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Inventory

An updated distribution list of Leptophlebiidae Banks, 1900 (Ephemeroptera: Insecta) for Piauí state

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Abstract: Leptophlebiidae is the second most diverse family within Ephemeroptera, with species distributed across various States in Brazil, but with gaps in distribution records in others. Currently, nine species of Leptophlebiidae are recorded for the state of Piauí. Based on this information gap, the objective of this study was to present an updated species list of the family Leptophlebiidae new occurrence records and distributional sites for the state of Piauí, Brazil. By analyzing 447 specimens, we have significantly expanded our knowledge about the distribution of Leptophlebiidae species in the state of Piauí, increasing the recorded species from nine to 17. We have also added new occurrence records for six species and, for the first time, documented the presence of four genera. It is important to highlight that there is still an extensive area within the Cerrado and Brazilian semiarid regions where the occurrence of Ephemeroptera is unknown, confirming that the diversity in this area is underestimated and that knowledge of Ephemeroptera species and their distributions can expand with increased sampling efforts in the coming years, reducing the Linnean and Wallacean shortfall regarding this group. Our results also demonstrate the urgent need for inventories in the southern part of the state of Piauí, particularly in the sub-basins of the middle and upper Parnaíba river, which are considered suitable for monoculture expansion in Brazil.
Keywords: *Aquatic insect; Freshwater ecosystem; Parnaíba river basin.*

Uma lista de distribuição atualizada de Leptophlebiidae Banks, 1900 (Ephemeroptera: Insecta) para o estado do Piauí

Resumo: Leptophlebiidae é a segunda família mais diversa de Ephemeroptera, com espécies distribuídas em vários estados do Brasil, mas com lacunas no registro de distribuição em outros. Por exemplo, no estado do Piauí tem registrado apenas nove espécies de Leptophlebiidae. Baseada nessa lacuna de informação, o objetivo deste estudo foi apresentar uma lista atualizada de espécies da família Leptophlebiidae, novos registros de ocorrência e sítios de distribuição para o estado do Piauí, Brasil. Ao analisar 447 exemplares, ampliamos significativamente nosso conhecimento sobre a distribuição das espécies de Leptophlebiidae no estado do Piauí, aumentando o número de espécies registradas de nove para 17. Também adicionamos novos registros de ocorrência para seis espécies e, pela primeira vez, documentamos a presença de quatro gêneros. Destacamos que ainda existe uma extensa área do Cerrado e semiárido brasileiro que se desconhece a ocorrência de Ephemeroptera, confirmando que a diversidade nessa área é subestimada e que o conhecimento sobre as espécies de Ephemeroptera e suas distribuições podem se expandir com o aumento do esforço amostral nos próximos anos, diminuindo as lacunas Lineana e Wallaceana sobre esse grupo. Nossos resultados também demonstram a necessidade emergencial de inventários no sul do Estado do Piauí, principalmente nas sub-bacias do médio e alto rio Parnaíba que é considerado adequado para a expansão da monocultura no Brasil.
Palavras-chave: *Inseto aquático; Ecossistema de água doce; Bacia do rio Parnaíba.*

Introduction

Ephemeroptera Hyatt & Arms, 1890 is currently represented by approximately 3500 species, 400 genera, and 42 families (Sartori & Brittain 2015; Jacobus et al. 2021), occupying nearly all freshwater environments except Antarctica (Barber-James et al. 2013). In Brazil, there are 447 species distributed among 83 genera and 10 families: Caenidae, Euthyplociidae, Leptohyphidae, Melanemerellidae, Oligoneuriidae, Coryphoridae, Ephemeridae, Polymitarcyidae, Baetidae, and Leptophlebiidae (Salles et al. 2023). Leptophlebiidae Banks, 1900 is a cosmopolitan and morphologically diverse family (Raimundi et al. 2017), ranking as the second most diverse family in the Neotropical region within the order Ephemeroptera (Barber-James et al. 2013, Domínguez & Dos-Santos 2014). This family comprises seven subfamilies: Castanophlebiinae, Habrophlebinae, Leptophlebiinae, Terpidinae, Atalophlebiinae, Choroterpinae, and Hagenulinae (Monjardim et al. 2020). In Brazil, the family Leptophlebiidae is classified into 30 genera and 146 species, with 95 species being endemic to the country (Salles et al. 2023).

