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# ICHTHYOFAUNA OF STREAMS FROM THE PIRAJU AND TEJUPÁ MUNICIPALITIES, SÃO PAULO STATE, BRAZIL

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**Abstract:** Fish surveys are important in the context of the freshwater biodiversity crisis. Ichthyological surveys provide information before the species become extinct; and, therefore, may propitiate policies for conservation measures. Studies in this scope area needed especially in municipalities such as Piraju and Tejupá, which are located in a populous and impacted region of the São Paulo State, southeastern Brazil. Both municipalities are in the Paranapanema River drainage, which is part of the upper Paraná River system. Here, we provide the results of an ichthyological survey carried out in watercourses of Piraju and Tejupá. We sampled 13 stream reaches using hand nets and cast nets. We captured 284 individuals belonging to 29 fish species belonging to 10 families and five orders. Almost all species are native to the region, with the exception of the poeciliid *Poecilia reticulata*. Our study revealed a high diversity of fish species in the Piraju and Tejupá regions. However, we emphasize the need for additional sampling in the streams of both municipalities, particularly through the use complementary methods (*e.g.* gillnets). If local governments implement initiatives to protect and restore just the streams sampled in this study, about 18 % of the fish species of Paranapanema River drainage will be benefited in some way.

**Keywords:** Inventory; La Plata basin; Paranapanema River; Survey; Upper Paraná River

Conducting and publishing ichthyological surveys have been proven to be essential for our understanding on fish diversity (*e.g.* Guimarães *et al.* 2020; Camargo *et al.* 2021; Brandão *et al.* 2022; Loeb & Ohara 2022; Vieira *et al.* 2023). Therefore, studies in this scope are extremely important in a context of "freshwater biodiversity crisis", *i.e.* the drastic extinction rates and population declines in freshwater species (Harrison *et al.* 2018; Ottoni *et al.* 2023). Fish surveys provide information before the species become extinct; and may propitiate policies for conservation measures. This kind of information is especially important in areas with high human densities and under the pressure of anthropic impacts.

In Brazil, the São Paulo State is the most populated and one of the most impacted by anthropogenic activities (*e.g.* Azevedo-Santos *et al.* 2022) — thus requiring information about its biodiversity to support conservation policies. In fact, the freshwater fishes of the São Paulo State are generally well-known in many watersheds, including the Grande and Paranapanema rivers. This scenario was propitiated especially due to the support provided by the BIOTA project of FAPESP (Castro *et al.* 2003; Castro *et al.* 2004). Additional surveys, developed by undergraduate and graduate students, also provided information on fish diversity in watercourses of the state (*e.g.* Fragoso 2005; Azevedo-Santos *et al.* 2020). But many single localities (*e.g.* streams) remain with no information on its fish biodiversity.

Streams may be defined as small waterbodies presenting less 10 meters of width in the flooding period (Caramashi *et al.* 2021). This kind of environment holds a significant portion of fish diversity, which, generally, are imperiled by human actions (Castro & Polaz 2019). In the São Paulo State, the fish diversity of streams is even more negatively impacted by anthropogenic activities. This is a consequence, especially, of the high rate of urbanization and other habitat uses (*e.g.* irrigation, pollution, small to large dams) (Flynn *et al.* 2011; Azevedo-Santos *et al.* 2022).

Our research group has been conducting fish surveys on a number of streams in different municipalities of São Paulo State. As part of this comprehensive study, here we present the results of this fish survey on the small watercourses of Piraju and Tejupá municipalities.

The territory of Piraju and Tejupá has springs or streams that flow into the drainage of the Paranapanema River. Numerous of these small watercourses flow to the UHE Piraju reservoir, the second largest dam in the Paranapanema River channel (Pelicice *et al.* 2018).

We sampled 13 streams sections/stretches (Table 1; Figure 1) distributed in both municipalities. The waterbodies were selected using satellite images, specifically Google Earth. Our selection was based on the accessibility and size of the watercourses. Altitudes and geographic coordinates for each section were also obtained from Google Earth. We elaborated the map of the sampling sites in the QGIS Version 1.8 (Sherman *et al.* 2012).

