Check List the journal of biodiversity data

LISTS OF SPECIES

Check List 11(6): 1815, 18 December 2015 doi: http://dx.doi.org/10.15560/11.6.1815
ISSN 1809-127X

Fish fauna from tributaries throughout the Tibagi River basin, upper Paraná basin, Brazil

Ana Cecília Hoffmann[1,2*], **Raul Henrique Cardoso Nascimento**[2] and **Oscar Akio Shibatta**[2]

1 Universidade Estadual do Norte do Paraná, Centro de Ciências Biológicas, Departamento de Biologia e Tecnologia, BR 369, Km 54, CEP 86360-000, Bandeirantes, PR, Brazil
2 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. E-mail: cecishoffmann@hotmail.com

Abstract: Fishes were collected at 36 sites in first order streams of Tibagi River basin, Paraná state, Brazil. A total of 2,669 individuals belonging to 47 species of 13 families and six orders were collected. The number of collected species represented 95.9% of the expected number of species for the studied area as estimated by Chao 1, and 93.4% by ACE, indicating an effective sampling. The highest richness was recorded in the tributaries at the lower region (Zone III) of the Tibagi River basin, with 33 species, including 16 species not found in the other regions of the basin. In the streams of the middle and upper regions (Zones II and I) each presented less richness, with 10 (two exclusive) and 25 (11 exclusive) species, respectively. This study shows a high geographic variation in the composition of fish fauna among zones, maybe related to historical and/or ecological influences.

Key words: freshwater, Neotropical Region, Upper Paraná River

INTRODUCTION

Fishes from the Tibagi River basin have been studied since 1989 (Shibatta et al. 2002). However, surveys of their diversity in first order streams were restricted to few localities. For example, there are studies encompassing only one stream (Oliveira and Bennemann 2005, Galves et al. 2007b, Vieira and Shibatta 2007; Shibatta et al. 2008), three (Galves et al. 2007a), eight (Shibatta and Cheida 2003), and 10 streams (Shibatta et al. 2002), but none of them compared the diversity along the basin.

Therefore, this work is intended to add species to the list of ichthyofauna of the Tibagi River basin, with sampling points in its three zones (Zone I: upper, Zone II: middle and Zone III: lower regions of the basin). The emphasis was given to the first-order streams, because a large part of the fish diversity in these environments is still poorly known, and because their environmental characteristics are being affected by increasing urbanization making urgent the study of fish fauna.

This study aims to survey the fish species in streams of the Tibagi River basin, and to test the hypothesis that its upper, middle, and lower regions present different species richness.

MATERIAL AND METHODS

Study sites

The Tibagi River is the main tributary of the left bank of the Paranapanema River, a tributary within the Paraná River basin (França 2002). The Tibagi River basin is located between the geographic coordinates 22°47′22″ and 25°36′25″ S and 049°36′00″ and 051°27′36″ W, and is formed by 65 direct tributaries, encompassing an area of 25,000 km². Its headwaters are located in southern Paraná State, in Palmeira city, at 1,060 m of altitude. The Tibagi River runs 550 km northward to its mouth at the Capivara dam, Paranapanema River, at 298 m altitude (Medri et al. 2002).

Fishes were collected in 36 sites (Table 1) in first-order streams along the Tibagi River basin (Figure 1). The sampled streams had widths ranging from 0.5–5 m and depths of 0.10–1.20 m.

According to the hydrodynamic behavior and water availability associated with regional climatic factors, the basin is divided into Zones I, II, and III (França 2002). The collection sites cover the first, second and third plateau of the Paraná state (Maack 2012). Zone I, or upper Tibagi River basin, corresponds to the headwaters. It is located in southern of the state, and includes the geomorphological region of the Ponta Grossa Plateau (França 2002). Zone II, or

Table 1. Location of the sampling sites along the Tibagi River basin.

Zone	Sampling Sites	Latitude (S)	Longitude (W)	Alt (m)
Zone I	S01	24°25′32.40″	049°50′35.90″	1,028
	S02	24°30′28.70″	049°54′42.90″	1,012
	S03	24°29′59.50″	049°53′45.10″	1,025
	S04	24°31′15.90″	049°55′08.20″	1,015
	S05	24°28′47.80″	049°51′29.70″	1,034
	S06	25°17′14.30″	049°50′33.00″	1,048
	S07	25°17′50.00″	049°55′50.40″	864
	S08	25°19′17.80″	049°50′40.50″	989
	S09	25°23′55.00″	049°49′20.40″	980
	S10	25°23′21.80″	049°49′34.00″	984
	S11	25°16′14.70″	049°56′32.30″	770
	S12	25°28′12.60″	050°19′44.40″	824
	S13	25°29′04.80″	050°19′17.50″	834
	S14	25°28′08.20″	050°23′19.10″	852
	S15	25°27′52.50″	050°23′24.70″	834
	S16	25°26′01.80″	050°36′39.30″	802
Zone II	S17	24°15′01.90″	050°54′55.00″	812
	S18	24°16′22.00″	050°54′05.10″	813
	S19	24°10′56.50″	050° 56′31.50″	693
	S20	24°14′42.80″	050° 56′12.90″	783
	S21	24°19′11.10″	050°51′09.10″	803
Zone III	S22	23°05′05.60″	051°07′36.80″	415
	S23	23°01′17.40″	051°07′58.20″	400
	S24	22°52′44.80″	051°03′30.10″	371
	S25	23°01′39.80″	051°08′32.70″	436
	S26	22°52′43.40″	051°00′47.70″	359
	S27	23°33′13.80″	050°46′00.50″	642
	S28	23°34′57.80″	050°43′06.20″	698
	S29	23°34′43.50″	050°47′08.90″	662
	S30	23°29′07.10″	050°45′20.30″	568
	S31	23°32′14.80″	050°47′37.40″	606
	S32	23°25′41.60″	051°23′00.20″	577
	S33	23°24′55.81″	051°24′03.49″	699
	S34	23°28′30.61″	051°21′38.64″	716
	S35	23°21′12.90″	051°21′22.50″	645
	S36	23°22′59.90″	051°18′37.60″	557

medium Tibagi River basin, has its territorial domain extending to the limits of the Second Paraná Plateau, running in a south to north direction. Zone III, or lower Tibagi River basin, is located on the Third Paraná Plateau (França 2002) (Figure 1).

Samples

Collections of fishes were conducted from December 2012 to August 2014 (collecting permit number SISBIO 12120-1, 09/16/2007). Each site was sampled for 60 minutes, using two sieves and a seine. The fishes were instantly fixed in 10% formalin and after 24 to 48 h transferred to 70% ethanol. The classification into orders and families follows Eschmeyer (2014). The vouchers are deposited in the collection of the Museu de Zoologia da Universidade Estadual de Londrina (MZUEL), Londrina, Paraná, Brazil. The list of vouchers is presented in Appendix 1, with number of individuals followed by the minimum and maximum standard length (SL), or total length (TL), per lot.

Data analysis

The collection efficiency was evaluated by the collector curve using the EstimateS 8.2 software (Colwell 2009). Non-parametric estimators Chao 1 (Incidence-based Coverage Estimator; Chao 1987) and ACE (Abundance-based Coverage Estimator; Lee and Chao 1994) were used to compare the estimates of richness among data sets of this inventory, considering the species-abundance distribution of the samples. Box plot analysis was used to compare the composition of species among zones, and was performed using the software PAST v.2.7c (Hammer et al. 2001). Data were standardized to evaluate the similarity of species among streams of the three zones, applying the square root on the ratio of the presence of the species (represented by "1") divided by its abundance. These data were submitted to a clusters analysis with Bray-Curtis similarities using the software PAST v.2.7c (Hammer et al. 2001). Quantum GIS 2.0.1 software was used to produce a map of geographical distribution of collection sites (QGIS Development Team 2014).

RESULTS

A total of 2,669 specimens of fishes were collected, belonging to 47 species (see photographs in Figure A1, A2, A3, A4, and A5) of 13 families and 6 orders (Table 2). The richest order was Siluriformes (19 species), followed by Characiformes (18 species), corresponding together to 78% of the total number of species.

The expected number of species for the study area, according to the accumulation curve of species based on Chao 1 was 49, and 50 by ACE. The observed species richness (47 species) represented 95.9% of the species estimated by Chao 1 and 93.4% by ACE, indicating the efficiency of the sampling methods (Figure 2).

The 36 sampling sites presented richness ranging from 1 to 11 species (Figure 3). The Zone II showed less variation and the lower species richness between the portions studied (2 to 4 species), and the Zone III the opposite, showed greater variation and richness (3 to 11 species).

