First report of the genera *Baetodes* and *Callibaetoides* in French Guiana, and notes on the habitat (Ephemeroptera, Baetidae)

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Abstract. – Nymphs of two genera belonging to the family Baetidae, *Baetodes* Needham & Murphy, 1924, and *Callibaetoides* Cruz, Salles & Hamada, 2013, were collected during hydrobiological surveys conducted in the La Trinité and Les Nouragues national reserves of French Guiana. These taxa are reported here for the first time in this French overseas department, and habitat information is provided. Both genera have been classified in the most pollutant-sensitive category (5) of the French Guiana biotic index SMEG. With these additions, the list of Ephemeroptera genera recorded in French Guiana now includes 43 genera, of which 38 are formally named. Twenty-four years after the first studies on the group, an updated inventory is required.

Résumé. – **Premier signalement des genres *Baetodes* et *Callibaetodes* en Guyane, et notes sur leurs habitats (Ephemeroptera, Baetidae)**. Les larves de deux genres appartenant à la famille des Baetidae, *Baetodes* Needham & Murphy, 1924, et *Callibaetoides* Cruz, Salles & Hamada, 2013, ont été récoltées en Guyane au cours d'études hydrobiologiques menées sur les réserves naturelles nationales de La Trinité et des Nouragues. Il s'agit du premier signalement pour le territoire. Des informations sur l'habitat sont fournies. Ces deux genres sont intégrés à l'indice biotique SMEG sous la catégorie 5, la plus polluo-sensible. La Guyane abrite désormais 43 genres d'éphéméroptères, dont 38 nommés. Vingt-quatre ans après les premières recherches, un inventaire actualisé est requis.

Keywords. – Guiana Shield, small mountain streams, nymphs, morphology, substrate.

French Guiana, part of the Guiana shield—a vast Precambrian geological formation spanning over 1,600 km—is located in the northeastern region of South America. It shares borders with Brazil to the east and south, and Suriname to the west. This French overseas department of approximately 84,000 km^2, 90% of which is covered by tropical rainforest (Hammond, 2005), is renowned for its outstanding biodiversity. Despite this, the region remains under-surveyed, with aquatic inventories particularly incomplete. Advancing taxonomic and ecological knowledge of benthic macroinvertebrates is crucial for developing effective bioassessment tools and guiding water management decisions focused on preserving and restoring water quality. This is especially important in Latin America, a region recognized for its extraordinary biodiversity and high levels of endemism (Clavier *et al.*, 2022; Cortelezzi & Paz, 2023).

With approximately 1,110 species and 113 genera worldwide, Baetidae is a diverse and cosmopolitan family of Ephemeroptera; the Neotropical Region hosts about 32

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genera and 260 species (Salles *et al.*, 2018; Cruz *et al.*, 2021, 2023). In French Guiana, Baetidae received significant attention during the early 2000s, leading to the description or redescription of eight species and one genus (Dominique *et al.*, 2000, 2005; Dominique & Thomas, 2002; Thomas *et al.*, 2003a, 2003b, 2005a; Thomas & Péru, 2003; Thomas & Dominique, 2006). A generic inventory was drawn up and the family was integrated into a biotic index based exclusively on the Ephemeroptera order: the SMEG ("Score Moyen des Ephéméroptères de Guyane") (Orth *et al.*, 2000; Dominique *et al.*, 2001; Thomas, 2001).

Baetodes Needham & Murphy, 1924, is one of the most speciose genera of Baetidae of the Neotropical Region. Fourty-six species are known from Arizona and Texas to Argentina, mostly described on nymphal stage (Salinas *et al.*, 2011; Nieto, 2016; Cruz *et al.*, 2023). Unlike most Baetidae, *Baetodes* nymphs lack the streamlined body and the caudal filaments with well-developed swimming setae (Salles *et al.*, 2018). Instead, they are mainly characterized by the presence of gills on abdominal segments 1-5 and a strong subapical seta on tarsal claws. Some species also possess coxal gills (Nieto, 2004). Despite recent advancements in the taxonomy of the genus (Nieto, 2016; Cruz *et al.*, 2023), *Baetodes* has so far been reported only from the Venezuelan Guayana's Uplands in the Guiana Shield (Nieto e*t al.*, 2011), with no records from the central region comprising Guyana, Suriname and French Guiana.