Collections were carried out between March and November 2022 with authorization provided by the Instituto Chico Mendes de Conservação da Biodiversidade (Permanent License – Number: 64415). Sampling was carried out with dip nets, which were passed through the vegetation or blocking the stream channel to catch fishes fleeing two researchers moving downstream. We also used a cast net (mesh size of 7 mm) to capture fishes in backwaters. In the field, specimens were anesthetized, using eugenol solution until no movement was detected; and later transferred to formaldehyde (10%). After fixation time (24–48 hours), fishes were immersed in water and then transferred to alcohol 70 ºGL. Part of the voucher material was deposited in the Coleção Ictiológica do Centro de Ciências Agrárias e Ambientais da Universidade Federal do Maranhão, (CICCAA).

In laboratory, fishes were identified to the lowest taxonomic level. Scientific names follow the updated list of Eschmeyer's Catalog of Fishes (Fricke *et al.* 2023).

We captured a total of 284 individuals belonging to 29 fish species (Figures 2–4), distributed in 10 families and five orders (Table 2). Siluriformes had the highest species richness (13 species), followed by Characiformes (10 species). Characidae and Loricariidae, each with seven species, exhibited the highest number of species among the families occurring in the study area (Table 2). The species richness varied among sampling sites, ranging from one to nine species; and abundance varied from five to 63 individuals (Table 2).

The upper Paraná bioregion (*sensu* Dagosta *et al.* 2020), where this study was conducted, comprises an important area of fish endemism. The 29 species recorded herein represents about 13% of the total estimated species richness for the entire Paranapanema River drainage (Jarduli *et al.* 2020). But, when we consider only numbers of native species, our data are more optimistic. Jarduli *et al.* (2020) found that just over 160 native species occur in the Paranapanema River drainage. Therefore, for Piraju and Tejupá municipalities, collectively, we found 18% of the regional native species richness.

