



Life stages of *Brasilocaenis mendesi* Malzacher, 1998 (Ephemeroptera: Caenidae) with redescription of male imago

LAURA ALMEIDA DE OLIVEIRA^{1*}, AMANDA DA SILVA CORRÊA², LUCAS R. C. LIMA³ & SHEYLA R. M. COUCEIRO^{1,2}

¹Programa de Pós-graduação em Biodiversidade e Biotecnologia, Universidade Federal do Pará, CEP 66075-110, Belém, PA, Brazil

✉ sheylacouceiro@yahoo.com.br; <https://orcid.org/0000-0001-8186-4203>

²Programa de Pós-graduação em Biodiversidade, Universidade Federal do Oeste do Pará, CEP 68040-470, Santarém, PA, Brazil

✉ amandadscent@gmail.com; <https://orcid.org/0009-0008-2522-1594>

³Laboratório de Zoologia, Núcleo de Pesquisa em Insetos Aquáticos do Piauí, Universidade Estadual do Piauí, CEP 64280-000, Campo Maior, PI, Brazil

✉ limalrc@cpm.uespi.br; <https://orcid.org/0000-0001-5943-3351>

*Corresponding author: ✉ lauraalmeidaoliver@gmail.com; <https://orcid.org/0000-0001-5907-773X>

Abstract

Brasilocaenis mendesi was described by Malzacher in 1998 based on male imagos collected in Mato Grosso, Brazil. However, knowledge about the species is still limited, as the nymph, female, and egg remained undescribed. Based on specimens collected in the state of Pará, this study presents morphological variations not reported in the original description and provides the first descriptions of the female imago, egg, and nymph. As a result, it was observed that the styliiger plate presents variations in the posterior margin, with deep emargination or subtle concavity, and a length between 0.09 mm and 0.12 mm. The forceps show variation at the tip, which can be shorter, subequal, or slightly longer than the plate. The female imago is differentiated by the projecting posterior margin of sternum IX. The chorion of the eggs is smooth, and the nymphs have dorsal microspines on the operculate gills, truncated sternite IX, and hind tarsal claws with approximately 14 denticles. A key to the nymphs of *Brasilocaenis* from Brazil is also proposed. These data expand morphological and taxonomic knowledge of the species.

Key words: Caeninae, Taxonomy, *Brasilocaenis* key, *B. elidioi*, *B. atawallpa*, Amazon

Introduction

Brasilocaenis Puthz (Ephemeroptera: Caenidae) was originally described based on male and female imagos and nymphal exuviae of *Brasilocaenis irmleri* (Puthz 1975). This genus, which occurs in almost all Brazilian biomes (Amazon, Caatinga, Cerrado, and Pantanal), has attracted the attention of many researchers, leading to taxonomic and phylogenetic revisions (Malzacher 1986, 1990, 1998; Lima *et al.* 2019; Nascimento *et al.* 2021). *Brasilocaenis* is represented by nine species from the Amazon biome: *Brasilocaenis amacayacu* (Lima, Molineri, Pinheiro & Salles, 2016); *B. atawallpa* Lima, Molineri, Vieira, Pinheiro & Salles, 2019; *B. elidioi* (Lima, Molineri, Pinheiro & Salles, 2016); *B. intermedia* Malzacher, 1986; *B. irmleri* Puthz, 1975; *B. mendesi* Malzacher, 1998; *B. puthzi* Malzacher, 1986; *B. renata* Malzacher, 1986; and *B. septentrionalis* Malzacher, 1990 (Salles *et al.* 2025).

Brasilocaenis mendesi was described based on male imagos collected in the state of Mato Grosso, in the Central-West region of Brazil, and has since been recorded in Colombia (Domínguez *et al.* 2006) and Bolivia (Lima *et al.* 2019). Although the species was described 27 years ago, some of its life stages remain unknown. This lack of information poses an obstacle to a comprehensive understanding of diversity patterns within the genus and the phylogenetic relationships between *Brasilocaenis* and other genera of Caenidae. The absence of knowledge regarding all life stages of the species is recognized as a “Haeckelian deficit” (Faria *et al.* 2020). This gap is particularly evident in the genus *Brasilocaenis*, especially considering that, for some species, nymphs and the female imago remain undescribed, except *B. elidioi*, *B. irmleri*, *B. puthzi* and *B. renata* which have all known life stages.

Recently, *B. mendesi* was recorded in the metropolitan region of Santarém, Pará, Northern Brazil (Oliveira *et al.* 2023). The analysis of this material, along with recent collections from the region, revealed some morphological variations in the male imago that were not mentioned in the original description, as well as the discovery of nymphs and female imagos of the species. Based on this material, we provide new taxonomic information for the male imago of *B. mendesi* and describe the previously unknown female adult and the egg and nymphal stages.

Material and methods

The study was conducted in the cities of Santarém and Mojuí dos Campos, located in western Pará (Fig. 1). The study area has a warm and humid climate, with well-defined dry and rainy seasons, an average temperature of 25.6 °C, relative humidity around 80%, and an annual rainfall of approximately 2,000 mm (FAPESPA 2015; De Andrade 2017). The sampled sites are part of the Tapajós and Curuá-Una hydrographic regions, with the main rivers being the Tapajós and Moju.

The nymphs were collected using a D-shaped net with a mesh size of 1 mm or less. Imagos were captured with a light trap (adapted bucket) operated from dusk to dawn (Nessimian *et al.* 2024, based on Frost 1957). Specimens were preserved in 80% ethanol and deposited in the Laboratory of Ecology and Taxonomy of Aquatic Invertebrates (LETIA), at the Federal University of Western Pará (UFOPA). Legs and genitalia of male imagos were dissected, examined in alcohol gel, and permanently mounted in Hoyer's medium. Descriptions and measurements followed standard protocols for mayflies, with a focus on Caenidae (Koss & Edmunds 1974; Hubbard 1995; Malzacher 1982).

Photographs were taken using a Leica MC120 HD camera coupled to a Leica S8AP0 stereomicroscope, and a Zeiss Axiocam ERc 5s photomicroscope was also used. Image stacking was performed with Leica Application Suite V4.12 and CombineZP (Hadley 2010) software to generate high-quality composite images from multiple focal planes. Photographs were assembled into plates using Adobe Photoshop®. Egg structures were examined using a Zeiss Evo 10 scanning electron microscope (SEM). For SEM analysis, eggs were dehydrated in a graded ethanol series, air-dried, mounted on aluminum stubs with double-sided adhesive tape, and sputter-coated with gold. Maps were created using QGIS (version 3.30.2).

