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Occurrence of *Hyphessobrycon langeanii* Lima & Moreira, 2003 (Characiformes, Characidae) in the upper Paraguay river basin

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Abstract. *Hyphessobrycon langeanii* was originally described as endemic to the upper Araguaia river basin, Brazil. However, our analysis of several *Hyphessobrycon* specimens collected in the Correntes river basin and another tributary of the Itiquira River in Mato Grosso state (both belonging to the Paraguay river basin) reveals the first verified record of *H. langeanii* from this basin and from the states of Mato Grosso do Sul and Mato Grosso. The objective of this study is to provide a novel record of *H. langeanii* from the basin of the Paraguay River and from the state of Mato Grosso do Sul. We compare the newly discovered populations with the populations in the Araguaia river basin, and we also provide a brief discussion on the biogeography of this species.

Keywords. Correntes river basin, headwater capture, piaba, Sonora municipality, upper Araguaia river basin

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Introduction

Hyphessobrycon Durbin, 1908 is a Neotropical genus of small-sized characids currently comprising more than 160 valid species (Fricke et al. 2023), which makes it one of the most diverse genera within the family Characidae and the order Characiformes. This genus is widespread throughout the Neotropical region, occurring from southern Mexico to northern Argentina, with the Amazon basin harboring about half of its species diversity (Ohara and Lima 2015).

Despite the large number of recently described species within the genus (e.g., García-Alzate et al. 2020; Faria et al. 2021; Dagosta et al. 2022), there are several still undescribed taxa. While the non-monophyletic status of the genus has been indicated in several studies of Characidae (e.g., Mirande 2019; Melo et al. 2022), the artificial diagnosis proposed by Eigenmann (1917) is still used when describing new species. Some authors have proposed putative monophyletic species-groups within *Hyphessobrycon*, using both color pattern and anal-fin hook morphology (e.g., Weitzman and Palmer 1997; Ingenito et al. 2013; Ota et al. 2020), but such species-groups still need to be tested in a more encompassing phylogenetic analysis.

Hyphessobrycon langeanii Lima & Moreira, 2003 was described from streams tributaries of the upper Araguaia river basin, with "córrego Mosquito" as the type locality, which is near the border of the states of Mato Grosso and Goiás. This species has been being treated as endemic to this region ever since. However, the recent mention of *Hyphessobrycon* cf. *langeanii* from the upper Paraguay river basin (Carvalho et al. 2022) led us to review material collected in tributaries

of this basin around the headwaters of the upper Araguaia River. Our analysis of recently collected specimens from the headwaters of the Correntes river basin, plus material collected in the 1970s from the Itiquira river basin, has allowed us to confirm with taxonomic certainty the occurrence of *H. langeanii* in the upper Paraguay river basin in both Mato Grosso and Mato Grosso do Sul states.

Methods

The studied specimens of *Hyphessobrycon langeanii* (Fig. 1, Table 1) were collected in tributaries of the Correntes river basin upstream a sinkhole, on the border of Mato Grosso do Sul and Mato Grosso states and in the ribeirão Sozinho, a tributary of the Itiquira River. The material is deposited in the following collections: Coleção Ictiológica de Três Lagoas, Universidade Federal de Mato Grosso do Sul, Câmpus de Três Lagoas (CITL); Museu Nacional, Universidade Federal do Rio de Janeiro (MNRJ), and Museu de Zoologia da Universidade de São Paulo (MZUSP).

Morphometric data were taken with digital calipers with 0.1 mm precision, and all measurements are in millimeters. Measurements and counts followed Fink and Weitzman (1974), with the exception of the scale rows below the lateral line, which were counted to the insertion of the pelvic fin. Horizontal scale rows between the dorsal-fin origin and the lateral line do not include the scale of the median predorsal series situated just anterior to the first dorsal-fin ray.

