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Inventory

Knowing biodiversity: Fishes from the Guareí River basin, a tributary of the Jurumirim reservoir, Paranapanema River, Brazil

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Abstract: The Guareí River is a tributary of the Paranapanema River (Brazil), located in the upper portion of the Jurumirim Reservoir. Fish fauna studies in this watershed began in the 2000s, but they were restricted to a few waterbodies. This work conducted a broad survey of the fish fauna in tributary streams and the main channel of the Guareí River. Sampling occurred between February 2017 and November 2018 at 36 sites and using different collection methods. We captured 2,169 specimens belonging to 50 species, 16 families and 6 orders. The species accumulation curve tended to stabilize but indicated that species richness is underestimated. Almost all species are native (46); only three were non-native (*Hyphessobrycon eques, Oreochromis niloticus* and *Poecilia reticulata*) and one was undefined (*Gymnotus pantanal*). Among the native species, two are unknown to science (*Bryconamericus* aff. *iheringii* and *Hypostomus* sp. n.) and three are migratory (*Leporinus friderici, Megaleporinus obtusidens* and *Pimelodus maculatus*). In this paper, we provide images of species collected. Results indicate that the Guareí River basin is a hotspot of fish diversity in the Upper Paranapanema River, stressing the need for adequate management and conservation actions.
Keywords: *Inventory; migratory fish; non-native fish; Paraná River basin; stream; undescribed species.*

Conhecendo a biodiversidade: Peixes da bacia do Rio Guareí, um afluente do reservatório de Jurumirim, Rio Paranapanema, Brasil

Resumo: O Rio Guareí é um afluente do Rio Paranapanema (Brasil), localizado na parte superior do reservatório de Jurumirim. Os estudos da fauna de peixes nesta bacia hidrográfica começaram nos anos 2000, mas estão restritos a poucos corpos d'água. Este trabalho realizou um amplo levantamento da ictiofauna em tributários e no canal principal do Rio Guareí. As amostragens ocorreram entre Fevereiro de 2017 e Novembro de 2018 em 36 sítios e utilizando diferentes métodos de coleta. Capturamos 2.169 espécimes pertencentes a 50 espécies, 16 famílias e 6 ordens. A curva de acumulação de espécies tendeu a se estabilizar, mas indicou que a riqueza de espécies está subestimada. Quase todas as espécies são nativas (46); apenas três não nativas (*Hyphessobrycon eques*, *Oreochromis niloticus*, e *Poecilia reticulata*) e uma não definida (*Gymnotus pantanal*). Entre as espécies nativas, duas são desconhecidas da ciência (*Bryconamericus* aff. *iheringii* e *Hypostomus* sp. n.) e três migradoras (*Leporinus friderici*, *Megaleporinus obtusidens* e *Pimelodus maculatus*). Neste artigo, fornecemos imagens das espécies coletadas. Os resultados indicam que a bacia do Rio Guareí é uma região importante em termos de diversidade de peixes no alto Rio Paranapanema, enfatizando a necessidade de ações adequadas de manejo e conservação.
Palavras-chave: *Bacia do Rio Paraná; espécies não descritas; inventário; peixe migrador; peixes não nativos; riacho.*

Introduction

The diversity of freshwater fishes in Brazil (> 3,000 species; ICMBio 2018) is higher than in any other Neotropical country (e.g., Litz & Koerber 2014; Mirande & Koerber 2015; DoNascimiento et al. 2017). In part, the high diversity is related to the presence of the Amazon basin, a megadiverse region (Dagosta & de Pinna 2019). However, other important river systems hold remarkable biodiversity, such as the Upper Paraná River (Langeani et al. 2007; Ota et al. 2018). This basin sums more than three hundred species, with dozens still undescribed (Langeani et al. 2007).

In the last century, numerous studies about fish composition, biology, ecology, taxonomy have been carried out in the Upper Paraná River (e.g., Agostinho & Júlio-Jr. 1999; Britto & Carvalho 2006; Brandão et al. 2009; Dias & Tejerina-Garro 2010; Esguícero & Arcifa 2011; Cionek et al. 2012; Carvalho & Langeani 2013; Santos et al. 2017; Frota et al. 2020), and this basin is possibly the most studied in Brazil. However, several questions remain open, including total diversity, biogeographic patterns and ecological aspects, demanding further studies. The occurrence of *Phenacorhamdia tenebrosa* (Schubart, 1964) on the Upper Paraná River is a good example: although this fish was recorded by several studies (e.g., Schubart 1964; Manoel & Uieda 2018; Cavalli et al. 2018; Vicentin et al. 2019), more detailed information on its distribution is lacking. Perhaps more important is the fact that several waterbodies remain uninvestigated, especially small and mid-size water courses, which may harbor species unknown (i.e., undescribed) to science (Langeani et al. 2007).

If the Upper Paraná River is the most studied, it is also the most disturbed (Agostinho et al. 2007). Urbanization, agriculture, invasive species and hydrological alterations related to human activities have caused significant perturbations to fish diversity. The construction of hydropower dams, in particular, has played a central role inducing habitat alterations and biodiversity losses (Agostinho et al. 2008; Pelicice et al. 2017). For instance, the main tributaries of the basin, such as the Tietê, Grande and Paranapanema rivers, are regulated by cascade of dams (Petesse & Petrere Jr. 2012; Loures & Pompeu 2018; Pelicice et al. 2018), blocking migratory dynamics and affecting population recruitment (Pelicice & Agostinho 2008). Ichthyological surveys remain incomplete in these highly disturbed systems, and once conservation initiatives rely mainly on those data (Azevedo-Santos et al. 2019), more research is needed to provide basic information in these impacted waterbodies.

Tributaries play important roles in impounded areas (Nunes et al. 2015; Silva et al. 2015; Marques et al. 2018), since they preserve fluvial conditions and a natural or semi-natural flow regime, reducing the impacts on the environment and biodiversity. The presence of tributaries may explain the maintenance of fish diversity in impounded areas, because reservoirs impose serious constraints to fish recruitment (Agostinho et al. 2008). Some studies in the Paranapanema River have pointed to the importance of tributaries (e.g., Hoffmann et al. 2005; Pelicice & Agostinho 2008). The Jurumirim Reservoir, in particular, has been investigated by multiple studies concerning its aquatic fauna (e.g., Panarelli et al. 2001; Sartori et al. 2009), including fish (e.g., Castro et al. 2003a; Lima et al. 2016; Lima et al. 2018; Queiroz-Sousa et al. 2019). Some studies (e.g., Seabra et al. 2012; Nobile et al. 2019) provided information about fishes in tributaries that flow into the Jurumirim Reservoir, such as the Taquarí and Guareí rivers.

The Guareí River has its mouth near the confluence between the Paranapanema River and the Jurumirim Reservoir (Leite et al. 2012). Few ichthyological studies have been conducted in this basin, and they have only investigated small watercourses (e.g., Castro et al. 2003b), lagoons (Seabra et al. 2012), population biology of two catfish species (Azevedo-Santos et al. 2018), and species description (Katz & Costa 2020), with no estimate of total diversity in the whole basin. Despite those studies, many tributary streams, as well as the Guareí River main channel, remain uninvestigated. In this sense, here we provide a broad survey of the fish species in the Guareí River basin, with the objective to provide the first report on fish diversity in this basin.