Results

Brasiloaenis mendesi Malzacher, 1998

(Figs. 2–8)

B. mendesi Malzacher, 1998: 2; Domínguez *et al.* 2006: 201; Lima *et al.* 2019: 91.

Diagnosis. This species can be characterized by the following combination of characters, male imago: 1) Body length 1.33–2.08 mm; 2) Base of antennal flagellum not dilated; 3) Forceps apically pointed, abruptly narrowing at the apex and slightly curved inward; basal half fused to the lateral margins of the styliger plate (Fig. 3A–D); 4) Styliger plate as wide as long, with a deep median emargination forming two long lateral lobes (Fig. 3A–D); 5) Presence of a dorsal structure associated with the penis (Lima *et al.* 2019). Nymph: 1) Anterolateral corners of pronotum pointed (Fig. 6A); 2) Middle coxa with well-developed semicircular projection, hind coxa with finger-like projection (Fig. 8B–C); 3) Hind tarsal claws with 14 small denticles (Fig. 8F); 4) Opercular gill with dorsal surface covered with microspines and short, simple bristles (Fig. 6C); 5) Sternum IX with a truncated posterior margin.

Descriptions

Male imago (Figs. 2–3). Length (in mm): Body 1.3–2.0 (n= 6); forewing: 1.4–2.0; foreleg: 1.1– 2.2; hind leg: 1.0–1.6; cercus: 4.8–6.6. Ratios. Foreleg 1.1–1.3× the length of hind leg. Ratio of first segment of the foretarsi length to 2nd:3rd:4th:5th = 0.2:0.4–0.5:0.5:0.7–0.8. Genitalia: styliger plate length 0.47–0.70× width; forceps length 6.7–7.4× width at half length.

Coloration. Head light brown to yellowish, shaded with dark markings in dorsal view (Fig. 2A); ventral surface yellowish (Fig. 2C). Antennae: scape pale; pedicel pale with dark brown apex; flagellum grayish, with basal half dark brown (Fig. 2A). Thorax. Prothorax light brown to yellowish, with black lateral margins. Meso- and metanotum

light brown to yellowish, shaded with brown on the keels; pleura and sterna pale light brown. Wings. Forewings hyaline; veins translucent, except C, Sc, Rs, and MA, which are black. Legs. Yellowish brown, with femora and tibiae each bearing a black subapical spot. Abdomen. Terga whitish: segments I–II with a black medial stripe and darker lateral areas; segments III–VI whitish with subtle black pigmentation medially; segment VII whitish, faintly yellowish, with black lateral spots; segment VIII similar, but lateral black spots are more subtle; segments IX–X faintly yellowish (Fig. 2A). Sterna pale, with segment IX yellowish (Fig. 2C); pleura pale (Fig. 2B). Genitalia. Sternum IX with distinctly yellow sclerites (Fig. 2C). Forceps dark brown; penis yellowish (Figs. 3A–D). Caudal filaments. Light and translucent.

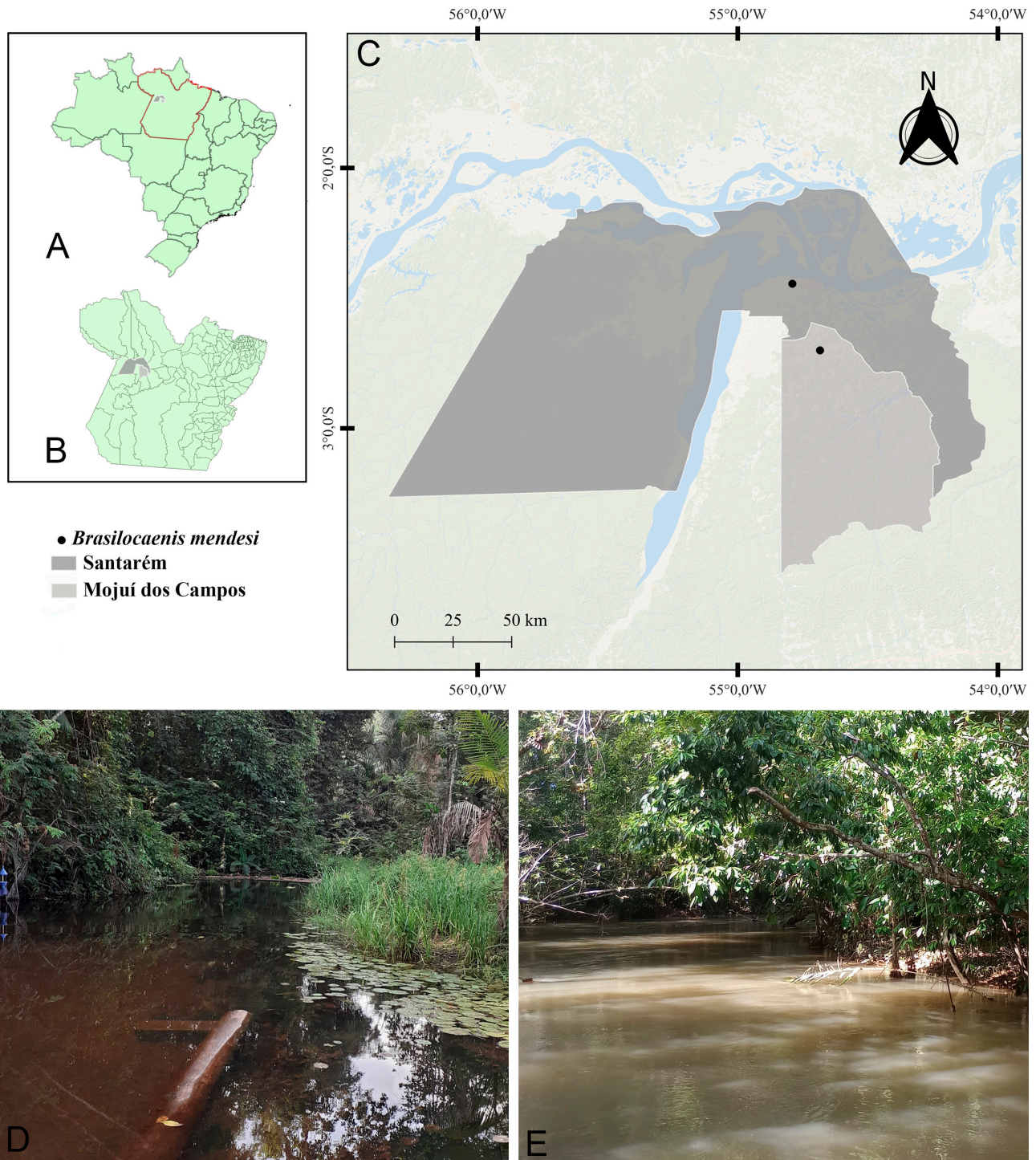


FIGURE 1. Location of the study area. A, Map of Brazil with highlighted area containing the state of Pará; B, state of Pará with location of sampled sites; C, municipalities of Santarém and Mojuí dos Campos; D, municipality of Mojuí dos Campos, Mojuí River; E, municipality of Santarém, Jua-casa stream.

