

Description of *Phthius* gen. n., with a new species from southeastern Brazil with possible vicariance relationships to Mesoamerica (Lepidoptera, Hepialidae)

Carlos G. C. MIELKE and John R. GREHAN

Carlos G. C. MIELKE, Caixa postal 1206, 84145-000 Carambeí, Paraná, Brazil; cmielke1@uol.com.br

John R. GREHAN, Research Associate, Section of Invertebrate Zoology, Carnegie Museum of Natural History; calabar.john@gmail.com

Abstract: *Phthius* gen. n. is erected for *Phthius punctatus* sp. n. (type species) from southeastern Minas Gerais and eastern São Paulo. It has features shared with other large-bodied hepialids from Central America and Mexico: *Pallas* MIELKE & GREHAN, 2015, *Phassus* WALKER, 1856, *Schausiana* VIETTE, 1950; and also *Viridigigas* GREHAN & RAWLINS, 2016 from Peru. The monophyly of *Phthius* gen. n. is based on characteristics of wing ornamentation and genitalia. The holotype male will be deposited in Entomological Collection of Oswaldo Cruz Institute, Rio de Janeiro, Rio de Janeiro, Brazil. The geographic disjunction between *Phthius* gen. n. and the *Phassus* clade is hypothesized to be the result of Mesozoic vicariance associated with the Romeral fault zone.

Key words: biogeography, morphology, Neotropical, *Phassus* clade, punctatus, systematics.

Beschreibung von *Phthius* gen. n., mit einer neuen Art aus Südost-Brasilien mit möglichen Vikarianzbeziehungen zu Mesoamerica (Lepidoptera, Hepialidae)

Zusammenfassung: Die neue Gattung *Phthius* gen. n. wird für die neue Art *Phthius punctatus* sp. n. aus dem südöstlichen Minas Gerais und dem östlichen São Paulo beschrieben. Sie hat Merkmale, die mit anderen großleibigen Hepialiden aus Mittelamerika und Mexiko geteilt werden, wie *Pallas* MIELKE & GREHAN, 2015, *Phassus* WALKER, 1856, *Schausiana* VIETTE, 1950, und auch *Viridigigas* GREHAN & RAWLINS, 2016 von Peru. Die Monophylie von *Phthius* gen. n. basiert auf Merkmalen von Flügelzeichnung und Genitalien. Der männliche Holotyp wird in der Entomologischen Sammlung des Oswaldo-Cruz-Instituts, Rio de Janeiro, Staat Rio de Janeiro, Brasilien, hinterlegt. Vermutlich basiert die geographische Disjunktion zwischen *Phthius* gen. n. und den übrigen Arten der *Phassus*-Verwandtschaft auf einer mesozoischen Vikarianz, die mit der Romeral-Störungszone verbunden ist.

Introduction

Recent studies of large-bodied Hepialidae have drawn attention to some remarkable new species with uncertain affinities (MIELKE & GREHAN 2015b, GREHAN & RAWLINS 2016). Before the discovery of *Viridigigas* GREHAN & RAWLINS, 2016, the only large-bodied hepialids known from South America were *Trichophassus* LE CERF, 1919 from the Atlantic forest of Brazil and Argentina, and *Andeabatis* NIELSEN & ROBINSON, 1983 from Chilean Patagonia. While *Trichophassus* was placed in the cibyrene group of Hepialidae its precise affinities remain unresolved and the same situation applies even more so to *Andeabatis* (GREHAN 2012).

All previously described South American Hepialidae outside the Andean region belong to the cibyrene clade (GREHAN 2012), but during visits to Brazilian museums in São Paulo and Rio de Janeiro, the first author recognized that a few specimens appeared to belong to a dif-

ferent clade, and to show some similarities to the *Phassus* WALKER, 1856 clade of GREHAN (2012). Here we present evidences for recognizing these specimens as a new genus and new species based on several unique characters on the external morphology. We discuss some of the potential sistergroup relationships with other genera of Hepialidae and consider a vicariance model to explain a geographic disjunction between the Mesoamerican *Phassus* clade and the distribution of the new genus.