Material and Methods

1. Study area

The Guareí River is a tributary of the Paranapanema River, that flows into the upper section of the Jurumirim Reservoir (Leite et al. 2012). Its drainage catchment is entirely located in the State of São Paulo (Brazil), and covers the municipalities of Guareí, in the upper course, and Angatuba in the middle and lower portions (Fulan et al. 2012).

The drainage area is about 70,860 ha (Leite et al. 2012). Many tributary streams had their vegetation totally or partially removed, a trend observed in the whole basin. At the end of the last century, the Guareí River basin was composed mostly of pasture (> 50%) and recovered vegetation (~ 11%) (Henry & Gouveia 1993), with fragments of Mata Atlântica and Cerrado vegetation.

2. Methodology

We sampled fish between February 2017 and November 2018 (Table 1), under license number 57047 (SISBIO). We sampled the Guareí River main channel and more than 20 tributary streams of different orders (Figure 1), totaling 36 sites (i.e., channel segments) across the basin. We sampled more than one site in the Guareí River and in some of its main tributaries (e.g., Guarda-Mor stream) (Table 1).

Sampling in streams was carried out with a hand net (mesh ~ 1.5 mm), and when possible, cast net (mesh 14 mm) and two gill nets (mesh 10 mm and 20 mm) were employed. In streams, the hand net was operated in 50-100 m segments always in the upstream direction, during the day (between 7:00 am and 6:00 pm). In the Guareí River channel we employed gill nets with 30, 40, 50, 60, 70, 80 and 100 mm mesh size, which remained deployed overnight (~ 12 hours soak time). In addition, a castnet (mesh of 14 mm) and a hand net (mesh about 1.5 mm) were used, both methods directed to sample areas close to the margin.

Table 1. Information about the sites sampled across the Guareí River basin, Paranapanema River basin, São Paulo, Brazil.

SITE	NAME OF THE WATERBODIES	ORDER (*sensu* Strahler 1954)	COORDINATES	MUNICIPALITY	MONTH AND YEAR
1	Areia Branca stream	2	23°16'54.11"S, 48° 9'37.59"W	Guareí	August 2017 and May 2018
2	Unknown name	2	23°18'29.75"S, 48° 7'36.23"W	Guareí	August 2017 and May 2018
3	Inholava stream	3	23°20'49"S, 48°13'10.3"W	Guareí	March 2017 and May 2018
4	Unknown name	1	23°21'26.9"S, 48°12'49.3"W	Guareí	March 2017
5	Jacutinga da Boa Vista stream	3	23°22'56.8"S, 48°10'37.1"W	Guareí	August and December 2017
6	Guarda-Mor stream (lower course)	4	23°22'48.27"S, 48° 9'43.17"W	Guareí	February, August, and December 2017
7	Guarda-Mor stream (middle course)	3	23°24'28.41"S, 48° 8'41.84"W	Guareí	February and August 2017
8	Guarda-Mor stream (high course)	2	23°26'9.17"S, 48° 7'45.42"W	Guareí	August 2017 and May 2018
9	Grande stream (limit)	4	23°28'7.04"S, 48°15'8.24"W	Guareí-Angatuba	August 2017 and May 2018
10	Martinho stream	1	23°28'13.47"S, 48°19'24.59"W	Angatuba	June 2017 and June 2018
11	Unknown name	1	23°26'33.29"S, 48°19'42.93"W	Angatuba	April 2017
12	Durvalino stream	2	23°26'36.97"S, 48°20'40.80"W	Angatuba	April 2017 and May 2018
13	Unknown name	1	23°26'44.26"S, 48°21'35.16"W	Angatuba	April 2017 and June 2018
14	Unknown name	1	23°27'3.11"S, 48°22'13.19"W	Angatuba	April 2017 and May 2018
15	Unknown name	1	23°27'20.00"S, 48°22'25.51"W	Angatuba	April 2017 and May 2018
16	Unknown name	1	23°27'17.21"S, 48°23'19.17"W	Angatuba	April 2017 and June 2018
17	Corrente stream	2	23°26'05.7"S, 48°23'19.3"W	Angatuba	March, June, and September 2017
18	Cachoeira stream (below the waterfall)	2	23°27'36.28"S, 48°24'50.84"W	Angatuba	August 2017 and November 2018
19	Cachoeira stream (above the waterfall)	2	23°25'34.39"S, 48°25'13.24"W	Angatuba	February and September 2017
20	Guareí River channel (middle course)	-	23°27'53.90"S, 48°25'18.84"W	Angatuba	February and August 2017 and February, May, June and November 2018
21	Esperança stream	2	23°28'59.80"S, 48°25'7.27"W	Angatuba	February 2017 and June 2018
22	Catanduva stream (lower course)	3	23°29'18.12"S, 48°24'37.36"W	Angatuba	February 2017 and May 2018
23	Catanduva stream (high course)	1	23°31'12.05"S, 48°24'43.48"W	Angatuba	February 2017 and May 2018
24	Grande stream (middle course)	3	23°29'15.2"S, 48°24'28.2"W	Angatuba	April 2017 and May 2018
25	Grande stream (high course)	3	23°29'37.65"S, 48°20'8.98"W	Angatuba	February, April, June 2017 and November 2018
26	Unknown name	2	23°29'47.51"S, 48°20'18.38"W	Angatuba	February 2017 and May 2018
27	Libânios stream	3	23°27'34.4" S, 48°26'50.9" W	Angatuba	February 2017
28	Zacarias stream	3	23°29'21.8"S, 48°27'08.4"W	Angatuba	April 2017 and June 2018
29	Barra stream	3	23°29'25.62"S, 48°29'49.69"W	Angatuba	April 2017
30	Unknown name	1	23°29'28.78"S, 48°30'9.95"W	Angatuba	April 2017
31	Unknown name	2	23°29'14.74"S, 48°30'30.15"W	Angatuba	June 2017 and May 2018
32	Unknown name	1	23°29'6.57"S, 48°31'13.40"W	Angatuba	June 2017 and May 2018
33	Cambuí stream	3	23°28'24.31"S, 48°30'33.54"W	Angatuba	June 2017
34	Ribeiro stream	2	23°27'34.91"S, 48°29'42.72"W	Angatuba	June 2017
35	Aterradinho stream	3	23°27'33.77"S, 48°34'26.71"W	Angatuba	May 2018
36	Guareí River channel (lower course)	-	23°27'51.57"S, 48°34'40.57"W	Angatuba	June 2017 and January and February 2018

