

***Thraulodes mariano* sp. nov., a remarkable new species of mayfly (Ephemeroptera: Leptophlebiidae) with dark wings from the southern Brazilian Atlantic Forest**

VINÍCIUS DE ASSIS SILVA^{1,2}, FREDERICO FALCÃO SALLES³ & ÂNGELO PARISE PINTO²



¹Programa de Pós-Graduação em Ciências Biológicas (Entomologia) - PPGEnto, Universidade Federal do Paraná, Curitiba, PR, Brazil.


²Laboratory of Systematics on Aquatic Insects (LABSIA), Departamento de Zoologia, Universidade Federal do Paraná, P. O. Box 19020, 81531-980, Curitiba, PR, Brazil.

³Museu de Entomologia, Departamento de Entomologia, Universidade Federal de Viçosa, MG, Brazil.

Corresponding author:

^{1,2}  viniciusdeassisidl@gmail.com;  <https://orcid.org/0000-0002-1002-1871>

³  frederico.salles@ufv.br;  <https://orcid.org/0000-0001-8331-5929>

²  <https://orcid.org/0000-0002-1650-5666>

Abstract

Thraulodes mariano sp. nov. is described, illustrated and diagnosed based on a single male imago from a subtropical forest at Pico do Marumbi State Park, in the protected area of Mananciais da Serra, state of Paraná, Brazil. Based on the dark coloration of legs and the large dark spot at base of forewing, *T. mariano* sp. nov. is similar to species of the *niger*-group (Peruvian Amazonia) and to *T. basimaculatus* Giordano & Domínguez, 2005, a species endemic to Bolivia. The new species can be distinguished from all other species in the genus *Thraulodes* Ulmer, by the combination of following characteristics: (1) four cross-veins basal to bulla in forewing; (2) brown area covering about of proximal half of the forewing; (3) pleura violet; (4) middle and posterior femora yellowish washed with dark brown; (5) terga and sterna I–IV white washed with dark brown on posterior and lateral margin terga and sterna V–X dark brown; (6) penes short and wide with distolateral area, “ear-like” and poorly developed lateral pouch; (7) styliger plate triangular, median projection short and rounded on the apex. This new species represents the first record of the genus from the state of Paraná, Brazil.

Keywords: Aquatic insects, Araucaria Forest, Hagenulinae, Neotropical Region, Taxonomy

Introduction

The leptophlebiid genus *Thraulodes* Ulmer, 1920 was erected to include *Thraululus laetus* Eaton, 1884, a mayfly species originally described based on a single male imago collected by Baron W. von Nolcken from New Granada (see Kimmins, 1960), currently Colombia (Traver & Edmunds, 1967). This Western Hemisphere genus has a wide range of distribution from the southern United States of America, in the states of Arizona and Texas, into Northwestern (Tucumán, Salta and Jujuy provinces) and Northeastern (Misiones province) Argentina (Traver & Edmunds, 1967). It is the most species-rich genus of Leptophlebiidae in the Neotropical region (Sartori & Brittain, 2015).

Thraulodes can be distinguished from the other leptophlebiid genera based on penes lobes totally divided, posterior margin of styliger plate acutely projected posteriorly (roughly rounded in some species), sockets of forceps fused, and MA slightly asymmetric (Domínguez *et al.*, 2006; Kluge, 2020). Based on the complete loss of patella-tibial suture on all legs of nymphs and imagos (Kluge, 2008), the genus is included in Hagenulus/fg1 (Hagenulinae sensu Monjardim *et al.*, 2020) and recently included in the unraked taxon Hermanellandria, which encompass other Neotropical genera such as *Farrodes* Peters, 1971, *Hermanella* Needham & Murphy, 1924 and *Simothraulopsis* Demoulin, 1966 (Kluge, 2020). The classification system by Kluge (2020) unfortunately overlooked the recent phylogenetic hypothesis based on sequences from cytochrome c oxidase I mtDNA and 28S rDNA markers that resulted into an up-to-date classification of Leptophlebiidae, in which *Thraulodes* is included in a newly erected tribe Miroculini (Monjardim *et al.*, 2020). Although Monjardim's *et al.* (2020) classification is largely in agreement

with Kluge's (2020) framework, the putative close phylogenetic relationship among *Hermanellandria* taxa requires further investigation.

