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PENSOFT

The fish fauna of the upper Piraí drainage, a transposed mountain river system in southeastern, Brazil

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Abstract
An annotated checklist of the ichthyofauna from the upper Piraí river drainage is provided. The Piraí river was a major right-bank tributary of the Paraíba do Sul river, but it has been artificially diverted to the coastal Guandu river system in southeastern Brazil to generate electric power and water for the metropolitan area of Rio de Janeiro. Based on our field sampling of 23 sites, 32 species belonging to 24 genera and 12 families were collected in 6 headwater tributaries of the Piraí river between 2009 and 2016. *Phalloceros harpagos* (Lucinda, 2008), *Astyanax intermedius* (Eigenmann, 1908), and *Neoplecostomus microps* (Steindachner, 1877b) were the most abundant and most widely distributed species in the samples. The sampled ichthyofauna is mostly composed by species from the Paraíba do Sul basin. Eight species are reported for the first time in the upper Piraí drainage, showing the importance of continuous ichthyofaunal surveys of fish in remaining areas of Atlantic Forest.

Key words
Atlantic Forest, coastal streams, ichthyological survey, Neotropical fishes, Paraíba do Sul.

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Introduction

The Brazilian Atlantic Forest is the second largest biome in South America, with one of the highest rates of species richness and endemism on the planet (Galindo-Leal and Câmara 2003, Ribeiro et al. 2009). Due to environmental impacts originating from human activities, only 16% of the original forest is preserved in reduced and isolated patches (Ribeiro et al. 2009, 2011). Freshwater streams in southeastern Brazil are directly affected by the degradation of the Atlantic Forest, as their headwaters are located in these few remaining patches of forest, and the reduction of the riparian vegetation is one of the main sources of environmental impact in water bodies (Cetra and Ferreira 2016). Systematic surveys of fish communities that inhabit these streams are necessary to reduce knowledge gaps about biodiversity and to understand the state of conservation of the Atlantic Forest (Buckup et al. 2014).

The upper Piraí river drainage is a former tributary of the Paraíba do Sul river basin that has been artificially diverted to the Guandu river system through a complex system of tunnels and pumps to generate electric power and water for the metropolitan area of Rio de Janeiro. The Piraí river drains the Biodiversity Corridor Tinguá-Bocaina (BCTB) (Paiva and Coelho 2015). The BCTB