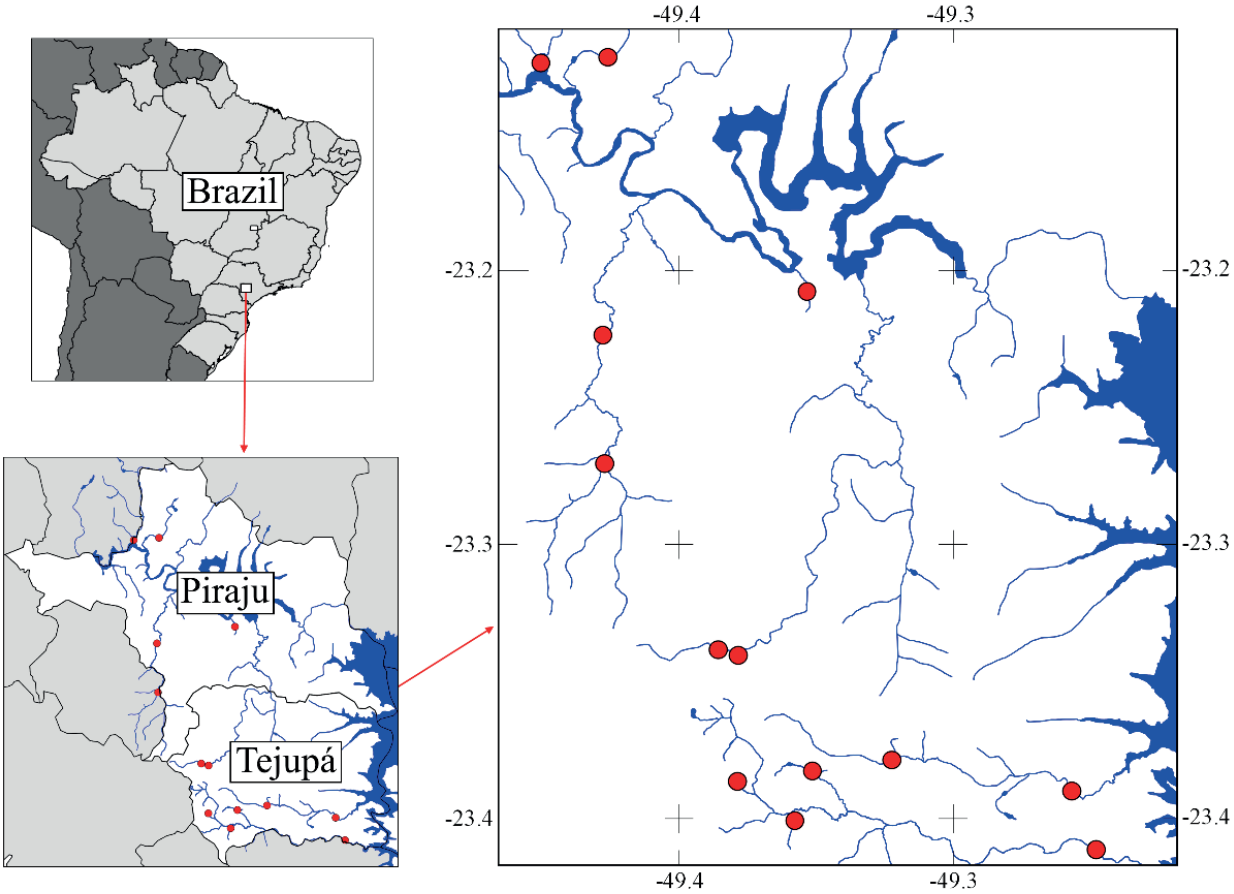


**Figure 1.** Sampling sites in streams of Piraju and Tejupá municipalities, São Paulo State, Brazil.

**Table 1.** Sampled stretches from Piraju and Tejupá municipalities, São Paulo State, Brazil.

| Stretches (S) | Coordinates | Altitude | Microbasin (*sensu* IBGE 2010) | Municipality |
|---|---|---|---|---|
| S1 | 23° 7’29.03”S, 49°27’0.83”W | ~478 m | Cachoeira stream | Piraju |
| S2 | 23°13’24.50”S, 49°25’40.67”W | ~621 m | Neblina stream | Piraju |
| S3 | 23°16’13.50”S, 49°25’37.26”W | ~638 m | Neblina stream | Piraju |
| S4 | 23° 7’21.07”S, 49°25’33.36”W | ~533 m | Água do Padre stream | Piraju |
| S5 | 23°12’27.30”S, 49°21’11.70”W | ~567 m | Nossa Senhora Aparecida stream | Piraju |
| S6 | 23°20’18.48”S, 49°23’7.86”W | ~768 m | Pedra Branca stream | Tejupá |
| S7 | 23°23’10.25”S, 49°22’43.59”W | ~725 m | Bonito stream | Tejupá |
| S8 | 23°24’0.86”S, 49°21’26.59”W | ~648 m | Bonito stream | Tejupá |
| S9 | 23°22’58.52”S, 49°21’3.31”W | ~652 m | Bonito stream | Tejupá |
| S10 | 23°22’43.08”S, 49°19’21.99”W | ~635 m | Jacu stream | Tejupá |
| S11 | 23°23’24.80”S, 49°15’25.00”W | ~586 m | Jacu stream | Tejupá |
| S12 | 23°24’42.57”S, 49°14’52.03”W | ~584 m | Bonito stream | Tejupá |
| S13 | 23°20’25.20”S, 49°22’42.45”W | ~714 m | Pedra Branca stream | Tejupá |