There was no capture of endemic species in the Tibagi River basin, but nevertheless, there were differences in the ichthyofauna richness among the three regions of the basin. The Zone III showed the highest richness, with 33 species, including 16 exclusive to this region. The Zone II and Zone I presented less richness than the Zone III, with 10 (2 exclusive) and 25 (11 exclusive) species, respectively. These results were similar to those shown in the similarity analysis (Figure 4), which showed a trend of different clustering of the sampled points of Zones I and III, and only the sites of Zone II of the Tibagi River basin mixing fish fauna with the Zone I.

All the collected specimens were small to medium-sized. The species with smallest maximum size was *Poecilia reticulata* (31.0 mm SL) and the largest maximum size was *Gymnotus omarorum* (220.5 mm TL).

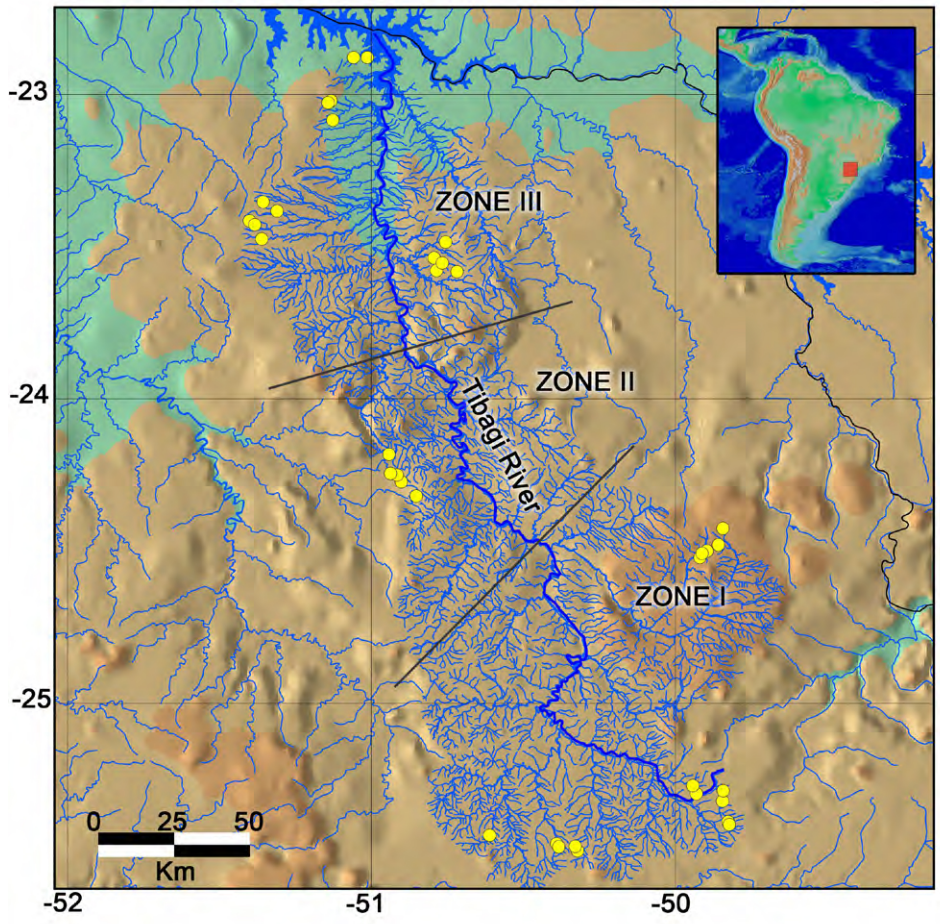

Figure 1. Sampling sites in first order streams of three zones of the Tibagi River basin, Paraná state, Brazil.

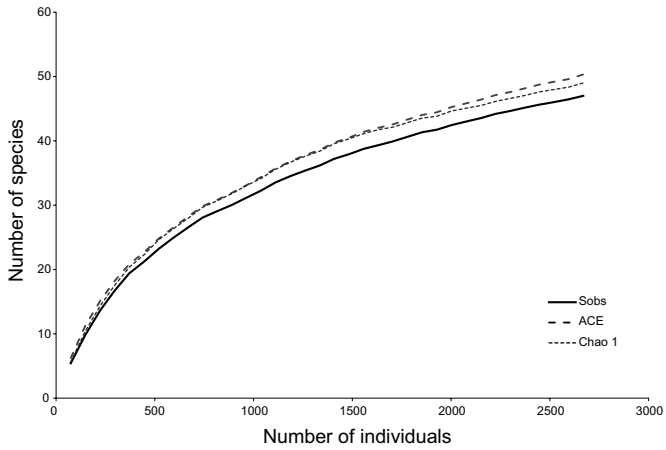

Figure 2. Comparison of species accumulation curves generated by species richness (Sobs) and the richness estimators (ACE and Chao 1), for collections made in the tributaries of the Tibagi River basin, Paraná state, Brazil.

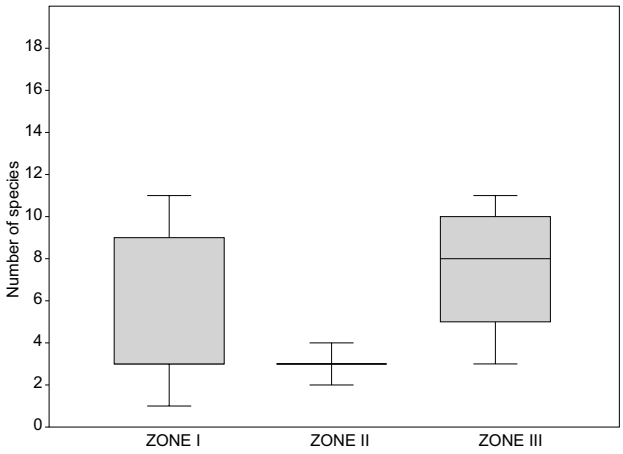

Figure 3. Box plot comparing the richness of species between the three zones of the Tibagi River basin.

Four species were widely distributed at sampling sites of this study, occurring in all zones: *Phalloceros harpagos*, which occurred in 22 localities, *Trichomycterus davisi*, which occurred in 14 localities, *Astyanax paranae*, which was found in 12 localities, and *Geophagus brasiliensis*, which occurred in six localities. Furthermore, three species that are considered rare were sampled in the Zone I of the basin; they are *Mimagoniates microlepis*, *Rhamdiopsis moreirai* and *Characidium schubarti*.

DISCUSSION

The pattern observed in composition, with predominance of Siluriformes and Characiformes, has been extensively discussed for Neotropical rivers and streams (Lowe-McConnell 1999). However, the order with highest abundance was Cyprinodontiformes, which represented 48% of the total sampled, with 1,284 individuals. This is due to the high dominance of a single species *Phalloceros harpagos*, with a total of 1,180 individuals captured.

Table 2. List of freshwater fish species and number of specimens from the streams of Tibagi River basin sampled in this study.