In recent years, there has been an increase in studies on the Leptophlebiidae family in Brazil, especially in the Northeast region (e.g., Mariano 2010, Lima et al. 2012ab, 2013, 2014, 2015, 2016, Costa & Mariano 2013, Almeida et al. 2016, Takiya et al. 2016, Lima 2018, Nascimento et al. 2019, 2020, Campos et al. 2022, Rodrigues et al. 2023). Despite these efforts, there is still an imbalance in the number of distribution records for Leptophlebiidae species among the nine states that make up the Brazilian Northeast region. While Bahia, Maranhão, and Pernambuco have an average distribution of 18 species, the states of Alagoas, Ceará, and Piauí have an average of three species, and there are no recorded species of Leptophlebiidae in Rio Grande do Norte, Paraíba, and Sergipe (Salles et al. 2023).

Currently, the state of Piauí have recorded nine species of Leptophlebiidae: *Farrodes tepui* Domínguez, Molineri & Peters 1996; *Fittkaulus cururuensis* Savage 1986; *Hagenulopsis minuta* Spieth, 1943; *Miroculis botafora* Rodrigues, Nascimento, Raimundi & Lima, 2023; *Miroculis fittkaui* Savage & Peters, 1983; *Simothraulopsis demerara* (Traver, 1947); *Simothraulopsis sinuosus* Lima, 2018; *Thraulodes sternimaculatus* Lima, Mariano & Pinheiro, 2013; and *Ulmeritoides flavopedes* (Spieth, 1943) (Takiya et al. 2016, Nascimento et al. 2017, Boldrini et al. 2018, Lima 2018, Campos et al. 2022, Rodrigues et al. 2023). These records were obtained within a small area of the Parnaíba river basin, underscoring the substantial knowledge gap regarding the distribution of Leptophlebiidae species in the state of Piauí, often referred to as the 'Wallacean shortfall' (Hortal et al. 2015).

The state of Piauí covers an area of 251,755.485 km² (IBGE 2020) and is characterized by a high floristic diversity in the transitional zone (ecotone) between the Cerrado and Caatinga biomes (Souza et al. 2017). The main basin in the state is the Parnaíba River, which has a drainage area of 343,000 km², with approximately 73.1% of its surface located within the territorial limits of Piauí (JICA 1995). The extensive hydrographic network formed by this basin is being heavily impacted by human activities and the deforestation of natural vegetation. In 2022 alone, there was a cumulative deforestation of 1,188.76 km² and 2,282.04 km² in the states of Piauí and Maranhão, respectively (Assis et al. 2019). In this scenario, understanding the distribution of Leptophlebiidae diversity in the state of Piauí becomes essential to comprehend the current threats to biodiversity and proactively prevent damage to the natural ecosystem (Barnosky et al. 2011, Pimm et al. 2014, Steffen et al. 2015, Díaz et al. 2019) and local extinctions of species, particularly in biodiversity hotspots like the Cerrado.

The objective of this study was to present an updated species list of the family Leptophlebiidae Banks 1900 (Ephemeroptera), new occurrence records and distributional sites for the state of Piauí, Brazil.

Materials and Methods

The updated list of Leptophlebiidae for Piauí state was based on individuals collected and deposited in the Entomological Collection of the State University of Piauí, Campus Heróis do Jenipapo (CEHJ), Campo Maior, Piauí, Brazil; and the Invertebrate Collection of the National Institute of Amazonian Research (INPA), Manaus, Amazonas, Brazil. The collections were carried out between April 2017 and June 2023 at 20 sites distributed within the Parnaíba River basin (Table 1).

The nymphs were collected from random samples of all visible substrates at each site using a D-shaped net (34 cm diameter, 250 µm mesh), with an average scanning time of four hours per site. The observed substrate types at the sites included sand, leaf banks, wood, roots, stones, and macrophytes. Some nymphs with well-developed anterior wing pads were separated to observe the transition from the aquatic form to the winged form. The nymphs were individually placed in plastic containers with water, and the opening was covered with a fine mesh fabric to prevent the individual from flying after emergence (Boldrini & Cruz 2013). After the subimago stage, the specimen was transferred to a dry vial until the imaginal ecdysis occurred. Once the transition cycle was complete, the specimen was fixed in 96% ethanol.

Some imagos were collected during the daytime, using a sweep net through the vegetation near the water's edge at the site. During the nighttime, both active and passive collecting methods were employed using a light trap placed near the water. For active collection, a white sheet illuminated with LED lamps was set up perpendicular to the water, capturing all individuals that landed on the sheet between 6:00 pm and 8:00 pm. For passive collection, a Pennsylvania trap was used, which remained deployed for 12 hours.

The identification of adults was performed by removing the wings, which were then mounted dry between a slide and a cover slip, sealed only with colorless enamel. The genitalia were also removed and mounted on permanent or temporary slides. Canada balsam was used to secure the structures on the permanent slides. After mounting the slides, they were placed in an oven with an average temperature of 60 °C for 2 to 3 days to ensure complete drying, following the procedures outlined by Waltz & McCafferty (1987). The identifications were based on Domínguez et al. (2006) and careful comparisons with the original descriptions (e.g., Lima et al. 2013, Salles et al. 2016, Nascimento et al. 2017).

