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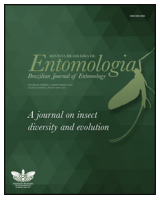

Redescription of adults, nymphs and taxonomic notes on the Southern Brazilian mayfly *Ulmeritus saopaulensis* (Traver, 1946) (Ephemeroptera: Leptophlebiidae)

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ABSTRACT

The small mayfly genus *Ulmeritus* Traver, 1956 currently includes three species of Neotropical Leptophlebiidae (Ephemeroptera) distributed in southern South America in the Pampean and Atlantic Forest dominions: *U. carbonelli* (Uruguay), *U. balteatus* (Brazil and Uruguay) and *U. saopaulensis* (Brazil). *Ulmeritus saopaulensis* is a poorly known endemic species from Brazil. Based on material from a single locality in Minas Gerais, we complement the knowledge on this species with a redescription of adults and nymphs and describe the eggs for the first time. The confusing nomenclatural history and the correct spelling of the specific name *saopaulensis* is discussed in light of International Code of Zoological Nomenclature. This paper points out that in despite of recent advances on the knowledge of this genus a full taxonomic review and phylogenetic analyses are pending to solve species delimitation and evolutionary relationships.

Introduction

The genus *Ulmeritus* Traver, 1956 was originally erected to include two species of Neotropical mayflies of Leptophlebiidae: *Ulmeritus carbonelli* Traver 1956, its type-species from Uruguay; *Ulmeritus saopaulensis* (Traver, 1946), transferred from *Atalophlebioides* and recorded from Southeastern Brazil; and another unnamed species from Uruguay. A few years later, Traver (1959) divided *Ulmeritus* into three subgenera and described or transferred the following species: *Ulmeritus* (*Ulmeritus*) *haarupi* (Esben-Petersen, 1912); *Ulmeritus* (*Pseudoulmeritus*) *flavopedes* (Spieth, 1943); *Ulmeritus* (*Ulmeritoides*) *uruguayensis* Traver, 1959 and *Ulmeritus* (*Ulmeritoides*) *luteotinctus* Traver, 1959. Soon after that, Thew (1960) described three additional species, but without allocating them in any of the subgenera proposed by Traver (1959): *Ulmeritus adustus* Thew, 1960; *Ulmeritus balteatus* Thew, 1960 (= *Ulmeritus* sp. from Traver, 1956); and *Ulmeritus patagiatus* Thew, 1960.

In a series of two papers dealing with the group, Domínguez (1991, 1995) redefined the genus and gave full generic status to the subgenus *Ulmeritoides* Traver, 1959. Except for *U. carbonelli, U. saopaulensis* and *U. balteatus*, the remaining species once combined with *Ulmeritus* were synonymized or transferred to *Ulmeritoides*, a genus that currently comprises 20 species distributed in South and Central America (Salles et al., 2022).

Among the three species of *Ulmeritus*, little is known about *U. saopaulensis*. Since the original description, in which only the hind wing and genitalia were illustrated (Figs. 3 to 6 of Traver, 1946), no additional data or even illustrations have been provided for the adults. Importantly, the description was based on a single male and a single female imago, from the states of São Paulo and Minas Gerais, respectively. Later, based on three specimens reared to the adult stage, Da-Silva and Pereira (1992) described the ultimate nymphal instar of this species for the first time, and illustrated it. Notes with biological data were also provided, including the unusual occurrence of the nymphs in lentic habitats.

In the present study, based on extensive material from a single locality in Minas Gerais, we complement the knowledge of this poorly known species by presenting the description of the eggs and subimagos for the first time, and a full taxonomic treatment including synonymy, diagnoses, redescriptions of the imagos and nymphs, as well as a map

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including the distribution of the three species of *Ulmeritus*. Finally, we also comment on the habitat and life cycle.

Material and methods

Specimens of *U. saopaulensis* were collected in Paula Cândido municipality, Minas Gerais State, Brazil. The nymphs were captured using a regular aquatic net. Subimagos and imagos were captured using a light sheet trap, while some of them were reared in the laboratory from nymphs. All material was preserved in ethanol 80–100%. Mouthparts and legs of nymphs, as well as male genitalia, were mounted on permanent slides with Canada Balsam or Euparal. Fore and hind wings were dry mounted on slides. General morphological terminology was based on Domínguez et al. (2006) except for the thorax which follows Kluge (2004) and eggs that follows Koss and Edmunds (1974). Images from scanning electron microscope (SEM) were obtained from dissected structures and eggs, transferred from ethanol, and subsequently treated—to be cleaned and dehydrated during 15 minutes to 24 hours—using three distinct chemical solutions: (1) ethanol series (80%–absolute), (2) 100% acetone and (3) hexamethyldisilazane (HDMS). After that they were air dried for double mount preparation then mounted on stubs. SEM images were undertaken under low vacuum, without or with metallic coating, at the Centro de Microscopia Eletrônica (CME) of the Universidade Federal do Paraná (UFPR) with a JEOL JSM 6360-LV microscope and at the Núcleo de Microscopia e Microanálise (UFV) with a Zeiss - LEO 1430 VP microscope. The focus stacking photos of external morphology were carried out with a Leica stereomicroscope and source images stacked with LAS MONTAGE auto-montage software (Version 4.7) or through macrophotography techniques and stacked in Helicon Focus (Version 8.0). Material from the following collections was examined:

DZUP – Entomological Collection Pe. Jesus Santiago Moure, Departamento de Zoologia, Setor de Ciências Biológicas, Universidade Federal do Paraná, Curitiba, PR, Brazil.

