Check List the journal of biodiversity data

LIST OF SPECIES

Check List 14 (1): 43–53
https://doi.org/10.15560/114.1.43

PENSOFT

Diversity and distribution of ichthyofauna in streams of the middle and lower Tibagi river basin, Paraná, Brazil

Alexander Claro-García, Fernando M. Assega, Oscar A. Shibatta

Universidade Estadual de Londrina, Departamento de Biologia Animal e Vegetal, Programa de Pós-Graduação em Ciências Biológicas, Rodovia Celso Garcia Cid PR 445, km 380, Campus Universitário, CEP 86057-970, Londrina, PR, Brazil.
Corresponding author: Alexander Claro-García, alessclaro@gmail.com

Abstract

This study investigates the distribution and structure of the assemblages of fishes in tributaries of middle and lower sections of Tibagi river basin. The samples were conducted quarterly from December 2013 through December 2014, in 24 sampling sites of 8 tributaries. A total of 5643 individuals belonging to 44 species distributed in 13 families and 5 orders are reported. The families Characidae, Loricariidae, and Heptapteridae were predominant; *Astyanax paranae*, *Phalloceros harpagos*, *Piabina argentea*, *Astyanax bockmanni*, and *Trichomycterus davisi* were the most abundant species. Four non-native species were collected: *Coptodon rendalli*, *Poecilia reticulata*, *Xiphophorus hellerii*, and *Oreochromis niloticus*. The fish fauna of the middle and lower sections of Tibagi river basin has previously been threatened by human activities such as urbanization, industry, agriculture, and currently with dam construction.

Key words

Freshwater fishes; Neotropical region; species inventory; upper Paraná river basin.

Academic editor: Sarah Steele | Received 18 October 2016 | Accepted 27 June 2017 | Published 5 January 2018

Citation: Claro-García A, Assega FM, Shibatta OA (2017) Diversity and distribution of ichthyofauna in streams of the middle and lower Tibagi river basin, Paraná, Brazil. Check List 14 (1): 43–53. https://doi.org/10.15560/14.1.43

Introduction

Freshwater fishes in the Neotropical region are remarkably diverse, especially in Brazil, representing an estimate between 8000 and 9000 species, possibly because of the presence of the largest and independent river basins in the world (Reis et al. 2016), as for example, the Amazonas and Paraná rivers. Many of these basins are isolated and mainly composed of small tributaries, with a large percentage of ichthyofauna understudied (Stevaux et al. 1997).

Despite this great diversity, Brazilian water systems are under strong human pressure (e.g. agriculture, dam-building, urbanization), causing strong alterations in the landscape (Allan et al. 1997). These alterations can cause loss of diversity and simplification of ecosystems (Matson et al. 1997, Tscharntke et al. 2005), mainly in small streams, because the impacts on terrestrial ecosystems are strongly reflected in aquatic environments (Lee 2000).

The ichthyofauna of the Tibagi River, according to Shibatta et al. (2007), has been studied since the 1980s; however, most of these studies were directed to the main channel of the river and larger tributaries, as evidenced by the studies of Bennemann et al. (1995), Shibatta et al. (2002), Shibatta et al. (2006), Galves et al. (2007), and Shibatta et al. (2007). On the other hand, studies aimed at inventorying the fish fauna of small tributaries have intensified in recent years (Shibatta and Cheida 2003, Oliveira

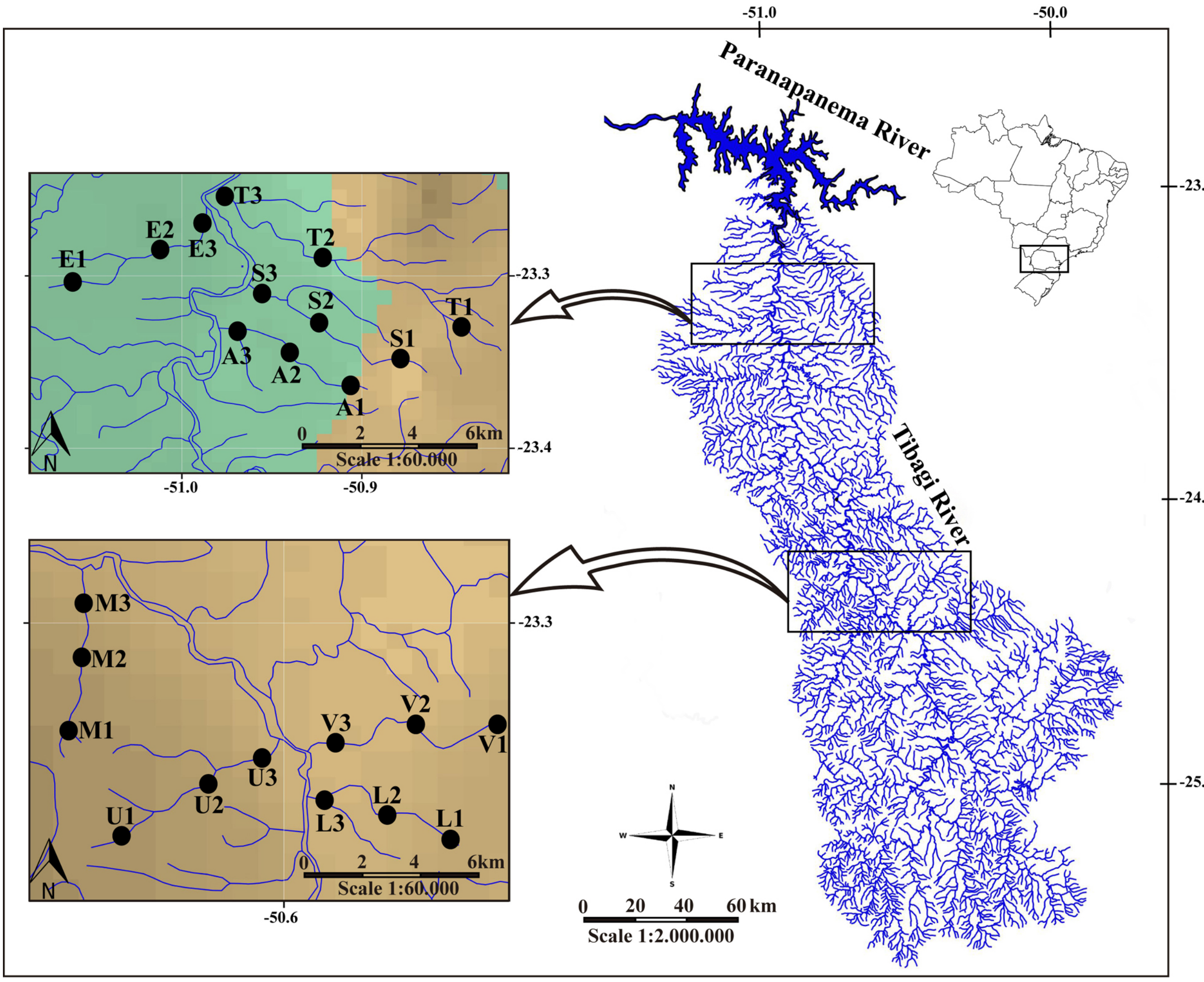

Figure 1. Map of the study area showing the collecting sites in the middle and lower section in the Tibagi river basin, Paraná State, Brazil. Varanal stream (V1, V2, V3), Lambedor stream (L1, L2, L3), Uvaranal stream (U1, U2, U3), Mandaçaia stream (M1, M2, M3), Saltinho stream (S1, S2, S3), Água Branca stream (A1, A2, A3), Tigre stream (T1, T2, T3), Engenho de Ferro stream (E1, E2, E3).

and Bennemann 2005, Vieira and Shibatta 2007, Shibatta et al. 2008, Silva et al. 2013, Hoffmann et al. 2015.