Taxa	Zone I	Zone II	Zone III
CHARACIFORMES			
Curimatidae			
Steindachnerina insculpta (Fernández-Yépez, 1948)			16
Parodontidae			
Apareiodon ibitiensis Amaral Campos, 1944			10
Apareiodon piracicabae (Eigenmann, 1907)			2
Erythrinidae			
Hoplias malabaricus (Bloch, 1794)	2		2
Characidae			
Astyanax altiparanae Garutti & Britski, 2000			18
Astyanax bockmanni Vari & Castro, 2007			77
Astyanax fasciatus (Cuvier, 1819)	10		4
Astyanax paranae Eigenmann, 1914	49	1	16
Astyanax sp.		5	
Bryconamericus iheringii (Boulenger, 1887)		14	61
Bryconamericus stramineus Eigenmann, 1908	5		32
Hyphesobrycon boulengeri (Eigenmann, 1907)	1		
Mimagoniates microlepis (Steindachner, 1877)	1		
Oligosarcus paranensis Menezes & Géry, 1983		25	3
Piabina argentea Reinhardt, 1867			61
Crenuchidae			
Characidium gomesi Travassos, 1956	36		1
Characidium schubarti Travassos, 1955	30		
Characidium zebra Eigenmann, 1909	7		17
SILURIFORMES			
Heptapteridae			
Cetopsorhamdia iheringi Schubart & Gomes, 1959			18
Imparfinis mirini Haseman, 1911	7		33
Phenacorhamdia tenebrosa (Schubart, 1964)			7
Pimelodella gracilis (Valenciennes, 1835)	7		
Rhamdia quelen (Quoy & Gaimard, 1824)	4		11
Rhamdiopsis moreirai Haseman, 1911	3		
Trichomycteridae			
Trichomycterus candidus (Miranda Ribeiro, 1949)	15		
Trichomycterus castroi de Pinna, 1992	6		
Trichomycterus davisi (Haseman, 1911)	266	15	12
Trichomycterus diabolus Bockmann, Casatti & de Pinna, 2004	11		19
Callichthyidae			
Callichthys callichthys (Linnaeus, 1758)	1		
Corydoras aeneus (Gill, 1858)			21
Corydoras ehrhardti Steindachner, 1910	110		
Loricariidae			
Hisonotus francirochai (Ihering, 1928)	20		26
Hypostomus ancistroides (Ihering, 1911)		2	168
Hypostomus nigromaculatus (Schubart, 1964)			6
Hypostomus strigaticeps (Regan, 1908)			19
Neoplecostomus paranensis Langeani, 1990			1
Neoplecostomus selenae Zawadzki, Pavanelli & Langeani, 2008	13		
Neoplecostomus yapo Zawadzki, Pavanelli & Langeani, 2008		3	8
Otothyropsis biamnicus Calegari, Lehmann A. & Reis, 2013	2		
GYMNOTIFORMES			
Gymnotidae			
Gymnotus omarorum Richer-de-Forges, Crampton & Albert, 2009			3
CYPRINODONTIFORMES			
Poeciliidae			
Phalloceros harpagos Lucinda, 2008	1110	61	9
Poecilia reticulata Peters, 1859			97
Cnesterodon hypselurus Lucinda & Garavello, 2001	7		
SYNBRANCHIFORMES			
Synbranchidae			
Synbranchus marmoratus Bloch, 1795			2
PERCIFORMES			
Cichlidae			
Crenicichla jaguarensis (Holmberg, 1891)			1
Geophagus brasiliensis (Quoy & Gaimard, 1824)	22	6	9
Oreochromis niloticus (Linnaeus, 1758)		2	

The high dominance of a species usually is related to the environmental disturbances, when one species is favored by the new conditions in contrary to the majority (Casatti et al. 2006; Pinto et al. 2006).

The low richness in streams of upper Paraná basin was also reported by other authors (Bennemann et al. 1995; Shibatta et al. 2002; Costa et al. 2013). Also, only 15 species was recorded by Oliveira and Bennemann (2005) and 12 species by Vieira and Shibatta (2007) in streams of Zone III.

All the specimens collected are of small size, typical habitants of small streams (Castro 1999). Besides, small species represent the vast majority of species found in streams, nearly 50% of all fish species described for this kind of environments in South America (Castro 1999), and more than 65% of the species of the Upper Paraná River basin (Langeani et al. 2007).

Two introduced species were recorded, *Poecilia reticulata* and *Oreochromis niloticus*, which together account for 3.7% of total captured specimens. The origin of introduction of these species is not known, but the first is very common in the local aquarium stores, and the second is raised in regional aquacultures. It is not difficult to consider that the introduction of *P. reticulata* was by aquarists who released fish into the wild, and the escape of *O. niloticus* from overflowing tanks during heavy rains.

This study shows that streams within the same river basin, of the same order, but in different portions of the river, may differ in species richness. Only four species (*Astyanax paranae*, *Geophagus brasiliensis*, *Phalloceros harpagos*, and *Trichomycterus davisi*) occurred in all Zones, and can be considered representative species of first order streams of Tibagi River basin. The presence of *Mimagoniates microlepis*, a species widely distributed in streams of Brazilian coastal region (Menezes et al. 2007), and *Rhamdiopsis moreirai*, a species described from Iguaçu River basin (Haseman 1911), in Zone I, is an indication of influence of adjacent basins in the fish composition of Tibagi River basin. *Characidium schubarti* was first recorded to the Tibagi River basin, in Zone I only. Its distribution is probably restricted due to differences in the environment along the Tibagi River basin.

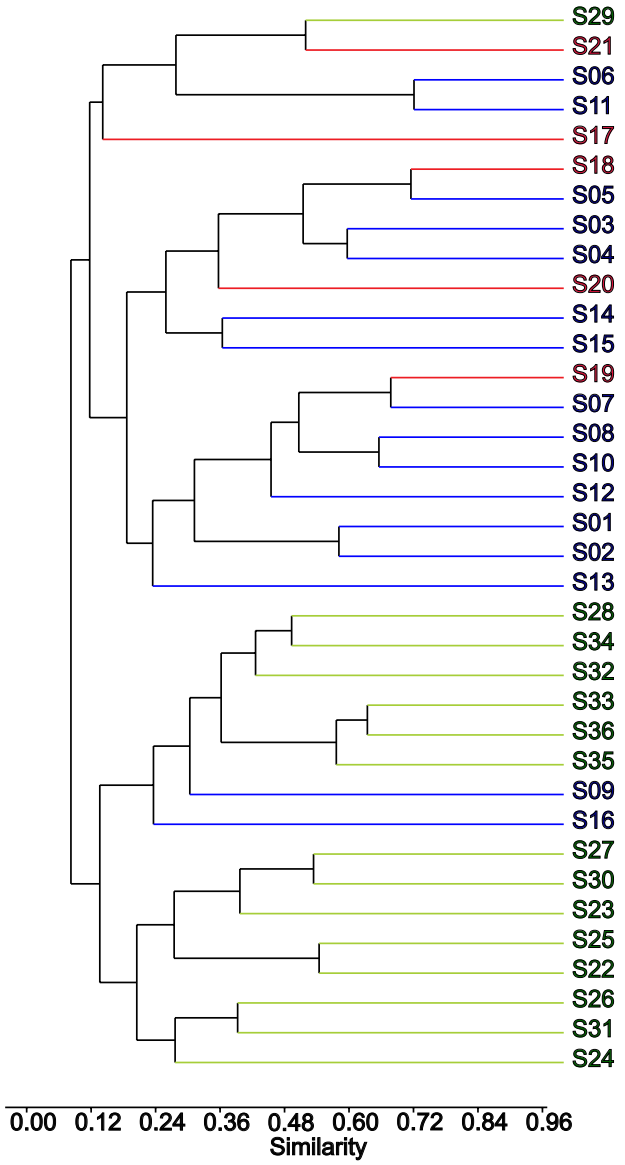

Figure 4. Clusters analyses of Bray Curtis similarities of sampling sites (S) from Tibagi River between the three Zones: I (blue), II (red) and III (green).

The Jaguariaiva River and the upper Tibagi River streams of Zone I are located in a region named "Campos Gerais", with similar soil and topography. The physical characteristics of the "Campos Gerais" are distinct from the remaining portions of the Tibagi River basin (Torezan 2002).

The highest number of species in Zone III may represent influences of the Paranapanema River, acting as a corridor for species dispersion. Comparing the species composition of this study to that of Castro et al. (2003), we find that of 16 exclusive species collected in Zone III, 12 is common to that study, evidencing more similarity in composition of this part of Tibagi River with the Paranapanema River basin than to the Zones II and I. Therefore, the differences in composition are maybe related to historical and ecological features of the basin.

ACKNOWLEDGEMENTS

We are indebted to Edson Santana (UEL), Aparecido de Souza (UEL), and coworkers of the Museu de Zoologia da Universidade Estadual de Londrina for helping in the collection of fishes; to the Parque Estadual do Cerrado for hosting in Jaguariaíva and Floresta Nacional de Irati; to Fernando C. Jerep (UEL) and José Luís Birindelli (UEL), for help in identifying the species, and for both and Sirlei T. Bennemann (UEL) for suggestions that improved the paper; to Universidade Estadual de Londrina for providing the logistic support; and to Coordenadoria de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for financial support to ACH and RHCN. OAS has a research productivity grant of Fundação Araucária.

LITERATURE CITED

Bennemann, S.T., A.T. Silva-Souza and G.R.A. Rocha. 1995. Composicion ictiofaunistica en cinco localidades de la cuenca del rio Tibagi, PR–Brasil. Interciencia 20(1): 7-13. http://www.interciencia.org.ve

Casatti, L., F. Langeani and C.P. Ferreira. 2006. Effects of physical habitat degradation on the stream fish assemblage structure in a pasture region. Environmental Management 38(6): 974–982. doi: 10.1007/s00267-005-0212-4

Castro, R.M.C. 1999. Evolução da ictiofauna de riachos sul-americanos: padrões gerais e possíveis processos; pp. 139–155, in: E. P Caramaschi, R. Mazzoni, and P. R. Peres-Neto (ed.). Ecologia de peixes de riachos. Série Oecologia Brasiliensis VI. Rio de Janeiro, PPGE-UFRJ. 260 pp.