Material and methods

Appendages were heated in an aqueous solution of 10% KOH. Genitalia are kept in glycerol to allow for three-dimensional analysis of the structures. Terminology follows that of MIELKE & CASAGRANDE (2013) and KRISTENSEN (2003) for wing venation and female genitalia. Wing venation diagrams were traced over photos and rechecked directly against specimens.

The following abbreviations for collections are used

CEIOC	Entomological Collection of Oswaldo Cruz Institute, Rio de Janeiro, Rio de Janeiro, Brazil.
MHNG	Muséum d'histoire naturelle, Genève, Switzerland.
MZSP	Museu de Zoologia, Lepidoptera Collection, Universidade de São Paulo, São Paulo, São Paulo, Brazil.

Further abbreviations

FW	forewing.
PT	paratype.
HT	holotype.
HW	hindwing.

Systematic part

Phthius gen. n.

Type species: *Phthius punctatus* sp. n., by present designation.

Etymology: It is named for a son of LYCAON, as PALLAS and likely PHASSUS, since WALKER (1856) did not give evidence that the genus-group name *Phassus* was derived in this way.

Phthius gen. n. comprises the type species only. Medium to large moths with wingspans of 75 to 137 mm. Antennae filiform in both sexes. Labial palpi reduced and ovoid, first and second palpomeres partially fused. Scutum III mostly devoid of scales. ♂ metatibia hypertrophied. Distitarsus distally with unspecialized tarsal claws. Venation of “hepialine” pattern (DUMBLETON 1966) with (Rs1+Rs2)–Rs3 not stalked; FW with Sc1 visible in the ♀ only; M2 and M3 veins stalked at the base. HW with M2 and M3 same arrangement as the FW; CuP reaching the outer margin; anal veins free and extending to inner margin. FW ornamented throughout with

numerous dots, basal area at inner margin with black proximal stripe followed by sub-circular black spot. Tergosternal bar slightly pronounced dorso-posteriorly. Tergum and sternum VIII sclerotized in the ♂. Tergum and sternum VIII membranous and slightly sclerotized, respectively, in the ♀. Tergal lobes (tergite X) in the ♂ genitalia absent or reduced and fused to the pseudotegumen. Pseudotegumen medially unfused dorsally and ventrally. Valva prominent, broad and flat distally. Fultura superior absent. ♀ genitalia with anal papillae not expanded posteriorly; subanal plate as a horizontal sclerotized bar. Ductus bursae laterally inserted into the corpus bursae.

Diagnosis

Phthius gen. n. cannot be confused with any other described genus. Wing ornamentation, including numerous dots and concolourous black basal stripe and conspicuous subcircular spot on the FW are diagnostic of the genus. In addition, the dotted FW pattern, the greatly inflated size of the lateral lobes of the lamella antevaginalis lacking the dorsal digitiform extensions, and the distally expanded blade-like valva excludes *Phthius* gen. n. from inclusion in any other New World genus. Absence of a tergal lobe in the ♂ genitalia (or much reduced and fused to the pseudotegumen) and the lateral insertion of the ductus in the corpus bursae also represent derived conditions, although the latter condition also applies to various other species of Hepialidae. The combined presence of partially fused first and second palpomeres, Sc1 on the FW, androconial scales on the hypertrophied ♂ metatibia, and unfused pseudotegumen plates in the ♂ genitalia help to separate *Phthius* gen. n. from other American genera.

Remarks

The external and genitalic characteristics of *Phthius* gen. n. do not conform to any other genus of Hepialidae and therefore justify its description as a new genus. Several character similarities (see discussion section) suggest that its sister group relationships involve the *Phassus-Schausiana* VIETTE, 1950 clade as characterized by GREHAN (2012).

Phthius punctatus sp. n.

(Figs. 1a–b, 2a–b, 3, 4, 5a–d, 6a–d, 7, 8, 9a–b, 10a–d; 11.)

Holotype ♂ with the following labels (separated by forward slashes): /HOLOTYPUS, *Phthius punctatus* C. MIELKE & GREHAN det. 2017/ S. Paulo-Agua Funda [likely a neighbourhood of the metropolis], TRAV. F. III, 1934/ N. 1822/ I. Oswaldo Cruz (CEIOC). – Figs. 1a, 1b.