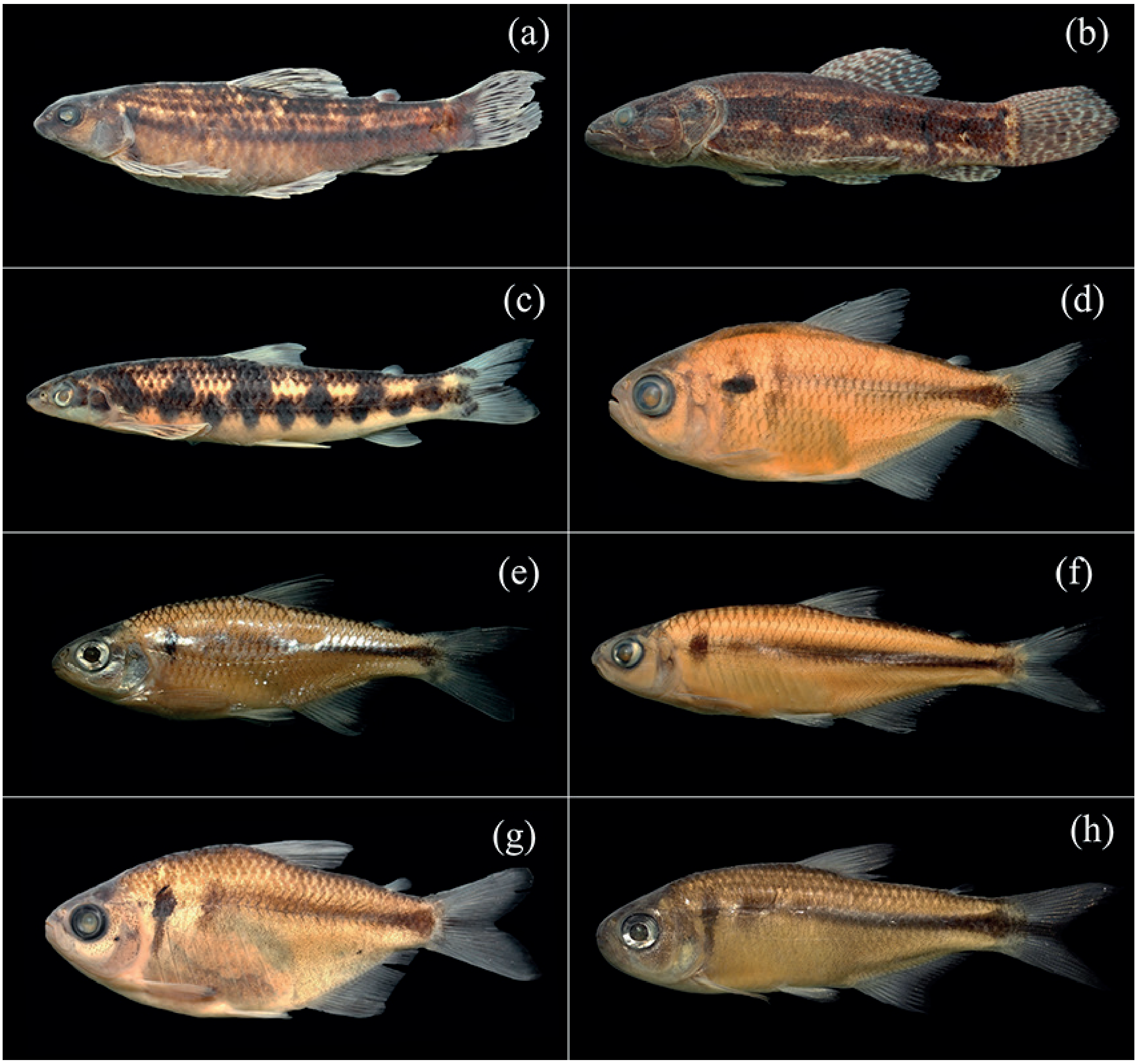


**Figure 2.** Representatives of Characiformes captured in the studied region: (a) *Characidium gomesi*, CICCAA07577, 56.2 mm SL; (b) *Hoplias malabaricus*, CICCAA07559, 131.9 mm SL; (c) *Apareiodon ibitiensis*, CICCAA07556, 73.2 mm SL; (d) *Astyanax lacustris*, CICCAA07561, 47.4 mm SL; (e) *Bryconamericus* cf. *iheringii*, CICCAA07593, 40.5 mm SL; (f) *Piabina* cf. *argentea*, CICCAA07557, 53.5 mm SL; (g) *Psalidodon bockmanni*, CICCAA07578, 45.3 mm SL; (h) *Psalidodon* cf. *paranae*, CICCAA07567, 46.9 mm SL.

Our study provides the greatest number of recorded species in the studied municipalities. For instance, Castro *et al.* (2003) sampled a single stream in the Piraju municipality and recorded nine species. Based on the photographs provided in Castro *et al.* (2003: 15-17), we identified eight species also recorded in our study, including *Astyanax altiparanae*, *Astyanax* sp. 1, *G.* cf. *carapo*, *Hisonotus* sp. 1, *Trichomycterus* sp., which were herein identified as *A. lacustris*, *Psalidodon bockmanni*, *G. pantanal*, *H. depressicauda*, and *Cambeva guareiensis*. Therefore, our study advances previous information provided by Castro *et al.* (2003) about the fish fauna of the Piraju municipality.