This study was conducted as a survey of ichthyofauna in streams of middle and lower Tibagi River, which are areas influenced by human activities such as urbanization (Mandaçaia, Uvaranal, and Engenho de Ferro streams) and agriculture (Saltinho, Tigre, and Água Branca streams), as well as in preserved areas (Lambedor and Varanal streams). Due to the incomplete knowledge of the diversity of fish fauna in small tributaries, and their vulnerability to the accelerated process of transformation, this study aims to investigate the distribution and structure of the assemblages of fishes in tributaries of middle and lower sections of Tibagi river basin.

Methods

Study site. The headwaters of the Tibagi River are located in the Palmeira region in Paraná State, at 1060 m altitude, and run 550 km until joining the Paranapanema river basin. The Tibagi river basin has an annual rainfall varying from 1400–1700 mm, and a temperature varying between 13–28 °C (Medri et al. 2002, Pinese 2002, De França 2002*)*. Fish were collected in streams from middle and lower Tibagi river basin, in the municipalities of Telêmaco Borba (Mandaçaia, Uvaranal, Lambedor, and Varanal streams), Assaí (Saltinho, Tigre, and Água Branca) and Ibiporã (Engenho de Ferro streams) (Fig. 1), in the Paraná State, Brazil. We selected 3 sites (headwaters, middle, and mouth) for each studied stream (Table 1).

Data collection. Fish were collected quarterly from December 2013 through December 2014. For the sampling we used standard ichthyological gear based on active capture with sieves, seine nets, and casting net. The fish were anesthetized with eugenol (3 g/L) (Vidal et al. 2008, Lucena et al. 2013), fixed in 10% formalin solution and after 48 hrs transferred to 70% ethanol. Species were identified up to the lowest possible taxonomic level, using available literature (Shibatta et al. 2002, Fernandes et al. 2005, Jerep et al. 2006, Graça and Pavanelli 2007, Bennemann et al. 2008, Lucinda 2008, Richer-de-Forges et al. 2009, Calegari et al. 2013, Lucena and Soares 2016). The taxonomic classification follows Eschmeyer et al. (2017). To evaluate the relationships between fish assemblages in streams we calculated the Bray-Curtis

Table 1. Geographic coordinates and mean values *of the physical-chemical* water *parameters* from the collecting sites in the Tibagi river basin, Paraná state, Brazil. Alt: altitude (m), Wid: width (m), Dep: depth (m), WS: water speed ($m \cdot s^{-1}$), DO: dissolved oxygen ($mg \cdot L^{-1}$), Con: conductivity ($\mu S \cdot cm^{-1}$), Tem: temperature (°C), Sub: substrate, Rip: riparian forest (%).

Stream	Site	Latitude (S)	Longitude (W)	Alt	Wid	Dep	WS	DO	Con	pH	Tem	Sub	Rip
Varanal	P1	24°19′56.6″	050°32′05.8″	772	1.9	0.2	0.3	6.8	37.8	6.7	17.5	sand/gravel	90
	P2	24°20′13.9″	050°34′41.9″	680	4.0	0.4	0.6	6.1	34.5	6.7	18.7	rocks/sand	100
	P3	24°20′18.8″	050°35′49.8″	648	4.2	0.4	0.5	5.9	29.8	6.6	17.9	pebbles/sand	100
Lambedor	P1	24°21′44.7″	050°33′53.9″	715	2.7	0.2	0.4	6.4	29.5	6.9	17.3	sand/gravel	70
	P2	24°21′44.2″	050°34′07.6″	699	2.7	0.3	0.4	6.3	34.5	6.3	17.6	sand/gravel	80
	P3	24°21′07.8″	050°34′35.8″	706	3.5	0.4	0.4	6.2	44.3	6.6	18.0	sand/pebbles	100
Uvaranal	P1	24°21′52.0″	050°38′30.1″	757	1.8	0.4	0.3	7.3	20.4	6.5	21.4	clay/sand	15
	P2	24°20′40.1″	050°37′20.1″	707	3.1	0.2	0.4	6.1	82.1	6.7	20.6	sand/clay	10
	P3	24°20′34.9″	050°36′34.8″	696	3.9	0.3	0.5	6.9	58.7	7.8	21.3	sand/gravel	9
Mandaçaia	P1	24°19′29.2″	050°39′46.0″	703	2.6	0.2	0.4	7.4	54.8	7.2	17.8	sand/gravel	20
	P2	24°18′32.9″	050°39′57.7″	695	3.1	0.3	0.4	7.6	66.7	7.1	18.9	sand/gravel	10
	P3	24°17′20.1″	050°39′54.1″	666	4.9	0.3	0.4	7.2	56.1	7.5	18.9	sand/clay	13
Saltinho	P1	23°22′40.3″	050°54′21.1″	503	1.9	0.3	0.4	6.1	102.0	6.9	21.1	clay/gravel	5
	P2	23°22′47.9″	050°57′17.3″	439	3.6	0.4	0.4	4.58	109.5	7.2	19.6	rocks/clay	5
	P3	23°21′49.7″	050°59′15.0″	374	3.7	0.3	0.4	4.7	110.5	7.2	19.9	rocks/pebbles	5
Água Branca	P1	23°21′18.9″	050°55′40.2″	439	2.1	0.2	0.4	5.1	120.5	7.1	21.0	gravel/clay	10
	P2	23°19′52.0″	050°57′34.2″	380	2.9	0.3	0.4	5.1	120.5	7.0	21.5	pebbles/sand	5
	P3	23°19′48.4″	050°58′16.2″	349	3.4	0.4	0.4	4.7	115.0	7.0	21.7	clay/sand	5
Tigre	P1	23°20′36.2″	050°54′00.4″	436	2.7	0.3	0.4	5.2	161.3	7.3	21.1	clay/gravel	5
	P2	23°19′42.5″	050°55′18.1″	415	4.9	0.3	0.4	5.5	155.5	7.2	21.2	pebbles/clay	13
	P3	23°18′21.0″	050°57′29.7″	366	4.8	0.4	0.4	5.8	189.5	7.2	21.8	pebbles/clay	3
Engenho de Ferro	P1	23°17′08.0″	051°00′40.6″	395	3.0	0.3	0.5	4.9	124.5	7.0	22.1	sand/clay	10
	P2	23°17′07.5″	051°00′40.9″	362	5.2	0.3	0.4	5.3	162.3	6.9	21.8	clay/gravel	7
	P3	23°15′56.0″	050°59′09.9″	353	4.3	0.4	0.4	4.9	174.5	6.8	21.9	clay/pebbles	5

similarity index (Bray and Curtis 1957). Voucher specimens were deposited in the fish collection of the Museu de Zoologia da Universidade Estadual de Londrina (MZUEL), Londrina, Paraná State, Brazil (Table 2). Collections were authorized by ICMBio (collecting permit number 12120-1); and approved by Ethics Committee on Animal Use of the Universidade Estadual de Londrina, Londrina (permit number 22201.2013.21).

Results

In the Tibagi river basin, a total of 5642 specimens were collected, distributed into 44 species belonging to 13 families, and 5 orders (Figs 2–5, Table 2). Siluriformes with 38.6% (17 spp.) and Characiformes, with 36.4% (16 spp.), were the most diverse orders, followed by Cichliformes with 11.6% (5 spp.), and Gymnotiformes, and Cyprinodontiformes with 6.8% (3 spp.). The most representative families were Characidae with 10 species (22.7%), followed by Loricariidae with 8 species (18.1%), Heptapteridae with 5 (11.4%), and Cichlidae with 5 (11.4%).