UFVB – Museu de Entomologia, Universidade Federal de Viçosa, Viçosa, MG, Brazil.

The coordinates of the map of the collecting sites were standardized following the toponyms list of IBGE (2011). The map was elaborated in the QGIS (2022).

Results

Ulmeritus saopaulensis (Traver, 1946)

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(Figs. 1–6)

Atalophlebioides são-paulense Traver, 1946: 421, 423, **424**, 426, Figs. 3–6 (descriptions of imagos male holotype and female allotype, BRAZIL, São Paulo State, Bauru municipality, 4.XII.1919, C. U. Entomological Expedition in CUIC, illustrations of hind wing and genitalia of the holotype, comparison with *Ulmeritoides haarupi* and *Ulmeritoides flavopedes*).

Ulmeritus são-paulensis (Traver, 1946): —Traver (1956: 12, **comb. nov.**, comparison with *Ulmeritus carbonelli*).

[*Ulmeritus* (*Ulmeritus*)] *sao-paulense* (Traver, 1946): —Traver (1959: 6, mention, combination implicit by the context ICZN, 1999, Art. 11.9.3 of the Code).

[*Ulmeritus*] *sao-paulense* (Traver, 1946): —Thew (1960: 123, mention, combination implicit by the context).

Ulmeritus (*Ulmeritus*) *saopaulensis* (Traver, 1946): —Hubbard (1982: 268, catalog to South America).

Ulmeritus (*U*[*lmeritus*]) *saopaulensis* (Traver, 1946): —Da-Silva and Pereira (1992: 855–858, Figs. 1–8, description, illustrations of habitus, gills, and mouthparts of the nymph from Minas Gerais State, comparison with *U. carbonelli* and *Homothraulus misionensis* [Esben-Petersen, 1912]).

Ulmeritus saopaulensis (Traver, 1946): —Domínguez (1991: 157, 160, taxonomic notes); —Domínguez (1995: 34, 35, 38, phylogenetic analysis); —Hubbard and Pescador (1999: 138, checklist to São Paulo state, Brazil); —Salles et al. (2004: 29, catalog to Brazil); —Domínguez et al. (2006: 40, 528–529, 531, 532, catalog to South America, taxonomic review, key to nymph and imago); —Mariano and Polegatto (2011: 594, checklist to São Paulo State); —Salles and Domínguez (2012: 51, 61, 65, phylogenetic analysis, key to nymph and imago); —Souto et al. (2016: 135, key to imago); —Campos et al. (2017: 60, 62, record to Bahia state, Brazil).

Material examined. BRAZIL. Minas Gerais State: 11 nymphs, Paula Cândido municipality, Buieié locality (-20.8738, -42.9800, 739 m a.s.l.), 17.v.2019, F. Salles and Marulanda leg. (DZUP 515219–515221); 3 nymphs, 6 nymphal exuviae, 2 male subimagos, 3 female subimagos,2 male and 9 female imagos, same data but 4.xii.2018, Salles, Chau, Maico and Marulanda leg. (UFVB 0019).

Type repository. Holotype ♂ and allotype ♀ by original designation in Cornell University Insect Collection (CUIC). Probably lost (pers. comm. Jason Dombroski, collection manager).

Diagnosis. *Ulmeritus saopaulensis* can be separated from the other species of the genus by the combination of the following characteristics. Male and female imagos (except for character 4): (1) pigmentation of cross-veins on fore wing not forming bands (Fig. 2C); (2) hind wing with few cross-veins (around 20); (3) maculae on hind wing restricted to subcostal cross-veins; (4) ventral projection of penis laterally positioned (Fig. 2I). Nymph: (5) distal emargination of labrum smooth, lacking denticles (Fig. 3B); (6) maxillary palp segment III shorter than segment II (Fig. 3D); (7) maxillary tusk short.

Redescription

Male imago (Fig. 1E). In alcohol: Body length: 8.0–8.3 mm; wing length: 7.8–8.3 mm; hind wing length: 1.7–1.8 mm. General coloration: orange brown.

Head (Figs. 2A, B). Orange brown. Upper portion of eyes reddish brown; lower portion dark brown. Ocelli white, surrounded by dark brown ring. Antenna dark brown.

Thorax (Figs. 2A, B). Orange brown. Pronotum with lateral margins dark brown, mesonotum with anterolateral scutal costa dark brown. Pleura white, washed with black. Sterna dark orange brown.

Wings (Figs. 2C–E). Membranes of fore wing hyaline (Fig. 2C), costal and subcostal areas tinged with brown, paler toward apex. Longitudinal veins yellowish brown, crossvein surrounded with a brown macula. Hind wing (Figs. 2D, E) with membrane hyaline, base tinged with light brown; few cross-veins present (around 20), clouded cross-veins restricted to space between Sc and R.

Legs (Figs. 2F–H). Orange brown. Fore leg (Fig. 2F) with femur stained with black on mid length and on apex; tibia almost completely washed with black, except at the joint with tarsus. Middle (Fig. 2G) and hind legs (Fig. 2H) similar to fore leg except the femur is not stained and tibiae completely orange brown.