Results

***Hyphessobrycon langeanii* Lima & Moreira, 2003**
Figure 1

New records. BRAZIL – **Mato Grosso do Sul** • Sonora, unnamed stream tributary to the stream Lajeadão, Correntes river basin; 17°35′13″S, 053°57′57″W; 531 m alt.; 9 and 15.III.2019; L.F.C. Tencatt, M.S. Nunes, V. Carvalho G. & M. Santos leg.; 16 spec., 13.3–34.5 mm SL; CITL 392 • Sonora, stream Lajeadão, Correntes

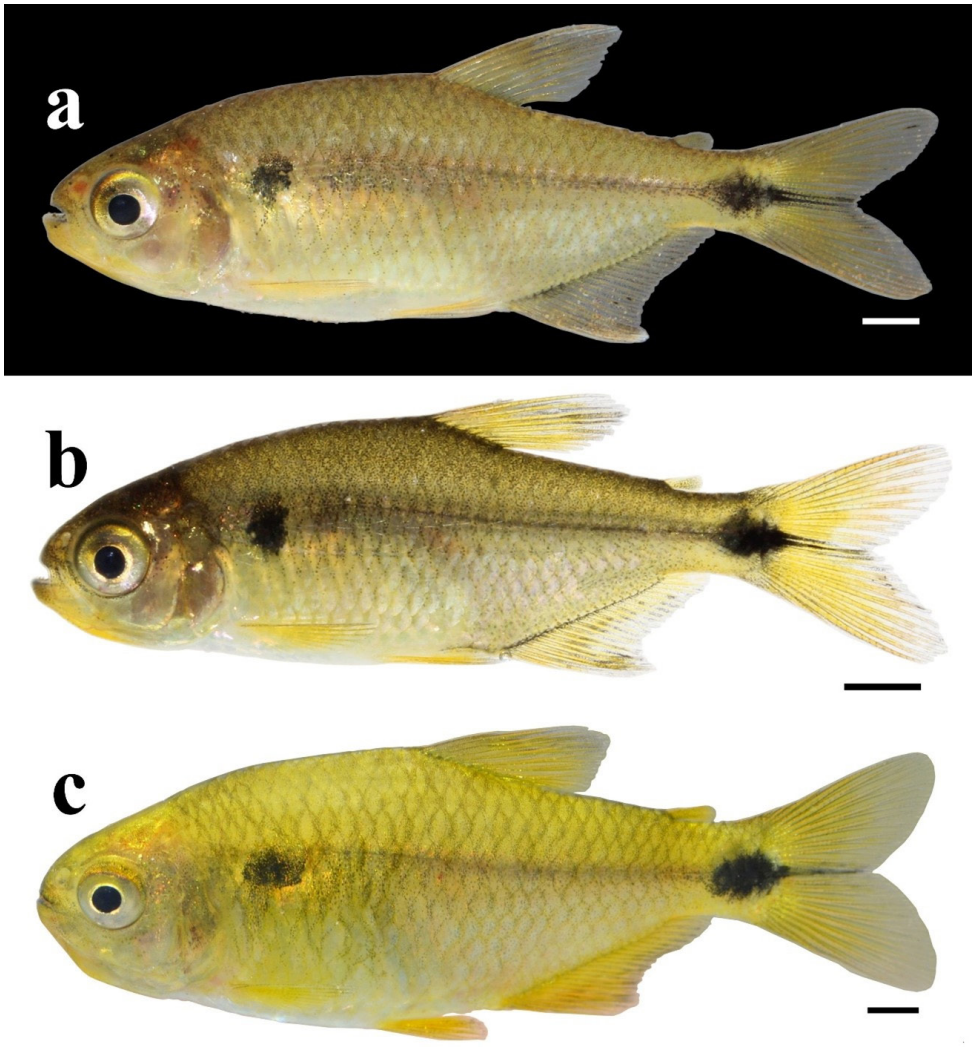

Figure 1. *Hyphessobrycon langeanii* photographed in life. **A, B.** CITL 392, from an unnamed tributary stream of the Lajeadão Stream, upper Paraguay river basin; SL approximately 27 mm and 20 mm, respectively. **C.** Uncataloged specimen, from Gordura Stream, tributary of the upper Araguaia river basin; SL approximately 30 mm. Scale bars = 2 mm. SL = standard length.

Table 1. Morphometric and meristic data of *Hyphessobrycon langeanii* from the Paraguay river basin. SD = standard deviation; *N* = number of specimens.