With the exception of *Poecilia reticulata* Peters 1859, all other sampled species are native to the Paranapanema River drainage. Of these, some may be undescribed species (*e.g. Cambeva* sp.). In particular, *P. reticulata* — a native fish from the northern region of South America (*sensu* Bragança *et al.* 2020) — was captured at only one site (S9) and in low abundance (three individuals) (see Table 2). This likely small, sampled population turns difficult to state if it is an established species.

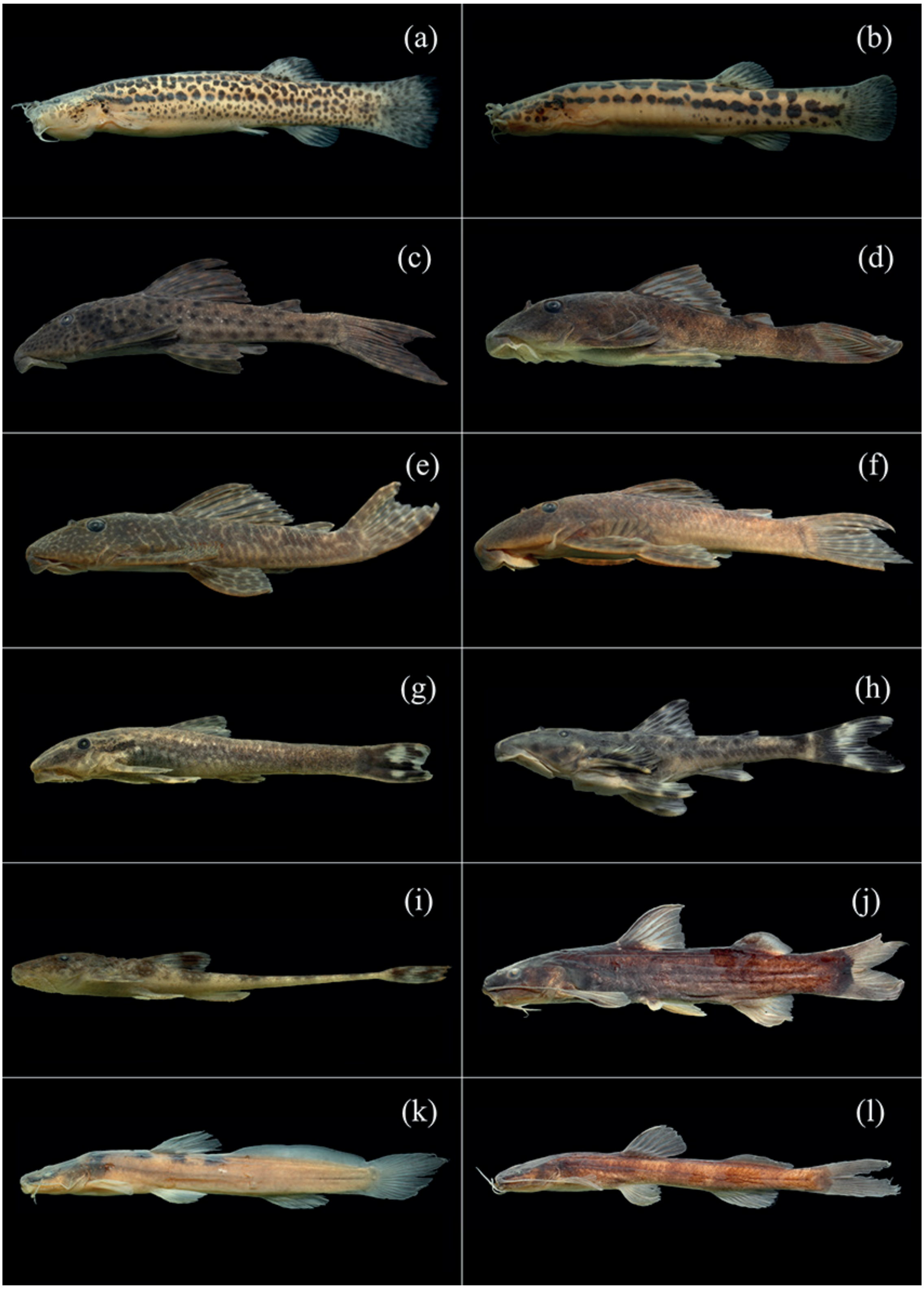


**Figure 3.** Representatives of Siluriformes captured in the studied region: (a) *Cambeva guareiensis*, CICCAA07565, 46.2 mm SL; (b) *Cambeva* sp., CICCAA07575, 49.2 mm SL; (c) *Hypostomus ancistroides*, CICCAA07564, 72.4 mm SL; (d) *Hypostomus iheringii*, CICCAA07576, 42.7 mm SL; (e) *Hypostomus paulinus*, CICCAA07554, 88.9 mm SL; (f) *Hypostomus strigaticeps*, CICCAA07555, 83.1 