Paratypes (in total 6 ♀♀). All **Brazil: Minas Gerais**: 1 ♀, Sapucaí-Mirim, Cidade Azul [45°45' W, 22°44'1" S], 1400 m, 7. XI. 1953, L. TRAVASSOS F., M. KUHLMANN, C. GANS & S. MEDEIROS leg. (MZSP). – **São Paulo**: 2 ♀♀, Salesópolis, Boraceia Biological Station, 850 m, 5. VIII. 1948, L. TRAVASSOS F. & E. X. RABELLO leg. (MZSP 30.633 [MZSP]); 2 ♀♀, Salesópolis, Boraceia Biological Station, Castelinho, 45°53'22.38" W, 23°39'15.63" S, 21. VIII. 2012, 14.–18. IX. 2012, F. F. ALBERTONI

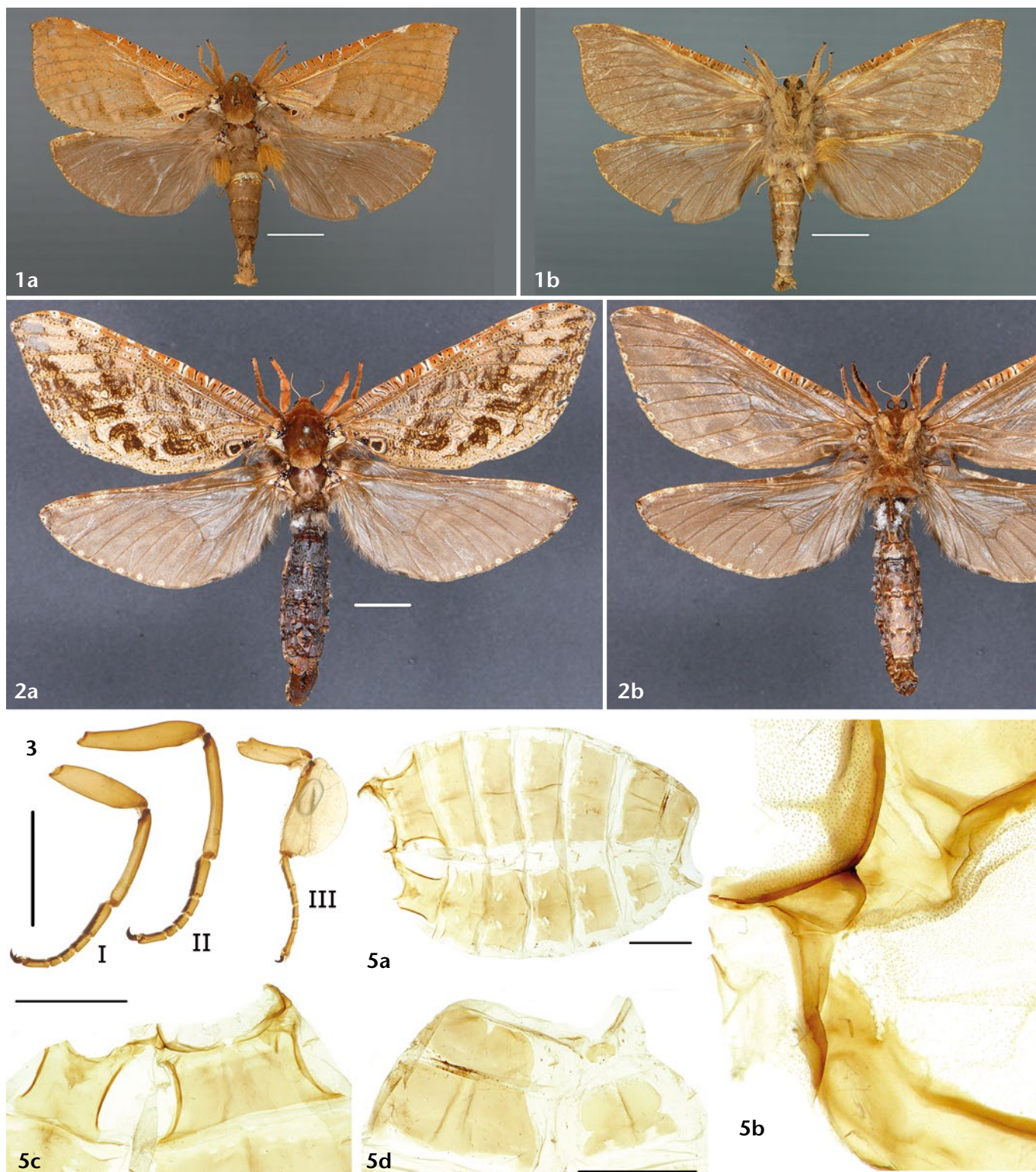
leg. (MZSP). 1 ♀, São Paulo, 1960, ex. coll. RIVIER (MHNG ENTO-00011173; MHNG).