Astyanax paranae (15.8%), *Phalloceros harpagos* (14.5%), *Piabina argentea* (13.4%), *Astyanax bockmanni* (9.9%), *Trichomycterus davisi* (8.6%), and *Piabarchus stramineus* (7.9%), were the most abundant species and represented more than 60% of the specimens captured. Seven species were broadly distributed among collection sites, mainly *Astyanax* aff. *fasciatus* (100% of sites), followed by *Hypostomus ancistroides* (87.5% of sites), *Piabina argentea* (75% of sites), *Astyanax bockmanni*, *Bryconamericus* aff. *iheringii*, *Piabarchus stramineus*, *Rhamdia* cf. *quelen*, and *Trichomycterus davisi* (60.5% of sites) (Table 2). Four non-native species were collected: *Coptodon rendalli*, collected in the streams of the middle section; and *Poecilia reticulata*, *Xiphophorus hellerii*, and *Oreochromis niloticus* in the streams of the lower section.

In the middle streams of the Tibagi, a total of 2581 individuals were collected, belonging to 22 species. In the lower section were registered a higher abundance and species richness, with 3,061 individuals of 36 species. From the 44 species collected in this study, 14 were common to both sections. The streams Saltinho, Tigre, and Engenho de Ferro reported the highest species richness with 22, 25, and 29 species, respectively. The highest abundance was registered in the Uvaranal stream, with 1,008 individuals; followed by Saltinho with 857 individuals, Engenho de Ferro with 808 individuals and Água Branca stream with 728 individuals, all from the lower Tibagi. The Bray-Curtis similarity analysis showed differences among the fish assemblages from the middle and lower portions of the Rio Tibagi (Fig. 6).

Discussion

In this study, the composition of fish assemblage was dominated mainly by Characiformes and Siluriformes, with more than 70% of total collected fish species; in particular, the predominance of families Characidae, Loricariidae, and Heptapteridae, represented more than 50% of the species. This dominance can be influenced

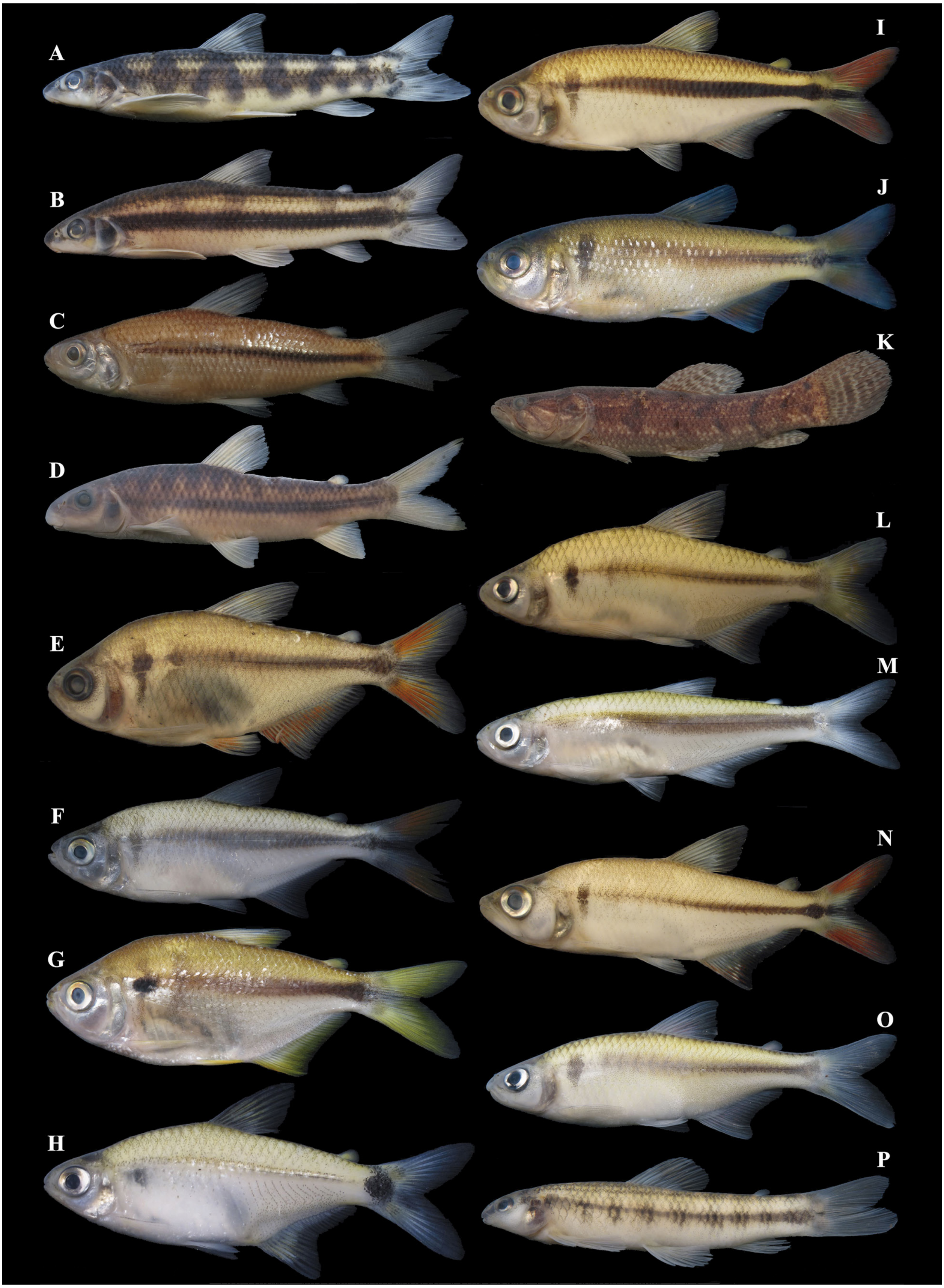

Figure 2. Fish species collected in streams from middle and lower sections of the Tibagi river basin, Paraná State, Brazil: **A**. *Apareiodon ibitiensis*, 78.2 mm SL, MZUEL 11012. **B.** *Apareiodon piracicabae*, 88.1 mm SL, MZUEL 10869. **C.** *Steindachnerina insculpta*, 58.8 mm SL, MZUEL 8569. **D**. *Leporinus amblyrhynchus*, 148.9 mm SL, MZUEL10868. **E**. *Astyanax bockmanni*, 64.1 mm SL, MZUEL 11058. **F.** *Astyanax* aff. *fasciatus*, 71.2 mm SL, MZUEL 8175. **G**. *Astyanax lacustris*, 72.5 mm SL, MZUEL 10044. **H**. *Serrapinnus notomelas*, 30.1 mm SL, MZUEL 11013. **I**. *Astyanax* aff. *paranae*, 78.3 mm SL, MZUEL 9986. **J**. *Astyanax paranae*, 63.1 mm SL, MZUEL 8191. **K**. *Hoplias* cf. *malabaricus*, 158.8 mm SL, MZUEL 8501. **L**. *Bryconamericus* aff. *iheringii*, 34.5 mm SL, MZUEL 10905. **M**. *Piabarchus stramineus*, 49.8 mm SL, MZUEL 8589. **N**. *Oligosarcus paranensis*, 110.9 mm SL, MZUEL 8284. **O**. *Piabina argentea*, 63.4 mm SL, MZUEL 8315. **P**. *Characidium* aff. *zebra*, 43.3 mm SL, MZUEL 10112.