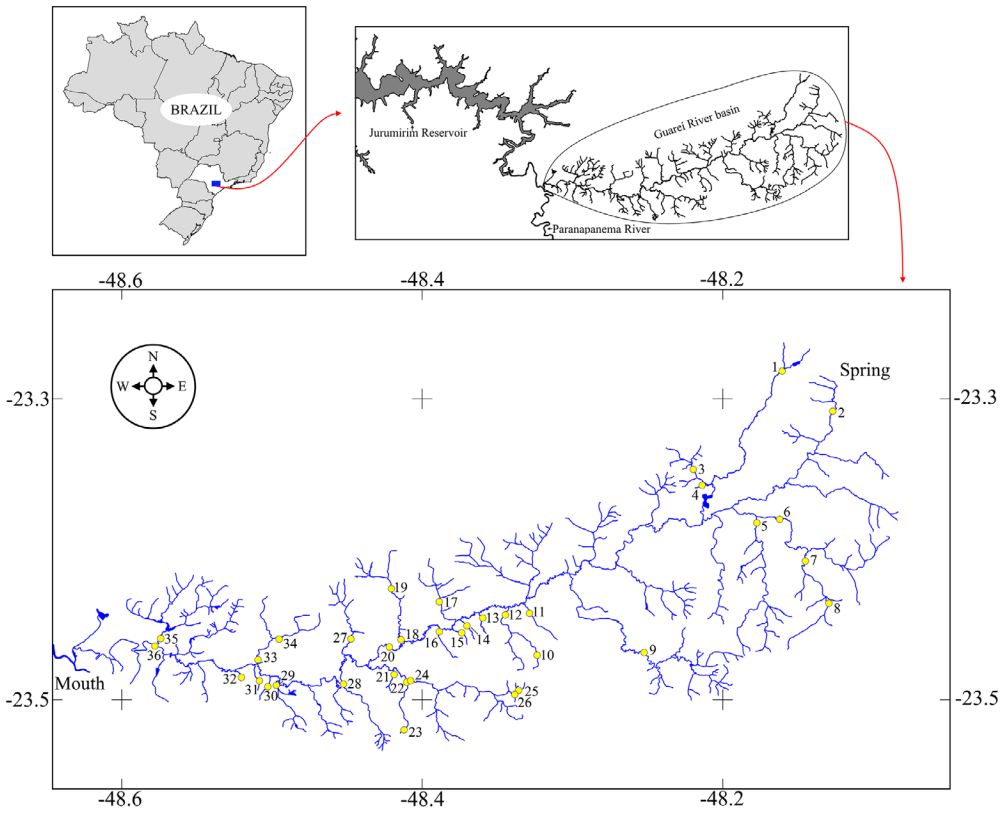

Figure 1. Guareí River basin and the location (yellow circles) of sampled sites (1 to 36). The map was drawn in the Software QGis (Sherman et al. 2012).

In the field, fishes were euthanized with a solution of water and eugenol or benzocaine (lethal dosage), and then preserved in formalin (10%). Voucher specimens were prepared (washed with water and transferred to 70% alcohol) and deposited in the following Brazilian biological collections: DZSJRP - Departamento de Zoologia e Botânica, Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Campus de São José do Rio Preto, São Paulo; LBP - Laboratório de Biologia e Genética de Peixes, Universidade Estadual Paulista "Júlio de Mesquita Filho", Campus de Botucatu, São Paulo; LIRP - Laboratório de Ictiologia de Ribeirão Preto, Universidade de São Paulo, Ribeirão Preto, São Paulo; MNRJ - Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Rio de Janeiro; NUP - Coleção Ictiológica do Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura (Nupélia), Universidade Estadual de Maringá, Maringá, Paraná; UFRGS - Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul; UNT - Universidade Federal do Tocantins, Porto Nacional, Tocantins. Taxonomic classification followed Fricke et al. (2020a) for families, and Fricke et al. (2020b) for orders.

A rarefaction curve was calculated considering all species captured in the 36 sampled sites (based on Table S1 and Table S2). The figure was drawn in PRIMER 6 (Clarke & Warwick 2001).

Results

We captured 2,169 individuals belonging to 50 species in the Guareí River basin (Table 2; Figure 2 to Figure 6). The rarefaction curve for the studied area tended to stabilize, but the asymptote was not reached (Figure 7). These fishes belonged to 6 orders and 16 families, being Characiformes the most diverse, with 48% of all species (Figure 8). Characidae was the most diverse family (24%), followed by Loricariidae (14%) and Heptapteridae (12%) (Figure 9). Families with the lowest number of specie (with 2% each one) were Erythrinidae, Serrasalmidae, Trichomycteridae and Synbranchidae (Figure 9).

Local richness in each site ranged between 1 to 25 species. Sites 20 and 36, located in the Guareí River main channel, had 25 and 21 species respectively. Total abundance within sites ranged from 1 to 283 individuals (Table S1 e Table S2).

Astyanax lacustris (Lütken 1875) [Figure 3(e) and Figure S1(d)], a characid, was widely distributed in the studied area, in 21 sites. Other common species were *Psalidodon fasciatus* (Cuvier 1819), found in 19 sites, and the catfish *Imparfinis mirini* Haseman 1911, present in 16 sites. The poecilid, *Phalloceros harpagos* Lucinda 2008, was the most abundant, with 253 individuals (Table 2), while *Leporinus friderici* (Bloch 1794), *L. striatus* Kner 1858, *Pimelodella gracilis* (Valenciennes 1835) and *Synbranchus marmoratus* Bloch 1795 were rare, with one individual each species.

Three species were non-native to the Guareí River basin, *Hyphessobrycon eques* (Steindachner 1882), *Oreochromis niloticus* (Linnaeus 1758) and *Poecilia reticulata* Peters 1859. Non-native species showed narrow distribution, being *H. eques* collected only in site 32, *O. niloticus* in site 29, and *P. reticulata* in sites 21 and 22, both located in the urban perimeter of the municipality of Angatuba. In general, non-natives were not abundant, excepting *P. reticulata* (cf. Table 2). The native status of *Gymnotus pantanal* Fernandes, Albert, Daniel-Silva, Lopes, Crampton, & Almeida-Toledo 2005, was uncertain (see Discussion section).

Table 2. Species (Actinopterygii) recorded in the Guareí River basin, Paranapanema River basin, São Paulo, Brazil.