mm SL; (g) *Hisonotus depressicauda*, CICCAA07570, 33.6 mm SL; (h) *Neoplecostomus selenae*, CICCAA07563, 50.9 mm SL; (i) *Rineloricaria pentamaculata*, CICCAA07569, 41.9 mm SL; (j) *Cetopsorhamdia iheringi*, CICCAA07574, 89.3 mm SL; (k) *Heptapterus longicauda*, CICCAA07573, 58.4 mm SL; (l) *Phenacorhamdia roxoi*, CICCAA07572, 55.4 mm SL.

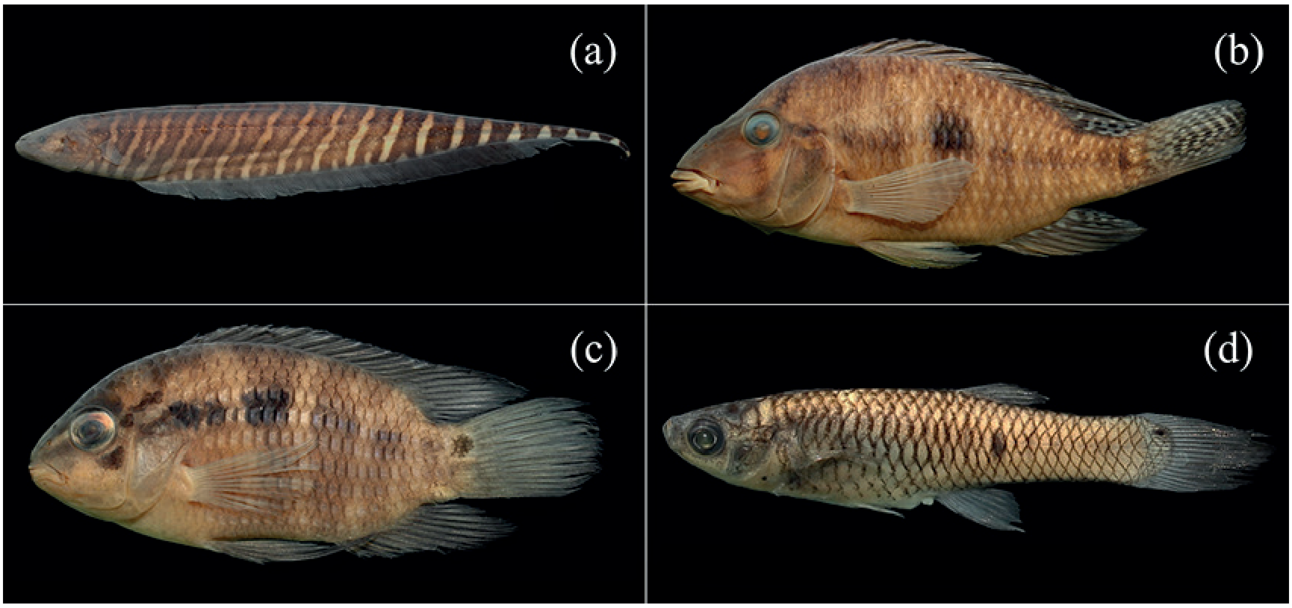


**Figure 4.** Representatives of Gymnotiformes, Cichliformes, and Cyprinodontiformes, captured in the studied region: (a) *Gymnotus* cf. *carapo*, CICCAA07560, 83.2 mm TL; (b) *Geophagus* cf. *brasiliensis*, CICCAA07558, 103.4 mm SL; (c) *Cichlasoma paranaense*, CICCAA07568, 60.6 mm SL; (d) *Phalloceros* cf. *harpagos*, CICCAA07562, 31.1 mm SL.

However, similar to other species (*e.g.* Pelicice & Agostinho 2009; Vitule *et al.* 2019), it may induce negative impacts (*e.g.* competition with other poeciliids) on fish assemblages in some level.