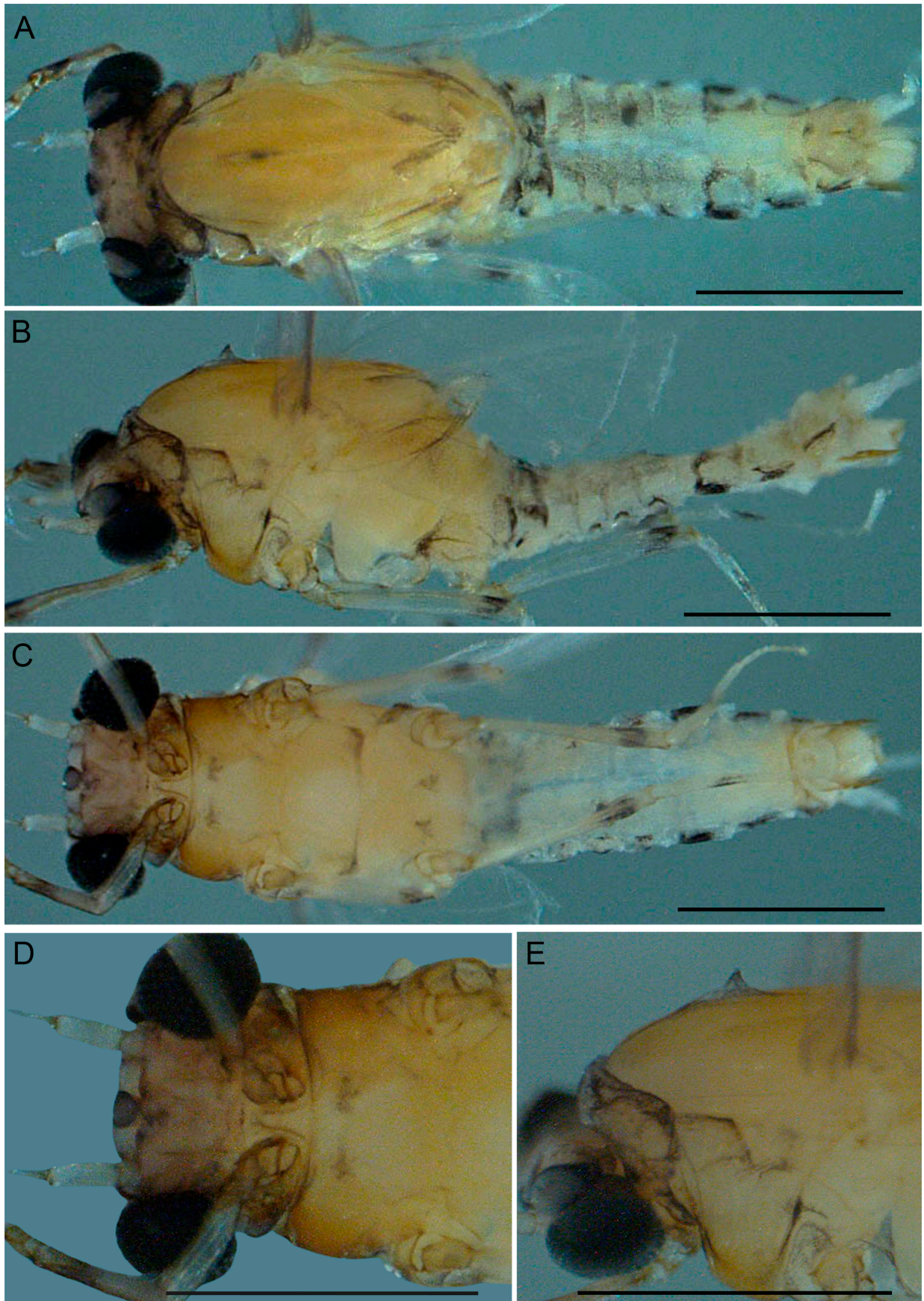


FIGURE 2. Male imago, *Brasilocaenis mendesi* Malzacher. A, habitus in dorsal view; B, habitus in lateral view; C, habitus in ventral view; D, details of pro- and mesosternum (ventral view); E, details of thorax (lateral view). (Scale = 0.5 mm).



FIGURE 3. Male genitalia, *Brasilocaenis mendesi* Malzacher. A–D, variations of styliger plate (dashed line indicates posterior margin). (Scale = 0.1 mm).

Morphology. Antenna: Base of antennal flagellum dilated. Thorax. Pronotum with lateral margins rounded and broader posteriorly (Fig. 2A); process on mesonotal membrane in lateral view triangular, pointed (shark-fin-shaped) (Figs. 2B, E); prosternal longitudinal ridges forming a triangular structure, closed and rounded anteriorly and with straight lateral margins (Fig. 2D). Abdomen. Lateral filaments and fingerlike process on tergum II lacking. Genitalia. Styliger plate sclerotized, with roundly projected lateroposterior margins, forming a variable broad and concave posterior margin in-between. Anterior margin roundly indented between the long and thick apophyses (Fig. 3A–D), barely discernible basolateral and central sclerites, wide lateral sclerite. Forceps middle third fused with



FIGURE 4. Female imago, *Brasilocaenis mendesi* Malzacher. A, habitus in dorsal view; B, habitus in lateral view; C, habitus in ventral view; D, detail of pro- and mesosternum (ventral view); E, detail of thorax (ventral view). (Scale = 0.5 mm).