Etymology. *P. punctatus* sp. n. is named for the conspicuous subcircular and black spot on the basoproximal area of the FW on both sexes. It is a noun in apposition.

♂ (Figs. 1a–b, 3, 4, 5a–d). FW length: 36 mm; wingspan: 75 mm. Antennae with 31 segments, ventrally covered with microtrichia, sensilla caetica present on each segment. Frons dark orangish-brown. Thorax coloured as the frons. Legs dorsally as the thorax, tarsi ventrally black; epiphysis absent. FW elongated, apex pronounced, slightly falcate, outer margin straight, tornus indistinct. FW ground colour pale orangish-brown, slightly darker apically, throughout speckled with tiny and brown dots; basal area, light pinkish-orange with scattered brown scales, marked distally by a slightly concave and oblique edge; anal area with black spot bordered by light yellow; postmedial area with subtle and rounded spots separated by light brown scales. Stigma not discernible. Costal area reddish-orange with brown transverse stripes, sometimes bordered by yellowish-white. Outer margin marked by dots between veins. HW ground colour uniformly pale brown, distal half of the costal margin with lighter spots and some orange; from apex to M3, marginally, between veins a small dot surrounded by light yellow. FW ventrally with costal area same pattern as dorsal surface, remainder pale brown, marginal area bordered with a narrow straw coloured band; basal and medial area with piliform scales. HW ventrally same pattern as the dorsal side, piliform scales concentrated on the basal and costal areas. Abdomen brown with longer scales on proximal segments; distal segments pale orange-brown; tergo-sternal bar slightly pronounced dorso-posteriorly; sternum II sub-rectangular, laterally concave edges ridged. Tergum VIII rectangular with a mesal notch posteriorly; sternum VIII reduced, reinforced, rectangular, convex with convex lateral margins.

♂ **genitalia** (Figs. 6a–d). Tegumen slightly S-shaped, fused to the pseudotegumen. Saccus U-shaped, enlarged mesally; posterior margin notched mesally, more sclerotized. Pseudotegumen triangular with postero-dorsal edge pronounced, ventral margin wavy, and anteriorly produced into a highly sclerotized and narrowly pointed process. Valva robust with a ventrally lobulated process basally, inner surface with a basal concavity, distal portion blade-shaped. Fultura inferior rectangular, base narrower than height, notched dorsally. Fultura superior absent. Phallus membranous and tubular when everted.

♀ (Figs. 2a–b, 7, 8, 9a–b). FW length: 52–67 mm; wingspan: 106–137 mm. Thorax and legs as in the ♂. FW ground colour paler brown with orangish shades, slightly darker apically, throughout speckled with small and brown stripes/dots surrounded by lighter brown. Stigma and costal area as the ♂. Medial and postmedial areas suffused with irregular brown patches, dots surrounded by ochre. Outer margin marked by dots surrounded by light yellow between veins from apex to CuA2. HW ground colour uniformly light pale brown, distal half of



Figs. 1–2: *Phthius punctatus* sp. n. HT ♂ dorsal view (1a), ventral view (1b); PT ♀ dorsal view (2a [MZSP 30633]), ventral view (2b). — Scale bars: 1 cm, i.e. approximately natural size. — Fig. 3: *Phthius punctatus* sp. n., HT ♂ legs. — Fig. 5: *Phthius punctatus* sp. n., HT ♂ abdomen: all segments (a), tergosternal bar (b), I and II segments (c), VII and VIII segments (d). — Scale bars Figs. 3 and 5: 5 mm.

the costal margin with lighter spots and some orangish; dots between veins as in the FW. FW ventrally as the ♂, but jugum with black scales, piliform scales reduced in area, and dots between veins well marked. HW ventrally as the FW.