Figure 3. Fish species collected in streams from middle and lower sections of the Tibagi river basin, Paraná State, Brazil: **A**. *Cetopsorhamdia iheringi*, 97.1 mm SL, MZUEL 8522. **B.** *Imparfinis mirini*, 72.2 mm SL, MZUEL 8504. **C.** *Phenacorhamdia tenebrosa*, 73.5 mm SL, MZUEL 8518. **D.** *Pimelodella gracilis*, 105.9 mm SL, MZUEL 10017. **E.** *Rhamdia* cf. *quelen*, 117.6 mm SL, MZUEL 10058. **F.** *Trichomycterus davisi*, 63.5 mm SL, MZUEL 11046. **G.** *Corydoras aeneus*, 41.4 mm SL, MZUEL 10873. **H.** *Corydoras ehrhardti*, 48.5 mm SL, MZUEL 10082. **I**. *Corydoras longipinnis*, 62.3 mm SL, MZUEL 8603.

by the high number of species contained in these orders (Characiformes and Siluriformes with approximately 2100 and 3700 species respectively, Eschmeyer and Fong 2017). Moreover, a large variety of specializations and adaptations, ecological, morphological, and physiological, allows them to survive in a wide variety of environments (Bruton 1996, Ortí 1997, Reis 2013).

According to Shibatta et al. (2002) and Vazzoler (1996), all specimens collected are small sized (200 mm or less) reflecting the expected pattern for streams of upper Paraná river basin, where more than 65% of all fish species described for this kind of environment are of small size (Langeani et al. 2007). According to Castro (1999) and Shibatta and Cheida (2003), one of the factors that can influence the small size of the species is the instability of the environmental conditions of the streams.

We do not find any species in the red book of Brazilian fauna threatened by extinction (ICMBIO, 2017). On the other hand, some of the species collected in this study, as *Astyanax bockmanni*, *Isbrueckerichthys* cf. *calvus*, *Neoplecostomus yapo*, and *Trichomycterus davisi* are associated with more pristine environments (Casatti et al. 2009, Jerep et al. 2006) and can be affected by changes in habitat complexity, water quality and hydromorphological aspects, influenced by common activities in the basin, such as agriculture and urbanization (Walsh et al. 2005, McKinney 2006, Alexandre et al. 2010).

We registered 4 non-native species, collected in the Uvaranal, Mandaçaia, and Engenho de Ferro streams; streams characterized for filing a degree of environmental degradation influenced by urbanization (municipalities of Telêmaco Borba and Ibiporã, Paraná). The degradation of aquatic environments influenced by urbanization can be associated with the invasion of non-native species

Figure 4. Fish species collected in streams from middle and lower sections of the Tibagi river basin, Paraná State, Brazil: **A**. *Hisonotus francirochai*, 33.3 mm SL, MZUEL 10120. **B**. *Hypostomus ancistroides*, 57.1 mm SL, MZUEL 8252. **C**. *Hypostomus strigaticeps*, 50.3 mm SL, MZUEL 9972. **D**. *Rineloricaria latirostris*, 74.5 mm SL, MZUEL 86.4. **E**. *Isbrueckerichthys* cf. *calvus*, 59.43 mm SL, MZUEL 11049. **F.** *Neoplecostomus yapo*, 65.2 mm SL, MZUEL 8182. **G**. *Otothyropsis biamnicus*, 33.2 mm SL, MZUEL 8187. **H**. *Hypostomus nigromaculatus*, 58.8 mm SL, MZUEL 8309.

and with increased pollution-tolerant species (Vieira and Shibatta 2007, Cunico et al. 2009, Leidy et al. 2011). *Coptodon rendalli* and *Oreochromis niloticus* are African species and possibly were introduced by escapes from pisciculture (Delariva and Agostinho 1999, Orsi and Agostinho 1999). *Poecilia reticulata* and *Xiphophorus hellerii* maybe were introduced to combat the mosquito's larvae or deliberate releases by aquarists (Shibatta et al. 2002, Rojas et al. 2004).

Astyanax was important in relation to species richness (5 species), distribution and abundance. The success of this genus can be influenced by high phenotypic plasticity and ability to adapt to diverse environments, a result of a series of ecological and morphological specializations, allowing access to most environments, mainly small streams (Ornelas-García et al. 2008, Matoso et al. 2013).

Bray-Curtis analysis showed the existence of similarity patterns in fish assemblages in streams sampled in each section (middle and lower); thus, the geographically closest streams have higher affinity among their ichthyofaunas. This pattern of similarity in relation to abundance and composition of fish assemblages between streams can be influenced by factors such as the physicochemical conditions of water and structural conditions such as substrate types. The streams of the middle and lower portions of the Rio Tibagi showed differences in variables like temperature, conductivity and dissolved oxygen, and proportion substrates like sand, gravel, clay, pebbles, and rocks (personal observation). Another factor that can influence the pattern of similarity between fish assemblages is the riparian forest, through the regulation of primary production and input of allochthonous resource (Vannote et al. 1980, Allan 2004). The riparian forest in Varanal and Lambedor streams is well preserved, while in others was affected by anthropic activities such as urbanization (Mandaçaia, Uvaranal, and Engenho de Ferro streams) or agriculture (Água Branca, Tigre and, Saltinho streams) (Table 1). There are other important factors such as water velocity, water flow, and the presence or absence of physical barriers such as waterfalls or rapids (Vannote et al. 1980, Araújo et al. 2009).

In general, the fish fauna of the middle section of Tibagi river basin has been threatened by human activities as urbanization, industry, agriculture, and currently with the construction of the hydroelectric plants. The Varanal, Uvaranal, Lambedor, and Mandaçaia streams will be influenced directly by the dams, isolation, or flooding. Thus, the Lambedor stream and part of private reserve of natural heritage in the Klabin S.A will be severely affected.

Acknowledgements

We are grateful to Aparecido de Souza, Edson Santana, and co-workers of the Museu de Zoologia da Universidade Estadual de Londrina in the assistance on fieldwork in the collection of fishes; to Klabin S.A. for the logistic support and for permitting collections in the Ecological Park; and to the Universidade Estadual de Londrina for providing the logistic support. ACG is granted with student fellowship by PEC-PG-CAPES/CNPq-Brasil. OAS is a research fellow of the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq Proc. 304868/2015-9).