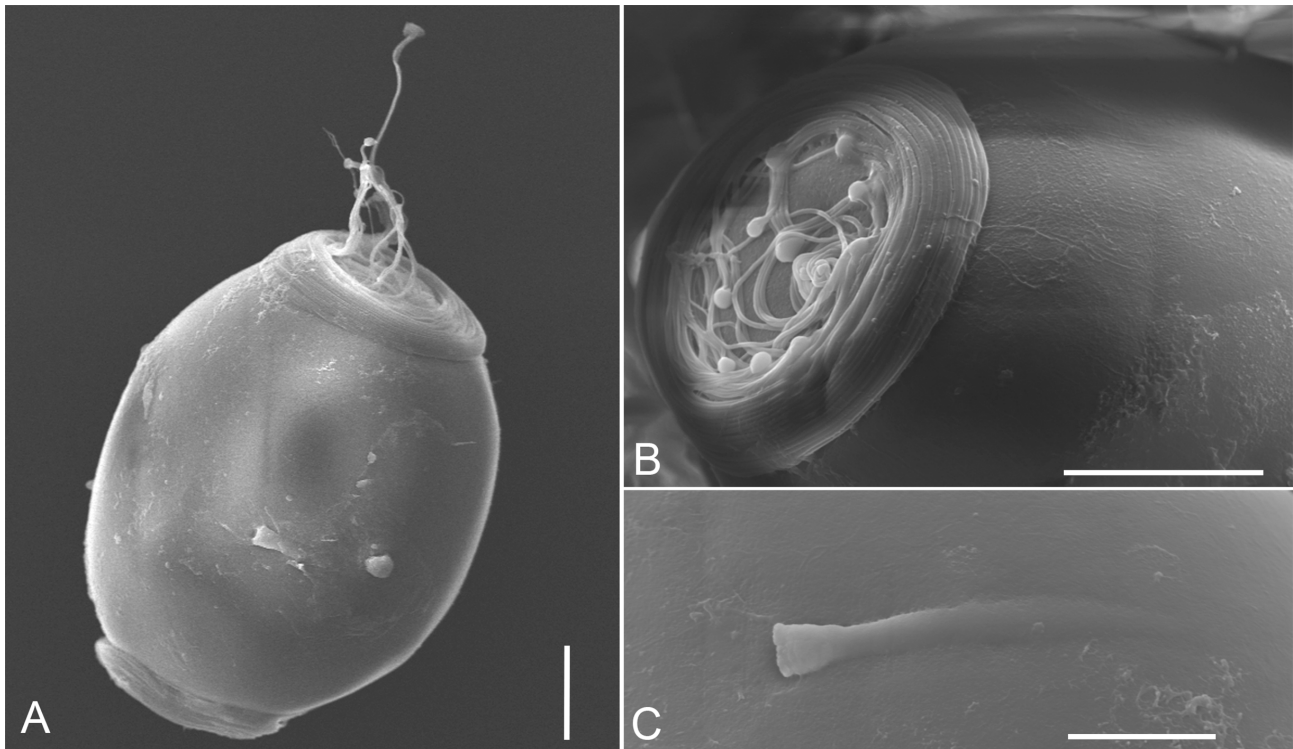


FIGURE 5. Egg, *Brasilocaenis mendesi* Malzacher. A, general view; B, structure of the polar cap and chorion; C, detail of the micropyle. (Scale: Figs. 5A, B = 20 μ m; 5C = 10 μ m).

styliger plate, tapering progressively towards apex and curving slightly inwards; smaller, subequal or larger than styliger plate. Penis protruding dorsally and laterally, with apical notch, deeper in some individuals, with sclerotic penile fold.

Female imago (Figs. 4A–E, 5A–C). Body length: 2.3–2.9 mm ($n = 7$); forewing: 1.9–2.1 mm; foreleg: 1.3–1.4 mm; cercus, broken. Thorax: Similar to that of males, but with more evident dark brown spots on the mesonotum and metanotum. The process on the mesonotal membrane is less elevated and less developed compared to males. Katepisternum pale yellow; mesopleural sclerites brown (Fig. 4B). Abdomen: similar to that of males, but with a distinct black line on the posterior margin of terga VII and VIII, more pronounced in some individuals. Abdominal sternum IX with the posterior margin slightly projected (Fig. 4C). Lateral filaments absent.

Egg (Figs. 5A–C). Length: 97–101 μ m; width: 64–73 μ m. Light yellow in color. Oval in shape. Chorion surface smooth. Micropyle funnel-shaped, narrow and elongated, without a sperm guide. Two rope-like polar caps, coiled with fine intertwined threads, located at the narrower end of the egg, each with approximately 12 terminal buttons.

Nymph (Figs. 6A–F, 7A–F, 8A–F). Length (in mm): Body, 3.2–3.3 mm ($n = 2$), cercus, broken. Ratios. Mouthparts. Width of maxillary palp segment I 2.4 width of segment II; length of maxillary palp segment I 2.0 \times length of segment II; length of maxillary palp segment I 1.3 \times length of segment III; length of labrum 0.3 \times its maximum width. Foreleg. Length of fore femur 3.0 \times its maximum width.

Coloration and Morphology. Head. Light brown with black spots, shaded black posterior to eyes; mouthparts light brown to translucent yellowish. Antennae with pedicel and flagellum pale. Labrum broad, with shallow anteromedial emargination and rounded lateral margins; dorsal surface with long bristles along the margin and serrated/denticulate apical edge. Linguae of hypopharynx rounded (Fig. 7B). Right mandible with subapical bristles of varying size on the inner margin and long, thin setae at the median area (Fig. 7F). Thorax. Notum light brown with dark brown sutures. Pronotum with light brown anterior margin and black-shaded areas; anterolateral corners pointed (Fig. 6A). Mesonotum with yellowish white spot anterior to wing bud bases and dark brown medial lines (Fig. 6A). Thoracic sternum yellowish with brownish outer margins; metasternum with a dark brown posterior line. Legs brownish yellow: femora yellowish-brown with subapical black spots; tibiae yellowish-brown, slightly darkened medially; tarsi yellowish-brown. Fore femur well-developed, without projection; middle and hind