	N	Range	Mean ± SD
Standard length (mm)	19	26.7–58.5	—
Percentage of standard length			
Depth at dorsal-fin origin	19	34.5–39.8	36.8 ± 1.5
Snout to dorsal-fin origin	19	55.3–58.0	56.6 ± 0.8
Snout to pectoral-fin origin	19	27.0–29.8	28.4 ± 0.8
Snout to pelvic-fin origin	19	48.3–63.3	50.4 ± 3.4
Snout to anal-fin origin	19	64.1–69.2	66.0 ± 1.4
Caudal peduncle depth	19	10.2–12.8	11.2 ± 0.7
Caudal peduncle length	19	9.5–13.4	11.5 ± 1.0
Pectoral-fin length	19	19.3–23.3	21.0 ± 1.0
Pelvic-fin length	19	17.1–19.4	18.1 ± 0.6
Pelvic-fin origin to anal-fin origin	19	16.6–20.1	18.1 ± 1.0
Dorsal-fin base	19	10.8–12.6	11.7 ± 0.5
Dorsal-fin length	19	27.2–29.0	27.9 ± 0.6
Dorsal-fin origin to caudal-fin origin	19	46.9–50.8	49.4 ± 0.9
Anal-fin base	19	25.0–28.6	27.2 ± 1.0
Anal-fin length	19	19.1–22.0	20.4 ± 0.9
Posterior margin of eye to dorsal-fin origin	19	40.2–44.0	42.3 ± 1.1
Percentage of head length			
Head length	19	26.4–29.2	27.8 ± 0.6
Horizontal orbital diameter	19	40.3–48.5	44.1 ± 2.2
Snout length	19	21.1–25.5	23.8 ± 1.1
Least interorbital width	19	29.9–35.3	32.6 ± 1.7
Upper jaw length	19	39.7–45.7	43.5 ± 1.6
Counts			**Mode**
Branched dorsal-fin rays	6	8–9	9
Branched anal-fin rays	7	18–21	18
Branched pectoral-fin rays	7	10–12	11
Branched pelvic-fin rays	7	6–7	7
Principal caudal-fin rays	5	i,8/8,i-i,9/8,i	i,9/8,i
Predorsal scales	7	11	11
Pored lateral line scales	7	8–12	8
Longitudinal line scales	7	32–33	33
Scale rows above lateral line	7	5–6	6
Scale rows below lateral line	7	4–5	5
Circumpeduncular scales	7	13–14	14
Maxillary teeth	7	1	1
Premaxillary teeth: outer row	7	3–4	4
Premaxillary teeth: inner row	7	4–5	4
Dentary teeth	7	4	4

river basin; 17°35′45″S, 053°58′16″W; 528 m alt.; 2 and 8.XI.2018; L.F.C. Tencatt, M.S. Nunes & M. Santos leg.; 3 spec., 24.4–27.0 mm SL; CITL 393 • Sonora, stream de Baixo, Correntes river basin; 4.X.2003; R. Campos-da-Paz leg.; 1 spec., 42mm SL; MNRJ 53295 • Sonora, stream Água Limpa tributary of stream Lajeadão, Correntes river basin; 17°36′31″S 53°52′03”W; 547 m alt.; 29.XII.2020; L.F.C. Tencatt, M.S. Nunes leg.; 3spec., 17.3–22.3 mm SL; CITL 466 – **Mato Grosso** • Itiquira, stream Ponte do Resolvido, Correntes river basin; 17°35′24″S, 054°20′30″W; 477 m alt.; 18.IV.2019; L.F.C. Tencatt, M.S. Nunes & V. Carvalho G. leg.; 1 spec., 25.9 mm SL; CITL 394. • Itiquira, ribeirão Comprido, tributary of Correntes River, Correntes river basin; 17°32′05″S 54°25′36″W; 501 m alt.; 27.I.2021; L. F. C. Tencatt & M. N. Souza leg.; 1 spec., 23.5 mm SL; CITL 467. • Itiquira, ribeirão Sozinho, tributary of Itiquira River; 17°18′05.4″S, 054°45′45.3″W; 14.X.1977; Cepipam leg.; 17 spec., 20.0–26.1 mm SL; MZUSP 67273. (Figs. 2, 4).