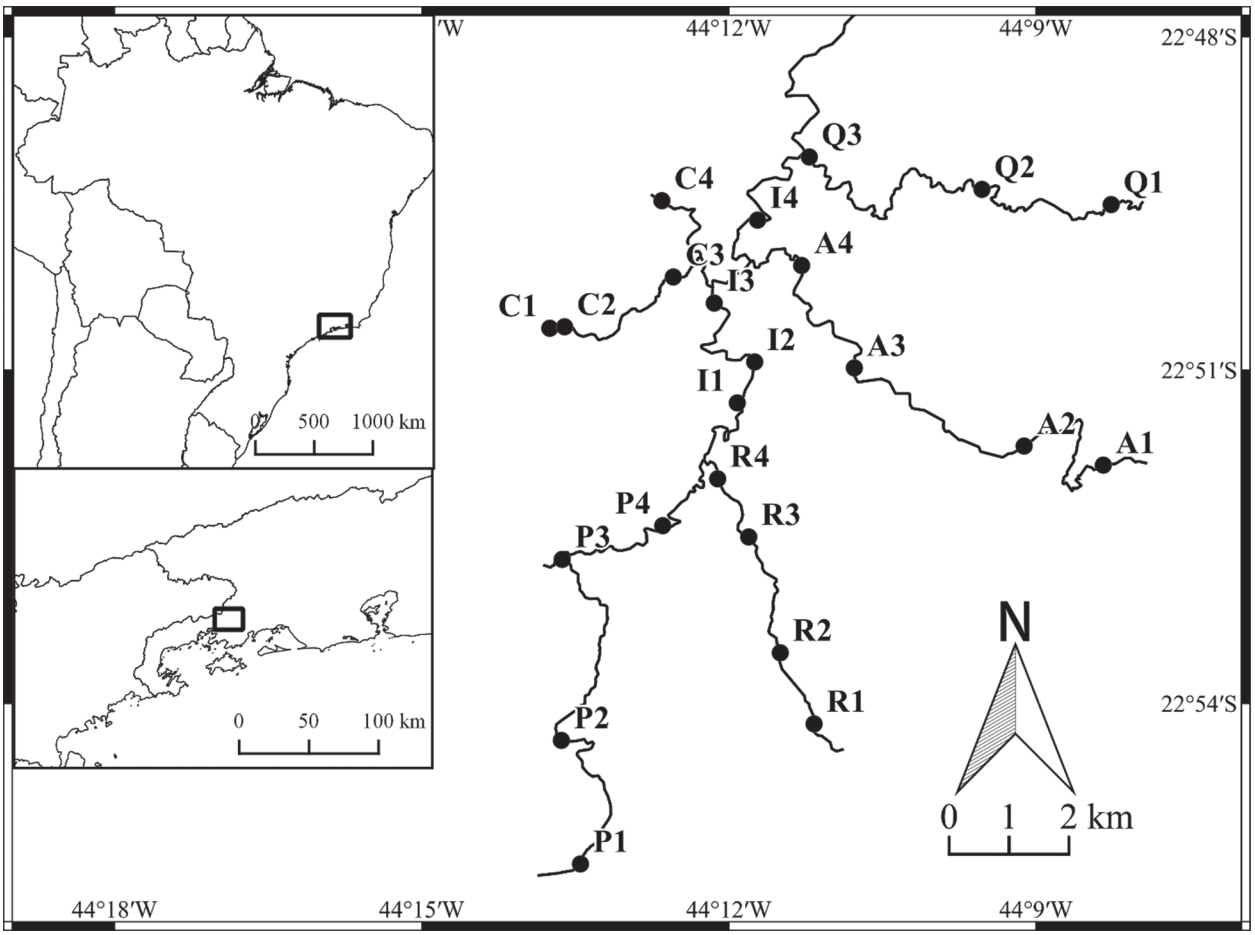

Figure 1. Map of the upper Piraí river drainage, indicating the collecting sites along rio Coutinhos (C), rio Papudos (P), rio Parado (A), rio Passa Quatro (Q), Rio das Pedras (R), and the main channel of rio Piraí (I). Geographic coordinates and altitude of the sites are listed in Table 1.

connects Atlantic Forest fragments delimited by the Tinguá Biologic Reserve, in the central region of Rio de Janeiro, and the National Park of Serra da Bocaina, on the southern coast of the state. The BCTB is one of the most important priority areas for the preservation of the Atlantic Forest biodiversity due to its location at the most critical point of fragmentation of the largest continuous area of this biome in the Serra do Mar (Vilar et al. 2012). In the present study, we surveyed the ichthyofauna from Upper Piraí drainage in order to provide an annotated checklist of freshwater fish species occurring in the area of study. This study is part of a long-term program to monitor the effects of forest restoration in the Guandu river system partly published by Vilar et al. (2012) and Castello Branco (2015). It includes a larger area and an updated inventory of fish species presented in previous studies (e.g. Buckup et al. 2014).

Methods

Study area. The Piraí river drainage (Fig. 1) is located within the boundaries of the municipalities of Rio Claro and Barra do Piraí, Rio de Janeiro state, southeastern Brazil. The Piraí river was a major tributary of the Paraíba do Sul river. Since the beginning of the 20th century, it has been diverted to the coastal Guandu river basin, in the Rio de Janeiro Metropolitan Region. The headwaters of the Piraí drainage are composed by streams that flow from the northern face of the mountain system of Serra do Mar. This mountain chain has an extension of 1,000 km between Rio de Janeiro state and north of Santa Catarina state (Almeida and Carneiro 1998).

Sampling. Fish were collected in 23 sampling sites along 6 streams, rio Coutinhos, rio Papudos, rio Parado, rio Passa Quatro, and Rio das Pedras, and the main channel of the upper rio Piraí (Table 1, Fig. 1) in 4 expeditions between the years of 2009 and 2016, under collecting permit 12129, issued by the Instituto Chico Mendes de Conservação da Biodiversidade. The sampling sites were selected to cover a wide range of habitats, from the alluvial plain of the streams to the high-mountain rapids. Each site was surveyed during 1 h of exhaustive sampling activity by a team of 5 ichthyologists. Fishing equipment included beach seines (2, 3, 5 and 15 m long, 4 mm nylon mesh), dip nets with metal handles (40 × 90 cm basket area, 2 mm plastic mesh), and casts nets (12 mm mesh size). An acoustic amplifier of electric signals was used to detect specimens of the order Gymnotiformes hidden in marginal vegetation and rocks. The collected specimens were preserved in 10% formalin solution and transferred to 70% ethanol after 48 h. Part of the specimens were preserved in anhydrous ethanol

Table 1. Geographic coordinates from the sampling sites in the Upper Piraí river drainage, Rio de Janeiro state, Brazil.