Abdomen (Fig. 1E). Terga orange brown, except for a dark brown macula on posterolateral corner of terga I to VII. Sterna orange brown. Caudal filaments orange brown, paler toward apex and region between articulations dark brown.

Genitalia (Figs. 2I, J). Orange brown, styliger plate with area between base of forceps tinged with brown. Forceps orange brown, paler at base. Penis lobe light brown. Ventral projection of penis lobe long and laterally positioned (Fig. 2J), gonopore located at apex of penis lobe.

Male subimago (Fig. 1C). Similar to imago, except for the following characteristics: membrane of fore and hind wings gray, longitudinal veins yellowish white; mesoscutum with mediolongitudinal suture,

Figure 1. Habitus of *Ulmeritus saopaulensis* (Traver, 1946): (A–B) nymph, alive (A) and fixed in ethanol (B); (C) subimago male; (D) imago female; (E) imago male. Photos A, C–E by FFS; B by VAS.

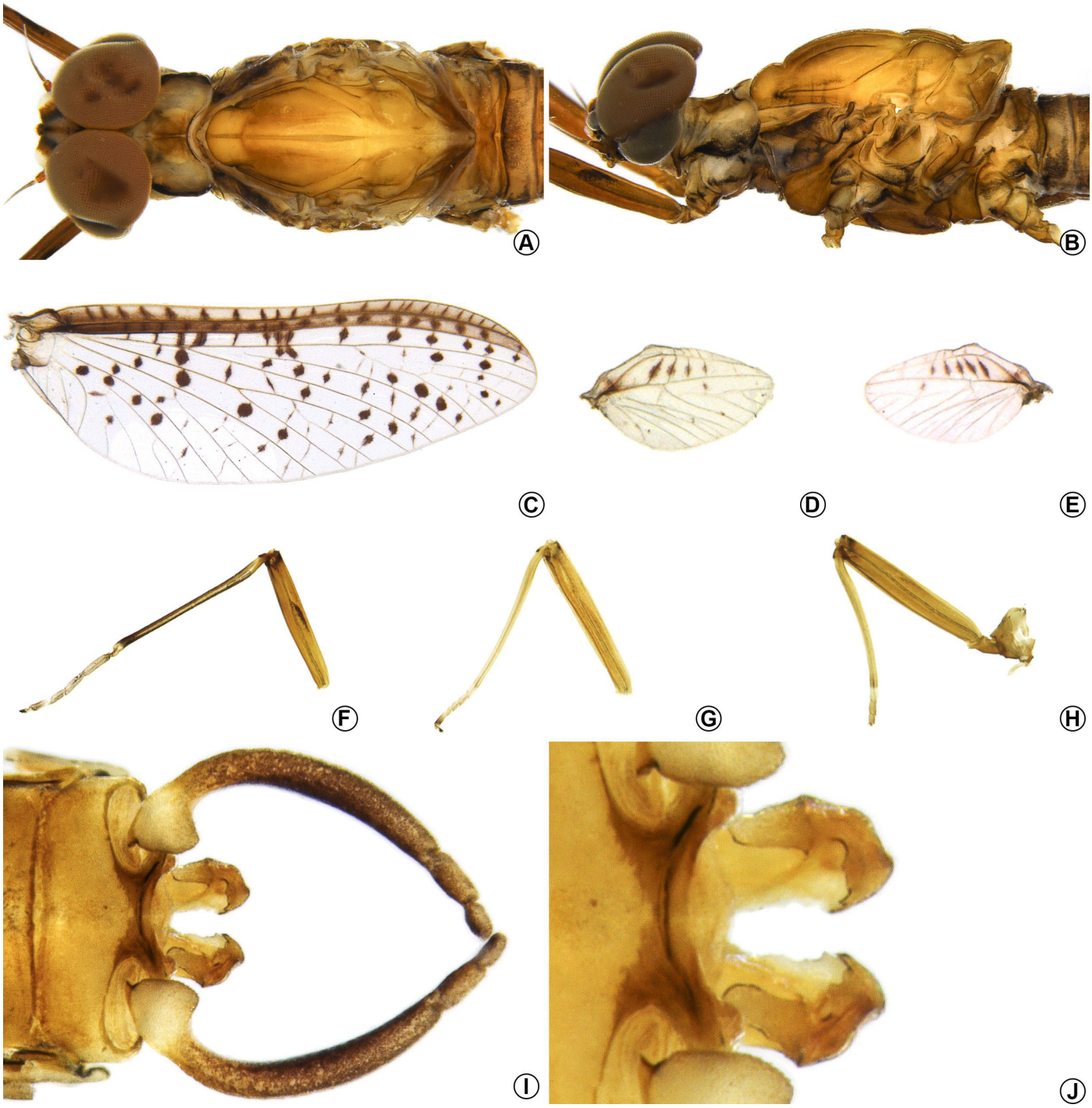

Figure 2. Imago male of *Ulmeritus saopaulensis* (Traver, 1946): (A–B) head and thorax in dorsal (A) and lateral (B) views; (C) fore wing; (D) right hind wing; I left hind wing; (F–H) legs in lateral view, (F) fore-, (G) mid-, and (H) hind leg; (I) genitalia in dorsal view; (J) penes in dorsal view. Photos A–E, I–J by FFS; F–H by VAS.

medioparapsidal suture, area between posterior scutal protuberance, and scutellum broadly tinged with yellowish white, outer half of posterior scutal protuberance yellowish brown.