Species distribution was consulted using the Taxonomic Catalog of the Fauna of Brazil database (http://fauna.jbrj.gov.br/), and the conservation status of the species was assessed using the Biodiversity Extinction Risk Assessment System (https://salve.icmbio.gov.br/#/) and the IUCN Red List of Threatened Species (https://www.iucnredlist.org/).

Table 1. Sample sites (S) in the Parnaíba river basin, Piauí state, Brazil. Latitude and longitude represent the specific coordinates of each sample site.

Municipality	Sites	Location	Latitude	Longitude
Pedro II	S1	Cachoeira do Urubu-Rei	−4.32617	−41.46264
Barras	S2	Longá river	−4.20233	−42.23922
Piripiri	S3	Açude Caldeirão	−4.34794	−41.72039
Esperantina	S4	Longá river	−3.91436	−42.11050
Castelo do Piauí	S5	Poti river	−5.18797	−41.70956
Coivaras	S6	Cachoeira da Campeira	−5.19586	−42.25942
Esperantina	S7	Cachoeira do Urubu	−3.91286	−42.11336
Brasileira	S8	Cachoeira do Bota Fora	−4.21419	−41.66714
Novo Santo Antônio	S9	Cachoeira da Coruja	−5.36739	−41.99803
Pedro II	S10	Cachoeira do Buriti	−4.42978	−41.63139
Pedro II	S11	Cachoeira das Tuncas	−4.42458	−41.64311
Alto Longá	S12	Nascente do Frei Pedro	−5.22839	−42.17334
Coivaras	S13	Parque Nacional de Sete Cidades	−5.19374	−42.26281
Pedro II	S14	Samambaia stream	−4.32794	−41.46289
Pedro II	S15	Corrente river	−4.43239	−41.45819
Piracuruca	S16	Parque Nacional de Sete Cidades	−4.09708	−41.68006
Piracuruca	S17	Parque Nacional de Sete Cidades	−4.10947	−41.72746
Floriano	S18	Parnaíba river	−6.763464	−43.022408
Castelo do Piauí	S19	Palmeira stream	−5.20356	−41.63028
Castelo do Piauí	S20	Cais stream	−5.203500	−41.689750

Results

We collected a total of 447 Leptophlebiidae specimens, distributed across 11 genera and 14 species. The inventory resulted in new records for five genera and eight species for Piauí state (Figure 1A). Seven species with new occurrences, and two species with previously known distribution in the state. Table 1 presents the geographical information of the described sites (S) in the examined material. With the exception of *Miroculis botafora*, all other recorded Leptophlebiidae species in Piauí are classified as least concern (LC) according to the Chico Mendes Institute for Biodiversity Conservation (ICMBIO).

Updated checklist and new geographical records

Farrodes carioca Domínguez, Molineri & Peters, 1996

Figure 2A–B

Previous distribution. Bahia (Lima et al. 2016), Goiás (Raimundi 2019), Espírito Santo (Salles et al. 2010), Rio de Janeiro (Domínguez et al. 1996). **New record for Piauí state**.

Material examined. Two ♂ imagos (light trap), S8, 28.x.2017, L.R.C. Lima and J.A.O. Rodrigues cols. (CEHJ); same data as preceding except four ♂ imagos, 15.xii.2018, L.R.C. Lima col.; same data as preceding except 16 ♂ imagos, 01.vi.2019, L.R.C. Lima col. 29 ♂ imagos (light trap), S11, 29.vi.2019, L.R.C. Lima col. (CEHJ). Two ♂ imagos (light trap), S14, 29.vi.2019, L.R.C. Lima col. (CEHJ). Two ♂ imagos (light trap), S15, 29.vi.2019, L.R.C. Lima col. (CEHJ). Four ♂ imagos (light trap), S19, 09.vi.2023, L.R.C. Lima, A.S. Carvalho, A.P.J. Faria cols. (CEHJ).

Farrodes tepui Domínguez, Molineri & Peters, 1996

Previous distribution. Ceará (Takiya et al. 2016), Bahia (Lima et al. 2016), Pernambuco (Lima et al. 2012b) and Piauí (Takiya et al. 2016).

Fittkaulus cururuensis Savage, 1986

Previous distribution. Pará (Savage 1986), Roraima (Gama-Neto et al. 2018), Bahia (Costa et al. 2018), Piauí (Takiya et al. 2016), Pernambuco (Lima et al. 2012b), Maranhão (Nascimento et al. 2020), Mato Grosso (Boldrini et al. 2009) and Espírito Santo (Boldrini et al. 2009).