♀ genitalia (Figs. 10a–d). Dorsal plate arc-shaped with anal papillae setose, not projected posteriorly. Subanal plate sclerotized as a wavy bar. Lamella antevaginalis robust and sclerotized; W-shaped, lateral lobes subtri-

angular and blunt, distally setose; mesal lobe reduced, subtriangular, setose ventrally and distally; anterior to the mesal lobe a wide and slightly curved plate extends towards the antrum. Corpus bursae 1.2 times longer than ductus bursae.

Diagnosis

See the generic diagnosis.

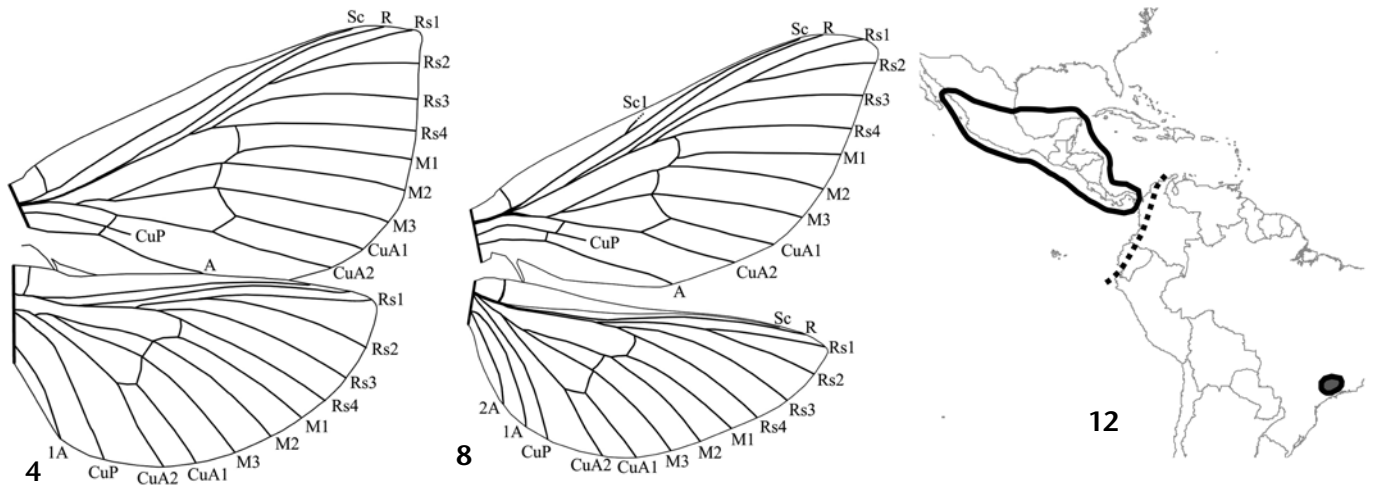


Fig. 4: *Phthius punctatus* sp. n., HT ♂ venation. — **Fig. 8:** *Phthius punctatus* sp. n., PT ♀ (MZSP 30633) venation. — **Fig. 12:** Potential biogeographic relationship between the distribution of *Phthius punctatus* sp. n. (shaded area, southeastern Brazil) and a *Phassus*-clade (shaded area, Mesoamerica). Distribution ranges generalized. Dashed line = Romeral fault zone.