This survey expanded the known distribution of species in the Paranapanema River drainage, including two recently described species. *Cambeva guareiensis* was described by Katz & Costa (2020) based on samples from the Guareí River drainage, in Angatuba, São Paulo State. Later, its known distribution was expanded within the Guareí River drainage (Azevedo-Santos *et al.* 2020) and discovered in a stream of the Itapetininga River basin (Lisboa *et al.* 2020). On the other hand, *Phenacorhamdia roxoi* was described by Silva (2020) based on samples from the upper and middle portions of the Paranapanema River basin (Silva 2020). In a straight line, we expand the distribution of *C. guareiensis* and *P. roxoi* in about 80 and 90 km, respectively.

In this study, we were not able to accurately identify some individuals at species level (Table 2). Therefore, the identification of these individuals needs to be revised for various reasons, such as lack of taxonomic knowledge and information about the genus, small size of the individuals, or by belonging to species complexes (requiring integrative tools for a better taxonomic understanding and making taxonomic decisions, *e.g.* molecular methods). For instance, *Cambeva* sp. has a color pattern very similar to a species from the Paranapanema River drainage that is being described by some of us. It may be the same entity, but only with more refined analysis (*i.e.*, osteology and molecular analysis) we can confirm this. Similarly, *Serrapinnus* sp. has the first dorsal-fin rays darkened, as in *Serrapinnus notomelas* (Eigenmann 1915), but lacks other features that characterize most specimens of the former (*e.g.* fins yellowish), and so, could either represent intra-specific variation of *S. notomelas* or an undescribed species.

The main limitation of our study was the sampling methods restricted to dip nets and cast nets. Some fishes, especially characiforms, display fast movements within pools and other environments, making them difficult to capture using the applied sampling methods. For this reason, it is recommended to apply other sampling methods when surveying stream fish assemblages, such as gill nets, trawl nets, and electrofishing. Furthermore, most sites were sampled only once, and this lack of temporal replicas may undersample the local ichthyofauna given sampling efficiency and spatiotemporal changes in fish assemblages. We recommend, therefore, further sampling in the streams of Piraju and Tejupá municipalities.

Our study provides a baseline to additional studies of the fish fauna of Piraju and Tejupá

**Table 2.** Fish species captured in the region of Piraju and Tejupá, São Paulo, Brazil.

| Taxon | Abundance in each site | | | | | | | | | | | | | Voucher |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 | S12 | S13 | |
| CHARACIFORMES | | | | | | | | | | | | | | |
| **Crenuchidae** | | | | | | | | | | | | | | |
| *Characidium gomesi* Travassos 1956 | - | - | - | - | - | - | - | - | - | - | 3 | - | - | CICCAA07577 |
| **Erythrinidae** | | | | | | | | | | | | | | |
| *Hoplias malabaricus* (Bloch 1794) | - | - | 1 | - | - | - | - | - | - | - | - | - | - | CICCAA07559 |
| **Parodontidae** | | | | | | | | | | | | | | |
| *Apareiodon ibitiensis* Amaral Campos 1944 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | CICCAA07556 |
| **Characidae** | | | | | | | | | | | | | | |
| *Astyanax lacustris* (Lütken 1875) | 1 | - | - | 1 | - | - | - | - | 1 | - | - | 3 | - | CICCAA07561 |
| *Bryconamericus* cf. *iheringii* (Boulenger 1887) | - | - | 1 | - | - | - | - | - | - | 1 | - | - | - | CICCAA07593 |
| *Piabina* cf. *argentea* Reinhardt 1867 | 4 | - | - | - | - | - | - | - | - | - | - | - | - | CICCAA07557 |
| *Psalidodon bockmanni* (Vari & Castro 2007) | 5 | - | 5 | - | - | 2 | - | 14 | - | - | - | - | 4 | CICCAA07578 |
| *Psalidodon fasciatus* (Cuvier 1819) | - | - | - | - | - | - | - | - | - | - | - | 1 | - | Not catalogued |
| *Psalidodon* cf. *paranae* (Eigenmann 1914) | - | - | - | - | - | - | 3 | - | - | - | - | - | - | CICCAA07567 |
| *Serrapinnus* sp. | - | - | - | - | - | - | - | 18 | - | - | - | 2 | - | Not catalogued |
| GYMNOTIFORMES | | | | | | | | | | | | | | |
| **Gymnotidae** | | | | | | | | | | | | | | |
| *Gymnotus* cf. *carapo* Linnaeus 1758 | - | - | 3 | 2 | - | - | - | - | 2 | - | - | - | - | CICCAA07560 |
| *Gymnotus pantanal* Fernandes, Albert, Daniel-Silva, Lopes, Crampton & Almeida-Toledo 2005 | - | - | - | 2 | - | - | - | - | - | - | - | - | - | Not catalogued |
| SILURIFORMES | | | | | | | | | | | | | | |
| **Trichomycteridae** | | | | | | | | | | | | | | |
| *Cambeva guareiensis* Katz & Costa 2020 | - | - | - | - | - | 6 | 2 | - | - | - | - | - | - | CICCAA07565 |
| *Cambeva* sp. | - | - | - | - | - | - | - | - | - | 12 | - | - | - | CICCAA07575 |