Stream	Site	Latitude (S)	Longitude (W)	Altitude (m)
Coutinhos	C1	22°50′37″	44°13′45″	610
	C2	22°50′37″	44°13′36″	582
	C3	22°50′10″	44°12′33″	537
	C4	22°49′28″	44°12′39″	572
Papudos	P1	22°55′27″	44°13′27″	1002
	P2	22°54′20″	44°13′38″	951
	P3	22°52′42″	44°13′38″	571
	P4	22°52′24″	44°12′39″	563
Parado	A1	22°51′51″	44°08′21″	1050
	A2	22°51′41″	44°09′07″	976
	A3	22°50′59″	44°10′46″	561
	A4	22°50′03″	44°11′17″	545
Passa Quatro	Q1	22°49′31″	44°08′16″	712
	Q2	22°49′22″	44°09′32″	622
	Q3	22°49′05″	44°11′13″	513
Piraí	I1	22°51′18″	44°11′55″	555
	I2	22°50′56″	44°11′45″	548
	I3	22°50′24″	44°12′09″	535
	I4	22°49′39″	44°11′43″	519
Rio das Pedras	R1	22°54′11″	44°11′10″	842
	R2	22°53′33″	44°11′30″	786
	R3	22°52′30″	44°11′48″	576
	R4	22°51′59″	44°12′07″	554

for DNA-sequencing studies. The examined specimens were deposited in the ichthyological collection of the Museu Nacional, Universidade Federal do Rio de Janeiro (MNRJ) (Appendix, Table A1). Standard length, abbreviated as SL, was measured to the base of the middle caudal-fin rays.

Results

We collected 7,860 fish specimens of 32 species belonging to 24 genera and 12 families in the upper Piraí river drainage (Table 2). Among the river sections that comprise the sampled drainage, the main channel of the Piraí river had the higher species richness, with 22 species. The number of species captured in the other 5 streams varied between 18 in the Coutinhos, Passa Quatro, and Rio das Pedras, and 17 in the Papudos and Parado. Catfishes were the most diverse taxonomic group, including 16 species of Siluriformes (50%), followed by 9 Characiformes (28%), 4 Cichliformes (13%), 2 Cyprinodontiformes (6%), and 1 Gymnotiformes (3%). The most diverse families were Loricariidae with 9 species (28%), Characidae and Cichlidae, with 4 species (13%) each, and Trichomycteridae and Heptapteridae, with 3 species (9%) each.

Phalloceros harpagos was the most abundant species, with 2,437 specimens (31.1%), followed by *Astyanax intermedius* with 1,597 specimens (20.4%), *Neoplecostomus microps* with 676 specimens (8.6%), *Pareiorhina rudolphi* with 553 specimens (7.1%), *Geophagus brasiliensis* with 497 specimens (6.4%), and *Characidium lauroi* with 444 specimens (5.7%). These 6 species combined represented 79.3% of all specimens collected in all sampled sites. Some species were notably rare in the samples, including *Astyanax* sp. aff. *scabripinnis*, *Hemipsilichthys gobio*, and *Hypostomus luetkeni,* which were represented by 1 specimen each. The 3 most abundant species were also the most widely distributed along the Upper Piraí drainage, with *P. harpagos* absent only in 1 site (C2), *N. microps* absent in 2 sites (A1, A2), and *A. intermedius* absent in 3 sites (A1, A2, R1). *Trichomycterus nigroauratus*, *G. brasiliensis,* and *T. macrophthalmus* were also widely distributed, having been present in 18, 16 and 14 sites, respectively.

The geographic distribution of the taxa collected in the study area and the diagnosis of the sympatric congeneric species are commented below. Although species listed here occur in other drainages, diagnostic characters described next are limited to identify the set of species that occur in the upper Piraí drainage. These diagnoses might be useful for ichthyological studies in other drainages of the Paraíba do Sul river basin, but in that case, the occurrence of other species not listed in the upper Piraí have to be considered.

Order Characiformes
Family Anostomidae

***Hypomasticus mormyrops* (Steindachner, 1875)**
Figure 2B

Geographic distribution: Coastal rivers between Mucuri and Paraíba do Sul river basins (Vieira et al. 2015).

Family Crenuchidae

***Characidium lauroi* Travassos, 1949**
Figure 2F

Geographic distribution: Upper reaches of Paraíba do Sul tributaries.

Diagnosis: *Characidium lauroi* differs from *C. vidali* by the presence of small rounded dark marks below the lateral stripe, which are separated from the dorsal-lateral bars, and pigmentation bars on the caudal fin are usually absent or inconspicuous (Melo 2001b, Buckup et al. 2014).