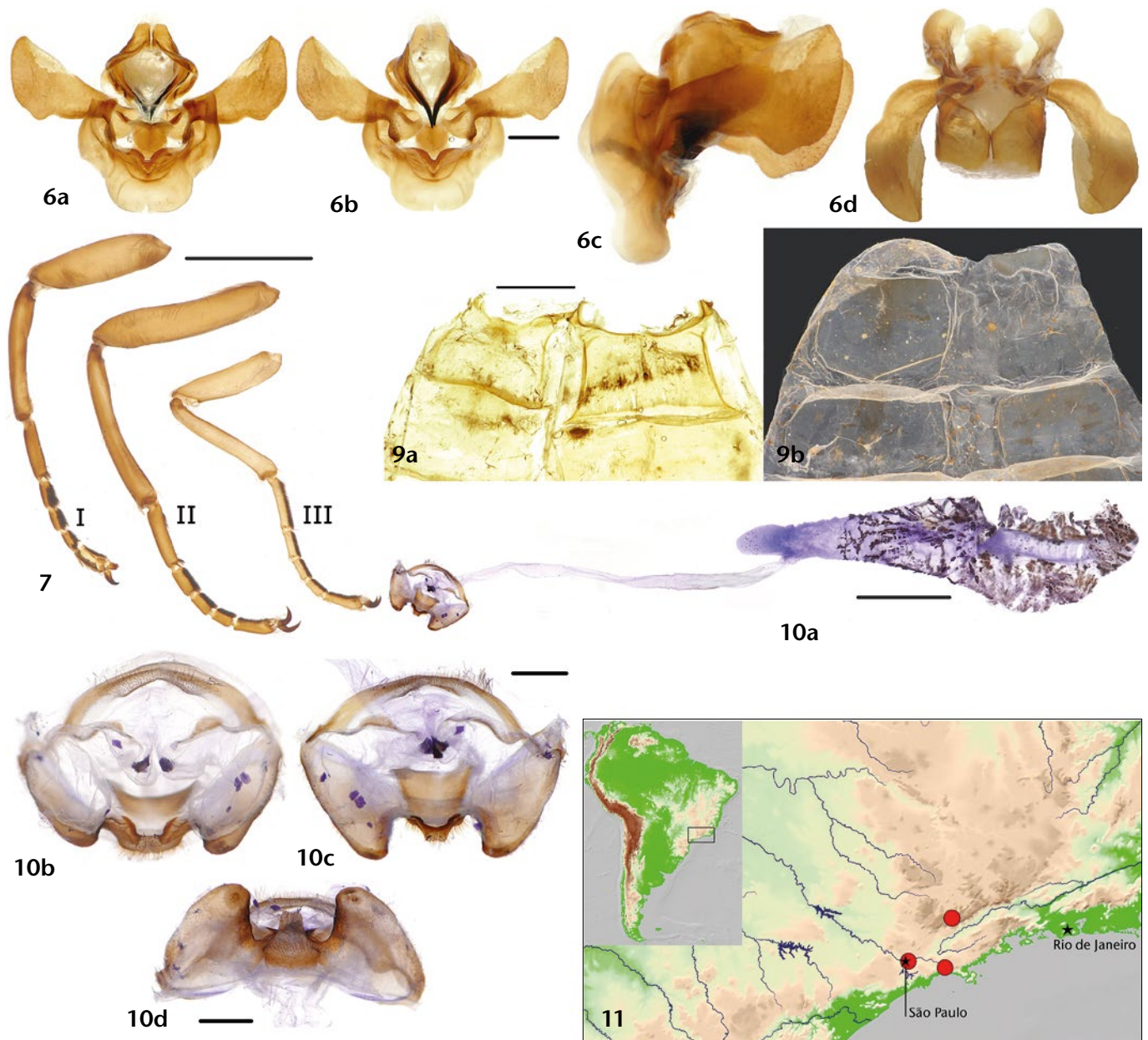


Fig. 6: *Phthius punctatus* sp. n., HT ♂ genitalia: dorsal (internal) view (a), ventral view (b), lateral view (c), posterior (d). — Scale bar: 1 mm. — **Fig. 7:** *Phthius punctatus* sp. n., PT ♀ (MZSP 30633) legs. — Scale bar: 5 mm. — **Fig. 9:** *Phthius punctatus* sp. n., PT ♀ (MZSP 30633) abdomen: I and II segments (a), VII and VIII segments (b). — Scale bars: 5 mm. — **Fig. 10:** *Phthius punctatus* sp. n., PT ♀ (MZSP 30633) genitalia: whole structure (a), posterior view (b), dorso-posterior view (c), ventral view (d). — Scale bars: 1 mm, Fig. 1a: 5 mm. — **Fig. 11:** *Phthius punctatus* sp. n., geographical distribution within southeastern Brazil.