Unlike *Baetodes*, *Callibaetoides* Cruz, Salles & Hamada, 2013, is one of the less-studied genera of South American Baetidae. The genus is monotypic, represented solely by *Callibaetoides caaigua* Cruz, Salles & Hamada, 2013, which is only known from the Brazilian Amazonia and the Mata Atlantica forests. Since its discovery in 2013, no additional records have been reported. *Callibaetoides* share numerous characters with *Callibaetis* Eaton, 1881 (Cruz *et al.*, 2013, 2017), but nymphs of *Callibaetoides* differ notably by the shape of the third segment of labial palps, which is subquadrangular rather than concave (Cruz *et al.*, 2013).

Here, we report for the first time the presence of these two genera, *Baetodes* and *Callibaetoides*, in the protected natural areas of French Guiana.

Materials and methods

Specimens were collected during surveys and inventories of aquatic macro-invertebrates of two national reserves in French Guiana: La Trinité and Les Nouragues (fig. 1). At La Trinité, two surveys were conducted: the Kokioko River in November 2020 (dry season) and an unnamed stream located in the "Mont Tabulaire" mountain in September 2022 (dry season). At Les Nouragues, an unnamed stream, a little tributary of the Crique Mazin River, was sampled in May 2023 (rainy season) in the ORION sector to assess the impact of illegal gold mining which has ceased one year and eight months before the sampling. These surveys were carried out by the environmental studies office ONIKHA.

Sampling was conducted using a Surber net/sampler (500 µm mesh size). The substratum was disturbed to a depth of several centimeters to dislodge any macro-invertebrates attached to or buried in the organic or mineral substrates.

Water quality measurements were taken with a WTW™ ProfiLine™ pH, 3110 meter, WTW™ ProfiLine™ Cond 3110 conductivity meter, VWR DO220 dissolved oxygen meter, and ThermoScientific™ Eutech TN-100 Turbidimeter.

Specimens were stored in a 96% ethanol solution and identified in the lab using Salles *et al.* (2018). Images were made at the UMR EcoFoG (Campus Agronomique

