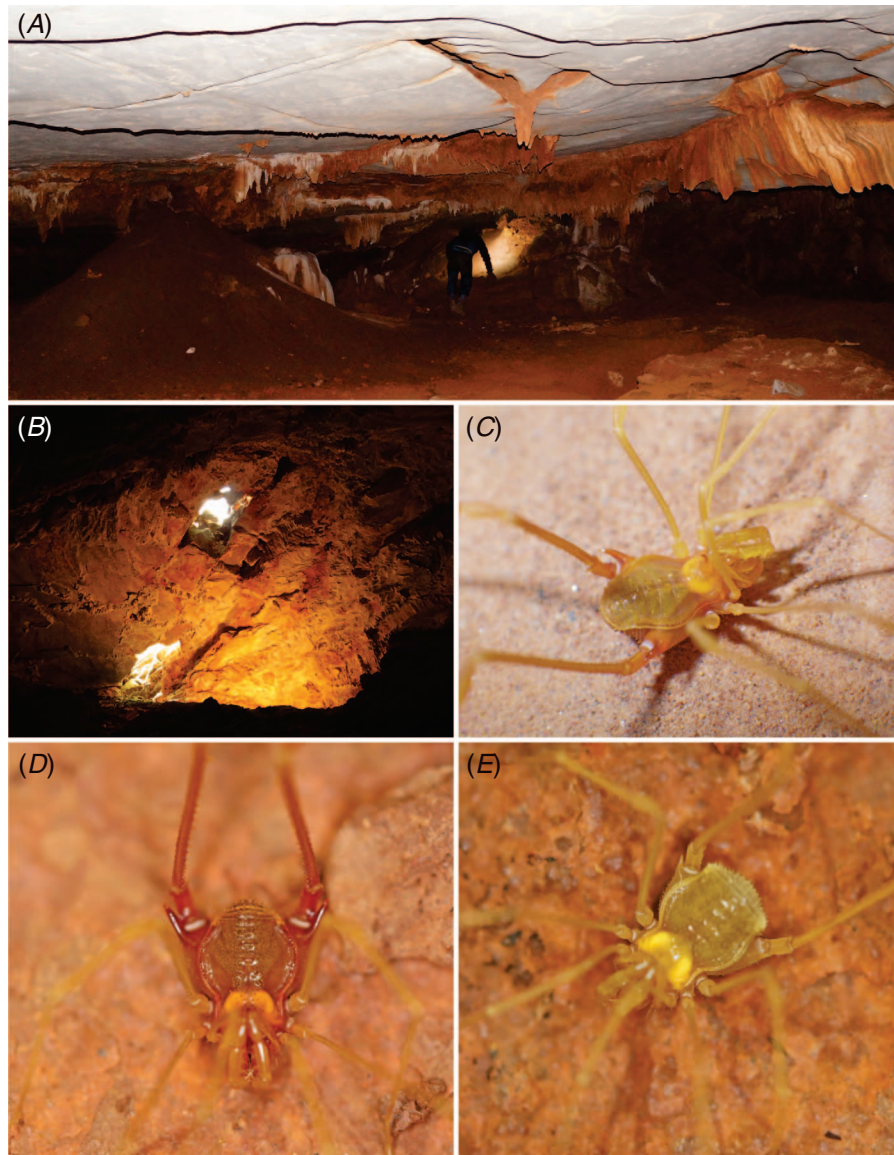


Fig. 15. Habitat and habitus of *Iandumoema smeagol* Pinto-da-Rocha *et al.*, 2015. (A) Inner chamber of the Toca da Velha Nova Cave, Monjolos, MG, Brazil; (B) entrance chamber of the Toca do Geraldo Cave, Monjolos, MG, Brazil; (C, D) living male and (E) female specimens inside the cave respectively. Photos by R. L. Ferreira (B–E) and M. Souza-Silva (A).