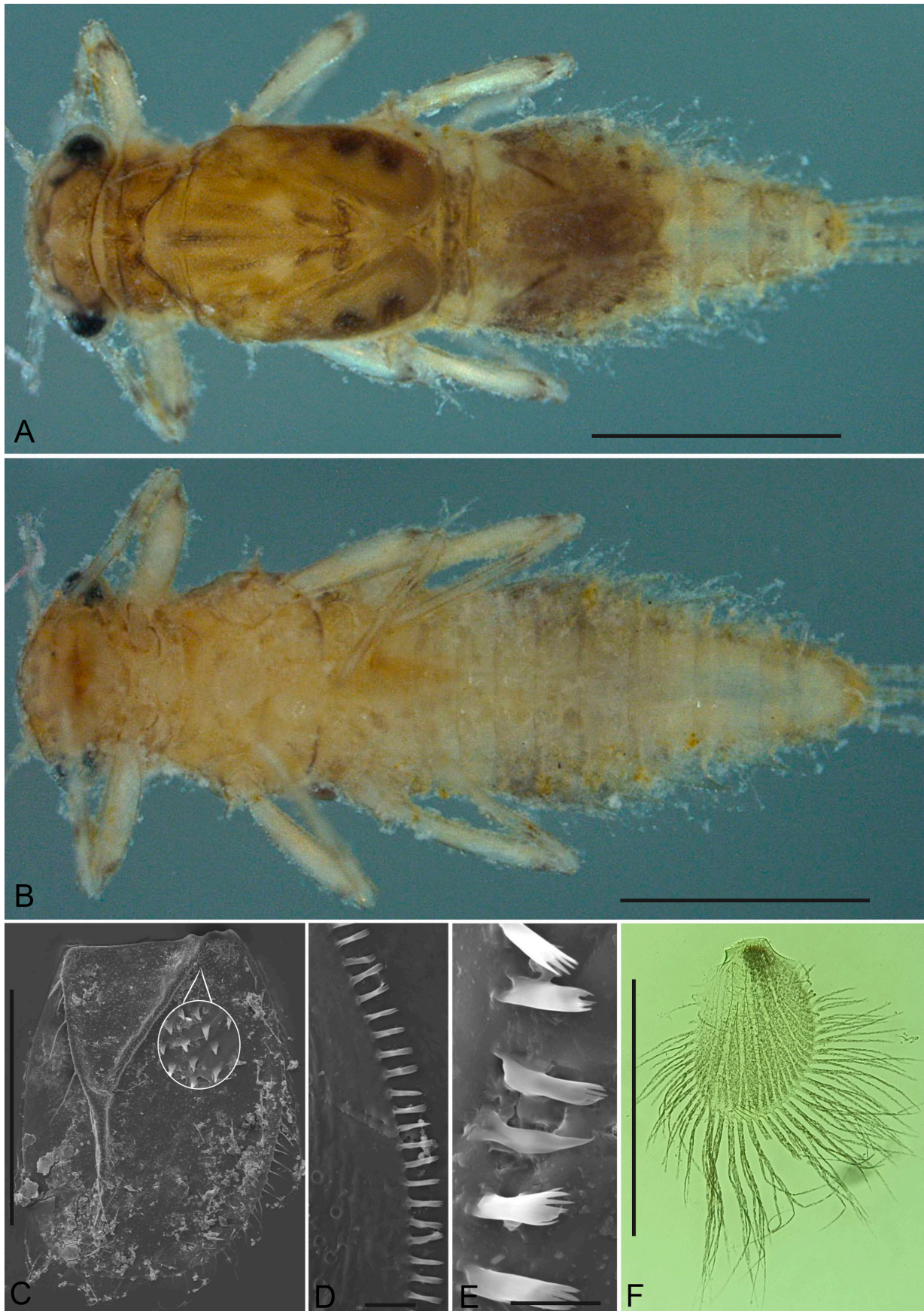


FIGURE 6. Nymph, *Brasilocaenis mendesi* Malzacher. A, habitus in dorsal view; B, habitus in ventral view; C, opercular gill (dorsal view; D, opercular gill (detail of the central row of microtrichia); E, enlarged detail of the central row of microtrichia; F, gill. (Scale: Figs. 6A–B = 1 mm; 6C, F = 0.5 mm; 6D = 20 µm; 6E = 10 µm).

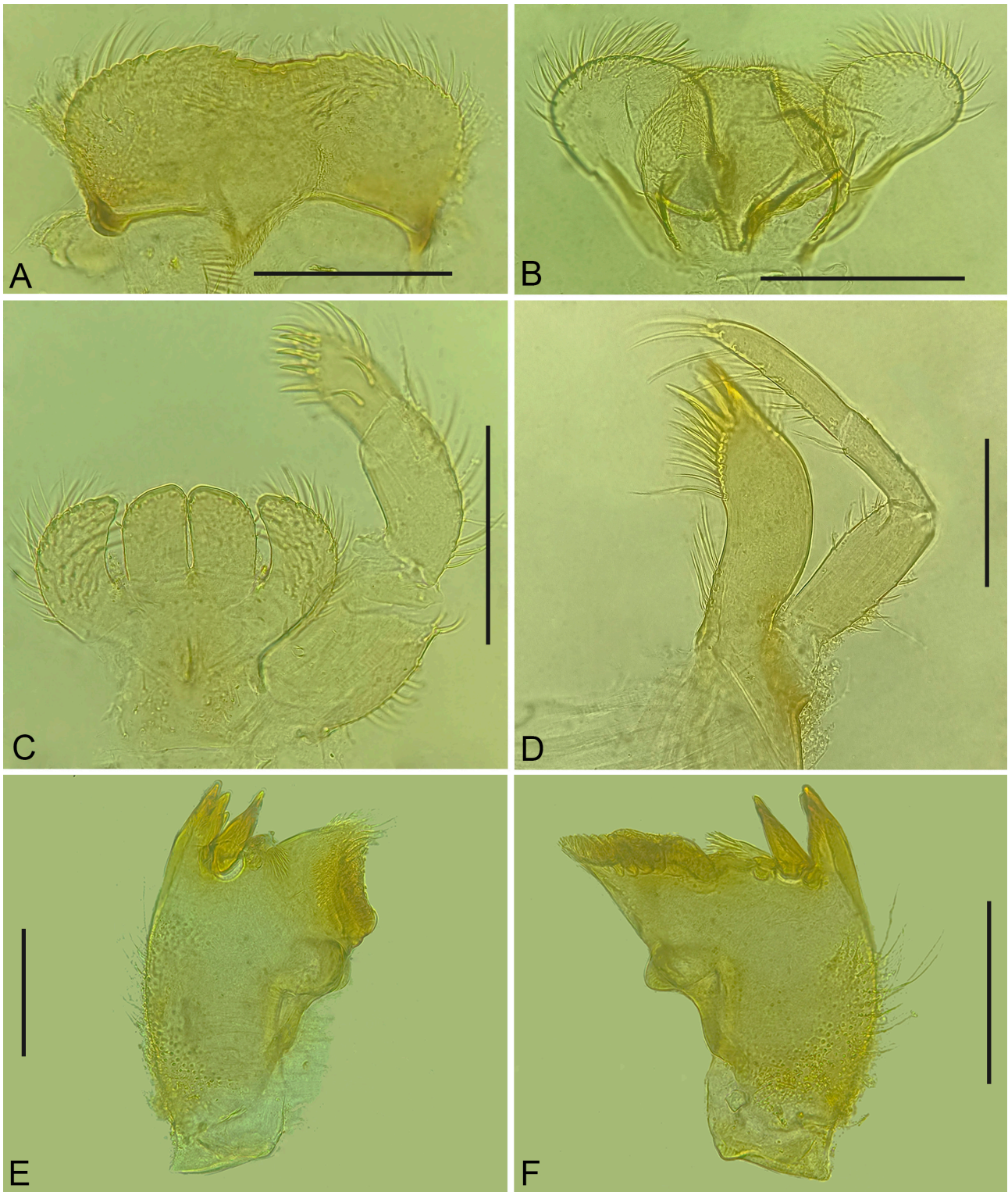


FIGURE 7. Nymph, *Brasilocaenis mendesi* Malzacher. A, labrum, dorsal view; B, hypopharynx, ventral view; C, labium, ventral view; D, maxilla, ventral view; E, left mandible, dorsal view; F, right mandible, dorsal view. (Scale = 0.1 mm).