SPECIES	ABUNDANCE	STATUS	VOUCHER
CHARACIFORMES			
Crenuchidae			
Characidium gomesi Travassos 1956	90	Native	MNRJ 50435
Characidium zebra Eigenmann 1909	7	Native	LBP 29211
Erythrinidae			
Hoplias malabaricus (Bloch 1794)	15	Native	LBP 29218
Parodontidae			
Apareiodon affinis (Steindachner 1879)	12	Native	LBP 29223
Parodon nasus Kner 1859	10	Native	LBP 29231
Serrasalmidae			
Serrasalmus maculatus Kner 1858	6	Native	LBP 29230
Anostomidae			
Leporinus friderici (Bloch 1794)	1	Native	DZSJRP 22777
Leporinus striatus Kner 1858	1	Native	LBP 29220
Megaleporinus obtusidens (Valenciennes 1837)	2	Native	LBP 29222
Schizodon nasutus Kner 1858	21	Native	LBP 29214
Curimatidae			
Cyphocharax modestus (Fernández-Yépez 1948)	56	Native	LBP 29228
Steindachnerina insculpta (Fernández-Yépez 1948)	33	Native	LBP 29221
Characidae			
Astyanax lacustris (Lütken 1875)	221	Native	DZSJRP 22817
Bryconamericus aff. *iheringii* (Boulenger 1887)	148	Native	DZSJRP 22812
'*Cheirodon*' *stenodon* Eigenmann 1915	23	Native	UFRGS 28084
Galeocharax gulo (Cope 1870)	8	Native	LBP 29229
Hyphessobrycon eques (Steindachner 1882)	3	Non-Native	LBP 29219
Oligosarcus paranensis Menezes & Géry 1983	6	Native	DZSJRP 22816
Piabarchus cf. *stramineus* (Eigenmann 1908)	24	Native	DZSJRP 22779
Piabina argentea Reinhardt 1867	11	Native	DZSJRP 22838
Psalidodon bockmanni (Vari & Castro 2007)	97	Native	DZSJRP 22747
Psalidodon fasciatus (Cuvier 1819)	166	Native	DZSJRP 22754
Psalidodon cf. *paranae* (Eigenmann 1914)	12	Native	DZSJRP 22757
Serrapinnus notomelas (Eigenmann 1915)	100	Native	DZSJRP 22756
GYMNOTIFORMES			
Gymnotidae			
Gymnotus carapo Linnaeus 1758	6	Native	LBP 29209
Gymnotus pantanal Fernandes, Albert, Daniel-Silva, Lopes, Crampton & Almeida-Toledo 2005	5	Indeterminate	LBP 29210
SILURIFORMES			
Trichomycteridae			
Cambeva guareiensis Katz & Costa 2020	71	Native	DZSJRP 22781
Callichthyidae			
Callichthys callichthys (Linnaeus 1758)	12	Native	LBP 29216
Hoplosternum littorale (Hancock 1828)	5	Native	LBP 29215
Loricariidae			
Hisonotus depressicauda (Miranda Ribeiro 1918)	26	Native	DZSJRP 22749
Hypostomus ancistroides (Ihering 1911)	26	Native	NUP 22311
Hypostomus iheringii (Regan, 1908)	62	Native	LBP 29213
Hypostomus sp. n.	57	Native	NUP 22310
Hypostomus tietensis (Ihering 1905)	2	Native	LBP 29212
Hypostomus strigaticeps (Regan 1908)	63	Native	NUP 22312
Rineloricaria pentamaculata Langeani & de Araujo 1994	7	Native	DZSJRP 22834

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Heptapteridae			
Imparfinis borodini Mees & Cala 1989	9	Native	DZSJRP 22741
Imparfinis mirini Haseman 1911	111	Native	LIRP 14330
Phenacorhamdia tenebrosa (Schubart 1964)	35	Native	DZSJRP 22752
Pimelodella avanhandavae Eigenmann 1917	37	Native	LBP 29226
Pimelodella gracilis (Valenciennes 1835)	1	Native	LIRP 14328
Rhamdia quelen (Quoy & Gaimard 1824)	9	Native	DZSJRP 22751
Pimelodidae			
Iheringichthys labrosus (Lütken 1874)	4	Native	LBP 29225
Pimelodus maculatus Lacepède 1803	7	Native	LBP 29224
SYNBRANCHIFORMES			
Synbranchidae			
Synbranchus marmoratus Bloch 1795	1	Native	DZSJRP 22827
CICHLIFORMES			
Cichlidae			
Geophagus brasiliensis (Quoy & Gaimard 1824)	60	Native	DZSJRP 22789
Oreochromis niloticus (Linnaeus 1758)	20	Non-Native	LBP 29217
CYPRINODONTIFORMES			
Poeciliidae			
Phalloceros harpagos Lucinda 2008	253	Native	UNT 016904
Phalloceros reisi Lucinda 2008	129	Native	UNT 16404
Poecilia reticulata Peters 1859	78	Non-Native	DZSJRP 22765

We collected two undescribed species, *Bryconamericus* aff. *iheringii* (Boulenger 1887) and *Hypostomus* sp. n. The first was widely distributed, while the second was recorded in the Guareí River and one stream (Table S1 and Table S2).

Discussion

This study recorded 50 fish species in the Guareí River basin. However, because the accumulation curve did not stabilize, other species may be found with further sampling effort. The Guareí River basin holds ~22% of all species richness known to the Paranapanema River basin (*sensu* Jarduli et al. 2020), an expressive value considering the relative small size of this catchment (~70.9 thousand ha; Leite et al. 2012). Moreover, the Guareí River basin hold ca. 16% of all species richness of the entire Upper Paraná River system (based on Langeani et al. 2007). These numbers and comparisons clearly indicate the importance of this tributary for the maintenance of fish diversity at multiple spatial scales (e.g., Guareí, Paranapanema and Paraná rivers). As a hotspot of fish diversity in the Upper Paranapanema River, the Guareí River basin needs adequate management and conservation actions to preserve its environmental integrity.

Characiformes and Siluriformes represented 84% of all species. Jarduli et al. (2020) asserted that these orders sum more than 70% of all species in the Paranapanema River basin. In the Guareí River basin, however, Characiformes dominated over Siluriformes, differing from the pattern observed in the Paranapanema River basin (*sensu* Jarduli et al. 2020). Characidae was the most diverse family in the studied area (24% of all species), followed by Loricariidae (14%). Cetra et al. (2016), studying streams in the Upper Paranapanema, found similar patterns, while Jarduli et al. (2020) recorded that both families hold 32% of all species in the Paranapanema River basin.

Almost all species (=46) are native to the Guareí River basin; only three were non-native and one indeterminate. This is an atypical trend in the Upper Paraná River, particularly the Paranapanema River, where several non-native species have been introduced (Garcia et al. 2018; Pelicice et al. 2018). The number of non-native species is also low when compared with areas close to the Guareí River basin, such as the Jurumirim Reservoir (Kurchevski & Carvalho 2014) and a tributary, the Taquari River (Nobile et al. 2017; Nobile et al. 2019).

The three non-native species are *Hyphessobrycon eques*, *Oreochromis niloticus* and *Poecilia reticulata*. Castro et al. (2003b) had previously registered *O. niloticus* in the Guareí River basin. Tilapias regularly escape from fish farms (Orsi & Agostinho 1999; Azevedo-Santos et al. 2011; Casimiro et al. 2018), and a fish farm is located upstream from the site where *O. niloticus* was collected. The characid *H. eques* is widely distributed in the Upper Paraná River, and some authors suggest that it is native to this watershed (Langeani et al. 2007). However, numerous other studies indicate that the species was introduced into the Paranapanema River basin (e.g., Kurchevski & Carvalho 2014; Vidotto-Magnoni et al. 2015; Pelicice et al. 2018; Jarduli et al. 2020). We agree that it is non-native to the Guareí River basin. *Poecilia reticulata* is widespread in southeastern Brazil (Dias et al. 2020), including the Upper Paraná basin (e.g., Araújo et al. 2011; Cunico et al. 2019; Pagotto et al. 2012; Alves et al. 2016). In our study, this fish was captured in sites with urban impact, within the city of Angatuba. Mosquito control is probably the cause of its introduction, as this species has been commonly used to control *Aedes* populations (Azevedo-Santos et al. 2016).