Identification. *Hyphessobrycon langeanii* can be distinguished from its congeners, except *H. lucenorum* Ohara & Lima, 2015, by the presence of a single, conspicuous, humeral spot, which is well defined, black, and round to horizontally oval; thin vertical lines extend posterodorsally and anteroventrally from this humeral spot (Lima and Moreira 2003; Fig. 3). In remaining congeners, this humeral blotch is absent, or double, or when single, never well defined and rounded to horizontally oval. *Hyphessobrycon langeanii* can be distinguished from *H. lucenorum* in having a conspicuous, narrow, longitudinal black stripe along the midline of the flank, extending from just posterior to the humeral blotch to the caudal-peduncle blotch (Lima and Moreira 2003), whereas in *H. lucenorum* there is a broad, diffuse, black longitudinal stripe along the midline of flank, extending from just posterior to the humeral blotch to the central caudal-fin rays. Additionally, *H. langeanii* can be distinguished from *H. lucenorum* by having a relatively large, conspicuous, horizontally elongated black blotch on the caudal-fin base (absent in *H. lucenorum*), and maxilla with one tri- or pentacuspid tooth (5–8 conical or tricuspid teeth in *H. lucenorum*).

Discussion

The Araguaia River, the main tributary of the left margin of the Tocantins River, is 2,600 km long and originates in the Brazilian Central Plateau (MMA 2006; ANA 2023). The Araguaia river together with the 2,400 km long Tocantins River form the Tocantins–Araguaia river basin, the largest exclusively Brazilian drainage (MMA 2006; ANA 2023). The river system has been divided into three stretches by Dagosta and de Pinna (2019): lower Tocantins, upper Tocantins, and Araguaia.

Several authors have recognized the high degree of endemism of the Tocantins–Araguaia river basin (e.g., Carvalho et al. 2010; Bertaco and Carvalho 2010; Dagosta and de Pinna 2017, 2019), mainly in the upper Tocantins River stretch (Dagosta and de Pinna 2017, 2019). According to Chamon et al. (2022), there are 751 fish species in the Tocantins–Araguaia basin, and 22% of them are endemic, most belonging to the family Characidae, followed by Rivulidae and Loricariidae, and almost one-quarter of these (51 species) have been

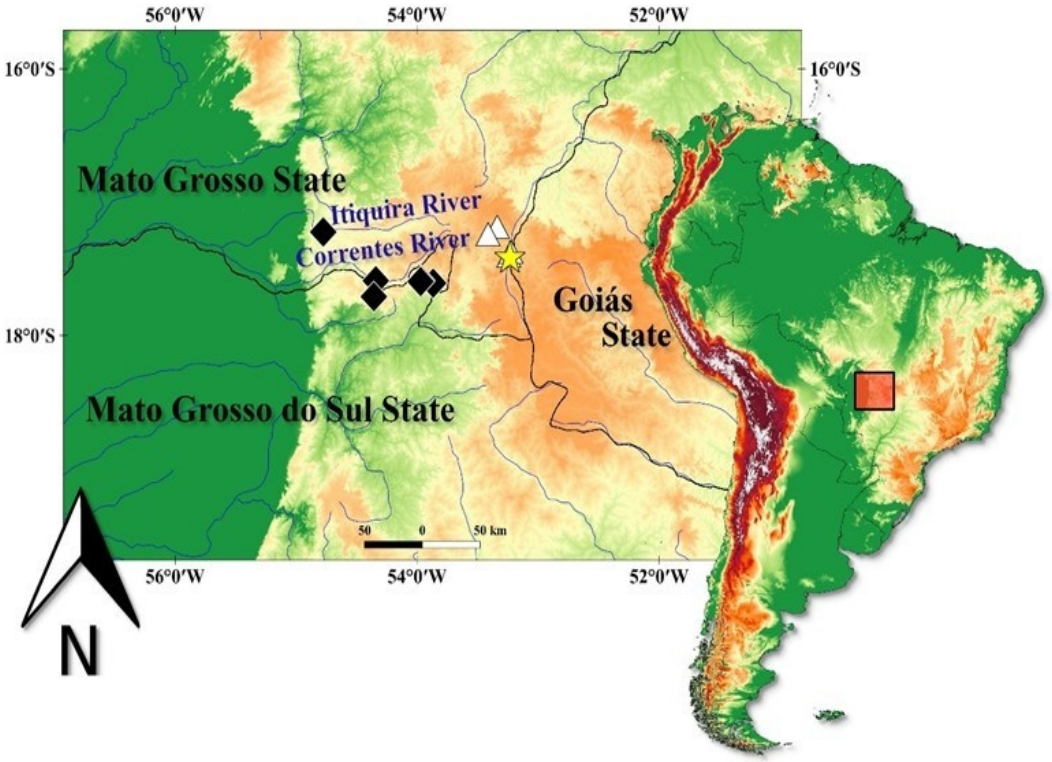

Figure 2. Geographic distribution of *Hyphessobrycon langeanii*. New records (black diamonds). Known occurrence (white triangle) and type locality (yellow star).