Female imago (Fig. 1D). Body length: 6.7–8.7 mm; fore wing length: 8.7–9.0 mm; hind wing length: 1.8–2.1 mm. Similar to male except for the following characteristics: body coloration lighter. Head dorsally washed with white and with a black stripe close to posterior margin, compound eye black. Pronotum and membranous areas on mesothorax washed with white.

Female subimago. Similar to male subimago.

Nymph (Figs. 1A, B). Body length: 6.8 mm. Tibia I: 1.92 mm. Tibia II: 1.68 mm. Tibia III: 1.72 mm. General coloration: brown.

Head (Figs. 1A, B). Brown, with black marks between compound eyes and ocelli. Ocelli whitish with inner margins black. Eyes of male with upper portions dark orange-brown, lower portion black. Eyes of female black. Antennae yellowish brown.

Mouthparts. Labrum (Fig. 3A), exposed area of mandibles, stipes, paraglossa, and maxillary (Fig. 3F) and labial palp (Fig. 3I) light brown,

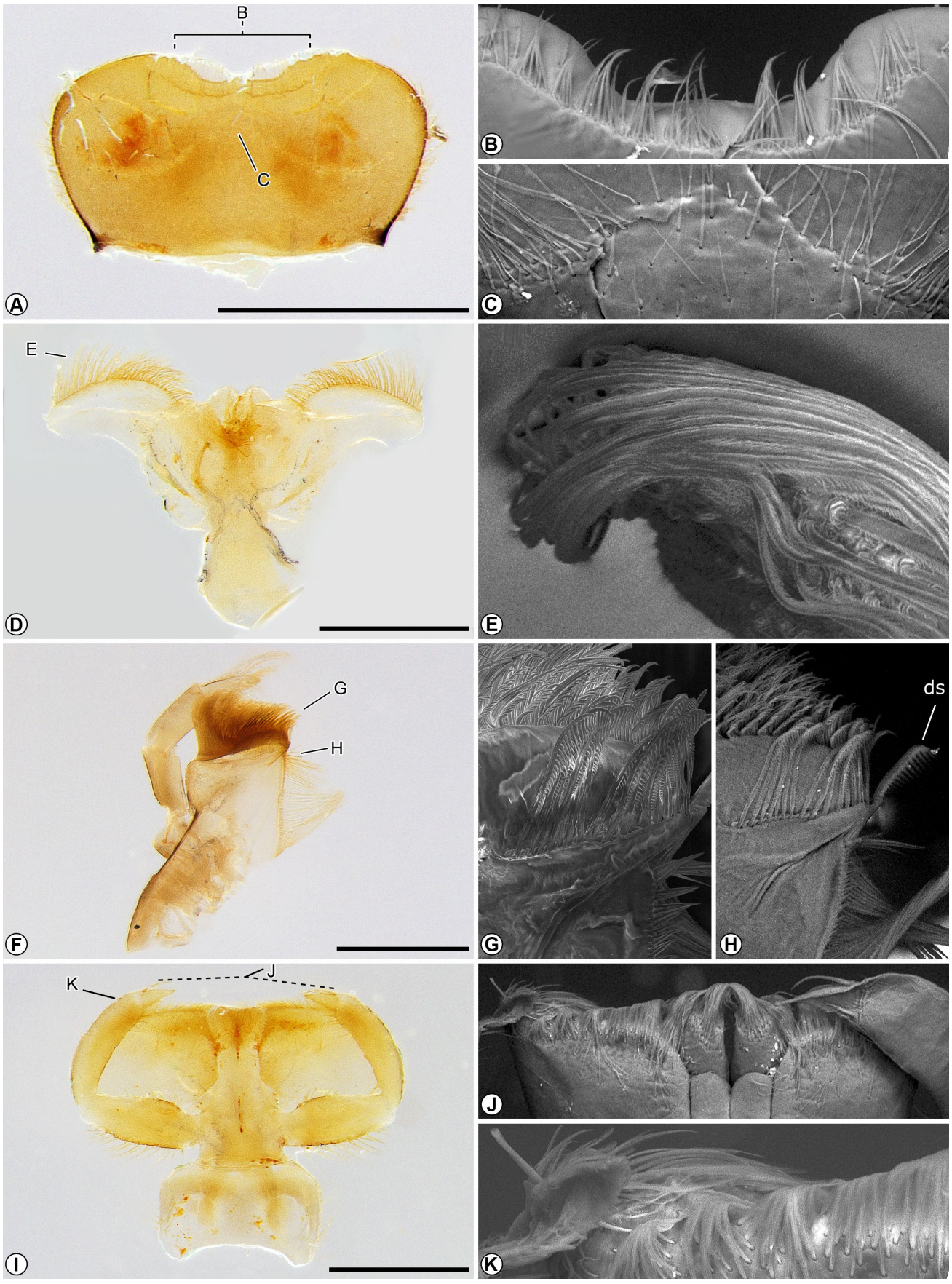

Figure 3. *Ulmeritus saopaulensis* (Traver, 1946): Mouth parts of nymph. (A) labrum in dorsal view; (B) distal emargination of labrum in detail; (C) row of setae on the dorsal surface in detail; (D) hypopharynx in dorsal view (E) apex of superlingua in detail; (F) left maxilla dorsal view; (G) pectinate setae of maxilla; (H) distal part of labrum with dentisetae; (I) labium in dorsal view; (J) apex of glossas and paraglossas of labium; (K) apex of labium showing the labial palp. Abbreviations: ds = dentisetae. Photos A–K by VAS.

remaining parts paler. Basal 2/3 of outer margin of mandibles with few scattered setae, apical 1/3 with two groups of setae: a basal one with few long setae and a distal one with denser and smaller setae (Figs. 4A, E). Tusk on inner apical margin of maxilla small (Fig. 3F). Maxillary palp segment I subequal to segment III, segment II 1.2 times longer than segment III.