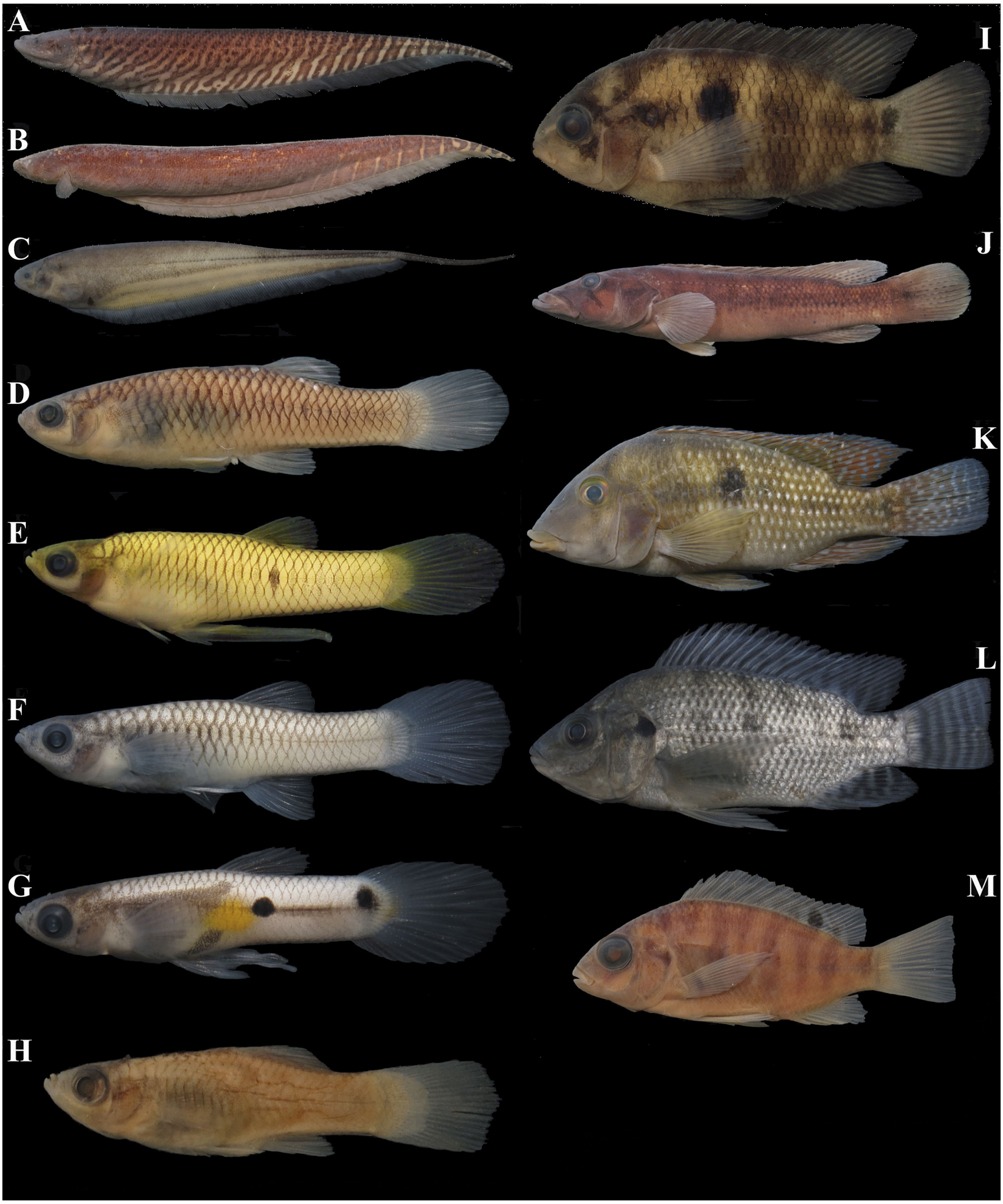

Figure 5. Fish species collected in streams from middle and lower sections of the Tibagi river basin, Paraná State, Brazil: **A**. *Gymnotus sylvius*, 105.3 mm SL, MZUEL 8223. **B**. *Gymnotus pantanal*, 191.2 mm SL, MZUEL 10021. **C.** *Eigenmannia virescens*, 185.4 mm SL, MZUEL 8280. **D**. *Phalloceros harpagos*, 36.75 mm SL, female, MZUEL 8258. **E**. *Phalloceros harpagos*, 20.8 mm SL, male, MZUEL 8258. **F**. *Poecilia reticulata*, 28.9 mm SL, female, MZUEL 10889; (**G**) *Poecilia reticulata*, 17.1 mm SL, male, MZUEL 10889. **H**. *Xiphophorus hellerii*, 23.5 mm SL, MZUEL, female, 8606. **I**. *Cichlasoma paranaense*, 58.7 mm SL, MZUEL 8482. **J**. *Crenicichla niederleinii*, 174.2 mm SL, MZUEL 10904. **K**. *Geophagus* cf. *brasiliensis*, 33.5 mm SL, MZUEL 9987. **L.** *Oreochromis niloticus*, 60.8 mm SL, MZUEL 8591. **M**. *Coptodon rendalli*, 54.6 mm SL, MZUEL 10086.

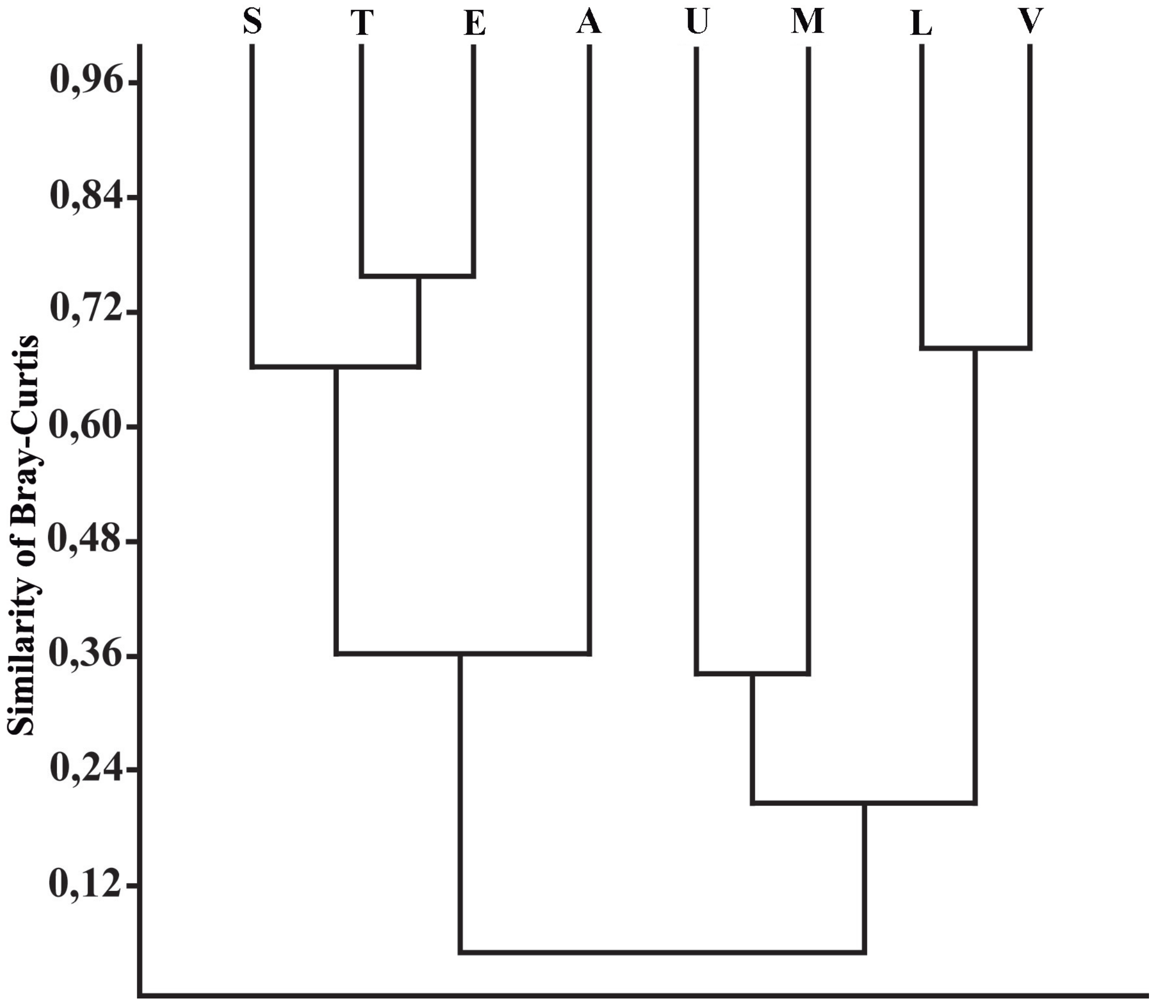

Figure 6. Similarity of Bray-Curtis of fish assemblages from streams of middle and lower section in the Tibagi river basin, Paraná State, Brazil. Varanal stream (V), Lambedor stream (L), Uvaranal stream (U), Mandaçaia stream (M), Saltinho stream (S), Água Branca stream (A), Tigre stream (T), Engenho de Ferro stream (T).