Castro, R.M.C., L. Casatti, H.F. Santos, K.M. Ferreira, A.C. Ribeiro, R.C. Benine, G.Z.P. Dardis, A.L.A. Melo, R. Stopiglia, T.X. Abreu, F.A. Bockmann, M. Carvalho, F.Z. Gibran and F.C.T. Lima. 2003. Estrutura e composição da ictiofauna de riachos do rio Paranapanema, sudeste e sul do Brasil. Biota Neotropica 3(1): 1–31. http://www.biotaneotropica.org.br/v3n1/pt/abstract?article+BN01703012003

Chao, A. 1987. Estimating the population size for capture-recapture data with unequal catchability. Biometrics 43(4): 783–791. doi: 10.2307/2531532

Colwell, R.K. 2009. EstimateS: Statistical estimation of species richness and shared species from samples. Version 8.2.

Costa, A.D.A., D.G. Ferreira, W.F. Silva, A.S. Zanatta, O.A. Shibatta and B.A. Galindo. 2013. Fishes (Osteichthyes: Actinopterygii) from the Penacho stream, upper Paraná River basin, Paraná State, Brazil. Check List 9(3): 519–523. http://www.checklist.org.br/getpdf?SL134-12

Eschmeyer, W.N. 2014. Catalog of fishes. Accessed at http://www.calacademy.org/scientists/projects/catalog-of-fishes, 23 September 2014.

França, V.D. 2002. O rio Tibagi no contexto hidrogeográfico paranaense; pp. 45–61, in: M.E. Medri, E. Bianchini, O.A. Shibatta and J.A. Pimenta (eds.). A bacia do rio Tibagi. Londrina: M.E. Medri. 595 pp.

Galves, W., F.C. Jerep and O.A. Shibatta. 2007a. Estudo da condição ambiental pelo levantamento da fauna de três riachos na região do Parque Estadual Mata dos Godoy (PEMG), Londrina, PR, Brasil. Pan-American Journal of Aquatic Sciences 2(1): 55–65. http://www.panamjas.org/pdf_artigos/PANAMJAS_2(1)_55-65.pdf

Galves, W., O.A. Shibatta and F.C. Jerep. 2007b. Fish, Taquara River basin, northern of the state of Paraná, Brazil. Check List 3(3): 353–359. doi: 10.15560/3.3.253

Hammer, O., D.A.T. Harper and P. D. Ryan. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4(1): 9 pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm

Haseman, J. D. 1911. Some new species of fishes from the Rio Iguassú. Annals of the Carnegie Museum 7(3–4): 374–387.

Langeani, F., R.M.C. Castro, O.T. Oyakawa, O.A. Shibatta, C.S. Pavanelli and L. Casatti. 2007. Diversidade da ictiofauna do Alto Rio Paraná: composição atual e perspectivas futuras. Biota Neotropica 7(3): 181–197. http://www.biotaneotropica.org.br/v7n3/pt/abstract?article+bn03407032007

Lee, S.M. and A. Chao. 1994. Estimating population size via sample coverage for closed capture-recapture models. Biometrics 50(1): 88–97. doi: 10.2307/2533199

Lowe-McConnell, R.H. 1999. Estudos ecológicos de comunidades.São Paulo: EDUSP. 534 pp.

Maack, R. 2012. Geografia física do estado do Paraná. Ponta Grossa: UEPG. 526 pp.

Medri, M.E., E. Bianchini, O.A. Shibatta and J.A. Pimenta (eds.). 2002. A bacia do rio Tibagi. Edition of Editors. Londrina: M.E. Medri. 595 pp.

Menezes, N.A., S.H. Weitzman, O. T. Oyakawa, F.C.T. Lima, R.M.C. Castro and M.J. Weitzman. 2007. Peixes de água doce da Mata Atlântica: Lista preliminar das espécies e comentários sobre a conservação de peixes de água doce neotropicais. São Paulo: Museu de Zoologia, Universidade de São Paulo. 408 pp.

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

Pinto, B.C.T., M.G. Peixoto and F.G. Araújo. 2006. Effects of the proximity from an industrial plant on fish assemblages in the Rio Paraíba do Sul, southeastern Brazil. Neotropical Ichthyology 4(2): 269–278. doi: 10.1590/S1679-62252006000200013

QGIS Development Team. 2014. QGIS Geographic Information System. Open Source Geospatial Foundation Project. Accessed at http://qgis.osgeo.org, 18 April 2014.

Shibatta, O.A., S.T. Bennemann, H. Mori and D.F. Silva. 2008. Riqueza biológica e ecológica dos peixes do Ribeirão do Varanal; pp.77–97, in: Bennemann, S.T., O.A. Shibatta and A.O.S. Vieira. A flora e a fauna do Ribeirão do Varanal. Um estudo da Biodiversidade do Paraná. Londrina: EDUEL. 158 pp.

Shibatta, O.A. and C.C. Cheida. 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. doi: 10.1590/S0101-81752003000300016

Shibatta, O.A., M.L. Orsi, S.T. Bennemann and A.T. Silva-Souza. 2002. Diversidade e distribuição de peixes na bacia do rio Tibagi; pp. 403–423, in: M.E Medri, E. Bianchini, O.A. Shibatta, J.A. Pimenta (eds.). A bacia do rio Tibagi. Londrina: M.E. Medri. 595 pp.

Torezan, J.M.D. 2002. Nota sobre a vegetação da bacia do rio Tibagi; pp. 103–107, in: M. E. Medri, E. Bianchini, O.A. Shibatta, and J. A. Pimenta (eds.). A bacia do Rio Tibagi. Londrina: M. E. Medri. 595 pp.

Vieira, D.B. and O.A. Shibatta. 2007. Peixes como indicadores da qualidade ambiental do ribeirão Esperança, município de Londrina, Paraná, Brasil. Biota Neotropica7(1): 57–65. doi: 10.1590/S1676-06032007000100008

Author contributions: ACH and RHCN collected and identified species and wrote the text. OAS and ACH made the analysis. RHCN made the map and pictures.

Received: 5 March 2015
Accepted: 27 November 2015
Academic editor: Manoela Marinho

APPENDIX

List of voucher specimens examined in the present study with number of individuals followed by the minimum and maximum standard length per lot. All from the Tibagi River basin, Paraná state, Brazil.