***Characidium vidali* Travassos, 1967**
Figure 2H

Geographic distribution: Coastal rivers between Guanabara bay and Paraíba do Sul river basins.

Diagnosis: *Characidium vidali* can be distinguished from *C. lauroi* by the presence of vertical polyhedric dark marks along the medium and inferior portion of the body and by having pigmentation bars on caudal fin (Buckup et al. 2014).

Family Bryconidae

***Brycon opalinus* (Cuvier, 1819)**
Figure 2G

Geographic distribution: Paraíba do Sul and Doce river basins.

Family Characidae

***Astyanax giton* Eigenmann, 1908**
Figure 2A

Geographic distribution: Coastal rivers between Paraíba do Sul and Itabapoana river basins.

Diagnosis: *Astyanax giton* is distinguished from its congeners in the Piraí drainage by presenting the posterior portion of pelvic fin surpassing the urogenital opening. A gradual variation of size in dentary teeth size and higher body height (approximately 41% SL) are also distinguishable features of this species in relation to *Astyanax intermedius* and *Astyanax* sp. aff. *scabripinnis* (Melo 2001a).

***Astyanax intermedius* Eigenmann, 1908**
Figure 2C

Geographic distribution: Paraíba do Sul and Doce river basins and coastal rivers of Rio de Janeiro state

Table 2. List of the freshwater fishes of upper Piraí river drainage.

	Sites																					
Taxon	**C1**	**C2**	**C3**	**C4**	**P1**	**P2**	**P3**	**P4**	**A1**	**A2**	**A3**	**A4**	**Q1**	**Q2**	**Q3**	**I1**	**I2**	**I3**	**I4**	**R1**	**R2**	**R3**	**R4**
CHARACIFORMES																							
Anostomidae																							
Hypomasticus mormyrops																			X			X	X
Crenuchidae																							
Characidium lauroi		X					X	X								X	X			X	X	X	X
Characidium vidali	X		X								X	X		X	X	X	X					X	X
Bryconidae																							
Brycon opalinus																						X	X
Characidae																							
Astyanax giton																X	X	X	X				X
Astyanax intermedius	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X		X	X	X
Astyanax sp. aff. *scabripinnis*							X																
Oligosarcus hepsetus		X	X				X	X			X				X	X	X	X	X			X	X
Erythrinidae																							
Hoplias malabaricus												X				X	X		X				
SILURIFORMES																							
Trichomycteridae																							
Trichomycterus macrophthalmus	X		X				X	X			X	X	X	X	X	X	X	X				X	X
Trichomycterus mariamole				X	X												X			X	X		
Trichomycterus nigroauratus		X	X	X	X	X	X	X	X	X	X	X	X			X	X			X	X	X	X
Callichthyidae																							
Scleromystax barbatus																		X					
Loricariidae																							
Harttia carvalhoi	X		X				X	X			X	X				X	X	X	X			X	X
Harttia loricariformis		X	X				X	X							X							X	X
Hemipsilichthys gobio																X							
Hemipsilichthys papillatus					X	X																	
Hypostomus affinis	X		X									X			X	X		X	X				X
Hypostomus luetkeni																			X				
Neoplecostomus microps	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X
Pareiorhina rudolphi					X	X			X											X	X		
Rineloricaria sp. cf. *R. lima*	X		X				X	X			X	X			X	X	X	X	X				X
Heptapteridae																							
Imparfinis minutus	X						X	X				X			X	X	X	X	X			X	X
Pimelodella lateristriga	X		X				X				X	X					X	X	X				X
Rhamdia quelen	X		X				X	X							X	X	X	X					X
GYMNOTIFORMES																							
Gymnotidae																							
Gymnotus pantherinus	X	X	X				X	X			X	X			X	X	X	X	X				
CYPRINODONTIFORMES																							
Poeciliidae																							
Phalloceros harpagos	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Poecilia reticulata														X	X								
CICHLIFORMES																							
Cichlidae																							
Australoheros sp.															X				X				
Crenicichla lepidota															X				X				
Geophagus brasiliensis		X	X				X	X		X	X	X	X	X	X	X	X	X	X			X	X
Oreochromis niloticus																X		X					