Grandcolas *et al.* (2003). In this study, we took a rather conservative approach, reducing the characters potentially associated to cave life to a minimum of two, namely the presence or absence of eyes and presence or absence of eye pigmentation (#3 and #4). We are aware that pigmentation of the eyes is rather a continuous character. However, we notice that there was no need to treat the pigmentation of the eyes as such based on the taxon sampling, i.e. we did not notice the need to create a character depicting the degree of pigmentation. The analysis under equal weights excluding these two characters resulted in the same topology as including them (Fig. 1), but with fewer steps and the same consistency and retention indexes values (L = 335 steps; CI =

35; RI = 56). This analysis indicates that *Iandumoema* is a monophyletic genus, regardless of the inclusion of characters that are associated with cave dwelling.

For obvious reasons, no relationship among the species of *Iandumoema* had been addressed until Pinto-da-Rocha *et al.* (2015). According to their hypothesis, *I. setimapocu* and *I. smeagol* are closely related. In the present analysis, *I. gollum*, sp. nov. is the sister-species of *I. smeagol*. In addition, *I. setimapocu* is the sister-species of the clade including *I. stygia*, sp. nov. plus *I. setimapocu* + *I. gollum*, sp. nov.

Although the monophyly of *Iandumoema* is undisputed under the many analyses, its placement among Brazilian

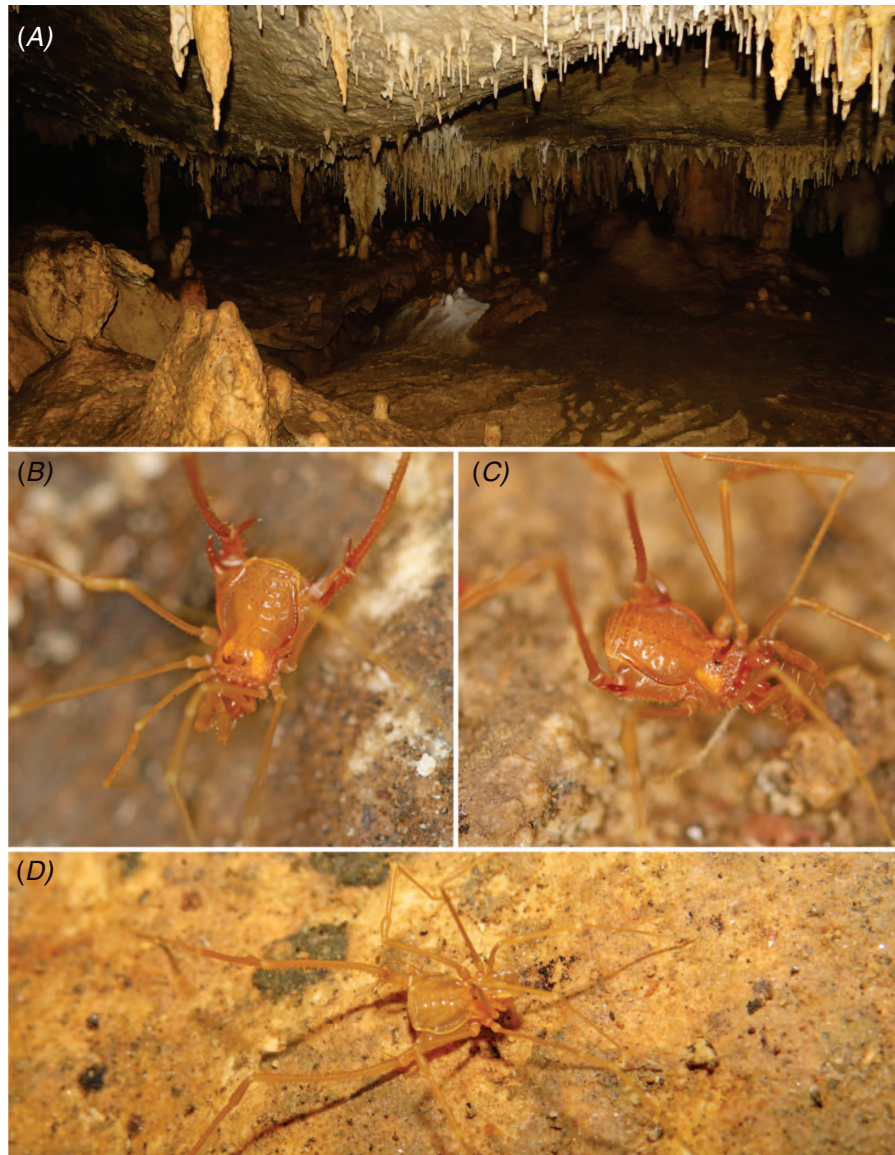


Fig. 16. Habitat and habitus of *Iandumoema stygia*, sp. nov. (A) Inner portion of the Gruta do Cedro, Montes Claros, MG, Brazil; (B–D) living specimens inside the caves: (B, D) males; (C) female. Photos by R. L. Ferreira.