Characiformes: Curimatidae: *Steindachnerina insculpta* (MZUEL 10427: 16: 54.30–78.06 mm). **Parodontidae:** *Apareiodon ibitiensis* (MZUEL 10380: 3: 30.06–39.43 mm, MZUEL 10381: 7: 28.34–43.98 mm); *Apareiodon piracicabae* (MZUEL 10382: 2: 61.50–69.14 mm). **Erythrinidae:** *Hoplias malabaricus* (MZUEL 10409: 1: 91.23 mm, MZUEL 10154: 1: 62.11 mm, MZUEL 10182: 2: 64.74–101.99 mm). **Characidae:** *Astyanax altiparanae* (MZUEL 10383: 3: 43.09–87.22 mm, MZUEL 10384: 3: 42.39–73.91 mm, MZUEL 10140: 12: 23.22–72.48 mm); *Astyanax bockmanni* (MZUEL 10385: 12: 23.38–71.03 mm, MZUEL 10386: 7: 32.30–46.70 mm, MZUEL 10387: 2: 42.04–46.97 mm, MZUEL 10388: 26: 21.89–55.16 mm, MZUEL 10141: 1: 52.06 mm, MZUEL 10142: 6: 29.00–45.10 mm, MZUEL 10143: 2: 44.69–53.47 mm, MZUEL 10144: 3: 18.75–34.90 mm, MZUEL 10145: 2: 29.24–32.18 mm, MZUEL 10321: 16: 29.06–66.51 mm); *Astyanax fasciatus* (MZUEL 10389: 5: 41.97–51.42 mm, MZUEL 13487: 5: 33.45–45.78 mm, MZUEL 10173: 4: 28.70–50.10 mm); *Astyanax paranae* (MZUEL 10357: 6: 29.45–46.33 mm, MZUEL 10358: 16: 40.48–64.52 mm, MZUEL 10390: 1: 63.33 mm, MZUEL 10127: 1: 44.30 mm, MZUEL 10128: 4: 21.40–27.75 mm, MZUEL 10129: 7: 33.74–94.06 mm, MZUEL 10174: 3: 26.74–68.13 mm, MZUEL 10175: 8: 23.38–46.37 mm, MZUEL 10319: 1: 23.48 mm, MZUEL 10320: 14: 22.66–79.07 mm, MZUEL 10342: 1: 36.12 mm, MZUEL 13486: 4: 24.57–72.83 mm); *Astyanax* sp. (MZUEL 10343: 1: 61.74 mm, MZUEL 10344: 4: 25.40–50.40 mm); *Bryconamericus iheringii* (MZUEL 10391: 21: 18.11–53.49 mm, MZUEL 10392: 12: 26.49–47.06 mm, MZUEL 10322: 9: 52.76–56.89 mm, MZUEL 10323: 4: 41.33–44.45 mm, MZUEL 10324: 1: 42.20 mm, MZUEL 10345: 14: 25.76–62.47 mm MZUEL 10146: 11: 34.57–45.68 mm, MZUEL 10322: 3: 43.52–47.81 mm); *Bryconamericus stramineus* (MZUEL 10146: 1: 33.60 mm, MZUEL 10359: 5: 22.15–35.50 mm, MZUEL 10393: 6: 23.95–72.12 mm, MZUEL 10394: 2: 19.18–19.31 mm, MZUEL 10395: 11: 17.82–23.65 mm, 10147: 12: 17.82–24.35 mm); *Hyphesobrycon boulengeri* (MZUEL 10183: 1: 40.35 mm); *Mimagoniates microlepis* (MZUEL 10302: 1: 55.04 mm); *Oligosarcus paranensis* (MZUEL 10419: 3: 43.60–45.94 mm; MZUEL 10349: 25: 37.47–81.36 mm); *Piabina argentea* (MZUEL 10421: 13: 24.70–47.60 mm, MZUEL 10422: 48: 26.17–54.01 mm). **Crenuchidae:** *Characidium gomesi* (MZUEL 10177: 4: 41.09–46.97 mm, MZUEL 10178: 29: 43.42–61.93 mm, MZUEL 10179: 3: 44.96–53.40 mm); *Characidium schubarti* (MZUEL 13501: 13: 35.55–47.55 mm, MZUEL 13502: 17: 37.28–48.95 mm); *Characidium zebra* (MZUEL 13497: 8: 50.70–63.50 mm, MZUEL 13496: 4: 45.05–51.00 mm, MZUEL 13498 2: 32.50–62.20 mm, MZUEL 10360: 7: 38.44–53.70 mm, MZUEL 10325: 1: 48.20 mm, MZUEL 10326: 2: 52.33–53.84 mm). **Siluriformes: Heptapteridae:** *Cetopsorhamdia iheringi* (MZUEL 10396: 3: 49.52–67.86 mm, MZUEL 10397: 11: 61.33–100.61 mm, MZUEL 10149: 4: 41.08–69.77 mm); *Imparfinis mirini* (MZUEL 10367: 2: 42.10–65.00 mm, MZUEL 10418: 2: 51.87–66.46 mm, MZUEL 10160: 20: 25.94–41.57 mm, MZUEL 10161: 3: 34.54–57.21 mm, MZUEL 10162: 8: 38.21–42.82 mm, MZUEL 10301: 5: 60.17–67.06 mm); *Phenacorhamdia tenebrosa* (MZUEL 10166: 3: 29.16–45.84 mm, MZUEL 10167: 2: 33.45–62.84 mm, MZUEL 10405: 2: 48.58–52.12 mm); *Pimelodella gracilis* (MZUEL 10309: 7: 46.43–60.53 mm); *Rhamdia quelen* (MZUEL 10425: 2:

44.47–44.98 mm, MZUEL 10426: 3: 65.75–99.86 mm, MZUEL 10137: 3: 41.29–64.94 mm, MZUEL 10171: 1: 111.95 mm, MZUEL 10310: 1: 62.80 mm, MZUEL 10336: 1: 73.30 mm, MZUEL 10337: 2: 116.69–124.59 mm, MZUEL 10338: 1: 83.23 mm, MZUEL 10339: 1: 68.16 mm); *Rhamdiopsis moreirai* (MZUEL 10311: 3: 31.59–41.92 mm). **Trichomycteridae:** *Trichomycterus candidus* (MZUEL 13490: 8: 12.10–19.00 mm, MZUEL 13491: 2: 15.78–38.90 mm, MZUEL 13492: 2: 40.10–43.56 mm, MZUEL 13493: 3: 36.70–41.40 mm); *Trichomycterus castroi* (MZUEL 13489: 6: 33.05–103.50 mm); *Trichomycterus davisi* (MZUEL 10376: 1: 43.51 mm, MZUEL 10378: 6: 34.70–54.30 mm, MZUEL 10138: 44: 24.22–91.71 mm, MZUEL 10139: 12: 19.33–21.99 mm, MZUEL 10172: 2: 23.26–29.12 mm, MZUEL 10312: 34: 18.78–44.53 mm, MZUEL 10313: 21: 30.42–87.16 mm, MZUEL 10314: 73: 17.82–89.90 mm, MZUEL 10315: 25: 18.54–42.82 mm, MZUEL 10316: 50: 24.29–70.30 mm, MZUEL 10340: 8: 35.22–64.68 mm, MZUEL 10341: 2: 52.48–57.61 mm, MZUEL 10355: 4: 30.90–83.77 mm, MZUEL 10356: 11: 23.10–45.00 mm); *Trichomycterus diabolus* (MZUEL 10379: 5: 30.00–47.50 mm, MZUEL 10317: 2: 26.85–32.87 mm, MZUEL 10318: 4: 22.38–50.04 mm MZUEL 13476: 9: 35.00 mm - 60.50 mm, MZUEL 13475: 10: 27.85–81.15 mm). **Callichthyidae:** *Callichthys callichthys* (MZUEL 10176: 1: 72.61 mm); *Corydoras aeneus* (MZUEL 10402: 10: 30.00–42.16 mm, MZUEL 10403: 11: 33.88–44.20 mm); *Corydoras ehrardti* (MZUEL 10361: 2: 37.71–37.75 mm, MZUEL 10362: 13: 15.37–47.28 mm, MZUEL 10363: 39: 25.99–42.00 mm, MZUEL 10364: 14: 30.94–37.43 mm, MZUEL 10180: 42: 12.97–46.03 mm). **Loricariidae:** *Hisonotus francirochai* (MZUEL 13480: 10: 18.00–32.00 mm, MZUEL 13477: 1: 31.20 mm, MZUEL 13478: 8: 32.30–41.78 mm, MZUEL 13479: 1: 29.00 mm, MZUEL 10407: 4: 30.47–37.00 mm, MZUEL 10408: 10: 32.03–34.07 mm, MZUEL 10152: 9: 36.17–38.15 mm, MZUEL 10153: 3: 30.01–39.79 mm); *Hypostomus ancistroides* (MZUEL 10410: 4: 34.32–38.49 mm, MZUEL 10411: 20: 24.93–78.69 mm, MZUEL 10412: 10: 24.94–44.68 mm, MZUEL 10413: 17: 19.06–54.18 mm, MZUEL 10414: 16: 37.60–75.60 mm, MZUEL 10155: 11: 21.60–63.19 mm, MZUEL 10156: 14: 19.57–92.92 mm, MZUEL 10157: 5: 24.90–72.30 mm, MZUEL 10158: 51: 16.04–95.83 mm, MZUEL 10328: 9: 28.47–73.84 mm, MZUEL 10329: 8: 48.46–52.79 mm, MZUEL 10330: 2: 37.80–42.00 mm, 10331: 1: 37.18 mm, MZUEL 10347: 2: 59.48–70.40 mm); *Hypostomus nigromaculatus* (MZUEL 10415: 3: 43.81–69.11 mm, MZUEL 10416: 3: 62.96–72.21 mm); *Hypostomus strigaticeps* (MZUEL 10417: 18: 49.79–101.12 mm, MZUEL 10159: 1: 21.67 mm); *Neoplecostomus paranensis* (MZUEL 10163: 1: 46.20 mm); *Neoplecostomus selenae* (MZUEL 13488: 3: 62.70–83.70 mm); *Neoplecostomus yapo* (MZUEL 10332: 3: 38.25–44.01 mm, MZUEL 10333: 5: 57.13–77.84 mm, MZUEL 10348: 3: 53.15–80.50 mm); *Otothyropis biamnicus* (MZUEL 10369: 2: 26.99–29.01 mm). **Gymnotiformes: Gymnotidae:** *Gymnotus omarorum* (MZUEL 10406: 1: 220.52 mm, MZUEL 10151: 1: 189.96 mm, MZUEL 10327: 1: 76.68 mm). **Cyprinodontiformes: Poeciliidae:** *Phalloceros harpagos* (MZUEL 10371: 224: 9.90–38.73 mm, MZUEL 10372: 3: 17.82–31.36 mm, MZUEL 10373: 245: 8.14–38.30 mm, MZUEL 10420: 1: 27.28 mm, MZUEL 10131: 52: 9.20–25.00 mm, MZUEL 10132: 75: 11.26–26.04 mm, MZUEL 10133: 73: 12.38–42.57 mm, MZUEL 10134: 27: 17.88–42.31 mm, MZUEL 10135: 88: 11.03–44.08 mm, MZUEL 10136: 157: 16.37–43.70 mm, MZUEL 10164: 2: 19.98–19.16 mm, MZUEL 10165: 4: 18.42–27.97 mm, MZUEL 13481: 1: 27.08 mm, MZUEL 13482: 39: 12.02–25.64 mm, MZUEL 13483: 81: 10.30–27.80 mm, 13484: 28: 15.39–31.75 mm, MZUEL 13485: 17: 12.81–26.98 mm, MZUEL 10334: 2: 26.89–28.11 mm, MZUEL 10351: 1: 15.26–38.63 mm, MZUEL 10352: 42: 17.29–29.14 mm, MZUEL 10353: 6: 15.20–29.60 mm, MZUEL 10354: 2: 19.04–24.13 mm); *Poecilia reticulata* (MZUEL 10423: 7: 18.23–19.29 mm, MZUEL 10424: 4: 18.12–27.96 mm, MZUEL 10168: 8: 16.11–19.68 mm, MZUEL 10169: 3: 21.84–25.82 mm, MZUEL 10170: 1: 16.65 mm, MZUEL 10335: 74: 16.44–30.95 mm); *Cnesterodon hypselurus* (MZUEL 13494: 7: 13.05–26.00 mm). **Synbranchiformes: Synbranchidae:** *Synbranchus marmoratus* (MZUEL 10428: 2: 40.51–55.09 mm). **Perciformes: Cichlidae:** *Crenicichla jaguarensis* (MZUEL 10404: 1: 37.13 mm); *Geophagus brasiliensis* (MZUEL 10366: 3: 37.89–68.45 mm, MZUEL 10365: 3: 46.24–101.12 mm, MZUEL 10130: 15: 25.79–77.49 mm, MZUEL 10150: 9: 23.95–61.43 mm, MZUEL 10181: 1: 38.86 mm, MZUEL 10346: 6: 47.40 mm–108.22 mm); *Oreochromis niloticus* (MZUEL 10350: 2: 76.48–77.94 mm).