femora developed and pointed (Figs. 8A–C). Coxae without bristles externally; middle coxa with well-developed semicircular projection, hind coxa with finger-like projection. Femora with few, variably sized bristles along dorsal, internal, and external margins (Figs. 8A–C), anterior and middle femora in the dorsal region with bifid setae (Figs. 8A–B). Tibiae with simple setae of variable size along the inner margins and with few simple setae on the outer margin (Figs. 8A–C). Anterior and middle tarsi with a single row of simple setae on the inner margin (Figs. 8A–C).

Hind tarsus with two rows of setae, one simple and the other serrated (Fig. 8C). Anterior and middle tarsal claws without denticles; posterior tarsal claws with approximately 14 small denticles (Fig. 8F). Abdomen. Terga light brown, segments I–II with medial black band; III–VI subtly pigmented medially; VII–IX whitish with lateral black spots, more distinct on segment VII; segment X slightly yellowish (Figs. 6A–B). Sterna light brown to grayish (Fig. 6B). Operculate gills light brown, nearly entirely shaded with black, and with three lateral black spots; dorsal surface covered by microspines and short, simple setae; medial crest Y-shaped, complete and well-developed; ventral surface with elongated, apically fringed microtrichia (Figs. 6C–E). Posterolateral projections on segments III–IX long and pointed (Figs. 6A–B). Sternum IX with a truncated posterior margin, bearing short, simple setae laterally and posteriorly. Caudal filaments brownish (Figs. 6A–B).

Life cycle association. The association was established based on shared morphological characteristics and coloration patterns among specimens collected from the same water body. Although five male imagos of *Brasilocaenis elidioi* were collected at the same location, the nymphs collected from the same habitat do not match the described morphological characteristics of *B. elidioi*, indicating that they likely belong to a different species. Additionally, coloration characteristics were used to assist in associating nymphs with adults, the main ones being: yellowish-brown legs; yellowish-brown femora with subapical black spots; and yellowish-brown tibiae, slightly darkened in the median region, patterns that can also be observed in both male and female adults. The alates of *Brasilocaenis elidioi* generally exhibit a whitish body coloration; however, the specimens we analyzed showed a yellowish hue.

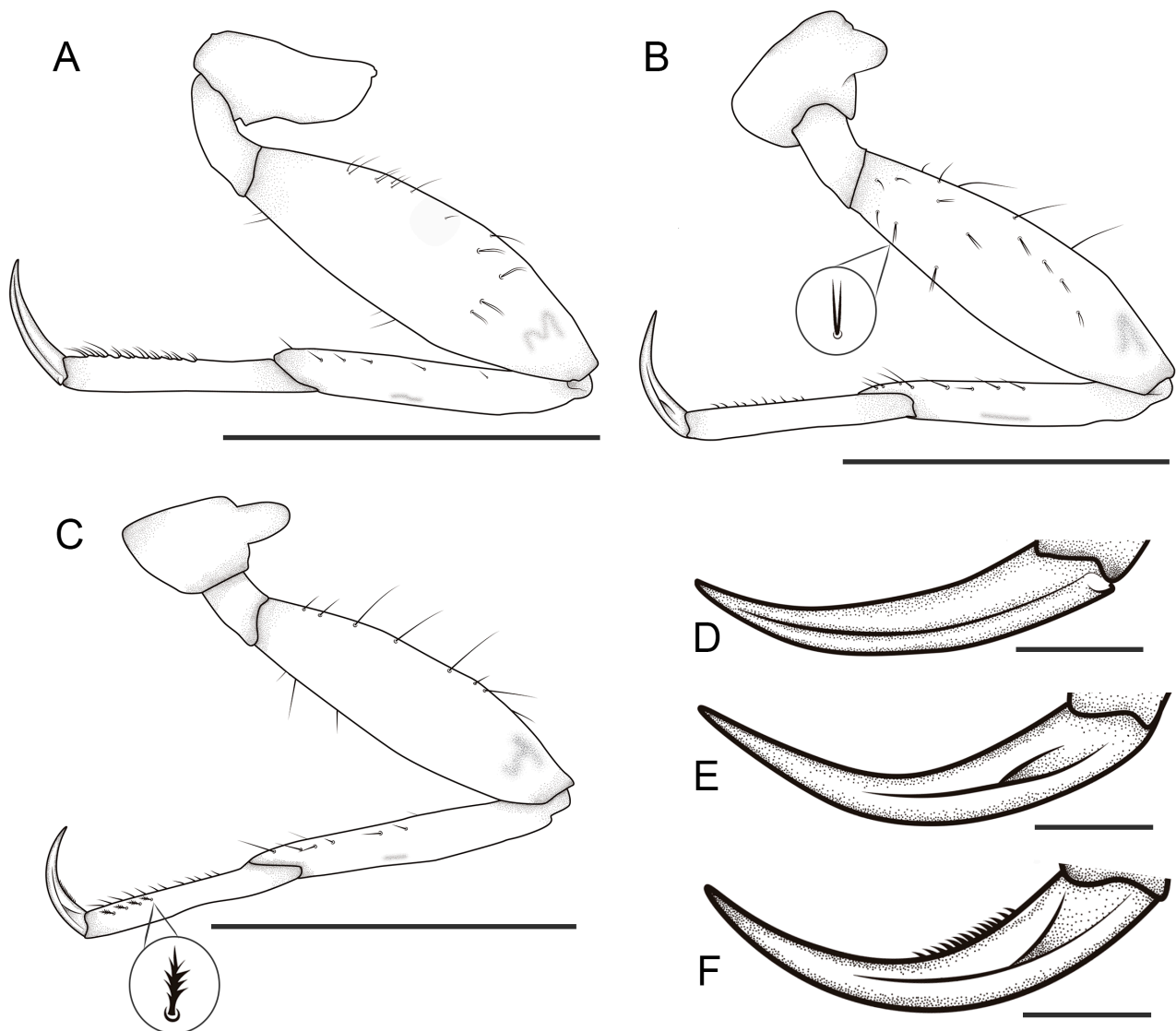


FIGURE 8. Nymph, *Brasilocaenis mendesi* Malzacher. A, foreleg; B, middle leg; C, hind leg; D, fore tarsal claw; E, middle tarsal claw; F, hind tarsal claw. (Scale: Figs. 8A–C = 0.5 mm; D–F = 0.05 mm).