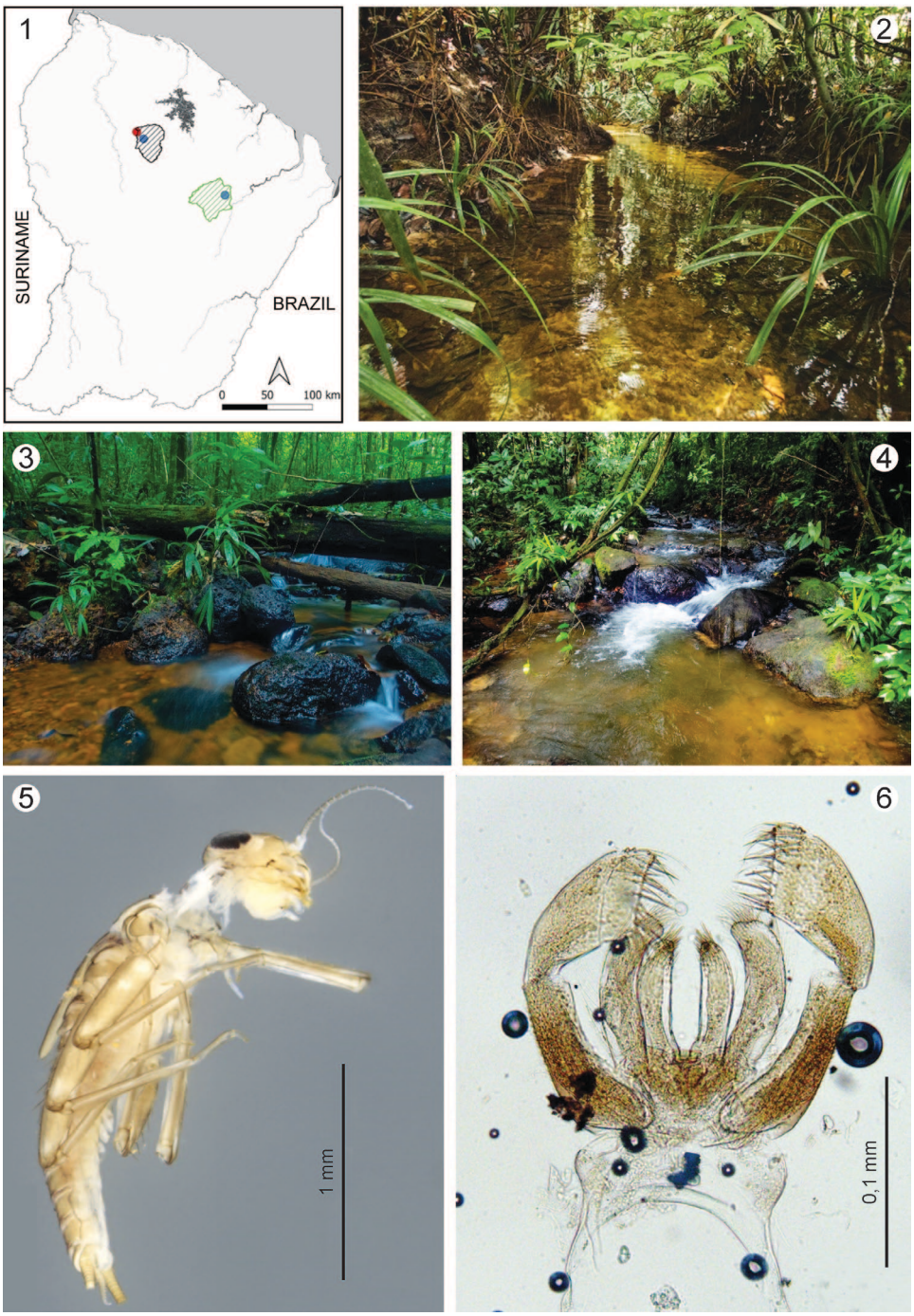

Fig. 1-6. – Distribution, and habitat of nymphs of *Baetodes* sp. and *Callibaetoides* sp. in French Guiana. – **1**, Distribution in French Guiana (red spot: *Callibaetoides*; blue spot: *Baetodes*; black hashed area: La Trinité National Reserve; green hashed area: Les Nouragues National Reserve). – **2**, Stream habitat of *Callibaetoides* sp.: Kokioko River in La Trinité National Reserve. –**3-4**, Stream habitats of *Baetodes* sp.: unnamed streams in La Trinité National Reserve (**3**) and in Les Nouragues National Reserve (**4**). – **5**, Habitus of *Baetodes* sp.: lateral view. – **6**, Labium of *Callibaetoides* sp.

de Kourou – French Guiana) with a Leica Z16APO stereo microscope and a Leica camera DC450 fitted with the Leica Application Suite V4.10 and the Helicon focus V8.0 software. The mouthparts of nymphs were photographed with a microscope Olympus BX51 and a Kern camera ODC82.

Specimens are stored in the ONIKHA collection (Kourou, French Guiana).

RESULTS

Order **Ephemeroptera** Hyatt & Arms, 1891

Family **Baetidae** Leach, 1815

Genus ***Baetodes*** Needham & Murphy, 1924 (fig. 5)

Material examined. – **French Guiana**. 1 nymph (damaged), La Trinité National Reserve – Mont Tabulaire – Upstream section of an unnamed stream near Drop Zone, 5.IX.2022, 306 m, 4°36'39.6"N 53°21'28.2"W, S. Clavier, ONIKHA collection: TRI22-SUD-A76, collected with a surber net/sampler in boulders with high current (25–75 cm/s) at about 10 cm depth; 2 nymphs (damaged), Les Nouragues National Reserve – ORION Sector – Upstream section of a tributary of the Crique Mazin River – Station 3, 24.V.2023, 250 m, 4°06'15.1"N 52°37'21.7"W, P. Le Page, ONIKHA collection: ORION23-C-A42, collected with a surber net/sampler; one in roots with high current (25–75 cm/s) at about 8 cm depth; one in leaf packs with very high current (> 75 cm/s) at about 5 cm depth.