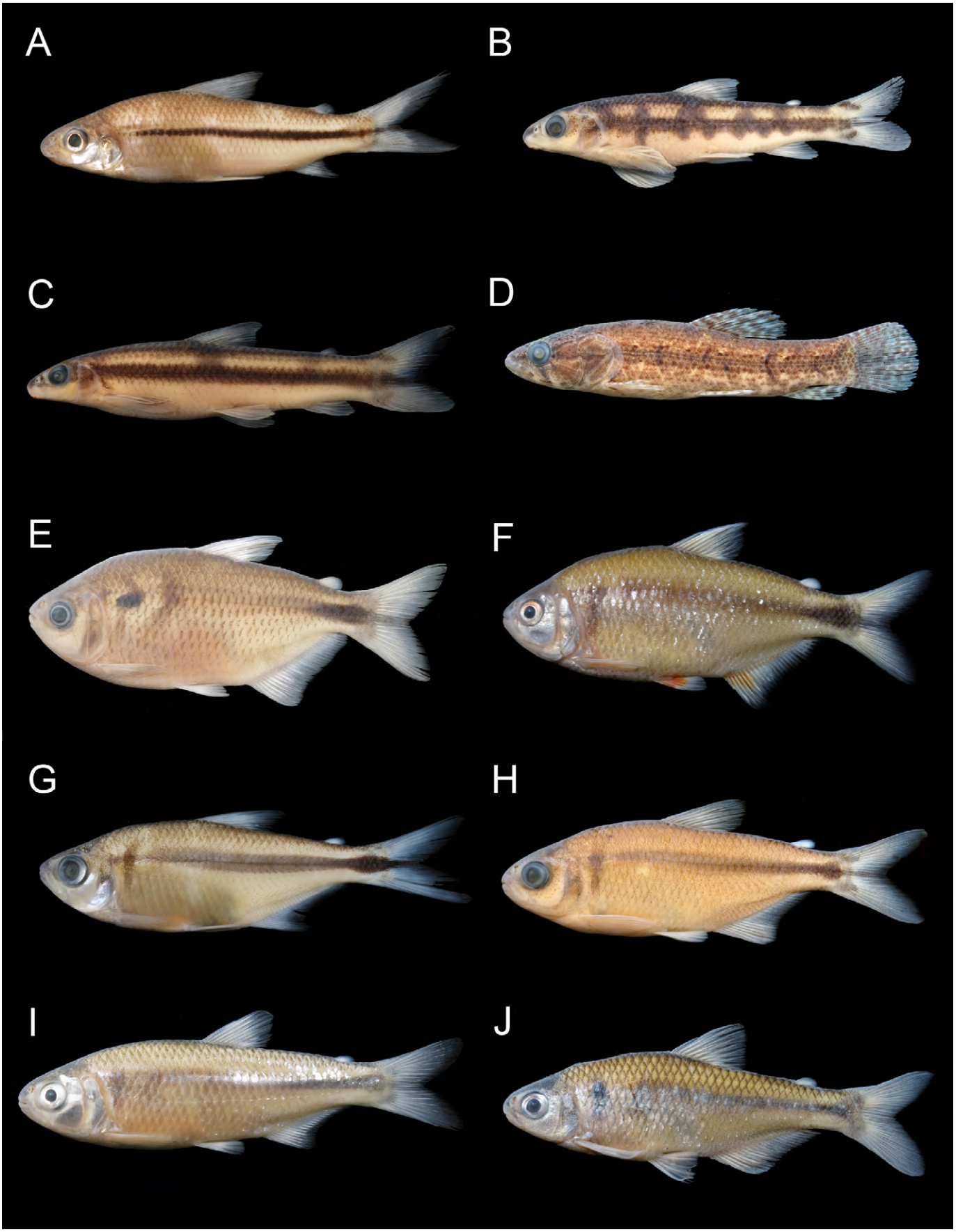

Figure A1. Species of fishes from streams of Tibagi River basin, Paraná state, Brazil. (**A**) *Steindachnerina insculpta* 68.5 mm SL; (**B**) *Apareiodon ibitiensis* 39.8 mm SL; (**C**) *Apareiodon piracicabae* 61.6 mm SL; (**D**) *Hoplias malabaricus* 66.3 mm SL; (**E**) *Astyanax altiparanae* 86.4 mm SL; (**F**) *Astyanax bockmanni* 68.8 mm SL; (**G**) *Astyanax fasciatus* 52.3 mm SL; (**H**) *Astyanax paranae* 42.8 mm SL; (**I**) *Astyanax* sp. 51.2 mm SL; (**J**) *Bryconamericus iheringii* 53.6 mm SL.