Distribution and Biology. This species is known from Bolivia, Brazil (states of Mato Grosso and Pará), and Colombia. The specimens analyzed in this study were collected from tributaries of the Curuá-Una (Moju River) and Tapajós (Juá stream) river basins. These habitats are characterized by moderate rapids and vary in width from 6 to 12 meters depending on the season. Notably, both environments have been subjected to significant anthropogenic pressure, particularly Juá stream, which flows through an urbanized area.

Material examined. Fourteen ♂ imagos, 2 ♂ subimagos, 1 ♀ imago, 2 ♀ subimagos from Brazil, Pará state, Santarém city, Júa-Casa Stream, 02°26'4"S; 54°47'21"W, 27–28.ix.2023, Oliveira L.A. col. (UFOPA); 100 ♂ imagos, 19 ♀ imagos, from Brazil, Pará state, Mojuí do Campos city, Moju river, 02°42'03"S, 54°41'01"W, 11.xi.2020, Oliveira L.A. col. (UFOPA); 1 nymph, same data except date 21.i.2020 (UFOPA); 1 nymph, same data except date 05.vii.2020 (UFOPA).

Discussion

Based on the morphological criteria provided by Malzacher (1998) and comparisons with the male imagos examined in this study, notable morphological variation was observed among the specimens, particularly in the structure of the styliger plate and forceps. These variations were not reported by Malzacher (1998) in the original species description. In our specimens, the posterior margin of the styliger plate exhibits both a deep and rounded emargination as well as a more subtle concavity, contrasting with the original description, which characterizes this margin solely as deep and rounded.

Another noteworthy observation concerns the variation in the length of the styliger plate among the specimens analyzed in this study. The individuals did not display consistent proportions, the length of the styliger plate varied from 0.09 mm to 0.12 mm between the anterior and posterior margins, a variation resulting from a more pronounced concavity in some specimens. Regarding the forceps, Malzacher (1998) described the apical portion as long, exceeding the length of the styliger plate and being subequal in size to the penis. In contrast, the specimens examined herein show variation in the forceps tip, which may be shorter, subequal, or only slightly longer than the styliger plate, but never reaching the length of the penis.

The female imagos of *Brasilocaenis mendesi* exhibit the same coloration pattern observed in males, which may help establish an association between females and males. On the other hand, it is also possible to distinguish the female imago of *B. mendesi* from that of *B. elidioi* based on the morphology of the posterior margin of sternum IX: in *B. elidioi*, it is not projected, while in *B. mendesi*, it is slightly projected (Lima *et al.* 2016).

In relation to egg morphology, *B. mendesi*, *B. renata*, *B. puthzi*, *B. irmleri*, and *B. elidioi* are similar, both exhibiting two polar caps in the form of a coiled cord. However, the surface of the chorion differs between species: in *B. renata*, it is a finely porous chorion with distinct reticular lines, with an irregular granular structure, usually in the center of the fields and partially fused (see figs. 7E–F in Lima *et al.* 2019). In *B. puthzi*, the chorion has a very fine pore structure. In *B. irmleri*, the chorion is finely porous, sometimes with very fine reticular striations. The surface has numerous granules, from each of which extends a thin, convoluted villus (see figs. 7C–D in Lima *et al.* 2019). In *B. elidioi*, the chorion is finely perforated (see figs. 14–15 in Lima *et al.* 2016), while in *B. mendesi*, the chorion is smooth (Figs. 5A–C) (Malzacher, 1986; Lima *et al.* 2016).

The nymphal stage of *B. mendesi* closely resembles that of *B. atawallpa*, particularly due to the absence of denticles on the anterior and middle tarsal claws (see figs. 3G–J in Nascimento *et al.* 2021) and *B. elidioi* (see figs. 31–33 in Lima *et al.* 2016), as well as the presence of blunt meso- and metacoxal projections, which is an atypical pattern within the genus. However, *B. mendesi* can be distinguished from both species by the dorsal surface of the operculate gill, which is covered with microspines (smooth in *B. elidioi* and *B. atawallpa*), by the truncated posterior margin of sternite IX, and by the posterior tarsal claws bearing approximately 14 small denticles (in contrast to ca. 20 in *B. elidioi* and ca. 30 in *B. atawallpa*).

Given these observations, this study provides clear evidence of intraspecific variation in the imago of *B. mendesi*, since the morphological differences observed, mainly in the styliger plate and forceps, involve structures known to exhibit high variability in other Caenidae species. In addition, the penis morphology, a key character for species-level distinction, showed no differences from the original description by Malzacher (1998), providing no consistent support for the proposition of a new species. Such findings can support future research, particularly within evolutionary and ecological contexts, as these morphological variations may arise from both genetic factors and environmental influences.

Keys to *Brasilocaenis* nymphs from Brazil

- 1 Dorsal surface of the operculate gill smooth 2
Dorsal surface of the operculate gill covered with short robust spines or microspines (Fig. 6C) 3
- 2 Posterior tarsal claw with about 30 denticles; long and sharp posterolateral projections on abdominal segments V–VIII (see Figs. 3G and 2C in Nascimento *et al.* 2021) *Brasilocaenis atawallpa*
Posterior tarsal claw with about 20 denticles; short posterolateral projections on abdominal segments V–VIII (see Figs. 33 and 16 in Lima *et al.* 2016) *B. elidioi*
- 3 Dorsal surface of the operculate gill covered with short robust spines (see Figs. 10B and 10D in Lima *et al.* 2019; triangular meso and metacoxal processes 4
Dorsal surface of the operculate gill covered with microspines (Fig. 6C); semicircular meso and metacoxal processes (Fig. 8B–C) *B. mendesi*
- 4 Long meso and metacoxal processes with pointed apex (see Fig. 9D in Malzacher, 1986); anterolateral margin of the pronotum rounded or pointed 5
Short meso and metacoxal processes with rounded apex (see Fig. 9E in Malzacher, 1986); rounded anterolateral margin of the pronotum (see Fig 8B in Malzacher, 1986) *B. puthzi*
- 5 Anterolateral margin of the pronotum rounded (see Fig 13B in Lima *et al.* 2019) *B. renata*
Anterolateral margin of the pronotum pointed (see Fig 8A in Malzacher, 1986) *B. irmleri*

Acknowledgements

This study was conducted with the support of the Federal University of Western Pará (UFOPA), through student assistance and the Postgraduate Program in Biodiversity and Biotechnology—Bionorte. LAO and SRMC received financial support from UFOPA via the Productivity Grant Program (06/2024). We also thank CAPES for the grant (07/2023). We are grateful to Suzane Evaristo dos Santos, Iandra Braz Sousa, Diego Costa, and Carlos Souza for their valuable assistance during field collection. Special thanks to Professor Advânio for capturing the scanning electron microscope (SEM) images of the eggs through the Analytical Center—RIDH UFOPA.