Among the 70 currently valid species included in *Thraulodes* (Kluge, 2020), 51 are recorded from South America (Francischetti *et al.*, 2019; Kluge, 2020; Salles *et al.*, 2020), with 23 species from Brazil, from 13 States: Roraima, Acre, Maranhão, Piauí, Pernambuco, Bahia, Mato Grosso, Goiás, Espírito Santo, Minas Gerais, Rio de Janeiro, São Paulo and Santa Catarina (Gama-Neto *et al.*, 2018; Francischetti *et al.*, 2019). Almost all Brazilian species are from the Atlantic Forest, with 20 species recorded from that domain (Salles *et al.* 2020). In spite of the recent advances in our understanding of the taxonomy of the genus in Brazil (e.g., Gonçalves *et al.*, 2013; Souto *et al.*, 2014; Gama-Neto *et al.*, 2018; Boldrini *et al.*, 2018; Campos & Mariano, 2019; Francischetti *et al.*, 2019) knowledge of the diversity and distribution of species of *Thraulodes* in the three states composing the South Region of that country (Paraná, Rio Grande do Sul and Santa Catarina) is poorly known, since Santa Catarina is the only state where the genus has been recorded (cf. Lima *et al.*, 2013 for data about Santa Catarina).

The goal of this study is to describe, illustrate and diagnose a remarkable new species of *Thraulodes* from the south of the Atlantic Forest in the state of Paraná, from the protected area of Mananciais da Serra, Piraquara municipality.

Material and methods

The examined material was collected in the protected area of Mananciais da Serra (Figs 1–2), in a well-preserved fragment of Atlantic Forest managed by the water and waste management company of the state of Paraná (SANE-PAR), at the Pico do Marumbi State Park, Piraquara municipality, state of Paraná, Brazil. A single male subimago was captured using a light (250w Mercury vapor) sheet trap (Fig. 2) and reared to the imago stage. The imago was fixed and preserved in 80% ethanol and deposited in the Entomological Collection Pe Jesus Santiago Moure, Departamento de Zoologia, Universidade Federal do Paraná, Curitiba, Brazil (DZUP). Male genitalia and legs were dissected and slide-mounted in Euparal®, while the wings were dry mounted. Morphological terminology of the genitalia follows Traver & Edmunds (1967).

Results

Thraulodes mariano sp. nov.

(Figs. 3–11, 13)

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Material examined. Holotype: Male imago (in alcohol), BRAZIL, Paraná State, Piraquara municipality, Pico do Marumbi State Park, Mananciais da Serra (SANEPAR), Reservatório do Carvalho, 21°29'47"S, 48°58'54"W, 1021 m a.s.l., light sheet, lic. 04/18, 28.XI.2018, A.P. Pinto, B.R. Araujo & A.C. Domahovski leg. (DZUP 515215).

Diagnosis. The new species can be distinguished from the other species of *Thraulodes* by the combination of the following characteristics: (1) four cross-veins basal to bulla in forewing; (2) brown area covering about of proximal half of the forewing; (3) pleura violet; (4) terga and sterna I–IV white washed with dark brown on posterior and lateral margin terga and sterna V–X dark brown; (5) penes short and wide with distinct lateral area “ear-like” and poorly developed lateral pouch; (6) styliger plate triangular, median projection short and rounded on the apex; (7) middle and posterior femora dark brown with yellowish hypodermal coloration.

Description of the male holotype.

(Figs. 3–11, 13)

Body length: 8.9 mm; forewing length: 11.5 mm; hindwing length: 2.0 mm.



FIGURES 1–2. Type locality of *Thraulodes mariano* sp. nov. at protected area of Mananciais da Serra, Pico do Marumbi State Park, Piraquara municipality, state of Paraná, Brazil: (1) artificial stream from the dissipation channel of the Carvalho catchment; (2) light sheet at Carvalho catchment. Photos: APP.

General coloration: Brown, legs yellowish washed with dark brown; membrane of forewing with proximal half dark brown, distal half hyaline.

Head (Figs. 3–5): Brown. Upper portion of eyes orange brown; lower portion blackish-brown. Median ocelli yellowish-brown; lateral ocelli white, surrounded by dark brown ring. Antennae with scape and pedicel dark brown; flagellum light brown.

Thorax (Figs. 3–5): Brown. Pronotum violet with median line dark brown; meso- and metanotum dark brown, stained with light brown in ill-defined areas. Pleurae violet. Sterna dark brown.