Figure 2. Some fish species (Actinopterygii) collected in the Guareí River basin: (a) *Characidium gomesi*, 51.5 mm SL; (b) *Characidium zebra*, 64.8 mm SL; (c) *Hoplias malabaricus*, 93.5 mm SL; (d) *Apareiodon affinis*, 89.7 mm SL; (e) *Parodon nasus*, 91.3 mm SL; (f) *Serrasalmus maculatus*, 86. 7 mm SL; (g) *Leporinus friderici*, 144.9 mm SL; (h) *Leporinus striatus*, 87.1 mm SL; (i) *Megaleporinus obtusidens*, 86.2 mm SL; (j) *Schizodon nasutus*, 137.2 mm SL.

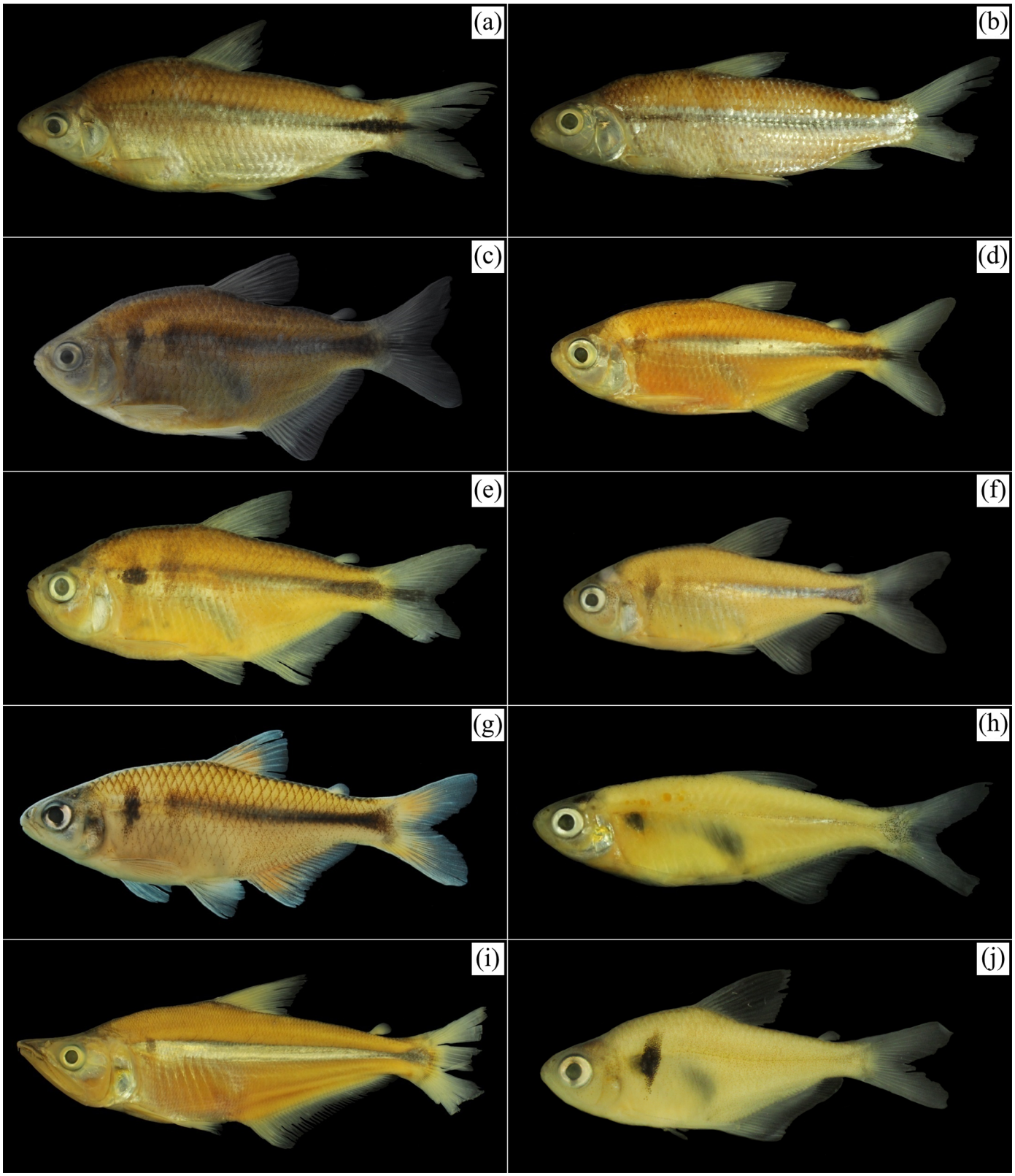

Figure 3. Some fish species (Actinopterygii) collected in the Guareí River basin: (a) *Cyphocharax modestus*, 96.4 mm SL; (b) *Steindachnerina insculpta*, 67.9 mm SL; (c) *Psalidodon bockmanni*, 59.8 mm SL; (d) *Psalidodon fasciatus*, 63.1 mm SL; (e) *Astyanax lacustris*, 64.3 mm SL; (f) *Psalidodon* cf. *paranae*, 38.1 mm SL; (g) *Bryconamericus* aff. *iheringii*, 49.1 mm SL; (h) '*Cheirodon*' *stenodon*, 29.1 mm SL; (i) *Galeocharax gulo*, 167.9 mm SL; (j) *Hyphessobrycon eques*, 22.1 mm SL.