Authors' Contributions

ACG and FMA collected the data; ACG, FMA and OAS wrote the text.

References

Albert JS, Reis RE (2011) Historical Biogeography of Neotropical Freshwater Fishes. University of California Press, London, 406 pp.

Alexandre VA, Esteves KE, Moura e Mello MAM (2010) Analysis of fish communities along a rural-urban gradient in a neotropical stream (Piracicaba river basin, São Paulo, Brazil). Hydrobiologia 641 (1): 97–114. https://doi.org/10.1007/s10750-009-0060-y

Allan JD (2004) Landscapes and riverscapes: the influence of land use on stream ecosystems. Annual Review of Ecology Evolution and Systematics 35: 257–284. http://doi.org/bx26nw

Allan JD, Erickson DL, Fay J (1997) The influence of catchment land use on stream integrity across multiple spatial scales. Freshwater Biology 37: 149–161. http://doi.org/crt5p2

Araújo FG, Pinto BCT, Teixeira TP (2009) Longitudinal patterns of fish assemblages in a large tropical river in southeastern Brazil: evaluating environmental influences and some concepts in river ecology. Hydrobiologia 618 (1): 89–107. http://doi.org/d9sh9r

Bennemann ST, Shibatta OS, Vieira AOS (2008) A flora e a fauna do ribeirão Varanal: um estudo da biodiversidade no Paraná. EDUEL, Londrina, 158 pp.

Bennemann ST, Silva-Souza AT, Rocha GRA (1995) Composición ictiofaunistica en cinco localidades de la cuenca del rio Tibagi, PR–Brasil. Interciencia 20 (1): 7–13.

Bray JR, Curtis JT (1957) An Ordination of the Upland Forest Communities of Southern Wisconsin. Ecological Monographs 27: 325–349. https://doi.org/10.2307/1942268

Bruton MN (1996) Alternative life-history strategies of catfishes. Aquatic Living Resources 9: 35–41. http://doi.org/ckr2tw

Calegari BB, Lehmann PA, Reis RE (2013) Two new species of cascudinhos of the genus *Otothyropsis* (Siluriformes: Hypoptopomatinae) from the rio Paraná basin, Brazil. Zootaxa 3619 (2): 130–144. https://doi.org/10.11646/zootaxa.3619.2.2

Casatti L, Ferreira C (2009) A fish-based biotic integrity index for assessment of lowland streams in southeastern Brazil. Hydrobiologia 623 (1): 173–189. https://doi.org/10.1007/s10750-008-9656-x

Castro RMC (1999) Evolução da ictiofauna de riachos sul-americanos: padrões gerais e possíveis processos. Oecologia Brasiliensis 6: 139–155.

Cunico AM, Graça WJ da, Agostinho AA, Domingues WM, Latini JD (2009) Fish, Maringá urban streams, Pirapó river drainage, upper

Paraná river basin, Paraná state, Brazil. Check List 5 (2): 273–280. https://doi.org/10.15560/5.2.273

De França VD (2002) O rio Tibagi no contexto hidrogeográfico paranaense. In: Medri ME, Bianchini E, Shibatta OA, Pimenta JA (Eds) A Bacia do Rio Tibagi. M.E. Medri, Londrina, 45–61.

Delariva RL, Agostinho AA (1999) Introdução de espécies: uma síntese comentada. Acta Scientiarum 21 (2): 255–262. https://doi.org/10.4025/actascibiolsci.v21i0.4431

Eschmeyer WN, Fricke R, Laan R van der (Eds) (2017) Catalog of fishes: genera, species, references. http://research.calacademy.org/research/ichthyology/catalog/fihcatmain.asp. Accessed on: 2017-3-23.

Eschmeyer WN, Fong JD (2017) Species by Family/Subfamily. http://research.calacademy.org/research/ichthyology/catalog/SpeciesByFamily.asp. Accessed on: 2017-4-14.

Fernandes FMC, Albert JS, Daniel-Silva MFZ, Lopes CE, Crampton WGR, Almeida-Toledo LF (2005) A new *Gymnotus* (Teleostei: Gymnotiformes: Gymnotidae) from the Pantanal Matogrossense of Brazil and adjacent drainages: continued documentation of a cryptic fauna. Zootaxa 933: 1–14. https://doi.org/10.11646/zootaxa.933.1.1

Froese R, Pauly D (2017) FishBase (Version 02-2017). http://www.fishbase.org. Accessed on: 2017-4-2.

Galves W, Shibatta OA, Jerep FC (2007) Fish, Taquara river basin, northern of the state of Paraná, Brazil. Check List 3 (3): 353–359. https://doi.org/10.15560/3.3.253

Garavello JC, Britski HA (1987) Duas novas espécies do género *Leporinus* Spix, 1829, da bacia do alto Paraná (Teleostei, Anostomidae). Comunicações do Museu de Ciências e Tecnologia da PUCRS 44: 153–165.

Graça WJ, Pavanelli CS (2007) Peixes da planície de inundação do alto rio Paraná e áreas adjacentes. EDUEM, Maringá, 241 pp.

Hoffmann AC, Nascimento RHC, Shibatta OA (2015) Fish fauna from tributaries throughout the Tibagi river basin, upper Paraná, basin, Brazil. Check List 11 (6): 1–12. https://doi.org/10.15560/11.6.1815

ICMBIO (2017) Livro vermelho da fauna brasileira ameaçada de extinção. Instituto Chico Mendes de Conservação da Biodiversidade, Brasília, 75 pp.

Jerep FC, Shibatta OA, Pereira EHL, Oyakawa OT (2006) Two new species of *Isbrueckerichthys* Derijst, 1966 (Siluriformes: Loricariidae) from the rio Paranapanema basin, Brazil. Zootaxa 1372: 53–68.

Kullander SO (1983) A revision of the South American cichlid genus *Cichlasoma* (Teleostei: Cichlidae). Naturhistoriska Riksmuseet, Stockholm, 296 pp.

Langeani F (1990) Revisão do gênero *Neoplecostomus*, com a descrição de quatro espécies novas do sudeste brasileiro (Ostariophysi, Siluriformes, Loricariidae). Comunicações do Museu de Ciências da PUCRS 3 (1): 3–31.

Langeani F, Castro RMC, Oyakawa OT, Shibatta OA, Pavanelli CS, Casatti L (2007) Diversidade da ictiofauna do Alto Rio Paraná: composição atual e perspectivas futuras. Biota Neotropica 7 (3): 181–197.

Lee TR (2000) Urban water management for better urban life in Latin America. Urban Water 2: 71–78. https://doi.org/10.1016/S1462-0758(00)00041-8

Leidy RA, Kristina CY, Carlson SM (2011) Persistence of native fishes in small streams of the urbanized San Francisco Estuary, California: acknowledging the role of urban streams in native fish conservation. Aquatic Conservation: Marine and Freshwater Ecosystems 21: 472–483. https://doi.org/10.1002/aqc.1208

Lima FCT, Malabarba LR, Buckup PA, Pezzi da Silva JF, Vari RP, Harold A, Benine R, Oyakawa OT, Pavanelli CS, Menezes NA, Lucena CAS, Malabarba MCSL, Lucena ZMS, Reis RE, Langeani F, Casatti L, Bertaco VA, Moreira C, Lucinda PHF (2003) Genera *incertae sedis* in Characidae. In: Reis RE, Kullander SO, Ferraris CJ (Eds) Check List of the Freshwater Fishes of South and Central America. Edipucrs, Porto Alegre, 134–141.