taxa is still an unsettled issue, as discussed below. Upon its description, Pinto-da-Rocha (1997) related *Iandumoema* to *Gyndulus* Roewer, 1929, *Acanthopachylus* Roewer, 1913 (= *Heteropachyloidellus* Mello-Leitão, 1927), *Platygyndes* Roewer, 1943, *Progyndes* Roewer, 1917, *Pseudoacrographinotus* Soares, 1966 and *Pucroliia* Sørensen, 1895 based on the Roewerian system. The knowledge about Neotropical harvestmen has improved considerably since that time and, despite not including taxa from those genera in the present analysis, we can rule out *Platygyndes*, as it is a Cosmetidae (Pinto-da-Rocha *et al.* 2012) and *Acanthopachylus*, which is closely related to *Pachylus* (Hara *et al.* 2012; Pinto-da-Rocha *et al.* 2014). *Gyndulus* and

Pseudoacrographinotus are difficult to include in the analysis because the type species of those genera are females and most of the characters in the present analysis are based on male features, such as penis and the dimorphic armature on the leg IV. The type species of *Pucroliia* is a male and, based on its description, it most likely belongs to *Eusarcus* Perty, 1833, possibly related to or even a synonym of *E. hastatus* Sørensen, 1884 (unpubl. data). Other species of *Pucroliia* are only known from females.

In the present analysis, the sister-group of *Iandumoema* is the clade including Pachylinae (except for *G. chagasi*, *E. catharinensis* and *D. inermis*) + K92 (Fig. 1). Considering that Pachylinae is polyphyletic and the most