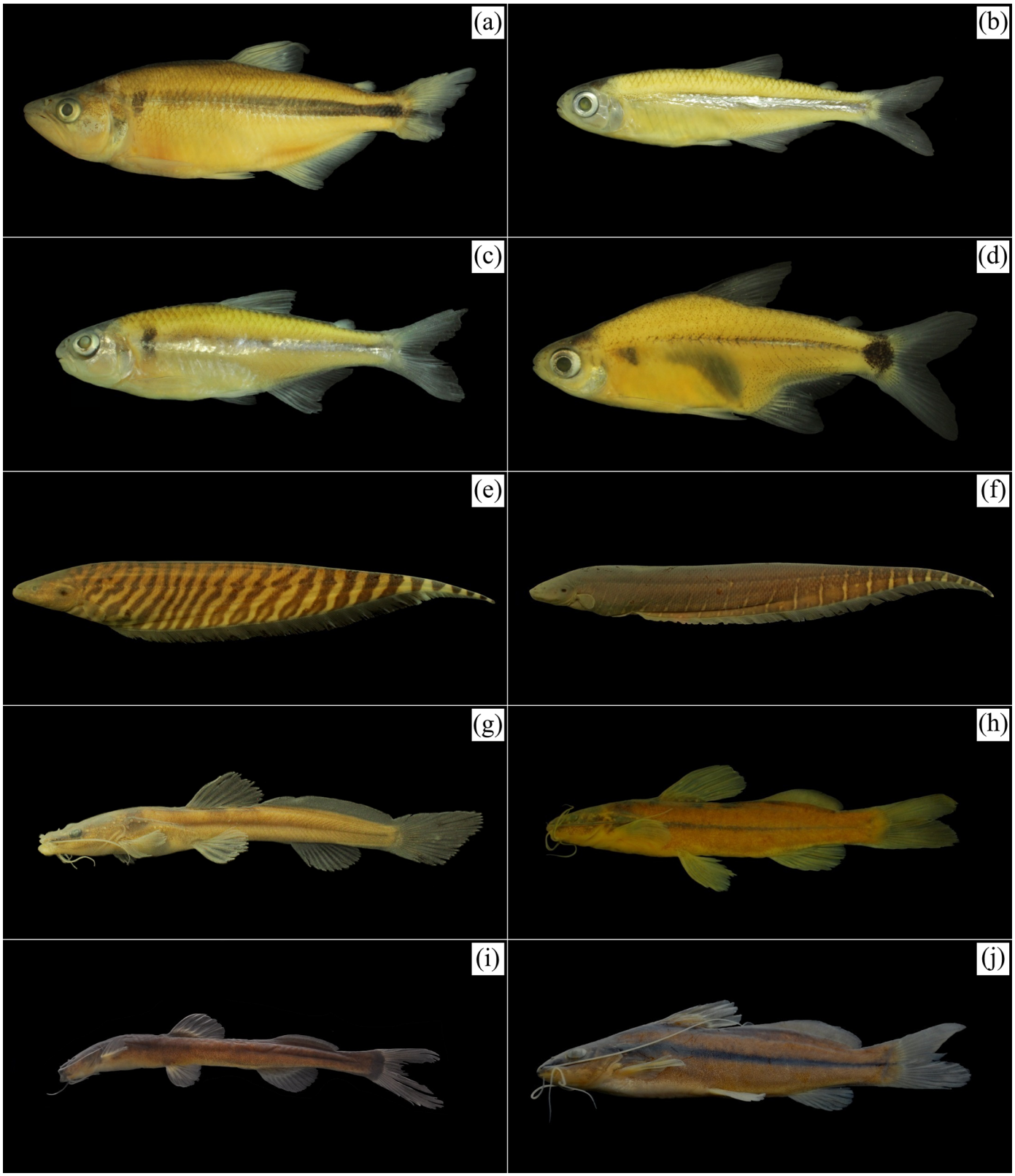

Figure 4. Some fish species (Actinopterygii) collected in the Guareí River basin: (a) *Oligosarcus paranensis*, 144.3 mm SL; (b) *Piabarchus* cf. *stramineus*, 48.1 mm SL; (c) *Piabina argentea*, 58.2 mm SL; (d) *Serrapinnus notomelas*, 29.5 mm SL; (e) *Gymnotus carapo*, 108.6 mm TL; (f) *Gymnotus pantanal* 197.2 mm TL; (g) *Imparfinis borodini*, 32.8 mm SL; (h) *Imparfinis mirini*, 60.2 mm SL; (i) *Phenacorhamdia tenebrosa*, 80.1 mm SL; (j) *Pimelodella avanhandavae*, 83.7 mm SL.

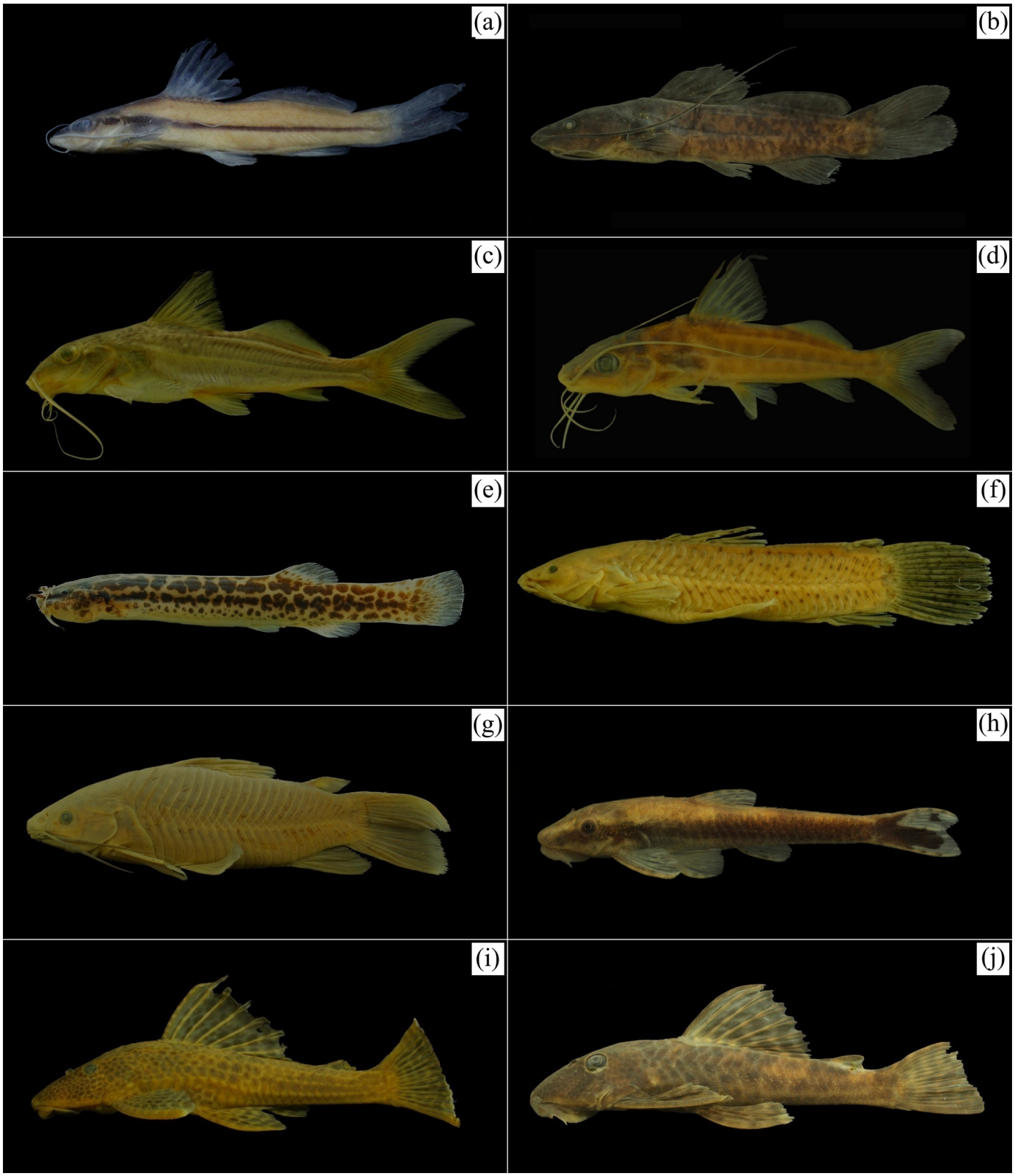

Figure 5. Some fish species (Actinopterygii) collected in the Guareí River basin: (a) *Pimelodella gracilis* 60.1 mm SL; (b) *Rhamdia quelen*, 47.6 mm SL; (c) *Iheringichthys labrosus*, 101.8 mm SL; (d) *Pimelodus maculatus*, 81.9 mm SL; (e) *Cambeva guareiensis*, 55. 4 mm SL; (f) *Callichthys callichthys*, 56.5 mm SL; (g) *Hoplosternum littorale*, 100.8 mm SL; (h) *Hisonotus depressicauda*, 34.8 mm SL; (i) *Hypostomus ancistroides*, 141.4 mm SL; (j) *Hypostomus iheringii*, 93.7 mm SL.