Lucena CAS, Calegari BB, Pereira EHL, Dallegrave E (2013) O uso de óleo de cravo na eutanásia de peixes. Boletim Sociedade Brasileira de Ictiologia 105: 20–24.

Lucena CAS, Castro JB, Bertaco VA (2013) Three new species of *Astyanax* from drainages of southern Brazil (Characiformes: Characidae). Neotropical Ichthyology 11 (3): 537–552. https://doi.org/10.1590/S1679-62252013000300007

Lucena CAS, Soares HG (2016) Review of species of the *Astyanax bimaculatus* "caudal peduncle spot" subgroup *sensu* Garutti & Langeani (Characiformes, Characidae) from the rio La Plata and rio São Francisco drainages and coastal systems of southern Brazil and Uruguay. Zootaxa 4072 (1): 101–125. https://doi.org/10.11646/zootaxa.4072.1.5

Lucinda PHF (2008) Systematics and biogeography of the genus *Phalloceros* Eigenmann, 1907 (Cyprinodontiformes: Poeciliidae: Poeciliinae), with the description of twenty-one new species. Neotropical Ichthyology 6 (2): 113–158.

Malabarba LR, Neto PC, Bertaco VA, Carvalho TP, Santos JF dos, Artioli LGS (2013) Guia de identificação dos peixes da bacia do rio Tramandaí. Via Sapiens, Porto Alegre, 140 pp.

Martins FO, Langeani F, Zawadzki CH (2014) A new spiny species of *Hypostomus* Lacépède (Loricariidae: Hypostominae) from thermal waters, upper rio Paraná basin, central Brazil. Neotropical Ichthyology 12 (4): 729–736. https://doi.org/10.1590/1982-0224-20140035

Matson PA, Parton WJ, Power AG, Swift MJ (1997) Agricultural intensification and ecosystem properties. Science 277: 504–509. https://doi.org/10.1126/science.277.5325.504

Matoso DA, Silva M da, Artoni RF, Torres RA (2013) Molecular taxonomy and evolutionary hypothesis concerning *Astyanax fasciatus* (Characiformes, Characidae) from Vila Velha State Park and Tibagi and Iguaçu Rivers. Genetics and Molecular Research 12 (1): 631–638. https://doi.org/10.4238/2013.March.7.1

McKinney ML (2006) Urbanization as a major cause of biotic homogenization. Biological Conservation 127 (3): 247–260. http://doi.org/10.1016/j.biocon.2005.09.005

Medri ME, Bianchini E, Shibatta OA, Pimenta JA (Eds) (2002) A bacia do rio Tibagi, Edition of Editors. M.E. Medri, Londrina, 595 pp.

Oliveira DC, Bennemann ST (2005) Ictiofauna, recursos alimentares e relações com as interferências antrópicas em um riacho urbano no sul do Brasil. Biota Neotropica 5(1): 95–107. https://doi.org/10.1590/S1676-06032005000100001

Ornelas-García CP, Domínguez-Domínguez O, Doadrio I (2008) Evolutionary history of the fish genus *Astyanax* Baird & Girard (1854) (Actinopterygii, Characidae) in Mesoamerica reveals multiple morphological homoplasies. BMC Evolutionary Biology 8: 340. https://doi.org/10.1186/1471-2148-8-340

Orsi ML, Agostinho AA (1999) Introdução de espécies de peixes por escapes acidentais de tanques de cultivo em rios da bacia do rio Paraná, Brasil. Revista Brasileira de Zoologia 16: 557–560. https://doi.org/10.1590/S0101-81751999000200020

Ortí G (1997) The radiation of Characiform fishes: evidence from mitochondrial and nuclear DNA sequences. In: Kocher TD, Stepien C (Eds) Molecular Systematics of Fishes. Academic Press, San Diego, California, 215–239.

Oyakawa OT, Akama A, Mautari KC, Nolasco JC (2006) Peixes de riachos da Mata Atlântica: nas unidades de conservação do Vale do Rio Ribeira de Iguape no Estado de São Paulo. Neotropica, São Paulo, 201 pp.

Pinese JPP (2002) Síntese geológica da bacia do rio Tibagi: In: Medri ME, Bianchini E, Shibatta OA, Pimenta JA (Eds) A bacia do rio Tibagi. M.E. Medri, Londrina, 21–38.

QGIS Development Team (2014) QGIS Geographic Information System. Open Source Geospatial Foundation Project. Version 2.10.1. http://www.qgis.org.

Reis RE, Kullander SO, Ferraris Jr C (2003) Check list of the freshwater fishes of South and Central America. EDIPUCRS, Porto Alegre, 742 pp.

Reis RE (2013) Conserving the freshwater fishes of South America. International Zoo Yearbook 47: 65–70. http://doi.org/cg53

Reis RE, Albert JS, Di Dario F, Mincarone MM, Petry P, Rocha LA (2016) Fish biodiversity and conservation in South America. Journal of Fish Biology 89 (1): 12–47. https://doi.org/10.1111/jfb.13016

Richer-de-Forges MM, Crampton WGR, Albert JS (2009) A new species of *Gymnotus* (Gymnotiformes, Gymnotidae) from Uruguay: description of a model species in neurophysiological research. Copeia 2009 (3): 538–544. https://doi.org/10.1643/CI-13-054

Rojas PE, Gamboa BM, Villalobos RS, Cruzado VF (2004) Eficacia del control de larvas de vectores de la malaria con peces larvivoros nativos de San Martin, Perú. Revista Peruana de Medicina Experimental y Salud Publica 21: 44–50.

Shibatta OA, Orsi ML, Bennemann ST, Silva-Souza AT (2002) Diversidade e distribuição de peixes na bacia do Rio Tibagi. In: Medri ME, Bianchini E, Shibatta OA, Pimenta JA (Eds) A Bacia do rio Tibagi. M.E. Medri, Londrina, 403–423.

Shibatta OA, Cheida CC (2003) Composição em tamanho dos peixes (Actinopterygii, Teleostei) de ribeirões da bacia do rio Tibagi, Paraná, Brasil. Revista Brasileira de Zoologia 20 (3): 469–473. https://doi.org/10.1590/S0101-81752003000300016

Shibatta OA, Orsi ML, Bennemann ST (2006) Os peixes do Parque Estadual Mata dos Godoy. In: Torezan JM (Ed) Ecologia do Parque Estadual Mata do Godoy. Itedes, Londrina, 156–167.

Shibatta OA, Gealh AM, Bennemann ST (2007) Ictiofauna dos trechos alto e médio da bacia do rio Tibagi, Paraná, Brasil. Biota Neotropica 7 (2): 125–134.

Shibatta OA, Bennemann ST, Mori H, Silva DF (2008) Riqueza biológica e ecológica dos peixes do Ribeirão do Varanal. In: Bennemann ST, Shibatta OA, Vieira AOS. A Flora e a Fauna do Ribeirão do Varanal, um Estudo da Biodiversidade do Paraná. EDUEL, Londrina, 77– 97.

Silva JFM, Raio CB, Bernardino DFS, Bennemann ST (2013) Longitudinal patterns of fish assemblages in mountain streams from tropical forest biome. Biota Neotropica 13 (3): 64–73.