Material examined. One ♀ imago (light trap), S8, 15.xii.2018, L.R.C. Lima col. (CEHJ); same data as preceding except one nymph (D-shaped net), 05.ix.2022. Three nymphs (D-shaped net), S16, 15.viii.2022, L.R.C. Lima col. (CEHJ).

Hagenulopsis minuta Spieth, 1943

Previous distribution. Amazonas (Peters & Domínguez 2001), Pará (Peters & Domínguez 2001), Roraima (Gama-Neto & Hamada 2014), Bahia (Lima et al. 2016), Piauí (Campos et al. 2022), Mato Grosso (Campos et al. 2022), Espírito Santo (Campos et al. 2022) and Minas Gerais (Campos et al. 2022).

Material examined. One ♂ imago (sweep net), S8, 28.x.2017, L.R.C. Lima and J.A.O. Rodrigues cols. (CEHJ); same data as preceding except

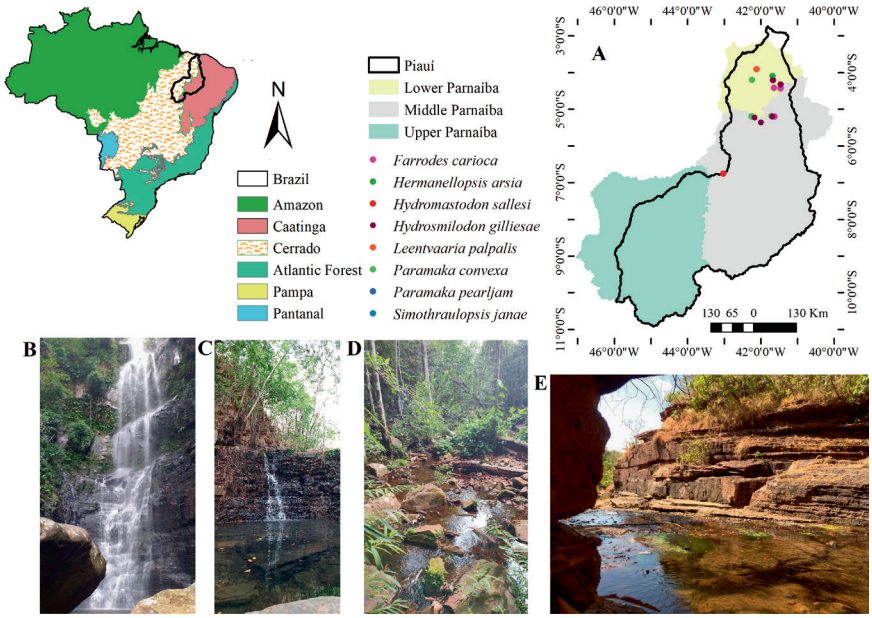

Figure 1. A, Distribution of sites with new records of Leptophlebiidae species (Ephemeroptera) for the Parnaíba river basin, Piauí, Brazil; B, Cachoeira do Urubu-Rei (site 1); C, Samambaia stream (site 14); D, Parque Nacional de Sete Cidades (site 16); E, Cachoeira da Campeira (site 27). See detailed information in Table 1.