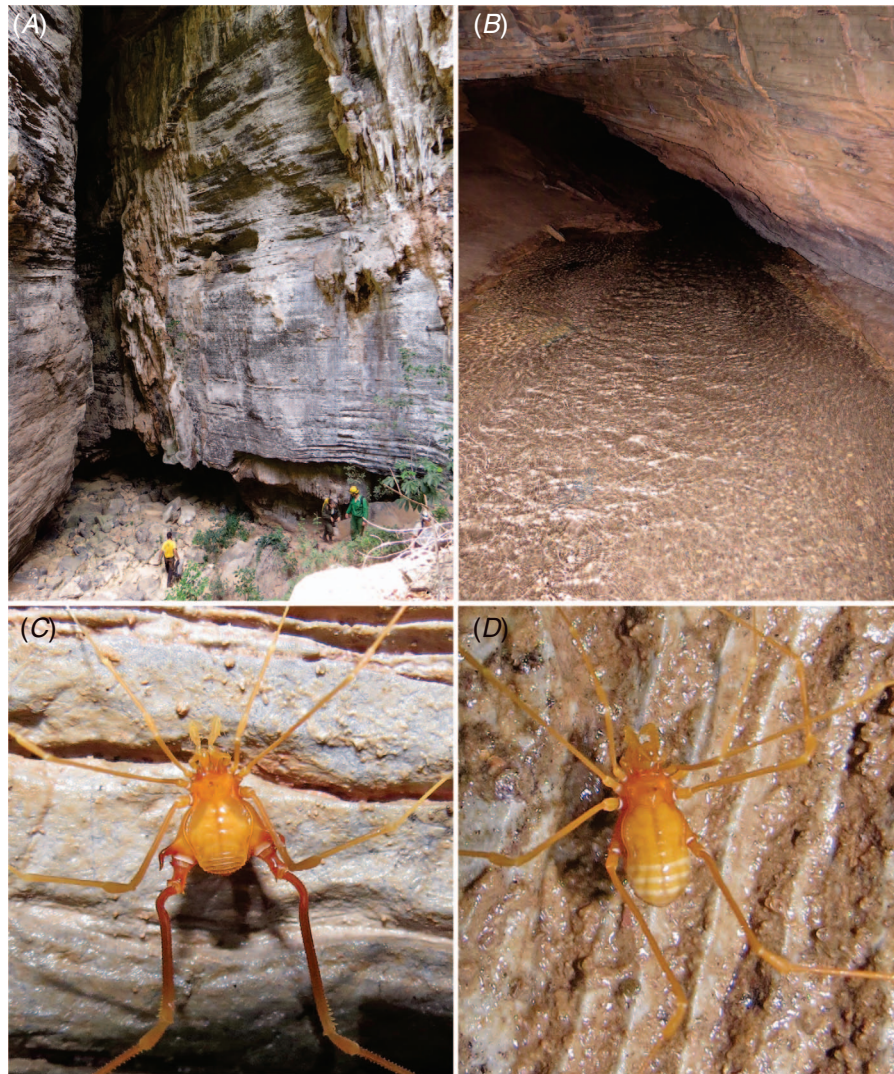


Fig. 17. Habitat and habitus of *Iandumoema uai* Pinto-da-Rocha, 1997. (A) Entrance of Lapa do Cipó, Itacarambi, MG, Brazil; (B) inner conduit of the cave; (C, D) living male and female specimens inside the cave respectively. Photos by R. L. Ferreira.

taxon-rich subfamily in the Gonyleptidae (with ~100 genera), we are aware of the sampling issue. We composed the outgroup seeking to include the main subfamilies of Gonyleptidae and as much of the morphological diversity in Pachylinae as possible, given the aim of this manuscript. Considering these, the sister-taxon relationship must be taken with care, as we included just over 10% of the known Pachylinae genera. In the present analysis, we can infer with certain confidence that it is not closely related to Pachylinae *sensu stricto*, but possibly close to the other Brazilian ‘Pachylinae’ lineage. As the taxonomic knowledge of the Brazilian ‘Pachylinae’ increases, it shall be dismantled in many monophyletic groups (Pinto-da-Rocha *et al.* 2014). Hence, the sister-taxon of *Iandumoema* shall be gradually understood with more confidence, and this study is the first step towards that goal. Ideally, we wish that future

phylogenetic studies including *Iandumoema* would be based on the present matrix, being further improved by addition of more taxa with proper sampling in some genera (as some might include over 50 species, such as *Discocyrtus* Holmberg, 1878) as well as more morphological characters, eventually also using different types of data (e.g. molecular). This should corroborate (or not) the present sister-taxon of *Iandumoema* and further enhance understanding of this cave-restricted genus.

Geographical distribution

Iandumoema is restricted to the limestone caves of the Bambuí group from northern to almost central Minas Gerais, corroborating previous authors (Hara and Pinto-da-Rocha 2008; Pinto-da-Rocha *et al.* 2015; Fig. 18). *I. gollum*, sp.