Wings (Figs 6-7): Forewing (Fig. 6) membrane and veins of proximal half brown, distal half with hyaline membrane and light brown veins; 4 cross-veins basal to bulla and 15 cross-veins distal to bulla. Costal brace tinged with dark brown. Hindwing (Fig. 7) light brown with 22 cross-veins.

Legs (Fig. 8): Brown. Foreleg yellowish; femur yellowish washed with dark brown. Coloration of middle and hind legs similar to foreleg; formula of foreleg: 0.74: 1.0 (3.5 mm): 0.04: 0.22: 0.17: 0.11: 0.08.

Abdomen (Fig. 3): Terga and sterna I–IV white, washed with dark brown on posterior and lateral margins; terga and sterna V–X dark brown. Caudal filaments dark brown.

Genitalia (Figs. 9–11, 13): Styliger plate light brown, triangular with posterior median projection short and apically rounded. Forceps light brown. Penes light brown, strongly sclerotized, short with distinct lateral area “ear-like” and poorly developed lateral pouch; spines short and wide, with subapical spine dorsally projected.

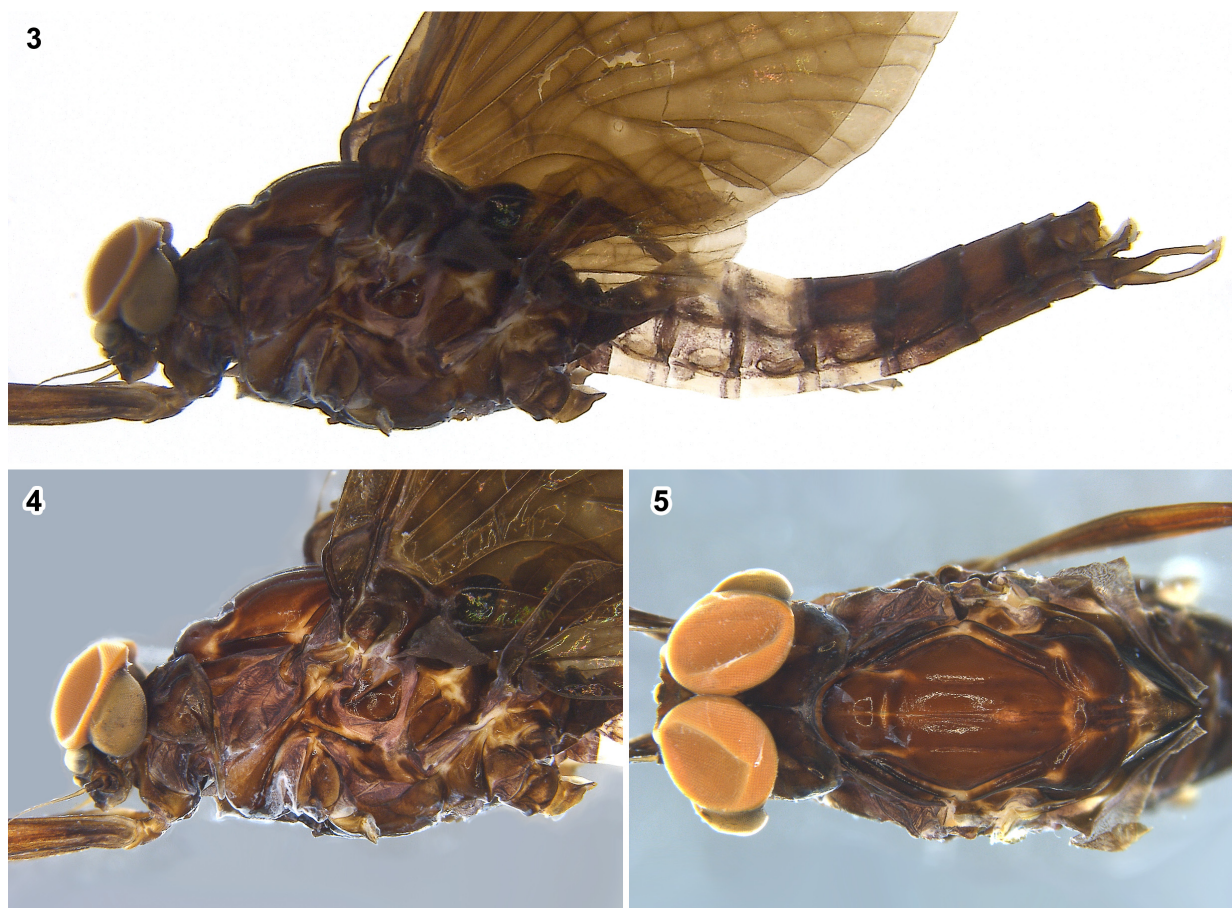


FIGURE 3–5. *Thraulodes mariano* sp. nov., holotype male (Brazil. PR: Pico do Marumbi State Park, DZUP 515215): (3) habitus in lateral view; (4) head and thorax in lateral view; (5) head and thorax in dorsal view.

Female: unknown.

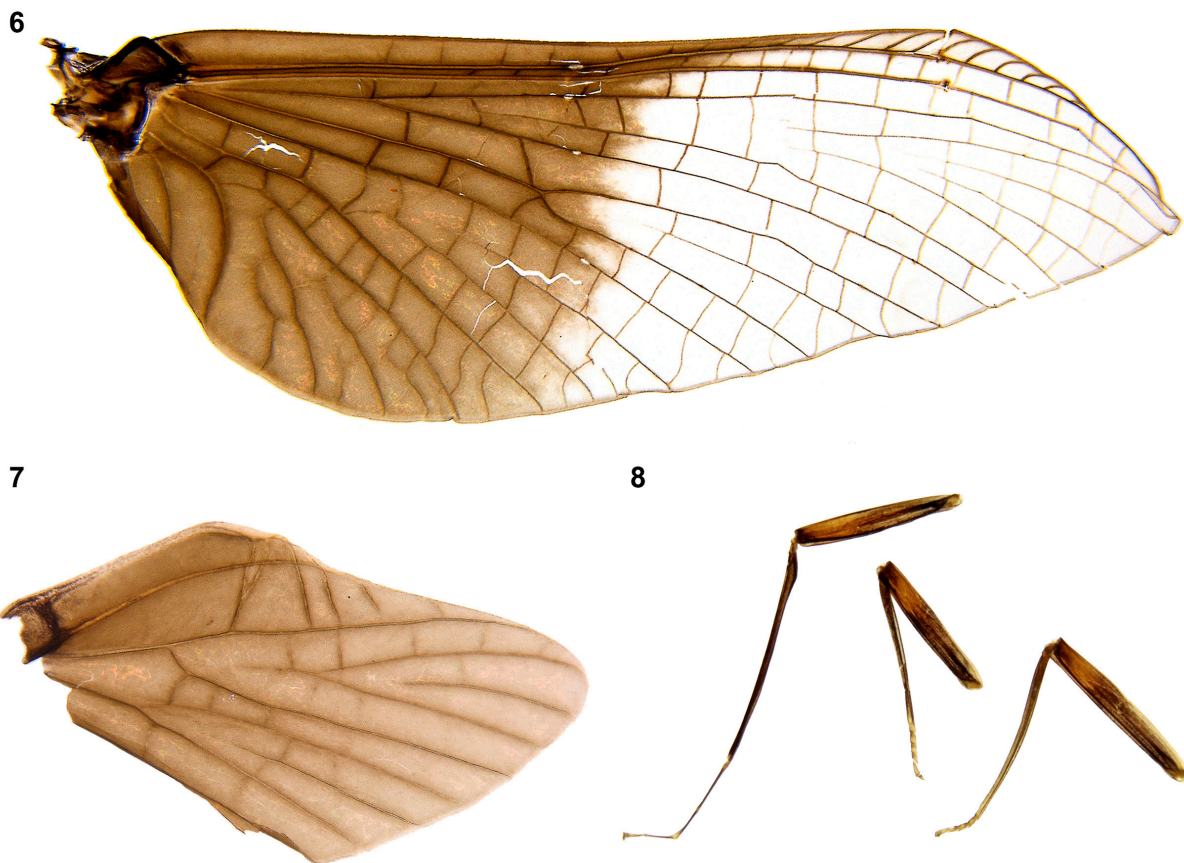
Nymph: unknown.

Etymology. The specific name, *mariano* (masculine, noun in the genitive case singular), is dedicated to entomologist colleague Rodolfo Mariano L. da Silva for his contribution to the knowledge of neotropical mayflies. In addition, he was the first researcher to review *Thraulodes* in Brazil.