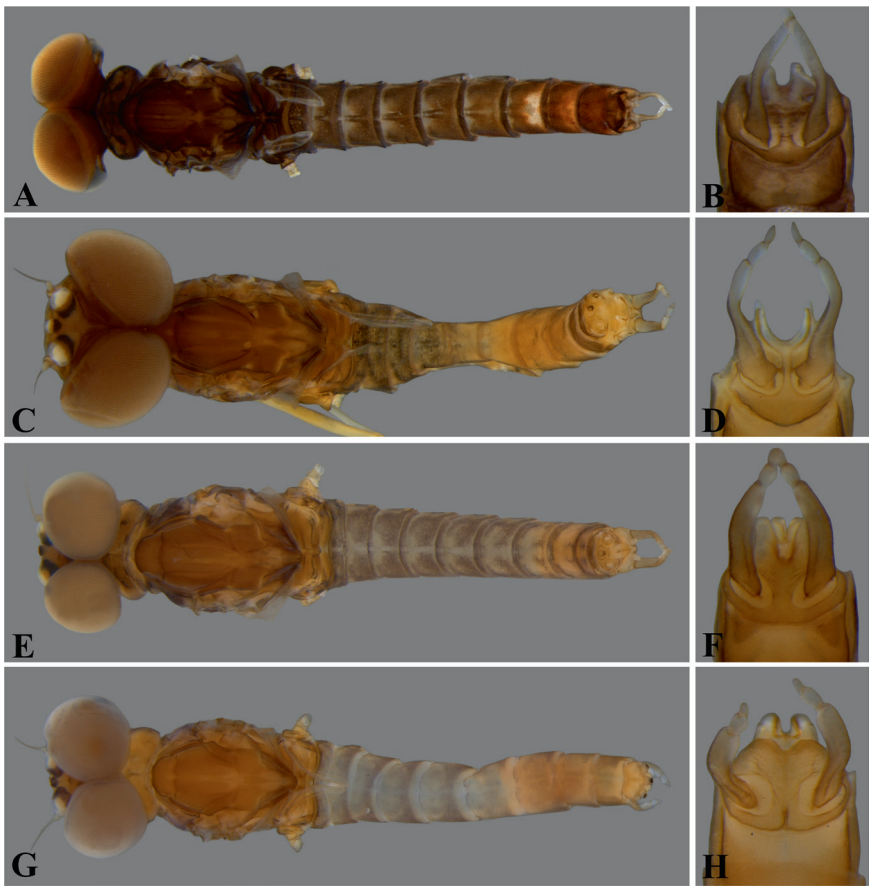

Figure 2. Male imagos of some Leptophlebiidae (Ephemeroptera) found in Piauí state, Brazil. A, Dorsal habitus of *Farrodes carioca*; B, Genitalia of *Farrodes carioca*; C, Dorsal habitus of *Hydromastodon sallesi*; D, genitalia of *Hydromastodon sallesi*; E, Dorsal habitus of *Hydrosmilodon gilliesae*; F, Genitalia of *Hydrosmilodon gilliesae*; G, Dorsal habitus of *Leentvaaria palpalis*; H, Genitalia of *Leentvaaria palpalis*.

two ♂ imagos, 10.ii.2018, L.R.C. Lima col.; same data as preceding except one ♂ imago (light trap), 15.xii.2018. One ♂ imago (light trap), S14, 18.vi.2022, L.R.C. Lima col. (CEHJ).

Hermanellopsis arsia Savage & Peters, 1983

Figure 3G–H

Previous distribution. Amazonas (Savage & Peters 1983), Roraima (Raimundi et al. 2017), Maranhão (Nascimento et al. 2020) and Pará (Oliveira et al. 2023). **New record for genus and specie for Piauí state**.

Material examined. 12 nymphs (D-shaped net), S16, 15.viii.2022, L.R.C. Lima col. (09 – CEHJ, 03 – INPA).

Hydromastodon sallesi Polegatto & Batista, 2007

Figure 2C–D

Previous distribution. Roraima (Polegatto & Batista 2007), Rondônia (Salles et al. 2016), Tocantins (Orlando et al. 2021), Maranhão (Nascimento et al. 2020), Mato Grosso (Polegatto & Batista 2007) and Mato Grosso do Sul (Silva & Salles 2017). **New record for genus and specie for Piauí state**.

Material examined. Four ♂ imagos (light trap), S8, 14.x.2017, L.R.C. Lima and J.A.O. Rodrigues cols. (CEHJ); same data as preceding except one ♂ imago, 10.ii.2018, L.R.C. Lima col. One ♂ imago (sweep net), S18, 11.iv.2023, L.R.C. Lima col. (CEHJ).

Hydrosmilodon gilliesae Thomas & Perú, 2004

Figure 2E–F

Previous distribution. Pará (Oliveira et al. 2023), Roraima (Salles et al. 2016), Tocantins (Orlando et al. 2021), Bahia (Lima et al. 2012a), Maranhão (Nascimento et al. 2020), Pernambuco (Lima et al. 2012b), Mato Grosso (Shimano et al. 2011), Espírito Santo (Salles et al. 2010) and São Paulo (Salles et al. 2016). **New record for genus and specie for Piauí state**.

Material examined. Four ♂ imagos (light trap), S1, 22.ii.2018, L.R.C. Lima col. (INPA). One nymph (D-shaped net), S2, 18.iv.2017, L.R.C. Lima and J.A.O. Rodrigues cols. (CEHJ, 03). 18 ♂ imagos (light trap), S8, 01.vi.2019, L.R.C. Lima col. (CEHJ); same data as preceding except one ♂ imago (rearing), 15.xii.2018; same data as preceding except 36 nymphs (D-shaped net), 05.ix.2022. One ♂ imago (light trap), S9, 29.iii.2018, L.R.C. Lima col. (CEHJ). One nymph (D-shaped net), S12, 27.ii.2021, L.R.C. Lima col. (CEHJ). One nymph (D-shaped net), S14, 06.ix.2022, L.R.C. Lima col. (CEHJ). 13 ♂ imagos (light trap), S19, 09.vi.2023, L.R.C. Lima, A.S. Carvalho, A.P.J. Faria cols. (CEHJ). One ♂ imago (light trap), S20, 08.vi.2023, L.R.C. Lima, A.S. Carvalho, A.P.J. Faria cols. (CEHJ).