Stevaux JC, Souza-Filho EE de, Jabur IC (1997) A história quaternária do rio Paraná em seu alto curso. In: Vazzoler AEAM, Agostinho AA, Hahn NS (Eds) A planície de inundação do alto rio Paraná: aspectos físicos, biológicos e socioeconômicos. EDUEM, Maringá, 47–72.

Tscharntke T, Klein AM, Kruess A, Steffan-Dewenter I, Thies C (2005) Landscape perspectives on agricultural intensification and biodiversity: ecosystem service management. Ecology Letters 8: 857–874. https://doi.org/10.1111/j.1461-0248.2005.00782.x

Vannote RL, Minshall GW, Cummins KW, Sedell JR, Cushing CE (1980) The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37 (1): 130–137. https://doi.org/10.1139/f80-017

Vari RP, Castro RMC (2007) New species of *Astyanax* (Ostraiophysi: Characiformes: Characidae) from the upper Rio Paraná system, Brazil. Copeia 2007 (1): 150–162. https://doi.org/10.1643/0045-8511(2007)7[150:NSOAOC]2.0.CO;2

Vazzoler AEAM (1996). Biologia da reprodução de peixes teleósteos: teoria e prática. EDUEM/SBI/CNPq/Nupélia, Maringá, 169 pp.

Vidal LVO, Albinati RCB, Albinati ACL, Lira AD, Almeida TR, Santos GB (2008) Eugenol como anestésico para a tilápia-do-nilo. Pesquisa Agropecuária Brasileira 43(8): 1069–1074. https://doi.org/10.1590/S0100-204X2008000800017

Vieira DB, Shibatta OA (2007) Peixes como indicadores da qualidade ambiental do ribeirão Esperança, município de Londrina, Paraná, Brasil. Biota Neotropica 7(1): 57–65. https://doi.org/10.1590/S1676-06032007000100008

Walsh CJ, Roy AH, Feminella JW, Cottingham PD, Groffman PM, Morgan II RP (2005) The urban stream syndrome: current knowledge and the search for a cure. Journal of the North American Benthological Society 24 (3): 706–723. https://doi.org/10.1899/04-028.1

Table 2. List of fish species and voucher numbers of the specimens collected in streams from middle and lower section in the Tibagi river basin, Paraná States, Brazil. Varanal stream (V), Lambedor stream (L), Uvaranal stream (U), Mandaçaia stream (M), Saltinho stream (S), Água Branca stream (A), Tigre stream (T), Engenho de Ferro stream (E). * Non-native species.

Taxa	Middle Tibagi				Lower Tibagi				Voucher specimens
	V	L	U	M	S	A	T	E	
Characiformes									
Parodontidae									
Apareiodon ibitiensis Amaral Campos, 1944			X				X	X	MZUEL 8250
Apareiodon piracicabae (Eigenmann, 1907)	X				X		X	X	MZUEL 8204
Curimatidae									
Steindachnerina insculpta (Fernández-Yépez, 1948)							X	X	MZUEL 8569
Anostomidae									
Leporinus amblyrhynchus Garavello & Britski, 1987	X								MZUEL 10868
Erythrinidae									
Hoplias cf. *malabaricus* (Bloch, 1794)					X				MZUEL 8501
Characidae									
Astyanax bockmanni Vari& Castro, 2007	X				X	X	X	X	MZUEL 8187
Astyanax aff. *fasciatus* (Cuvier, 1819)	X	X	X	X	X	X	X	X	MZUEL 8174
Astyanax lacustris (Lütken 1875)				X	X		X	X	MZUEL 8629
Astyanax paranae Eigenmann, 1914	X	X	X	X					MZUEL 8181
Astyanax aff. *paranae* Eigenmann, 1914					X	X	X	X	MZUEL 8228
Bryconamericus aff. *iheringii* (Boulenger, 1887)	X			X	X		X	X	MZUEL 8211
Piabarchus stramineus (Eigenmann, 1908)	X			X	X		X	X	MZUEL 8282
Oligosarcus paranensis Menezes &Géry, 1983	X			X	X		X		MZUEL 8177
Piabina argentea Reinhardt, 1867	X			X	X	X	X	X	MZUEL 8178
Serrapinnus notomelas (Eigenmann, 1915)				X			X	X	MZUEL 8286
Crenuchidae									
Characidium aff. *zebra* Eigenmann, 1909					X	X	X	X	MZUEL 8203
Siluriformes									
Heptapteridae									
Cetopsorhamdia iheringi Schubart & Gomes, 1959					X		X	X	MZUEL 8216
Imparfinis mirini Haseman, 1911					X	X	X	X	MZUEL 8207

Table 2. *Continued.*

Taxa	Middle Tibagi				Lower Tibagi				Voucher specimens
	V	L	U	M	S	A	T	E	
Phenacorhamdia tenebrosa (Schubart, 1964)					X			X	MZUEL 8308
Pimelodella gracilis (Valenciennes, 1835)								X	MZUEL 10017
Rhamdia cf. *quelen* (Quoy & Gaimard, 1824)	X				X	X	X	X	MZUEL 8179
Trichomycteridae									
Trichomycterus davisi (Haseman, 1911)	X	X	X	X				X	MZUEL 8183
Callichthyidae									
Corydoras aeneus (Gill, 1858)							X	X	MZUEL 8287
Corydoras ehrhardti Steindachner, 1910			X						MZUEL 8251
Corydoras longipinnis Knaack, 2007								X	MZUEL 8603
Loricariidae									
Hisonotus francirochai (Ihering, 1928)								X	MZUEL 8218
Hypostomus ancistroides (Ihering, 1911)	X		X	X	X	X	X	X	MZUEL 8180
Hypostomus nigromaculatus (Schubart, 1964)					X				MZUEL 8309
Hypostomus strigaticeps (Regan, 1908)					X	X	X	X	MZUEL 8210
Isbrueckerichthys cf. *calvus* Jerep, Shibatta, Pereira & Oyakawa, 2006		X							MZUEL 8195
Neoplecostomus yapo Zawadzki, Pavanelli & Langeani, 2008	X								MZUEL 8182
Otothyropsis biamnicus Calegari, Lehmann A. & Reis, 2013				X					MZUEL 8187
Rineloricaria latirostris (Boulenger, 1900)			X	X					MZUEL 8186
Gymnotiformes									
Gymnotidae									
Gymnotus sylvius Albert & Fernandes-Matioli, 1999					X		X	X	MZUEL 8223
Gymnotus pantanal Fernandes, Albert, Daniel-Silva, Lopes, Crampton & Almeida-Toledo, 2005								X	MZUEL 10021
Eigenmannia cf. *virescens* (Valenciennes, 1836)							X		MZUEL 8280
Cyprinodontiformes									
Poeciliidae									
Phalloceros harpagos Lucinda, 2008			X	X	X				MZUEL 8190
*Poecilia reticulata** Peters, 1859						X	X	X	MZUEL 8224
*Xiphophorus hellerii** Heckel, 1848								X	MZUEL 8606
Cichliformes									
Cichlidae									
Cichlasoma paranaense Kullander, 1983						X			MZUEL 8482
Crenicichla niederleinii (Holmberg, 1891)					X		X		MZUEL 8260
Geophagus cf. *brasiliensis* (Quoy & Gaimard, 1824)					X		X	X	MZUEL 8222
*Oreochromis niloticus** (Linnaeus, 1758)								X	MZUEL 8591
*Coptodon rendalli** (Boulenger, 1897)			X						MZUEL 10086