Specimen remarks. The specimen was dehydrated prior to preservation in ethanol. After it molted, the imago was kept alive in a vial and was not immediately fixed in alcohol, drying naturally, resulting in a slightly shriveled specimen.

Ecological and biological data. The single male subimago was collected in late Spring season of 2018 in the Carvalho catchment (Fig. 2), the largest reservoir of the old and now deactivated system for water supply to metropolitan region of Curitiba. This catchment is behind one of the dams on the Rio Braço do Carvalho river. Next to the reservoir there is a dissipation channel that forms a semi-artificial stream (Fig. 1) with typical characteristics found in running waters in the Atlantic Forest. This stream is inhabited by a rich aquatic insect community. In the

Atlantic Forest, *Thraulodes* occurs at both high and low levels of anthropic influences (Raimundi *et al.*, 2013). The protected area of Mananciais da Serra is a montane formation that represents an ecotone between Araucaria and Tropical Atlantic Forests (Reginato & Goldenberg, 2007). The drainage system is preserved because it integrates the watershed for an important water supply station for 345 municipalities in the state of Paraná (SANEPAR, 2020). Based on the season in which the subimago emerged, it is likely other species of *Thraulodes* in that region may be univoltine, with the emergence period beginning in the early spring season.



FIGURES 6–8. *Thraulodes mariano* sp. nov. holotype male (Brazil. PR: Pico do Marumbi State Park, DZUP 515215): (6) forewing; (7) hindwing, (8) fore-, middle- and hind legs in lateral view.