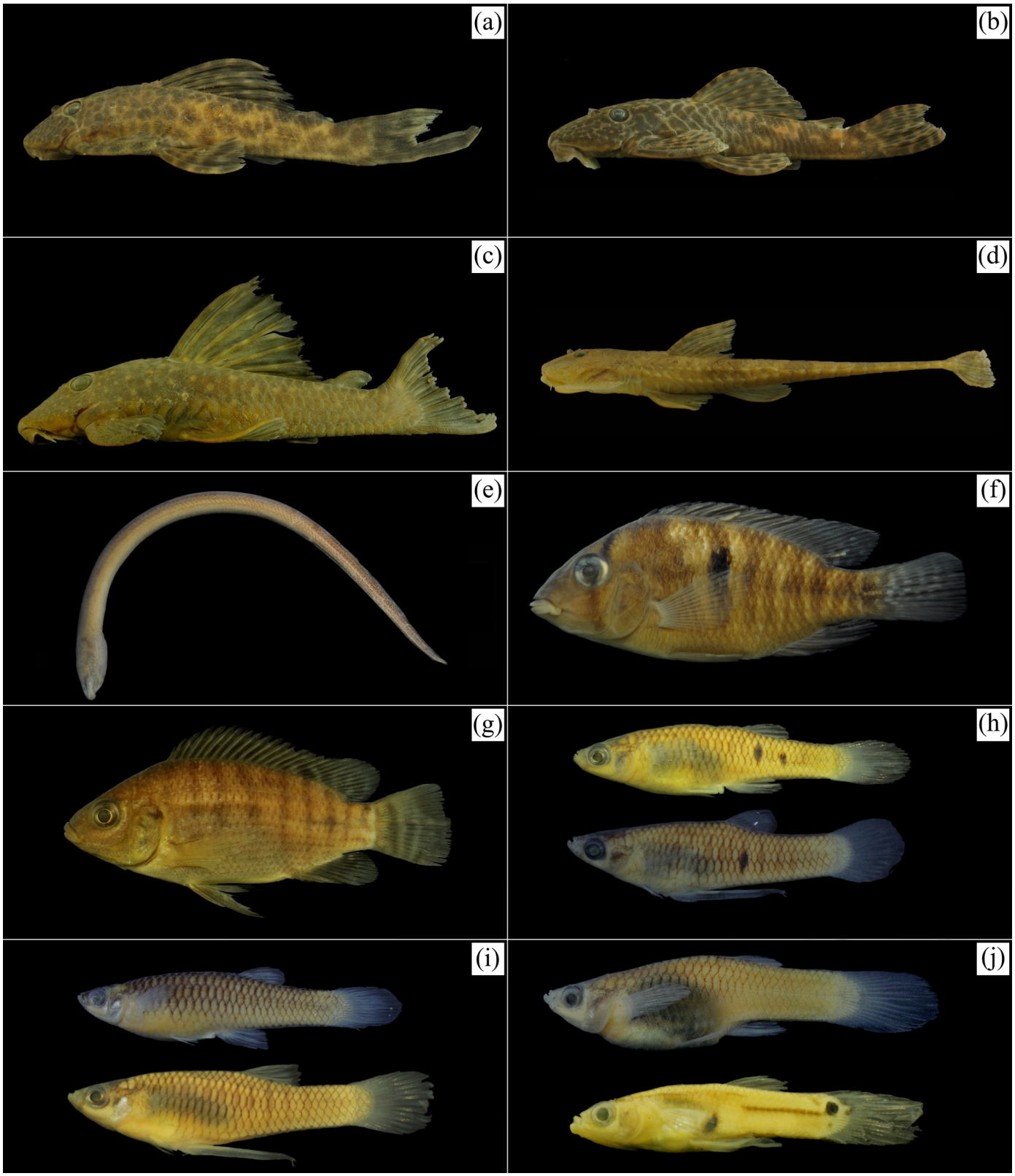

Figure 6. Some fish species (Actinopterygii) collected in the Guareí River basin: (a) *Hypostomus* sp. n., 81.3 mm SL; (b) *Hypostomus tietensis*, 81.5 mm SL; (c) *Hypostomus strigaticeps*, 129.4 mm SL; (d) *Rineloricaria pentamaculata*, 145.3 mm SL; (e) *Synbranchus marmoratus*, 131.7 mm TL; (f) *Geophagus brasiliensis*, 58.7 mm SL; (g) *Oreochromis niloticus*, 64.4 mm SL; (h) *Phalloceros harpagos*, 24.5 mm SL (female above), 16.3 mm SL (male below); (i) *Phalloceros reisi*, 40.7 mm SL (female above), 25.4 mm SL (male below); (j) *Poecilia reticulata*, 24.9 mm SL (female above), 16.4 mm SL (male below).

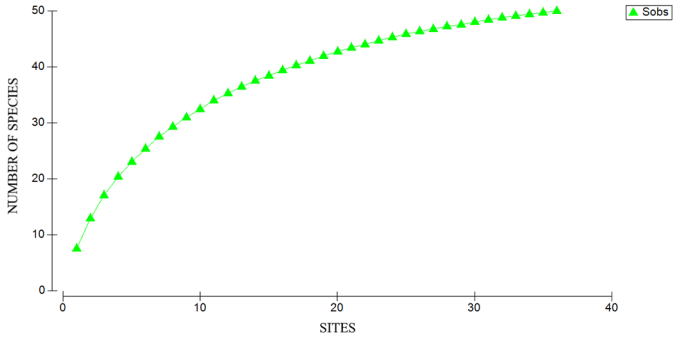

Figure 7. Species accumulation curve based on sampling effort in the Guareí River basin, Paranapanema River, São Paulo, Brazil.