Geographical distribution

P. punctatus sp. n. is confined to southeastern Minas Gerais and eastern São Paulo states of Brazil at altitudes ranging from 800 to 1400 m (Fig. 11).

Discussion

Lack of an established phylogenetic framework for the Neotropical Hepialidae precludes any conclusive identification of a sister-group relationship for *Phthius* gen. n. However, several features appear suggestive of likely possibilities.

Firstly, *Phthius* gen. n. lacks the specialized character states that would place it within the ‘cibyrene’ clade – an apparently monophyletic assemblage of at least 17 genera distributed between southern Mexico and at least the northern half of Argentina, east of the Andes. This clade, informally named after its oldest named genus, is defined by an anterior margin break, a posterior-lateral knob, and a strongly triangular central region in the tergo-sternal connection of the first and second abdominal segments (GREHAN 2010); and also the outer Sc and R veins of the HW are almost adjacent (GREHAN 2012). Characteristics in the following three topics suggest that *Phthius* gen. n. may be more closely related to the *Phassus/Schausiana* clade than to the cibyrine clade or any Andean genera.

♀ genitalia: The highly enlarged lateral lobes of the lamella antevaginalis represent an autapomorphic condition that separates *Phthius* gen. n. with all other Hepialidae, but its shape is similar to the configuration found in *Pallas* C. MIELKE & GREHAN, 2015 and *Phassus* (MIELKE & GREHAN 2015b). The ♀ genitalia of *Schausiana* is not described. The anal papillae of *Phassus* and *Pallas* are also similar to those of *Phthius* gen. n. with respect to being reduced compared with the relatively prominent or triangular anal papillae of the cibyrine genera and the southern Andean genera *Blanchardinella* NIELSEN, ROBINSON & WAGNER, 2000, *Calada* NIELSEN & ROBINSON, 1983, *Callipielus* BUTLER, 1882, *Dalaca* WALKER, 1856, and *Parapielus* VIETTE, 1949 (NIELSEN & ROBINSON 1983). *Puermytrans* VIETTE, 1951 and *Viridigigas* also lack enlarged or projecting anal papillae, but in these genera, the dorsal plate forms an inverted V rather than an inverted U. In addition, they lack a dorsally extended central lobe of the lamella antevaginalis. In consideration of these patterns of similarity *Phthius* gen. n. is closest to *Pallas* and then to *Phassus* (the latter having digitiform dorsal extension of the lateral lobes in the ♂ genitalia).

♂ genitalia: The relative size of the valve to the complete genitalia is much larger than most American species and most Hepialidae in general, and the broad flattened distal region of the valve is also distinct. The narrowly pointed and unfused ventral apex of the pseudotegumen contrasts with the cibyrines where the apex is either fused or strongly sclerotized and often subtended by a matching sclerotization of the central posterior margin

of the saccus. In *Phthius* gen. n., the pseudotegumen apex is matched by a central notch in the posterior margin of the saccus. These features show that the ♂ genitalia of *Phthius* gen. n. do not show any specialized similarity with cibyrine species or any necessary relationship with other American genera. This situation is not surprising as ♂ genitalia are highly variable even within genera and at this time no broader phylogenetic framework has yet been established for most features of the ♂ genitalia (GREHAN 2012).

Metatibial androconia

Within the Neotropical region, *Phthius* gen. n. shares the presence of orange-brown metatibial androconia with *Phassus* and *Schausiana*. The only other Neotropical genera with metatibial androconia are the monotypic Andean *Puermytrans* and *Viridigigas*, both of which have relatively long greyish-brown androconial scales. The presence of metatibial androconia are also present in *Aenetus* HERRICH-SCHÄFFER, 1855 (Australasia-eastern Indonesia), *Endoclita* C. & R. FELDER, 1874 (Asia), *Phymatopus* WALLENGREN, 1869 (North America and Eurasia), *Sthenopsis* Packard, [1865] (North America), *Hepialus* FABRICIUS, 1775 (western Eurasia), *Thitarodes* VIETTE, 1968 (eastern Asia), *Oncopera* WALKER, 1856 (Australia), and *Phassodes* BETHUNE-BAKER, 1905 (Fiji). There is no current evidence that these genera represent a monophyletic group and so the presence of metatibial androconia in *Phthius* gen. n. must be regarded as a phylogenetically equivocal, although derived, character state within the Hepialidae (GREHAN & RAWLINS 2016). The greyish brown colour and relatively long androconia in *Puermytrans* and *Viridigigas* contrasts with the orange-brown colour and shorter length of androconia in *Phthius* gen. n. and *Phassus/Schausiana*.