Figure 3. Preserved material of *Hyphessobrycon langeanii.* **A.** CITL 392 from a tributary of the Lajeadão Stream, upper Paraguay river basin in Sonora, Mato Grosso do Sul; SL approximately 30 mm. **B.** MZUSP 67273, from the ribeirão Sozinho, tributary of the Itiquira river basin in Itiquira, Mato Grosso; SL 25.3 mm. Black arrow showing the humeral spot. SL = standard length. Scale bars = 2mm.

classified as threatened (ICMBio 2018). Chamon et al. (2022) also pointed out the presence of 69 endemic species in the Araguaia river basin, but this number will certainly increase, as new species are described, such as *Paracanthopoma cangussu* Henschel, Katz & Costa, 2021, which is exclusive to the middle Araguaia river drainage.

Comparing the most recent species lists for the Paraguay river basin (Froehlich et al. 2017; Gimênes Jr and Rech 2022) and Araguaia river basin (Jarduli et al. 2014; Chamon et al. 2022), we note that several species occur in both basins, with some of them also in other watersheds, such as the Paraná and Amazon river basins. However, some shared species present a narrowly endemic distribution, exclusively occurring in the region drained by both upper portions of the Araguaia, Correntes, and Taquari river basins. *Aspidoras aldebaran* Tencatt, Britto, Isbrücker & Pavanelli, 2022 is an example of a species with this distribution pattern. Similar to *A. aldebaran*, our new record of *H. langeanii* from the Correntes river basin reinforces the high endemicity of this region as a whole.

Carvalho et al. (2022) identified populations of *Hyphessobrycon* from the upper Correntes river basin as *Hyphessobrycon* cf. *langeanii*; at that time, they were not sure of the specific identity of the taxon and used "cf." Our study of this material and the comparison of the diagnostic characteristics presented in the original description has allowed us to confirm its identity as *H. langeanii*. In addition to the material examined from the Correntes river basin, we studied specimens of *Hyphessobrycon* sp. from the Itiquira river basin collected in 1977 (MZUSP 67273; Fig. 2b) almost 30 years before the original description, and we can confirm their identity as *H. langeanii*. In the Paraguay river basin, with the exception of the few specimens collected in the ribeirão Sozinho, *H. langeanii* seems to be restricted to the Correntes river basin stretch upstream of its sinkhole (17°36′41″S, 054°50′04″W). This distribution pattern is also found in *Eigenmannia correntes* Campos-da Paz & Queiroz, 2017, *Melanorivulus dapazi* Costa, 2005, *Characidium chicoi* da Graça, Ota & Domingues, 2019, and *Cyphocharax caboclo* Melo, Tencatt & Oliveira, 2022; the upper Correntes River presents a relatively high degree of endemism within the upper Paraguay river basin. Ongoing studies in that region have revealed the presence of about 10 additional putatively undescribed and endemic species for the upper Correntes River (LFCT pers. obs.), which greatly increases the number of endemic species for this region.

Comparison of the morphometric data of the newly discovered population shows that the horizontal diameter of the eyes is larger from the Correntes River than specimens from the upper Araguaia river basin: 24.4–37.5 (mean 32.5) in the type specimens versus 40.3–48.5 (mean 44.1). This difference may represent intraspecific variation. Furthermore, the Correntes River specimens are relatively smaller than those originally described as