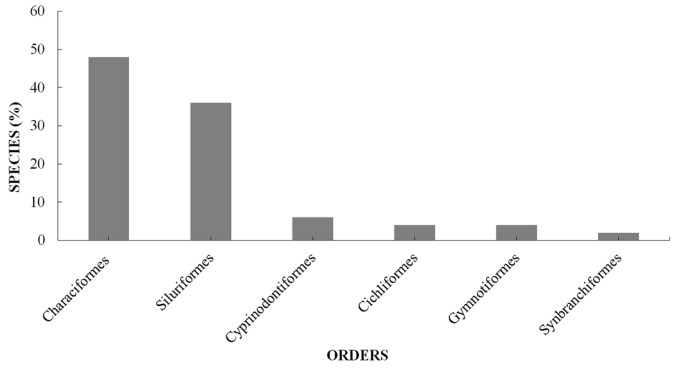

Figure 8. Species richness (%) in each taxonomic order found in the Guareí River basin, Paranapanema River, São Paulo, Brazil.

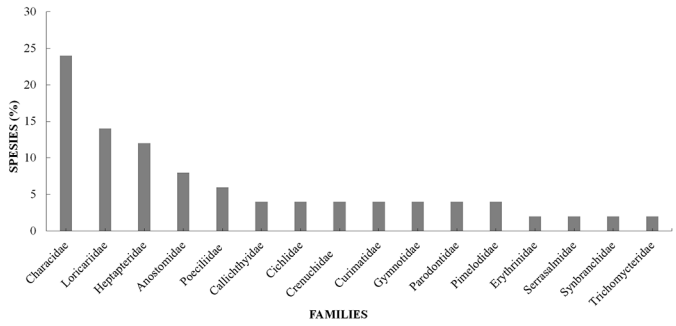

Figure 9. Species richness (%) in each taxonomic family found in the Guareí River basin, Paranapanema River, São Paulo, Brazil.

The natural origin of the electric eel *Gymnotus pantanal* is uncertain. This species was described by Fernandes et al. (2005), with occurrence to the lower portion of the Paraná River, the La Plata River, and a tributary of the Amazon basin. Some authors (Júlio Júnior et al. 2009; Jarduli et al. 2020) argued that *G. pantanal* reached the Upper Paraná after the flooding of Sete Quedas waterfalls (after the construction of Itaipu Dam), which worked as natural barrier between the Upper and Middle Paraná basins. It is unlikely, however, that the loss of Sete Quedas caused this introduction in the Guareí River basin, considering the distance and the number of dams along the Paranapanema River (cf. Pelicice et al. 2018), most of them built before Itaipu (e.g., Jurumirim). Alternatively, sport fishing has been an important vector causing the introduction of non-native species in Brazilian waters (e.g., Daga et al. 2016; Pereira & Vitule 2019), and could be responsible for the introduction of *G. pantanal* as live baits (Jarduli et al. 2020). However, it would need repeated events of introduction in the Guareí River basin, which seems unlikely. Therefore, the status of *G. pantanal* in the Guareí River basin deserves further examination.

We recorded three "migratory" species (*sensu* Vazzoler 1996: p. 96-97), *Leporinus friderici*, *Megaleporinus obtusidens* (Valenciennes 1837), and *Pimelodus maculatus* Lacepède 1803. These fishes provide important income for fishermen living in the Angatuba region (Novaes & Carvalho 2009) and other cities along the Paranapanema River. Other migratory fishes are found in the Jurumirim Reservoir and tributaries, such as *Prochilodus lineatus* (Valenciennes 1837) and *Salminus hilarii* Valenciennes 1850 (Kurchevski & Carvalho 2014; Nobile et al. 2019). They may occur in the Guareí River basin, particularly in the main channel, either year-round or seasonally, using this tributary as a feeding ground or spawning site.

In the description of *Phalloceros reisi*, Lucinda (2008) recorded the species for the upper Paraná River system, but only for waterbodies of the Tietê River basin. Cetra et al. (2012) were probably the first to record this species in the Paranapanema River basin. Later, other authors reported its presence in different waterbodies of the same watershed (Cerqueira et al. 2016; Cetra et al. 2016; Peressin et al. 2018). In this study, we found *P. reisi* in 12 sites, expanding its range in the Paranapanema River basin.

We also found two undescribed taxa, *Bryconamericus* aff. *iheringii* and *Hypostomus* sp. n. Both had already been captured in areas close to the Guareí River basin (Kurchevski & Carvalho 2014), and the present work expanded their known range. Herein, we just mention that the description of *Hypostomus* sp. n. is in progress (C. H. Zawadzki, pers. comm.). *Cambeva guareiensis* Katz & Costa 2020, a recently described species, is known only from streams in the Guareí River Guareí River basin (Katz & Costa 2020; this work). As observed for other species of the genus (e.g., *Cambeva diabola* Bockmann, Casatti, de Pinna 2004), it may have a wider distribution.

The identification of some species was uncertain. *Psalidodon* cf. *paranae* (Eigenmann 1914) integrates the complex '*Astyanax*' *scabripinnis*, which presents similar morphology (Bertaco & Lucena 2006), including undescribed species (e.g., Azevedo-Santos et al. 2019). Until a better definition of *P. paranae*, we treat the form captured in the Guareí River basin with caution. On the other hand, *Piabarchus* cf. *stramineus* (Eigenmann 1908) shows no trace of chromatophores in the humeral region, as reported by Eigenmann (1908) in the original description of this species. It is not known whether this character represents intraspecific variation, so we also treat its identification with caution.

Conclusion

This is the most comprehensive survey on fish diversity in the Guareí River basin. We recorded 50 species, most of which are native to the watershed, including migratory fishes and some taxa unknown to science. Fish diversity may be greater, considering the trend observed in the rarefaction curve. These results emphasize the role of tributaries as hotspots of fish biodiversity in impounded areas, with an important function in reservoirs that support fishing activity, such as the Jurumirim Reservoir. Therefore, conservation efforts must be directed to the Guareí River basin, especially to protect its tributaries.

Supplementary Material

The following online material is available for this article:

Figure S1 – Individuals (in life) of 15 species collected from the Guareí River basin: (a) *Characidium gomesi*; (b) *Hoplias malabaricus*; (c) *Psalidodon bockmanni*; (d) *Astyanax lacustris*; (e) *Bryconamericus* aff. *iheringii*; (f) *Serrapinnus notomelas*; (g) *Gymnotus carapo*; (h) *Phenacorhamdia tenebrosa*; (i) *Rhamdia quelen*; (j) *Callichthys callichthys*; (k) *Hisonotus depressicauda*; (l) *Rineloricaria pentamaculata*; (m) *Geophagus brasiliensis*; (n) *Oreochromis niloticus*; (o) *Phalloceros reisi*.

Table S1 – Species (Actinopterygii) collected and their abundance in each site (1 to 18) of the Guareí River basin, São Paulo, Brazil.

Table S2 – Species (Actinopterygii) collected and their abundance in each site (19 to 36) of the Guareí River basin, São Paulo, Brazil.

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Author Contributions

Valter M. Azevedo-Santos idealized the work, collected and identified species, provided ideas, wrote the first version of the manuscript.

Fernando M. Pelicice provided ideas and collaborated with the writing process.

Raoul Henry provided ideas and collaborated with the writing process.

Conflicts of Interest

None.

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