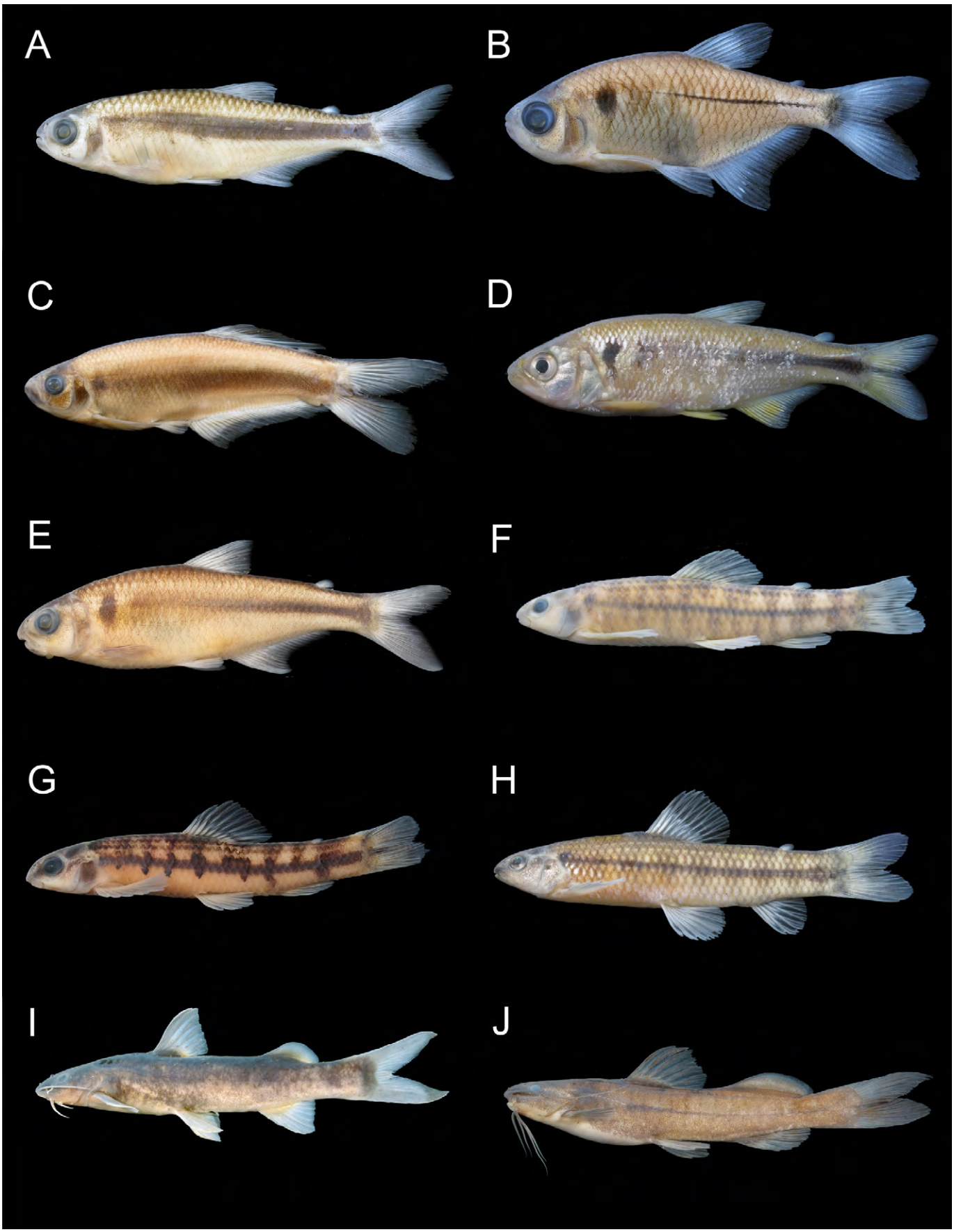

Figure A2. Species of fishes from streams of Tibagi River Basin, Paraná state, Brazil. (**A**) *Bryconamericus stramineus* 65.7 mm SL; (**B**) *Hyphesobrycon boulengeri* 41.9 mm SL; (**C**) *Mimagoniates microlepis* 55.9 mm SL; (**D**) *Oligossarcus paranensis* 77.9 mm SL; (**E**) *Piabina argentea* 62.1 mm SL; (**F**) *Characidium gomesi* 51.9 mm SL; (**G**) *Characidium schubarti* 39.5 mm SL; (**H**) *Characidium zebra* 52.3 mm SL; (**I**) *Cetopsorhamdia iheringi* 70.3 mm SL; (**J**) *Imparfinis mirini* 67.2 mm SL.

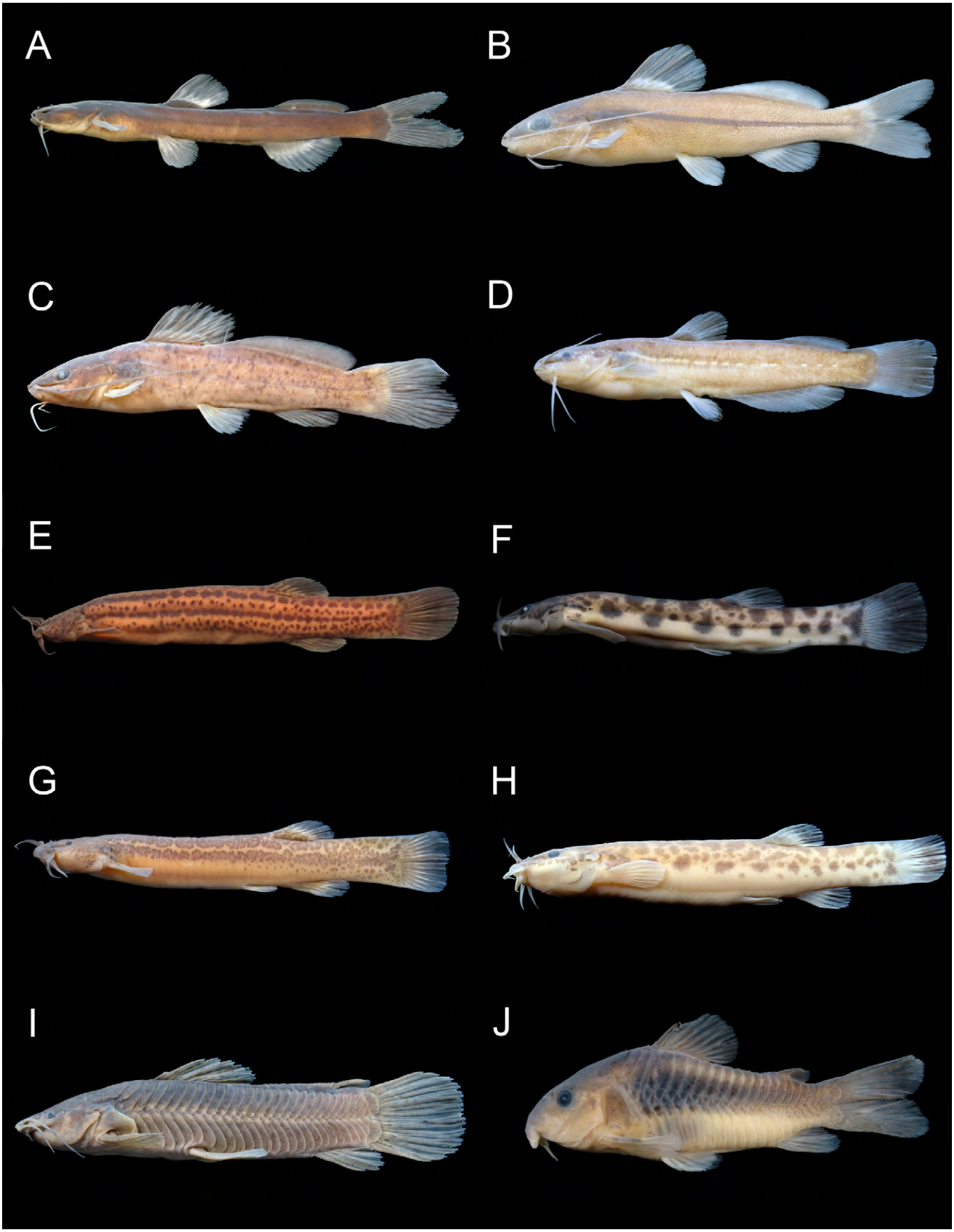

Figure A3. Species of fishes from streams of Tibagi River Basin, Paraná state, Brazil. (**A**) *Phenacorhamdia tenebrosa* 51.9 mm SL; (**B**) *Pimelodella gracilis* 49.5 mm SL; (**C**) *Rhamdia quelen* 66.0 mm SL; (**D**) *Rhamdiopsis moreirai* 38.9 mm SL; (**E**) *Trichomycterus candidus* 38.1 mm SL; (**F**) *Trichomycterus castroi* 43.7 mm SL; (**G**) *Trichomycterus davisi* 64.6 mm SL; (**H**) *Trichomycterus diabolus* 50.7 mm SL; (**I**) *Callichthys callichthys* 69.9 mm SL; (**J**) *Corydoras aeneus* 42.3 mm SL.