Thorax (Fig. 1B). Pronotum with lateral black mark and oblique submedian brown band, mesonotum with anterolateral black marks.

Legs (Figs. 5A–L). Yellowish brown. Femur of all legs stained with black at apex. Fore leg with femur with two median maculae, black and smaller on inner margin, dark brown and larger on outer margin; tibia stained with black, darker toward apex; tarsi slightly washed with black, except on base and apex; claw yellowish. Middle and hind leg similar to fore leg, except for smaller size of femoral maculae on middle leg and absence on hind leg, and for tibia completely yellowish brown. Row of pectinate setae on ventral surface of hind tibia mostly single.

Abdomen (Figs. 1A, B). Terga brown, lateral margins, including posterolateral projections, yellowish brown. Sterna yellowish brown. Caudal filaments yellowish brown, darker in the articulations.

Gills (Figs. 1A, B). Gray, tracheae and fimbriae dark gray.

Eggs. Size: 250–260 µm in length, 140–150 µm in width. Oval (Fig. 5M) with polar regions convex, chorionic surface smooth. Knob-terminated coiled threads (KCTs) equally distributed, overlapped and completely covering the chorionic surface: when threads are fully coiled, they remain glued to each other. Threads of KCTs long, entirely covering the KCT collar. Slick collar with hexagonal edge; (Fig. 5M). Micropyle present, two, both located close to one of the polar regions (arrows, Fig. 5M) and. located among three KCTs.

Distribution (Fig. 6). Brazil. Bahia State: Maracás municipality (-13.440833, -40.430833, 962 m a.s.l.); Minas Gerais State: Tiradentes (Serra de São José -21.076111, -44.159444, 1224 m a.s.l.) and Paula Cândido (Buieié -20.8738, -42.9800, 739 m a.s.l.) municipalities; São Paulo State: Bauru municipality (-22.3150, -49.0610, 530 m a.s.l.).

Ecological and biological data. In Paula Cândido, nymphs of *U. saopaulensis* were found in a pond among emergent macrophytes, habitat similar to that described by Da-Silva and Pereira (1992) while originally describing the nymphs. According to these authors, subimagos of the species emerge between 7:00 and 7:30 PM. We have no data on the period of emergence of subimagos, but we observed one subimago emerging at 7:45 PM. Female imagos of *U. saopaulensis* can carry a mass of eggs (Fig. 1D), similar to females of the closely related *Ulmeritoides*.

Nomenclatural notes

The nomenclatural history of the specific name *saopaulensis* is confusing. While there is no dispute that its etymology is a toponym in reference to the type locality in the state of São Paulo, Brazil, its spelling has changed many times. Traver (1946) made the nomen available in combination with the genus *Atalophlebioides* and used *são-paulense* as the original spelling. A decade later Traver (1956) transferred it to *Ulmeritus* changing to the subsequent spelling *são-paulensis*, and a few years later she returned to *sao-paulense*, but without the diacritic accent (Traver 1959). The current spelling *saopaulensis* was first adopted by Hubbard (1982) in his catalog with the combination *Ulmeritus* (*Ulmeritus*) *saopaulensis*, and since of the milestone studies by Domínguez (1991, 1995), this spelling persists. Hubbard (1982) nor Domínguez (1991, 1995) justified the emendation. The specific name *são-paulense* is formed by the stem *saopaul-* plus the suffix *-ense* on its neuter form, and it can be considered an adjective by affixation. According to the International Code of Zoological Nomenclature (ICZN, 1999, 2012, hereafter simply Code), two changes in the original spelling were mandatory—the exclusion of the diacritic mark and hyphen in the stem—to correct it from *são-paulense* to *saopaulense* (Art. 32.5.2.). However, the suffix change would be considered not mandatory, thus an unjustified emendation. The genus-group nomen *Ulmeritus* (masculine) means from Ulmer, a homage to the German entomologist Georg Ulmer (1877–1963), and it was formed by the stem *Ulmer-* plus adjective *-itus*, *-a*, *-um*. Whether *saopaulense* is considered a declinable adjective based on a blind interpretation of the Code (Art. 31.2 and 34.2) it must agree in gender with the generic name, therefore in this context the correct spelling shall be *saopaulensis*. Otherwise, the Code is noticeably clear which conditions need to be met for an original spelling to be considered incorrect which does not apply to this case. First, it is not clear in the original publication "itself without recourse to any external source of information, clear evidence of an inadvertent error" (Art. 32.5.1.), nor the original author "indicate whether he or she regarded it as a noun or as an adjective, and where it may be regarded as either and the evidence of usage is not decisive, it is to be treated as a noun in apposition to the name of its genus" (Art. 31.2.2). In addition, in the section "Recommendations on the Formation of Names" of the Appendix D, published in the third edition of the Code there are only general lines to be followed and there no is mentioned that the only suitable suffix is *-ensis*, indeed it states: "preferably an adjective derived from the geographical name, and ending in a suitable suffix, such as *-ensis* or *-iensis*". In short, under absence of any sound evidence and in accordance with the article 33.5 that states in any case of doubt different subsequent spellings should be treated as an incorrect subsequent spelling, one would judge a name in apposition with the original spelling to be correct, thus *Ulmeritus saopaulense*. However, considering by the stability stated in principle 4 of the Code, we endorse Hubbard's (1982) emendation and considered *Ulmeritus saopaulensis* the correct spelling for this mayfly species.