Leentvaaria palpalis Demoulin, 1966

Figure 2G–H

Previous distribution. Roraima (Salles et al. 2016), Pernambuco (Lima et al. 2012b), Maranhão (Nascimento et al. 2020), Mato Grosso (Salles et al. 2016) and Espírito Santo (Lima et al. 2012a). **New record for genus and specie for Piauí state**.

Material examined. 10 ♂ imagos (light trap), S7, 22.ii.2018, L.R.C. Lima col. (CEHJ); same data as preceding except five nymphs (D-shaped net), 21.v.2022. 10 ♂ imagos (light trap), S8, 10.ii.2018, L.R.C. Lima col. (CEHJ); same data as preceding except one nymph (D-shaped net), 14.x.2017, L.R.C. Lima and J.A.O. Rodrigues cols. 32 ♂ imagos (light trap), S19, 09.vi.2023, L.R.C. Lima, A.S. Carvalho, A.P.J. Faria cols. (CEHJ).

Miroculis botafora Rodrigues, Nascimento, Raimundi & Lima, 2023

Previous distribution. Piauí (Rodrigues et al. 2023).

Miroculis fittkaui Savage & Peters, 1983

Previous distribution. Pará (Savage & Peters 1983), Roraima (Gama-Neto et al. 2018), Bahia (Campos et al. 2016), Piauí (Rodrigues et al. 2023), Pernambuco (Lima et al. 2012b) and Espírito Santo (Salles et al. 2010).

Paramaka convexa (Spieth, 1943)

Figure 3A–B

Previous distribution. Pará (Savage & Domínguez 1992), Roraima (Raimundi et al. 2017), Maranhão (Nascimento et al. 2020), Bahia (Mariano 2011) and Mato Grosso (Shimano et al. 2011). **New record for genus and specie for Piauí state**.

Material examined. One nymph (D-shaped net), S2, 18.iv.2017, L.R.C. Lima and J.A.O. Rodrigues cols. (CEHJ). One ♂ imago (light trap), S5, 12.iii.2016, L.R.C. Lima col. (CEHJ). Five ♂ imagos (light trap), S6, 04.iii.2017, L.R.C. Lima and J.A.O. Rodrigues cols. (3 – CEHJ, 2 – INPA). 13 ♂ imagos (light trap), S19, 09.vi.2023, L.R.C. Lima, A.S. Carvalho, A.P.J. Faria cols. (CEHJ).

Paramaka pearljam Mariano, 2011

Figure 3C–D

Previous distribution. Mato Grosso (Mariano 2011). **New record for Piauí state**.

Material examined. 20 ♂ imagos (light trap), S19, 09.vi.2023, L.R.C. Lima, A.S. Carvalho, A.P.J. Faria cols. (CEHJ).

Simothraulopsis demerara (Traver, 1947)

Previous distribution. Pará (Domínguez et al. 1997), Amazonas (Domínguez et al. 1997), Roraima (Nascimento et al. 2017), Amapá (Nascimento et al. 2017), Rondônia (Nascimento et al. 2017), Tocantins (Boldrini & Krolow 2017), Ceará (Nascimento et al. 2017), Piauí (Takiya et al. 2016), Bahia (Lima et al. 2016), Pernambuco (Lima et al. 2012b), Maranhão (Nascimento et al. 2020), Mato Grosso (Nascimento et al. 2017), Goiás (Raimundi 2019), Espírito Santo (Salles et al. 2010) and Paraná (Faria & Salles 2019).

Material examined. Four ♂ imagos (light trap), S2, 18.iv.2017, L.R.C. Lima and J.A.O. Rodrigues cols. (CEHJ). 15 ♂ imagos (light trap), S7, 17.iv.2017, L.R.C. Lima and J.A.O. Rodrigues cols. (CEHJ). Nine ♂ imagos (light trap), S8, 14.x.2017, L.R.C. Lima and J.A.O. Rodrigues cols. (CEHJ); same data as preceding except five ♂ imagos, 10.ii.2018, L.R.C. Lima col.; same data as preceding except one ♂ imago (rearing), 15.xii.2018; same data as preceding except three ♂ imagos, 15.xii.2018; same data as preceding except four ♂ imagos, 01.vi.2019. 15 ♂ imagos (light trap), S11, 29.vi.2019, L.R.C. Lima col. (CEHJ). Seven ♂ imagos (light trap), S14, 18.vi.2022, L.R.C. Lima col. (CEHJ). One ♂ imago (rearing), S17, 16.viii.2022, L.R.C. Lima col. (CEHJ). Seven ♂ imagos (light trap), S19, 09.vi.2023, L.R.C. Lima, A.S. Carvalho, A.P.J. Faria cols. (CEHJ). 38 ♂ imagos (light trap), S20, 08.vi.2023, L.R.C. Lima, A.S. Carvalho, A.P.J. Faria cols. (CEHJ).