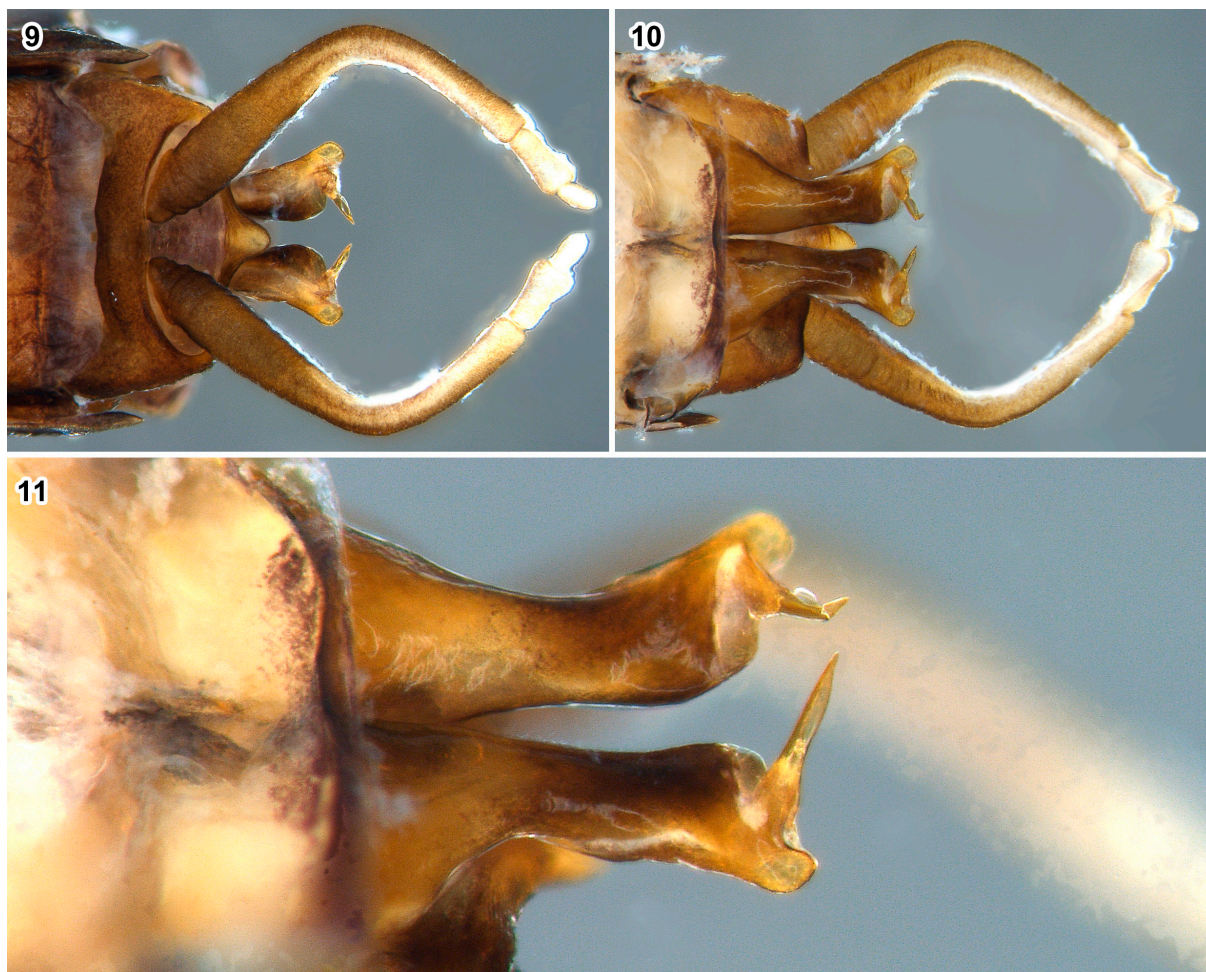
Discussion

Based on the dark coloration of tibiae of all legs, the new species keys-out (Kluge, 2020: couplet 7) as *T. nigrotibialis* Kluge, 2020, which it is included in *niger*-group by Kluge (2020). In this group of four Peruvian Amazonia species, *Thraulodes mariano* sp. nov. is easily distinguished by the basal half of the fore wing dark brown. Of the remaining species in the *niger*-group, the forewing is either hyaline (as in *T. nigrabdominalis* Kluge, 2020, *T. nigripes* Kluge, 2020 and *T. nigrotibialis*), or only with the costal-subcostal area brown (*T. niger* Kluge, 2020).

Comparing *T. mariano* sp. nov. with other species, it may be confounded with *T. basimaculatus* Giordano & Domínguez, 2005 from Bolivia, because both species have the basal half of the forewing membrane brown. However, the new species can be distinguished from *T. basimaculatus* by the posterior margin of the styliger plate, which is much more extended in that species (Figs. 12–13). Besides, in *T. mariano* sp. nov. the distolateral area of the penes is “ear-like” projected and has a poorly developed lateral pouch (Fig. 13), whereas in *T. basimaculatus* the medial and lateral margins of the penis lobe are straight. In addition, the forceps and penes are light brown in *T. mariano* sp. nov. and yellowish-white in *T. basimaculatus*.

Some would argue against the description a new species based on a single specimen, but rarity is the rule, rather than the exception, for a large portion of arthropod diversity in the tropics. In general, about 30% of species are sampled as singletons in diversity surveys, and even large samples would reveal a significant number of singleton

species (Coddington *et al.*, 2009). This phenomenon exceeds the innate explanation of under-sampling, however, and despite the putative explanation, individuals of some species are harder to collect than other species inhabiting in the same community. There are many cases in the literature of species that are only known from their type series (see Lim *et al.*, 2011). A brief review of *Thraulodes* species described in the last decade (2011–2020) reveals that at least 96% of species are known only from their type-series from a single locality, and for 52%, stages other than the imago were described.