Discussion

The nymph of *U. saopaulensis* have important characteristics to distinguish it from the other species in the genus. Unlike *U. carbonelli* and *U. balteatus*, those of *U. saopaulensis* (1) completely lack denticles on the distal emargination of the labrum, (2) the maxillary tusk is small, and (3) the maxillary palp segment III is shorter than segment II. While the first characteristic is unique among members of the *Ulmeritus-Ulmeritoides* lineage, the second is observed in some species of *Ulmeritoides*, and the third in all the species of that genus. Nevertheless, as in *U. carbonelli* and *U. balteatus* and unlike the species of *Ulmeritoides*, the row of setae on the dorsal surface of the labrum is medially interrupted in *U. saopaulensis* (Fig. 3C). In the nymphal stage, therefore, the most useful characteristics to distinguish *Ulmeritus* from *Ulmeritoides* are the dorsal row of setae on the labrum (interrupted in *Ulmeritus*, continuous in *Ulmeritoides*) and the development of the denticles of the distal emargination of the labrum (denticles absent to minute and flattened in *Ulmeritus*, developed in *Ulmeritoides*).

Adults of *U. saopaulensis*, male and female (Figs. 1A, C–E, 2C–E), are easily distinguished from its congeners based on having less pigmentation and fewer cross-veins on fore and hind wings. The ventral projection on the male genitalia of *U. saopaulensis* is also distinct from the remaining species: it is laterally displaced, instead of centrally positioned. According to Domínguez et al. (2006), besides its more lateral position, the projection is shorter than that of *U. carbonelli* [which agrees with the illustrations provided by Traver (1946)]. On our material, however, the length is similar in both species. A noteworthy aspect about the male genitalia, which has not been mentioned previously for the genus, is the location of the gonopores. They are at the apex of the penis lobe and not at the