Genus ***Callibaetoides*** Cruz, Salles & Hamada, 2013 (fig. 6)

Material examined. – **French Guiana**. 2 nymphs (very damaged), La Trinité National Reserve – Upstream section of Crique Kokioko, 15.XI.2021, 184 m, 4°28'37.5"N 53°13'03.8"W, S. Clavier, ONIKHA Collection: TRI22-01-28 and TRI22-08-10, collected with a surber net/sampler in leaf packs with no current (< 5 cm/s) at about 20 cm depth.

HABITAT DESCRIPTION

Specimens of the two genera were collected in the upstream sections of little altitudinal streams, in the central part of French Guiana (fig. 2-4).

Baetodes sp. was found in two National Reserves: La Trinité and Les Nouragues. In La Trinité, one nymph was collected in an unmanned small-sized stream (mean width 1.5 m, mean depth 30 cm) (fig. 3) located in the "Mont Tabulaire". The drainage area was covered by tropical rainforest and representative of pristine conditions. At 306 m, the stream was gravel-bottomed with boulders and rocks in the channel. Organic substrates were rare mainly represented by leaf packs trapped in logs in the current. Water was transparent with substantial current (25 cm/s) and faster areas (25–75 cm/s). Water temperature was 23.7 °C, pH 6.54, dissolved oxygen 8.19 mg/L (96.8%), conductivity 42.3 µS/cm, and turbidity 1.78 NTU.

In Les Nouragues, two nymphs of *Baetodes* sp. were collected in the upstream section of a little tributary of the Crique Mazin River (Comté-Mahury watershed) (fig. 4) in the ORION sector where illegal gold mining occurred. The drainage area of the stream still shows the stigma of this activity (e.g., deforestation, river diversion, wastes) but they are mainly located downstream from the collecting point. At the station 3, at 250 m elevation, no apparent impact was shown and the stream shares numerous characteristics with the unnamed stream of La Trinité: stream gauge (mean width 2 m, mean depth 30 cm), dominance of mineral substrates, gravel-bottomed with boulders and rocks delineating a succession of small waterfalls. The waters are

clear with substantial (25 cm/s) to high current (25–75 cm/s). Water temperature was 24.5 °C, pH 7.37, dissolved oxygen 8.84 mg/L (100%), and turbidity 8.25 NTU (table I).

Callibaetoides sp. was only found in the upstream section of the Kokioko River in La Trinité National Reserve. The drainage area is covered by tropical rainforest and is representative of pristine conditions.

The upstream section of the Kokioko River is a small-sized stream (mean width 1 m) in the Mana River watershed at an elevation of about 184 m at the collection site. The stream was shallow (mean depth 30 cm), sand-bottomed with numerous macrophytes belonging to the species *Thurnia sphaerocephala* (Rudge) Hook.f., 1883, logs, branches, leaf packs and litter patches on the channel. The banks were covered by tropical rainforest and patches of roots from the riparian vegetation were found in the water.

The water was slightly tannin-stained, and the current slow (5–25 cm/s), with numerous depositional areas with no current. The water temperature was 24.4 °C, pH 5.96, dissolved oxygen 7.89 mg/L (89,5%), conductivity 21.8 µS/cm, and turbidity 1.79 NTU (table I).

Discussion

Ephemeroptera are particularly well-represented in the freshwater ecosystems of French Guiana. This order ranks as second most abundant in lotic habitat, and on stony bottoms, their contribution generally exceeds that of Diptera (Horeau, 1996). Previously, forty-one genera were documented in the region, with 16 belonging to the Baetidae family (Orth *et al.*, 2001; Dominique *et al.*, 2001, 2005; Thomas *et al.*, 2005b; Thomas & Dominique, 2006). With the addition of the current findings, the total now rises to 43 genera, 18 of which belong to the Baetidae. Despite this progress, an updated inventory is essential. Three genera remain unnamed (one Leptohlebiidae and two Oligoneuriidae) and the earlier citation of *Brachycercus* Curtis, 1834, was incorrect. In South America, the Brachycercinae are represented only by *Alloretochus* Sun & McCafferty, 2008, and *Latineosus* Sun & McCafferty, 2008 (Sun & McCafferty, 2008). Furthermore, new reports are anticipated, especially in the Leptohyphidae family -one of the most diverse Ephemeroptera families in the New World family- encompassing some of the smallest representatives of the order (e.g. *Tricorythopsis* Traver, 1958).