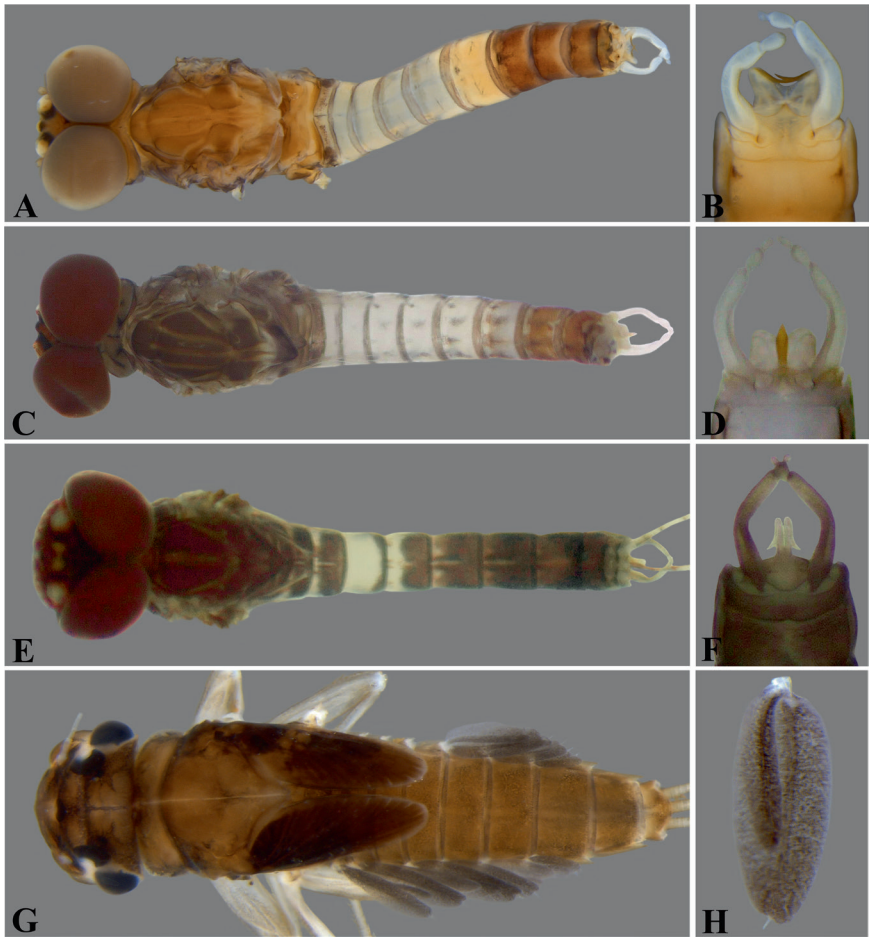

Figure 3. Male imagos and nymph of some Leptophlebiidae (Ephemeroptera) found in Piauí state, Brazil. A–F) Male imagos: A, dorsal habitus of *Paramaka convexa*; B, genitalia of *Paramaka convexa*; C, dorsal habitus of *Paramaka pearljam*; D, genitalia of *Paramaka pearljam*; E, dorsal habitus of *Simothraulopsis janae*; F, genitalia of *Simothraulopsis janae.* G–H) Nymph of *Hermanellopsis arsia*: G, dorsal habitus of *Hermanellopsis arsia*; H, gill IV of *Hermanellopsis arsia*.

Simothraulopsis janae Mariano, 2010

Figure 3E–F

Previous distribution. Bahia (Mariano 2010), Mato Grosso (Nascimento et al. 2017), Maranhão (Nascimento et al. 2020), Minas Gerais (Nascimento et al. 2017), Pará (Nascimento et al. 2017), Pernambuco (Lima et al. 2012b), Rondônia (Nascimento et al. 2017), and Roraima (Gama-Neto & Hamada 2014). **New record for Piauí state.**

Material examined. Two ♂ imagos (light trap), S19, 09.vi.2023, L.R.C. Lima, A.S. Carvalho, A.P.J. Faria cols. (CEHJ).

Simothraulopsis sinuosus Lima, 2018

Previous distribution. Maranhão (Nascimento et al. 2020) and Piauí (Lima 2018).