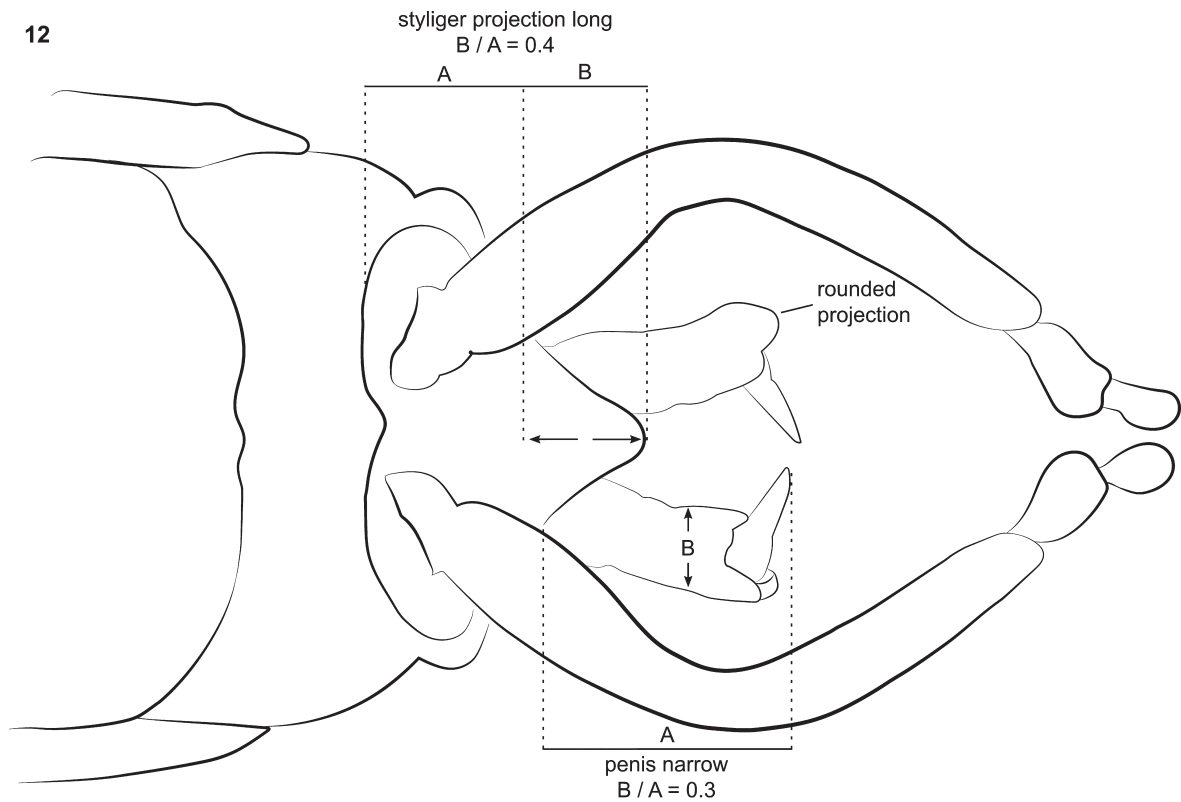


FIGURES 9–11. Genitalia of *Thraulodes mariano* sp. nov. holotype male (Brazil. PR: Pico do Marumbi State Park, DZUP 515215): (9) dorsal view, (10) ventral view and (11) ventrolateral view. Figures 10–11 with the 9th segment removed.

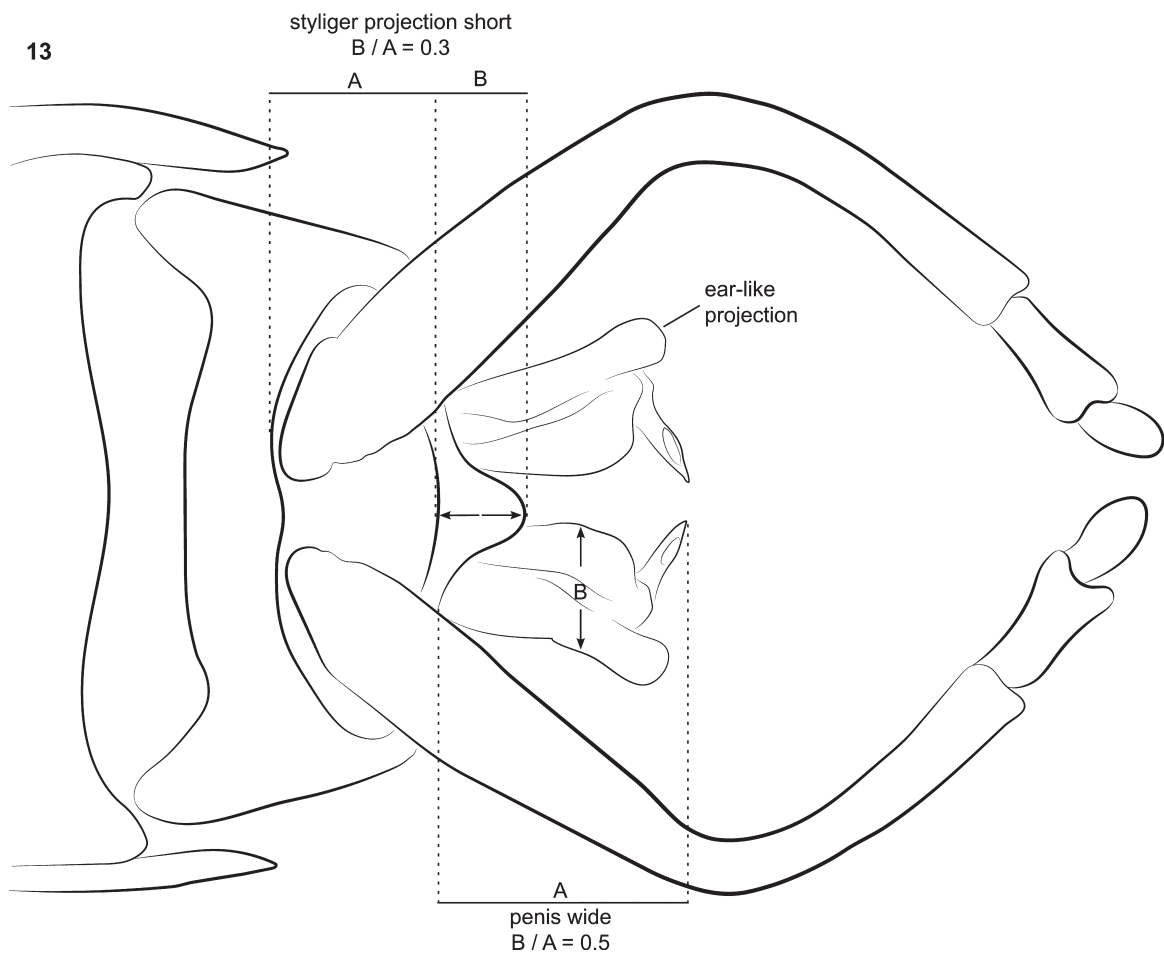
Limitations of describing a new species based on a single specimen are well-known, and among the major underlying shortcomings of such action resides the fact that such a description cannot reflect intraspecific variation (e.g., Jörger & Schrödl, 2013); thus, a misleading species hypothesis may result. The new species erected here is easily differentiated from other species in the genus based on coloration of the wings and shape of the structures of the genitalia, characteristics that usually do not present intraspecific variation in mayflies, especially the latter one.