**Table 2.** Continues on next page...

**Table 2.** ...continued

| Taxon | Abundance in each site | | | | | | | | | | | | | Voucher |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 | S12 | S13 | |
| **Loricariidae** | | | | | | | | | | | | | | |
| *Hypostomus ancistroides* (Ihering 1911) | - | 8 | 3 | - | - | 7 | - | - | - | - | - | - | 12 | CICCAA07564 |
| *Hypostomus iheringii* (Regan 1908) | - | - | - | - | - | - | - | - | - | - | 2 | - | - | CICCAA07576 |
| *Hypostomus paulinus* (Ihering 1905) | 3 | - | - | - | - | - | - | - | - | - | - | - | - | CICCAA07554 |
| *Hypostomus strigaticeps* (Regan 1908) | 7 | - | - | - | - | - | - | - | - | - | - | - | - | CICCAA07555 |
| *Hisonotus depressicauda* (Miranda Ribeiro 1918) | - | - | - | - | - | - | - | - | - | 2 | - | - | 2 | CICCAA07570 |
| *Neoplecostomus selenae* Zawadzki, Pavanelli & Langeani 2008 | 1 | 14 | - | - | - | 2 | - | - | - | - | - | - | 2 | CICCAA07563 |
| *Rineloricaria pentamaculata* Langeani & de Araujo 1994 | - | - | - | - | - | - | - | - | - | 1 | - | - | - | CICCAA07569 |
| **Heptapteridae** | | | | | | | | | | | | | | |
| *Cetopsorhamdia iheringi* Schubart & Gomes 1959 | - | - | - | - | - | - | - | - | - | 3 | 1 | - | - | CICCAA07574 |
| *Heptapterus longicauda* (Borodin 1927) | - | - | - | - | - | - | - | - | - | 2 | - | - | - | CICCAA07573 |
| *Imparfinis mirini* Haseman 1911 | - | 4 | 1 | - | - | - | - | - | - | 6 | - | - | - | CICCAA07571 |
| *Phenacorhamdia roxoi* Silva 2020 | - | - | - | - | - | - | - | - | - | 5 | - | - | - | CICCAA07572 |
| CICHLIFORMES | | | | | | | | | | | | | | |
| **Cichlidae** | | | | | | | | | | | | | | |
| *Geophagus* cf. *brasiliensis* (Quoy & Gaimard 1824) | - | - | 3 | - | - | - | - | 4 | 1 | - | - | - | 5 | CICCAA07558 |
| *Cichlasoma paranaense* Kullander 1983 | - | - | - | - | - | - | - | 7 | - | - | - | - | - | CICCAA07568 |
| CYPRINODONTIFORMES | | | | | | | | | | | | | | |
| **Poeciliidae** | | | | | | | | | | | | | | |
| *Phalloceros* cf. *harpagos* Lucinda 2008 | - | 1 | 1 | - | 63 | 7 | - | - | - | 1 | - | - | - | CICCAA07562 |
| *Poecilia reticulata* Peters 1859 | - | - | - | - | - | - | - | - | 3 | - | - | - | - | Not catalogued |

municipalities and Paranapanema River drainage. In addition, it can support initiatives to conserve species at the regional level. For example, if local government implement initiatives to protect and restore the streams sampled in this study, about 18 % of the native fish species of the Paranapanema River drainage could be benefited in some way.

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