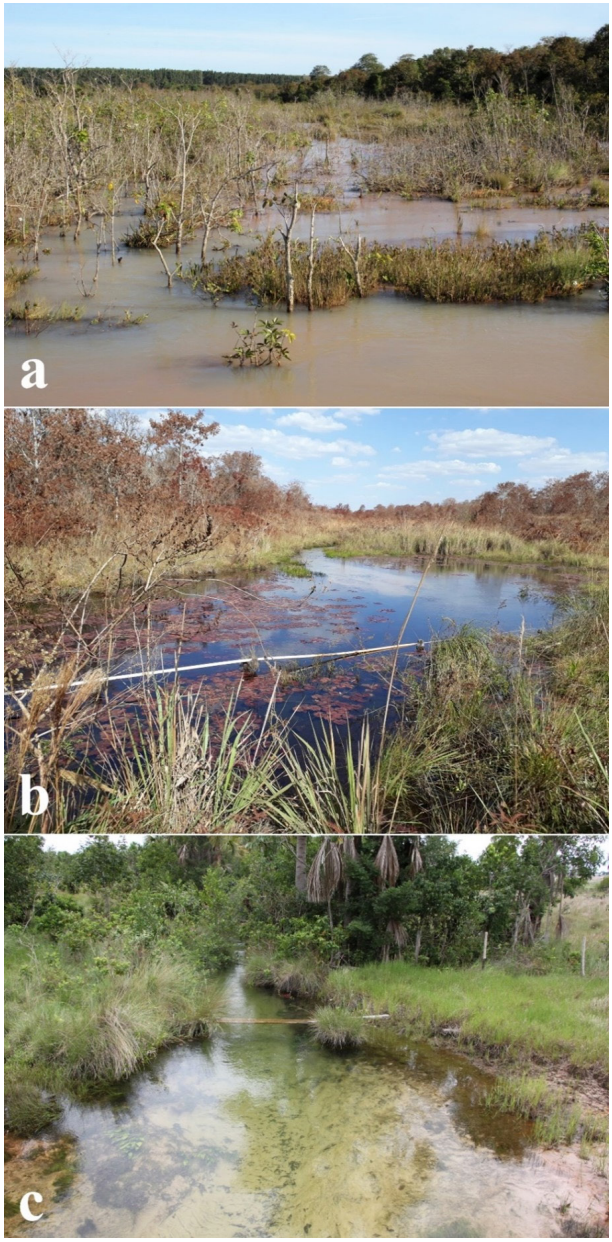

Figure 4. Habitat of *Hyphessobrycon langeanii* in some tributaries of the Correntes River, upper Paraguay river basin. **A.** Unnamed stream tributary of the Lajeadão Stream. **B.** De Baixo Stream. **C.** Another unnamed stream affluent of the Lajeadão Stream.

H. langeanii from the Araguaia River. Another possible explanation is that the orbit diameter typically tends to be smaller in larger individuals when compared to juveniles due to negative allometry. Given that the only conspicuous difference found between the two populations is the orbit diameter, it seems unfounded to consider the Correntes river basin population as not conspecific with the Araguaia river basin population. The specimens examined from the Paraguay river basin present the same variations in color pattern as mentioned by Lima and Moreira (2003: 24), who noted small variations in the humeral spot in specimens preserved in alcohol: "Humeral spot well-defined, black, and round to horizontally oval. Thin vertical lines extend posterodorsally and anteroventrally from humeral spot".

This variation was also observed in living individuals (Fig. 1b).

Melo et al. (2022) proposed a headwater-capture event between the Correntes River and the Araguaia river basin to explain the close relationship between *Cyphocharax caboclo* (endemic to the upper Correntes river basin) and *C. boiadeiro* (endemic to the upper Araguaia river basin). This seems to be the case for *H. langeanni*, but with no speciation after the geographic isolation. Nevertheless, additional molecular studies can test if there are significant genetic differences. Beyond the sharing of species itself, the region drained by the headwaters of both Correntes and Taquari rivers, the upper Paraguay river basin, and the headwaters of the upper Araguaia river basin upstream the vicinity of the city of Barra do Garças, central Brazil, represent one of the smallest Amazonian bioregions; named "Upper Araguaia", it presents a high degree of endemism and species richness (Dagosta et al. 2020; Melo et al. 2022). This bioregion is located within the Cerrado, one of the world's biodiversity hotspots (Myers et al. 2000; Cardoso da Silva and Bates 2002). Contrasting its remarkable biodiversity, the Cerrado has suffered severe anthropogenic effects (Klink and Machado 2005), and there are alarming prospects for the integrity of its watersheds (Salmona et al. 2023). Considering this, there is an urgent need for additional research to better understand this bioregion's ichthyofauna by describing its diversity, assessing the conservation status of species, and proposing management programs—to help mitigate of the expected future threats to the drainages of the Cerrado.

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Author Contributions

Data curation: LT, FC, CM, VG. Formal analysis: LT, VG, FC, CM. Investigation: LT, VG, FC, CM. Methodology: FC, CM, LT, VG. Project administration: VG, LT. Supervision: LT, FC, CM. Validation: FC, CM, LT. Writing – original draft: VG. Writing – review and editing: FC, LT, CM.

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