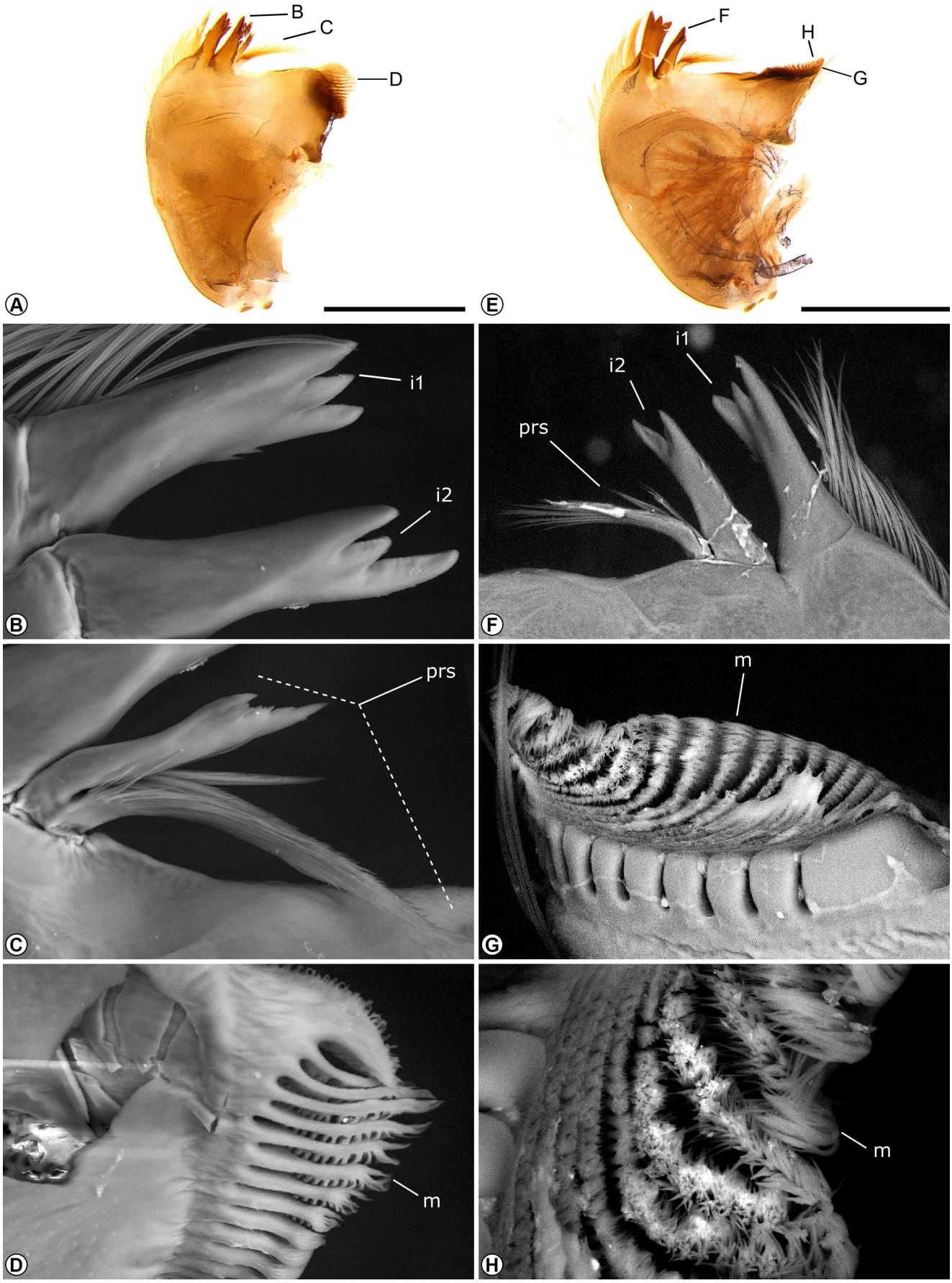

Figure 4. *Ulmeritus saopaulensis* (Traver, 1946): mandibles of nymph: (A–D) left mandible in dorsal view; (E–H) right mandible in ventral view; (B) incisors; (C) prostheca; (D) molar; (F) incisors and prostheca; (G–H) molar. Abbreviations: i1 = outer incisor; i2 = inner incisor; m = molar; prs = prostheca. Photos A–H by VAS.

ventral projection, a similar condition found in the related genus *Diamantina* Salles, Domínguez & Nascimento, 2020 (see Figures 9a to 9c in Salles et al. 2020).

The eggs of *U. saopaulensis* can be differentiated from *U. carbonelli* by the number of micropyles. The first species has two (Fig. 5M) while the last has one.

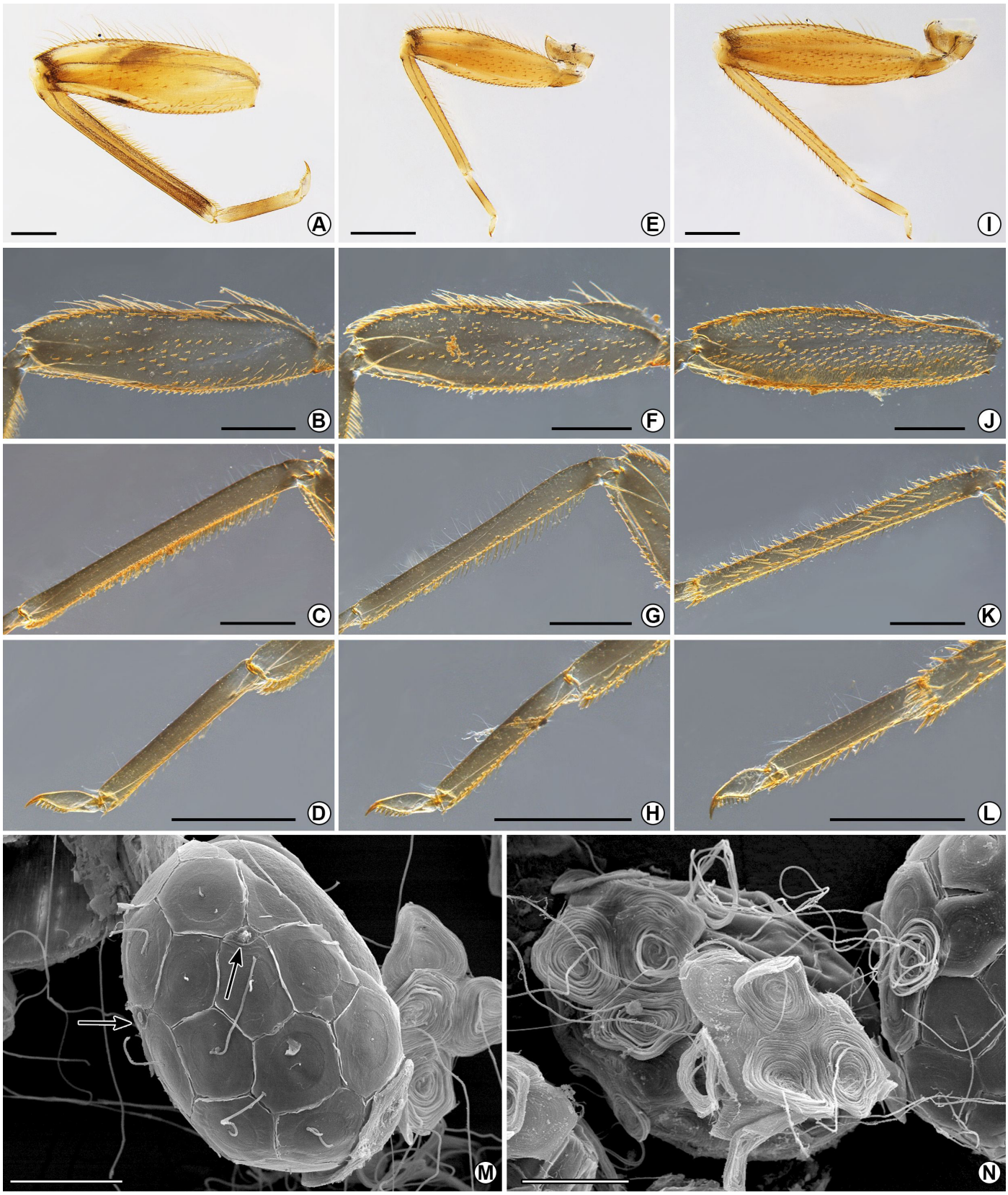

Figure 5. *Ulmeritus saopaulensis* (Traver, 1946): (A) fore leg with (B) femur, (C) tibia, and (D) tarsus; (E) middle leg with (F) femur, (G) tibia and (H) tarsus; (I) hind leg with (J) femur, (K) tibia and tarsus (L; (M) chorionic surface of egg with micropyles (arrows); (N) KCTs coiled. Photos A, E, I by VAS. B–D, F–H, J–L and M–N by FFS.