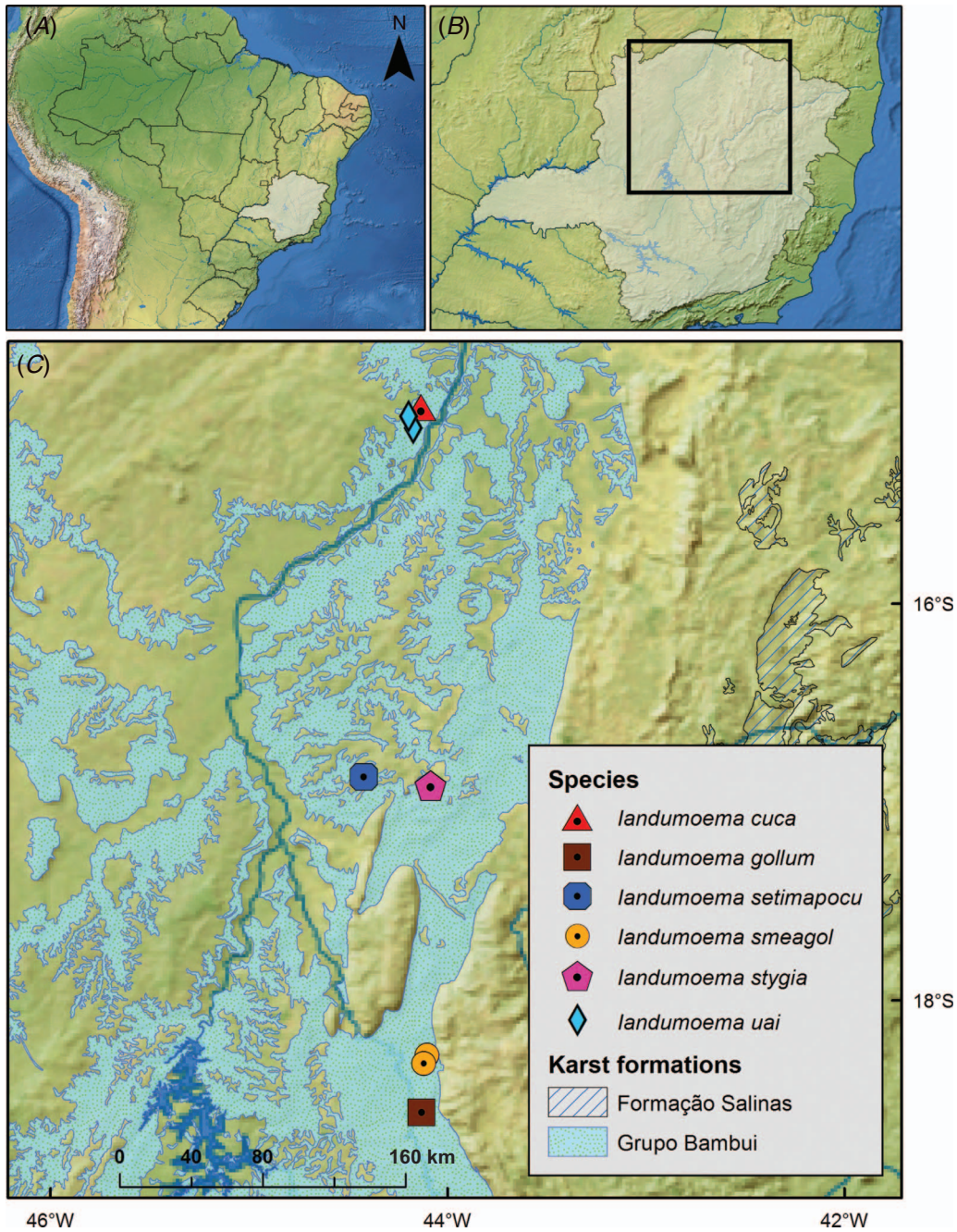


Fig. 18. Known distribution of *Landumoema* species. (A) Brazil; (B) Minas Gerais State; (C) detail of the area with karst formations highlighted.

nov. expands the genus distribution towards the southern part of the karstic formation, and we agree with Pinto-da-Rocha *et al.* (2015) that the eastern limit seems to be limited by quartzites from the Serra do Espinhaço. All *landumoema* species are associated with the deeper chambers or conduits of limestone caves with some kind of drainage, except for *I. stygia*, sp. nov. The lack of data regarding the conduits and microconduits that *landumoema* species are able to use in the

hypogean system, as well as the difficulty for humans to actually check them to find subterranean barriers, considerably hinders further inferences regarding the speciation process in the genus. A biogeographical study is beyond the scope of this manuscript, but such a study considering all the geomorphological data available is desirable in the near future to understand subterranean speciation processes.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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Appendix 1. Data matrix for *Iandumoema* and outgroup species

Polymorphisms: A = 0/1, B = 1/2. '-', '1/2': inapplicable data; '?', missing data