References

- De Andrade, V.M.S., Cordeiro, I.M.C.C., Schwartz, G., Rangel-Vasconcelos, L.G.T. & Oliveira, F.D.A. (2017) Considerações sobre clima e aspectos edafoclimáticos da mesorregião Nordeste paraense. In: Cordeiro, I.M.C.C., Rangel-Vasconcelos, L.G., Schwartz, G. & Oliveira, F.D.A. (Eds.), *Nordeste Paraense. Vol. 1. Panorama geral e uso sustentável das florestas secundárias*. EDUFRA, Belém, pp. 59–96.
- Domínguez, E., Molineri, C., Pescador, M., Hubbard, M.D. & Nieto, C. (2006) *Ephemeroptera of South America. Vol. 2*. Pensoft, Moscow, 646 pp.
- FAPESPA [Fundação Amazônia de Amparo a Estudos e Pesquisas do Pará] (2015) *Estatísticas Municipais Paraenses: Santarém*. Diretoria de Estatística e de Tecnologia e Gestão da Informação, Belém, 58 pp.
- Faria, C.M.A., De Marco, P. & Dias, P.G.B. (2020) The Haeckelian shortfall or the tale of the missing semaphoronts. *Journal of Zoological Systematics and Evolutionary Research*, 58 (2), 409–414.
<https://doi.org/10.1111/jzs.12341>
- Frost, S.W. (1957) The Pennsylvania insect light trap. *Journal of Economic Entomology*, 50 (3), 287–292.
<https://doi.org/10.1093/jee/50.3.287>
- Hadley, A. (2010) CombineZP. Version 7.0.0.1. Software. Available from: <http://www.hadleyweb.pwp.blueyonder.co.uk/CZP/Installation.htm> (accessed 17 August 2025)
- Hubbard, M.D. (1995) Toward a standard methodology for the description of mayflies (Ephemeroptera). In: Corkum, L.D. & Ciborowski, J.J.H. (Eds.), *Current Directions in Research on Ephemeroptera*. Canadian Scholars' Press, Toronto, pp. 361–369.
- Koss, R.W. & Edmunds Jr, G.F. (1974) Ephemeroptera eggs and their contribution to phylogenetic studies of the order. *Zoological Journal of the Linnean Society*, 55 (4), 267–349.
<https://doi.org/10.1111/j.1096-3642.1974.tb01648.x>
- Lima, L.C., Molineri, C., Pinheiro, U. & Salles, F.F. (2016) Two new species of *Caenis* Stephens, 1835 (Ephemeroptera: Caenidae) from South America. *Zootaxa*, 4170 (1), 114–124.
<https://doi.org/10.11646/zootaxa.4170.1.5>
- Lima, L.R.C., Juen, L., Brasil, L.S., Firmino, V.C., Silva, M.S., Cruz, P.V. & Nascimento, S.R. (2021) Description of nymph of *Brasilocaenis atawallpa* Lima, Molineri, Vieira, Pinheiro & Salles, 2019 (Ephemeroptera: Caenidae) and notes on its taxonomic status. *Zootaxa*, 5027 (1), 136–144.

- <https://doi.org/10.11646/zootaxa.5027.1.8>
- Lima, L.R., Molineri, C., Vieira, L.M., Pinheiro, U. & Salles, F.F. (2019) Phylogenetic analysis supports the monophyly of the South American mayfly genus *Brasilocaenis* Puthz, 1975 (Insecta: Ephemeroptera: Caenidae). *Zoologischer Anzeiger*, 280, 78–94.
- <https://doi.org/10.1016/J.JCZ.2019.04.001>
- Malzacher, P. (1982) Eistrukturen europäischer Caenidae (Insecta, Ephemeroptera). *Stuttgarter Beiträge zur Naturkunde*, 356, 1–15.
- Malzacher, P. (1986) Caenidae aus dem Amazonasgebiet. *Spixiana*, 9, 83–104.
- Malzacher, P. (1990) Neue Arten der Eintagsfliegen-Familie Caenidae (Insecta, Ephemeroptera) aus Südamerika. *Studies on Neotropical Fauna and Environment*, 25 (1), 31–39.
- <https://doi.org/10.1080/01650529009360799>
- Malzacher, P. (1998) Remarks on the genus *Brasilocaenis* (Ephemeroptera: Caenidae), with the description of a new species: *Brasilocaenis mendesi*. *Staatliches Museum für Naturkunde*, 580, 1–6.
- Nascimento, S.R., Cruz, P.V., Silva, M.S., Firmino, V.C., Brasil, L.S., Juen, L. & Lima, L.R. (2021) Description of nymph of *Brasilocaenis atawallpa* Lima, Molineri, Vieira, Pinheiro & Salles, 2019 (Ephemeroptera: Caenidae) and notes on its taxonomic status. *Zootaxa*, 5027 (1), 136–144.
- <https://doi.org/10.11646/zootaxa.5027.1.8>
- Nessimian, J.L., Santos, A.P.M., Sampaio, B.H.L., Dumas, L.L., Pes, A. & Ferreira-Jr, N. (2024) The collapsible light trap: a portable Pennsylvania light trap for collecting aquatic insects. *Anais da Academia Brasileira de Ciências*, 96, e20230784.
- <https://doi.org/10.1590/0001-3765202420230784>
- Oliveira, L.A.D., Couceiro, S.R.M. & Nascimento, J.M.C.D. (2023) Ephemeroptera (Insecta) from the metropolitan region of Santarém, Pará, Brazil. *Biota Neotropica*, 23 (1), e2022143.
- <https://doi.org/10.1590/1676-0611-BN-2022-1437>
- Puthz, V. (1975) Eine neue Caenidengattung aus dem Amazonasgebiet (Insecta: Ephemeroptera: Caenidae). *Amazoniana*, 5, 411–415.
- Salles, F.F., Fernandes, O.L., Boldrini, R., Lima, L., Lima, M., Hoehne, L. & Del Ponte, E.M. (2025) EphemBrazil. Available from: <https://edelponte.shinyapps.io/ephembrazil/> (accessed 10 April 2025)