In summary, the affinities of *Phthius* gen. n. we have been able to observe suggest that the closest relationships will be to one more of the non-cibyrene and non-Andean genera, i.e. *Pallas*, *Schausiana*, or *Phassus*. But the shared similarities are of a very general nature and further detailed comparative analyses will be necessary to develop a more specific and cladistically based hypothesis. Potentially informative characters for future investigation include details of the tergo-sternal connection and the relative orientation and length of tarsal scales as both *Phthius* gen. n. and *Phassus* show some derived conditions (JRG personal observations).

Biogeography

The central southeastern distribution of *Phthius* gen. n. is located within a region of local endemism for South American Hepialidae including *Cibyra* (16 of 18 species MIELKE 2014, 2015, MIELKE & CASAGRANDE 2013), and the endemic genera *Aepytyus* (5 species, MIELKE & GREHAN 2015a), *Trichophassus* (monotypic, MIELKE & GREHAN 2012), and *Vietteogorgopis* (7 species, MIELKE & GREHAN 2012).

This pattern of endemism is a characteristic of other animal and plant groups in South America and is geographically correlated with the rift shoulder mountains of southeastern Brazil that were uplifted during the initial formation of the Atlantic basin (HEADS 2016). A putative sister-group relationship between *Phthius* gen. n. and *Pallas*, *Phassus* or *Schausiana* results in a geographic disjunction between southeastern Brazil and Mesoamerica (= Mexico + Central America). The southern distributional boundary of *Phassus* abuts the Romeral fault zone extending between the Cordillera Occidental and Cordillera Central in Colombia (Fig. 12), and since *Phassus* comprises distinctive and generally large-bodied species it is very unlikely that they would escape notice if they were present east of the Romeral fault zone.

The Romeral fault zone is associated with a complex history of regional tectonics involving Late Jurassic-Cretaceous accretion of volcanic arc terranes in Western Mexico and Central America (HEADS 2016). Some other animal and plant groups with member taxa endemic to Mesoamerica and southeastern Brazil also have related taxa within the region of disjunction between *Phthius* gen. n. and *Phassus*. This allopatry suggests that the distributions are the result of a widespread ancestor that differentiated locally with respect to geological disruptions occurring at these tectonic boundaries (HEADS 2016). A Mesoamerican disjunction for *Phthius* gen. n. would be the result of vicariance at the Romeral fault zone followed by extinction across most of northern South America.

Another intriguing possibility is that *Phthius* gen. n. and the Mesoamerican genera have a sister-group relationship with the cibyrine clade which does occupy the disjunct region as well as overlapping with these genera. If future analysis confirms such a sister-group relationship it is possible that the cibyrine ancestor was formerly allopatric and occupied the central region of South America between the Romeral Fault and southeastern Brazil in the Mesozoic and subsequently dispersed to overlap the local distributions of formerly allopatric sister taxa.

Acknowledgements

We thank Marcelo DUARTE, Rafael DELL'ERBA and Renato SILVA for access to the collection in São Paulo (MZSP) and Jane COSTA and Aline MIRANDA for access to the collection in Rio de Janeiro (CEIOC). We thank Bernard LANDRY (MHNG) for sharing information from the collection. Finally, Dr. Wolfgang A. NÄSSIG (Frankfurt am Main, Germany) for suggestions and reviewing the manuscript.

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Received: 18. iv. 2017

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Jahr/Year: 2017

Band/Volume: [38](#)

Autor(en)/Author(s): Mielke Carlos G. C., Grehan John R.

Artikel/Article: [Description of *Phthius* gen. n., with a new species from southeastern Brazil with possible vicariance relationships to Mesoamerica \(Lepidoptera, Hepialidae\) 132-137](#)