Furthermore, large series of perfectly preserved specimens may be a utopic quest. Although it is highly desirable to erect a new species based on large series containing all stages (e.g., nymph, subimago, imago), including males and females from different localities, and to analyze all of these using distinct sources of data combined into an integrative approach (e.g., Dayrat, 2005), it is not always feasible—or even realistic. In the case of the work presented here, expeditions to the type locality of *T. mariano* sp. nov. were conducted often during the last three years (see Araujo & Pinto, submitted), and many Ephemeroptera specimens, including nymphs, subimagos and imagos, were collected, but the holotype of *T. mariano* sp. nov. is the single *Thraulodes* specimen among all of these samples. We carefully evaluated the putative benefits and tradeoffs of describing a new species based on a single specimen, and in this instance, decided that shedding light on this still unknown part of the diversity of Atlantic Forest mayflies, by allowing the species to be recognizable in future surveys, outweighed the potential for creating a potential new junior synonym (which we considered to be extremely unlikely).

12



13



FIGURES 12–13. Outline of male genitalia of *Thraulodes* species in ventral view: (12) *T. basimaculatus* holotype (redrawn from Giordano & Domínguez, 2005); (13) *T. marianoii* holotype.

In conclusion, this work shows that there is a gap to be filled about the knowledge of Ephemeroptera in Paraná, as the order is poorly known on that State. Other recent studies of mayflies from the southern region of Brazil also have resulted in several new records (Lima *et al.*, 2013; Raimundi *et al.*, 2013; Raimundi & Freitas, 2019; Faria & Salles, 2019). Certainly, further studies are needed to comprehend the diversity of mayflies in southeastern Brazil.

Acknowledgements

The authors would like to thank Ana Cristina do Rego Barros (SANEPAR), Breno Rodrigo Araujo, Alexandre C. Domahovski and Rodney R. Cavichioli (UFPR) for fieldwork support. To the Laboratory of Termitology at UFV for allow us to use its equipment. Thank are also due to Instituto Ambiental do Paraná (IAP) and ICMBIO/SISBIO for collecting licenses. This study was partially supported by Ph.D.'s scholarship from Coordination for the Improvement of Higher Education Personnel (CAPES) via PPGento/UFPR to VAS; FFS is researcher fellowship (Process n. 309666/2019-8) of CNPq. At last we appreciated the critical reviews from I. Gonçalves, L. Lima, N. Kluge, and R. Boldrini which significantly improved the final version of this study.

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