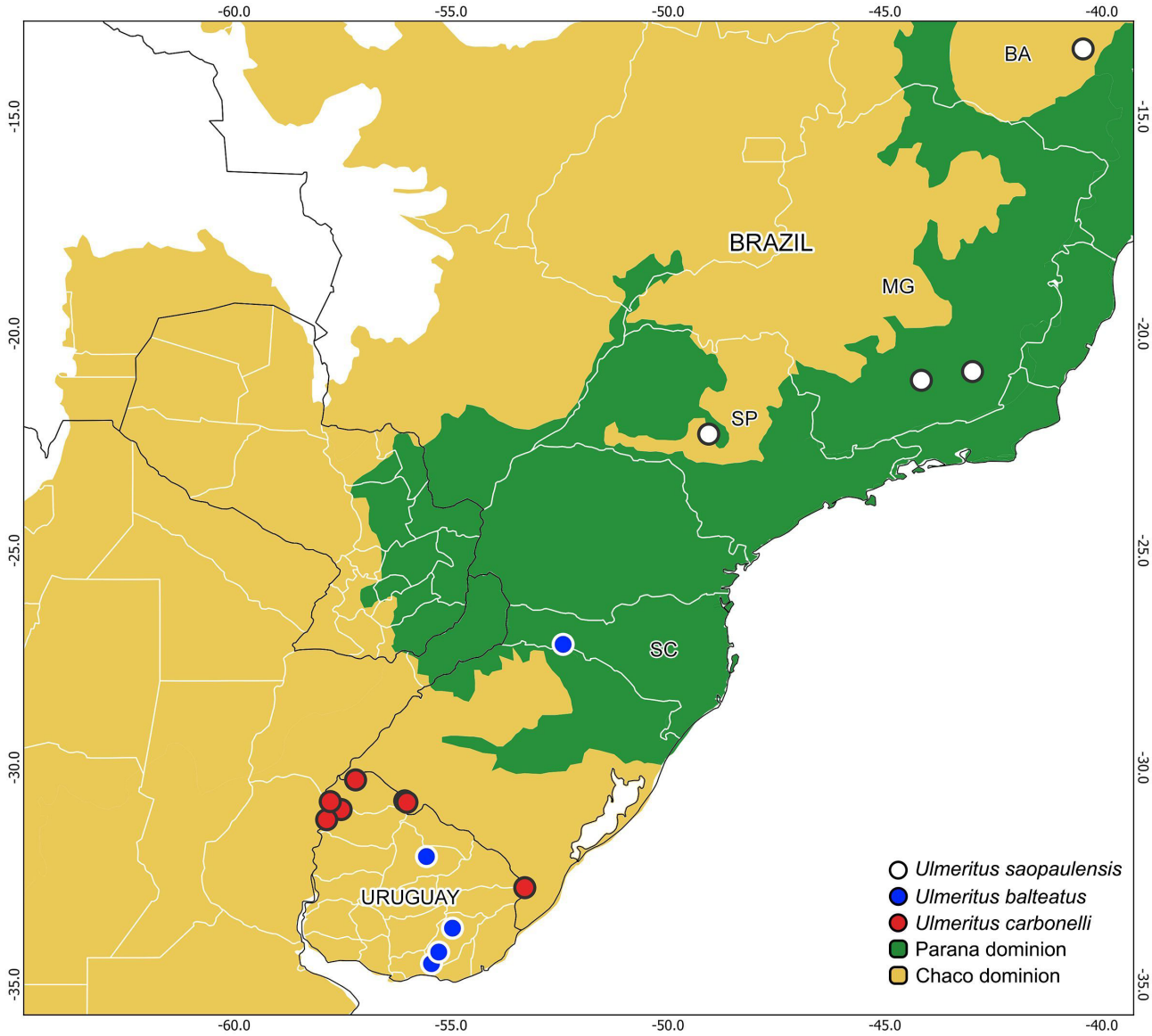

Figure 6. Map of southern South America with occurrence records to species of *Ulmeritus* Traver, 1956. Abbreviations: MG, Minas Gerais; SC, Santa Catarina; SP, São Paulo. Biogeographic regionalization based on Morrone (2014).

In conclusion, even after a series of recent studies on the group, including phylogenetic analyses proposed by Domínguez (1995) and Salles and Domínguez (2012), some species of the *Ulmeritus-Ulmeritoides* lineage are still poorly known with inter- and intraspecific variations not fully comprehended. Furthermore, since the last phylogenetic hypothesis and taxonomic revision of the group, 6 species have been described. Therefore, a of taxonomic review plus phylogenetic analyses studies could be very enlightening on this lineage.

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Conflicts of interest

The authors declare there is no conflicts of interest.

Author contribution statement

VAS and FFS designed the study. All authors made the images and illustrations and contributed equally to the analysis, writing and revision of the manuscript and approved this version.

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