Table I. – Water measurements (measurements are missing for conductivity at Orion – Station 3).

	National Reserve La Trinité		National Reserve Les Nouragues
	Kokioko	**Mont Tabulaire**	**ORION - Station 3**
Date	6.XI.2020	5.XI.2022	24.V.2023
Hour	12 h	10 h	11 h
Altitude (m)	184	306	250
pH	5,96	6,54	7,37
Temperature (°C)	24,4	23,7	24,5
Conductivity (µS/cm)	21,8	42,3	
O_2 (mg/l)	7,49	8,19	8,84
O_2 (% Sat.)	89,5	96,8	100
Turbidity (NTU)	1,79	1,78	8,25

Unfortunately, species-level identification was not possible for these specimens, which were transported in vials containing both the sediment and the nymphs. The latter were damaged during the transport to the lab, especially the *Callibaetoides* specimens, and most of the specific characters were lost. While *Callibaetoides* is currently monotypic, the possibility of a new species cannot be excluded in French Guiana. Therefore, we have opted to report only the presence of the genus at this time. To resolve this uncertainty, it would be interesting to return to the collection sites to obtain nymphs in better condition, but also adults by deploying light traps, for example.

Habitat information gathered in this study aligns with the limited data available in the literature. Nymphs of *Baetodes* always live in well-oxygenated streams (Nieto, 2016). Here, they were only found in waters with a dissolved oxygenation comprising around 90% and 100% in areas with high current (25-75 cm/s or more). French Guianese specimens were collected in two types of substrates (*i.e.* leaf packs and roots in Les Nouragues and boulders in La Trinité) and belong to the 'two coxal gills' group.

As in Brazil, in French Guiana, *Callibaetoides* nymphs were collected in stagnant areas of small streams. Unlike most Baetidae, *Callibaetoides* appears to be one of the few genera adapted to inhabit still water of lotic habitats, like *Callibaetis* to which it is closely related (Cruz *et al.*, 2017), although the latter can also colonize lentic environments (e.g., ponds, lakes) (Salles *et al.*, 2018).

Baetodes and *Callibaetoides* can be considered rare in French Guiana. On the one hand, they escaped the research carried out specifically on this group in the early 2000s, and on the other, by our unsuccessful searches for these genera since 2006. Despite intensive sampling in habitats where they typically occurred, very few specimens were collected. In the Kokioko River, 1189 macroinvertebrates were collected during the surveys, including 230 Ephemeroptera, 22 of which belonged to the Baetidae family, and only two nymphs of *Callibaetoides*. In the unnamed stream of La Trinité, 1048 macroinvertebrates were collected, including 136 Ephemeroptera, 12 of which belonged to the Baetidae family, and a single *Baetodes* larva. In the unnamed stream of Les Nouragues, 699 macroinvertebrates were collected, including 128 Ephemeroptera, 17 of which belonged to the Baetidae family, and two nymphs of *Baetodes.* Other Baetidae genera found in association with *Baetodes* were *Americabaetis* Kluge, 1992, *Cloeodes* Traver, 1938, and *Zelusia* Lugo-Ortiz & McCafferty, 1998, at La Trinité, and *Americabaetis, Camelobaetidius* Demoulin, 1966, and *Zelusia* at Les Nouragues. Other Baetidae genera found in association with *Callibaetoides* were *Aturbina* Lugo-Ortiz & McCafferty, 1996, *Waltzoyphius* McCafferty & Lugo-Ortiz, 1995, and *Zelusia.*

Due to its rarity and its presence in pristine streams, the species of *Callibaetoides* present in French Guiana is most likely very sensitive to human pressure.

Baetodes has been found in pristine streams too, but also in an area formerly impacted by illegal gold mining. However, a total of four stations were sampled in this area, and *Baetodes* nymphs were only found at the one with the lowest apparent impact (station 3). Biotic index calculations, including the SMEG and IBMG indices (Dedieu *et al.*, 2016), confirmed the resilience of this station, classifying it in the best category of very good ecological status. We therefore consider this genus to be highly polluosensitive too, and propose to include *Baetodes* and *Callibaetoides* in the SMEG index under the most polluosensitive category 5. Adding new genera to the SMEG index will improve its sensitivity and enable better pressure detection.

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