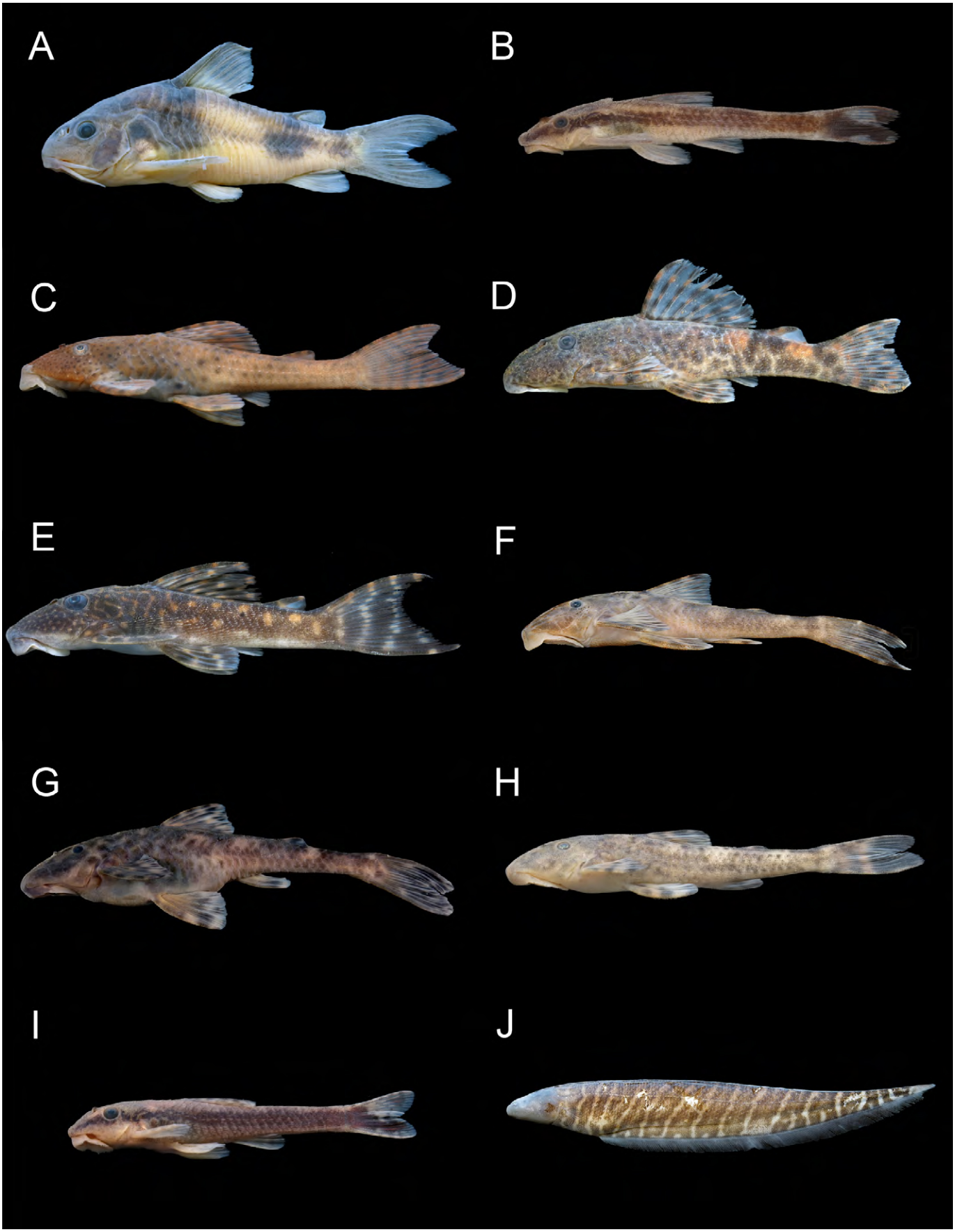

Figure A4. Specimens of fishes from streams of Tibagi River Basin, Paraná state, Brazil. (**A**) *Corydoras ehrhardti* 45.0 mm SL; (**B**) *Hisonotus francirochai* 34.3 mm SL; (**C**) *Hypostomus ancistroides* 57.0 mm SL; (**D**) *Hypostomus nigromaculatus* 43.1 mm SL; (**E**) *Hypostomus strigaticeps* 57.7 mm SL; (**F**) *Neoplecostomus paranensis* 46.5 mm SL; (**G**) *Neoplecostomus selenae* 63.4 mm SL; (**H**) *Neoplecostomus yapo* 39.5 mm SL; (**I**) *Otothyropsis biamnicus* 31.7 mm SL; (**J**) *Gymnotus omarorum* 72.3 mm TL.

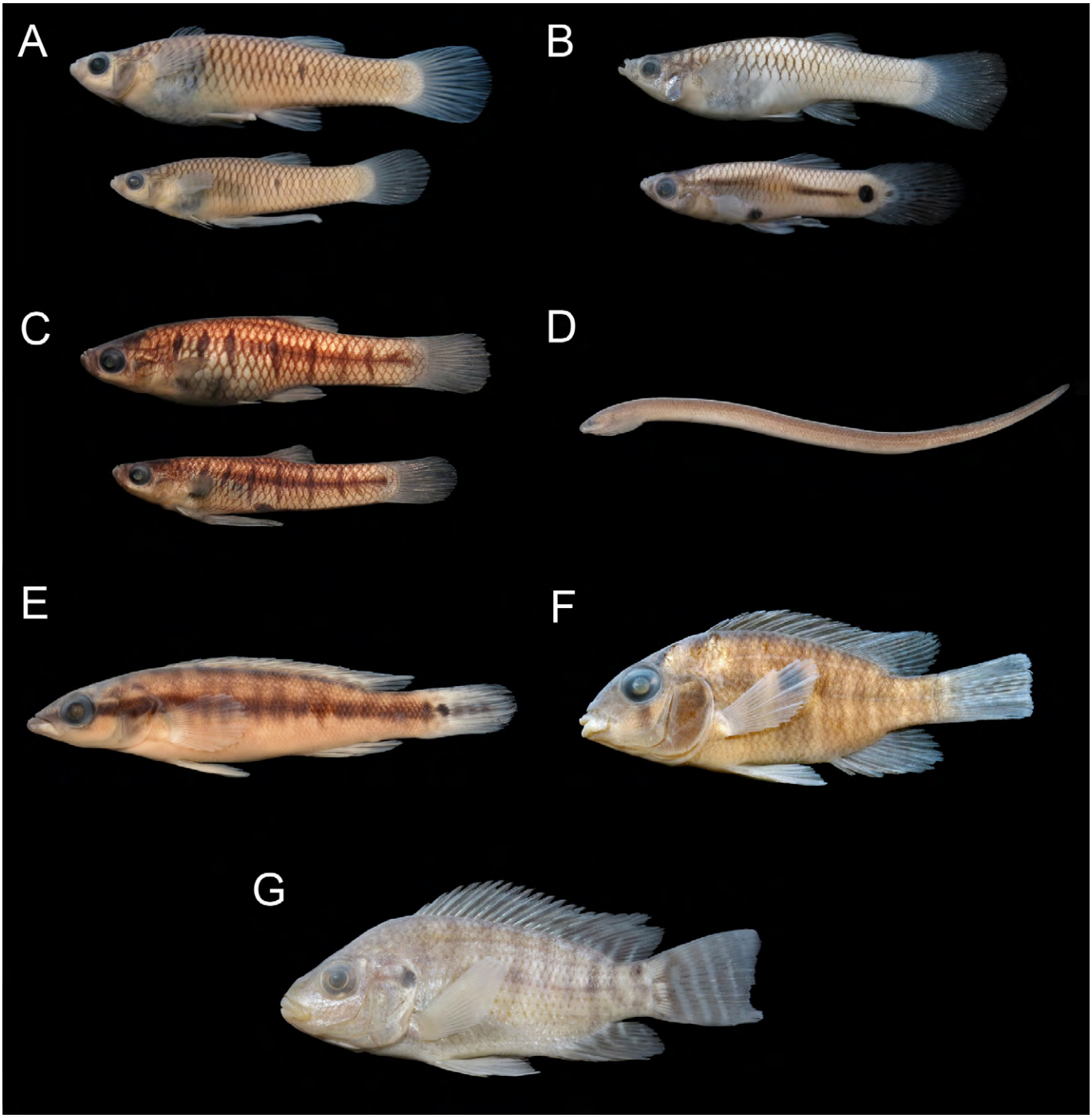

Figure A5. Specimens of fishes from the streams of Tibagi River Basin, Paraná state, Brazil. (**A**) *Phalloceros harpagos* 35.3 mm SL female (up), 25.4 mm SL male (down); (**B**) *Poecilia reticulata* 28.5 mm SL female (up), 18.5 mm SL male (down); (**C**) *Cnesterodon hypselurus* 28.4 mm SL female (up), 25.7 mm SL male (down); (**D**) *Synbranchus marmoratus* 58.1 mm TL; (**E**) *Crenicichla jaguarensis* 36.4 mm SL; (**F**) *Geophagus brasiliensis* 40.1 mm SL; (**G**) *Oreochromis niloticus* 77.3 mm SL.