Taxa	001100--0-	1111111112	2222222223	3333333334	4444444445	5555555556	6666666667	7777777778
	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
	Character states							
<i>Cymorta conspersa</i>	001100--0-	0010301000	00000-0-00	0--001000	000-00020-	0000000000	0010-02000	0010-02000
<i>Incasarcus ochoai</i>	001100--0-	0000001000	00000-0-10	0--002000	000-00020-	0000000100	0010-02200	0010-02200
<i>Pachylus chilensis</i>	001121000-	0100101000	11100-0-00	1101011001	0010000210	0211231211	1111000001	60--04101
<i>Acrogonyleptes spinifrons</i>	111110--11	0111100-00	0000101000	1211113?01	0010000211	0014220111	1111011201	011201111
<i>Ampheres leucopheus</i>	111100--10	0100300-10	00000-0-01	1210112001	001100020-	2011220000	0011111211	011201211
<i>Carlotta serratipes</i>	101111000-	0111101110	00000-0-00	1200013?10	0010010-11	0114222211	1111102111	710104111
<i>Daguerreia inermis</i>	001120--10	0100001000	00000-0-10	1100011010	001000020-	0011111011	0011010101	111102110
<i>Discocyrtus invalidus</i>	001120--12	0100101000	00000-0-10	1102112110	0011011211	0011111000	0011010111	111101110
<i>Discocyrtus prospicius</i>	001110--10	0100201000	00000-0-10	1132112110	0010010211	0010111011	1111010111	111101101
<i>Eusarcus catharinensis</i>	00110100A1	0100011000	00000-0-10	1100011001	100-00020-	000020A000	0011000111	51110111?
<i>Guaraniticus lesserti</i>	001122000-	0100301000	00000-0-10	1031112010	1010011211	0004110000	0011000111	1110011A1
<i>Goniosoma varium</i>	001100--12	0100300-10	00000-0-10	1000112010	100-00010-	0001012001	0011000101	41220111?
<i>Gonyleptes horridus</i>	111100--11	0100100-10	0000101010	1221113010	0010010211	2010222000	0011011211	011101111
<i>Hypophyllonemus longipes</i>	001111000-	0111101000	00000-0-10	1002111110	0111010210	0010222020	1111010101	51100111?
<i>Metagyndes martensii</i>	001101000-	0101001000	0000111100	1100011001	001000120-	0011231211	1111000001	60--0-201
<i>Neopachylus bellicosus</i>	001111000-	0110101100	00000-0-10	1101111101	1011011111	0011120210	1111012111	811101101
<i>Paradisocycrtus trochanteralis</i>	001110--11	0110101010	00000-0-10	1131112010	1011011211	0111111000	0001010100	--0-01101
<i>Progonyleptoidellus stritatus</i>	111110--12	0100100-10	00000-0-01	1220112010	0010000211	0033221111	0011211211	011201111
<i>Pseudogynedesoides latus</i>	001101000-	0100101000	00000-0-10	1100111110	0110010110	0010222021	1111010101	51020110?
<i>Sodreana sodreana</i>	111100--12	0100000-10	00000-0-01	1212112001	0010000111	0000220000	0011011211	011201111
<i>Triglochmura curvispina</i>	001100--10	0100101000	0000111110	1102111000	1010010011	2120222201	1111113101	910101110
<i>Giupponia chagasi</i>	100-22020-	1000001000	00000-0-01	0--013000	000000120-	0000000000	0000-01000	-0--0210?
<i>Iandumoema uai</i>	121022100-	1100001000	00000-0-10	1120011010	001010100-	0011111101	0111010101	210003111
<i>Iandumoema setinapocu</i>	121022110-	1100001000	00000-0-10	1210011010	0111010120-	0011111000	0011110101	21000120?
<i>Iandumoema smeagol</i>	120022100-	1101011010	00000-0-00	1200013010	0011010120-	0111110100	0011100111	911001BA?
<i>Iandumoema cuca</i>	121022100-	1100001000	00000-0-10	1211011010	001010100-	0011111101	0011010101	310002001
<i>Iandumoema gollum</i>	1210221100-	1111101101	00000-0-00	1200113010	0011101210	0102121100	0011100111	310002111
<i>Iandumoema stygia</i>	121122120-	1110101100	00000-0-1?	1210011010	011210110-	0010111000	0011200111	210002B01