Material examined. Two ♂ imagos (light trap), S7, 18.iv.2017, L.R.C. Lima and J.A.O. Rodrigues cols. (CEHJ); same data as preceding except one ♂ imago, 07.ix.2018, L.R.C. Lima col.

Thraulodes sternimaculatus Lima, Mariano & Pinheiro, 2013

Previous distribution. Maranhão (Nascimento et al. 2020), Piauí (Boldrini et al. 2018) and Pernambuco (Lima et al. 2013).

Material examined. One ♂ imago (light trap), S7, 17.iv.2017, L.R.C. Lima and J.A.O. Rodrigues cols. (CEHJ). 11 ♂ imagos (light trap), S8, 10.ii.2018, L.R.C. Lima col. (CEHJ). 56 ♂ imagos (light trap), S19, 09.viii.2023, L.R.C. Lima, A.S. Carvalho, A.P.J. Faria cols. (CEHJ).

Ulmeritoides flavopedes (Spieth, 1943)

Previous distribution. Roraima (Lopes et al. 2003), Tocantins (Boldrini & Krolow 2017), Bahia (Lima et al. 2016), Maranhão (Nascimento et al. 2020), Piauí (Takiya et al. 2016), Pernambuco (Lima et al. 2015) and Mato Grosso (Shimano et al. 2011).

Material examined. Two ♂ imagos (rearing), S8, 15.xii.2018, L.R.C. Lima col. (CEHJ). One ♂ imago (rearing), S16, 15.vii.2022, L.R.C. Lima col. (CEHJ).

Discussion

Our study provides new information about the distribution of Leptophlebiidae species in the state of Piauí, northeastern Brazil. This represents an increase from nine to 17 species with valid occurrences in the state, and five genera reported for the first time. Although the species recorded in this study are also found in other Brazilian states and in other South American countries, this study provides a significant

contribution to the knowledge of Ephemeroptera in the Northeast region of Brazil, particularly in semi-arid environments.

Leptophlebiidae inventories have been conducted in only a few areas of the Cerrado biome. The state of Piauí follows a similar pattern, with studies concentrated in the northern part of the state, specifically in the lower and middle sub-basins of the Parnaíba river (Figure 1A). This concentration is primarily due to the location of our research group, which faces resource constraints in conducting field expeditions to more distant regions. Despite notable efforts between the first record of Leptophlebiidae species distribution in Piauí (Takiya et al. 2016) and the findings presented in this study, there is still a vast unknown area in Piauí, particularly in the middle and upper sub-basins of the Parnaíba River. This knowledge gap limits our ability to understand the effects of multiple human-caused stressors on biodiversity or to utilize this information to create local conservation strategies (e.g., Baranzelli et al. 2023). This becomes even more relevant considering that to the west of the upper and middle sub-basins of the Parnaíba river lies the region known as MATOPIBA. This name refers to the area encompassing the states of Maranhão (MA), Tocantins (TO), Piauí (PI), and Bahia (BA), which is considered suitable for monoculture expansion in Brazil (Miranda et al. 2014, Polizel et al. 2021). Consequently, the transformation of this area can incur significant environmental costs, including fragmentation, water pollution, and loss of Ephemeroptera specimens unknown to science.

The new records and additional occurrence points presented in this study significantly contribute to our knowledge of Leptophlebiidae species distribution in Brazil, reducing the Wallacean shortfall of the Ephemeroptera in the Cerrado biome. We highlight that there is still a vast area in the Cerrado and Brazilian semiarid regions where the occurrence of Ephemeroptera is unknown, confirming that the diversity in this area is underestimated and that knowledge of Ephemeroptera species and their distributions can expand with increased sampling efforts in the coming years. This effort has the potential to reduce the Linnean and Wallacean shortfall about the Leptophlebiidae species. Our results also highlight the urgency of inventory efforts in the southern region of the state of Piauí, particularly in the middle and upper sub-basins of the Parnaíba river, as they are heavily influenced by MATOPIBA.

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Author Contributions

Ana Paula Justino de Faria: contributed to conceptualization; data collection; methodology and original draft.

Jackson A. O. Rodrigues: collected and identified the species; contributed to conceptualization of the manuscript.

Stênio Raniery de Sousa Nascimento: produced the photographs; reviewed and edited the manuscript.

Lucas Ramos Costa Lima: collected and identified the species; contributed to conceptualization, reviewed and edited the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Ethics

This study did not involve human beings and/or clinical trials that should be approved by one Institutional Committee.

Data availability

The data used in our analysis is available at Biota Neotropica Dataverse https://doi.org/10.48331/scielodata.JTYTUS

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