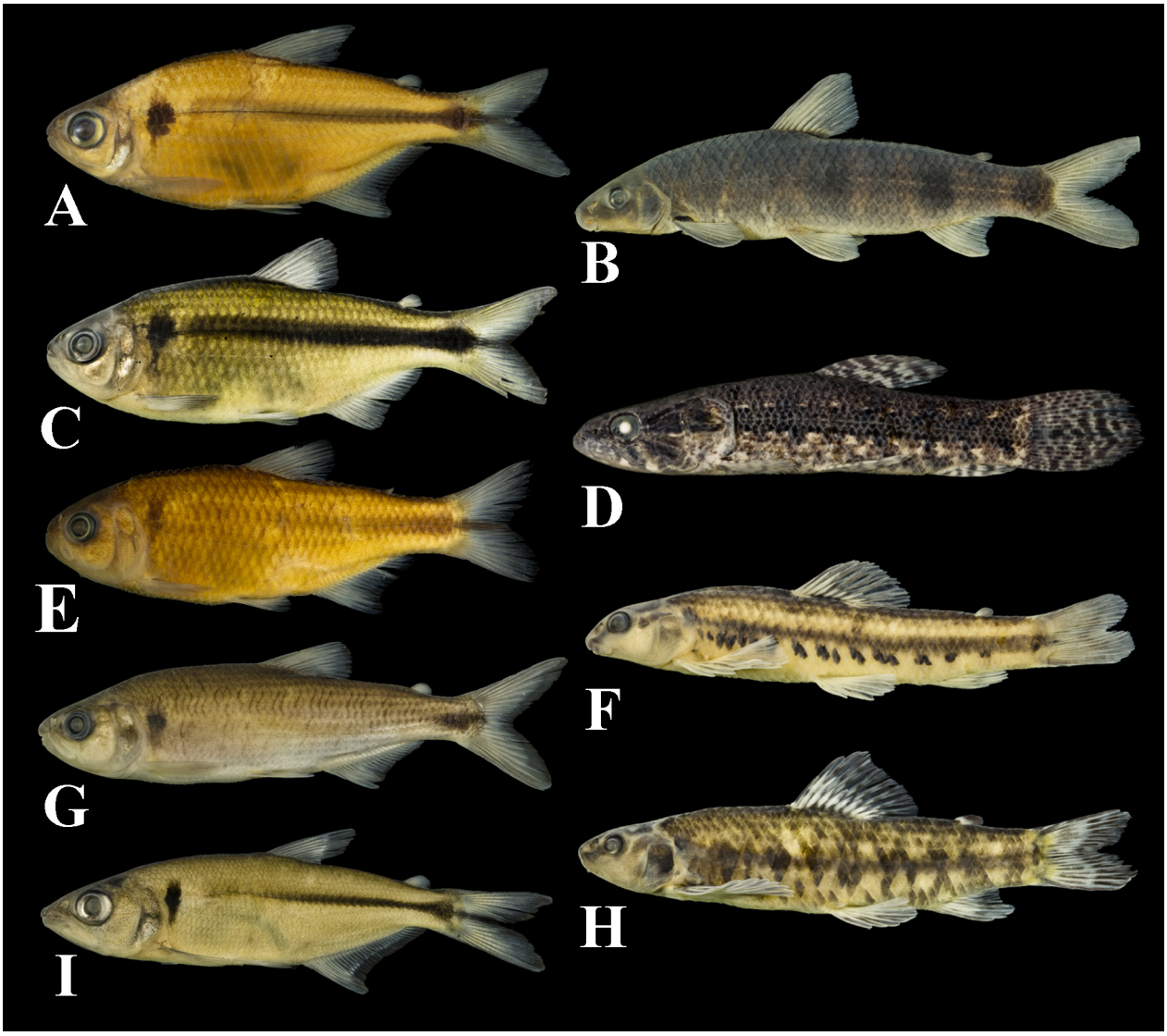

Figure 2. Fish species collected in upper Piraí river drainage. **A.** *Astyanax giton*, MNRJ 37986, 63.6 mm SL. **B.** *Hypomasticus mormyrops*, MNRJ 46698, 128.6 mm SL. **C.** *Astyanax intermedius*, MNRJ 43805, 77.2 mm SL. **D.** *Hoplias malabaricus*, MNRJ 43830, 70.8 mm SL. **E.** *Astyanax* sp. aff. *scabripinnis*, MNRJ 36427, 71.8 mm SL. **F.** *Characidium lauroi*, MNRJ 43823, 57.3 mm SL. **G.** *Brycon opalinus*, MNRJ 47259, 116.6 mm SL. **H.** *Characidium vidali*, MNRJ 43807, 66.6 mm SL. **I.** *Oligosarcus hepsetus*, MNRJ 43812, 63.1 mm SL.

(Lezama et al. 2011).

Diagnosis: *Astyanax intermedius* differs from *A. giton* by body depth less than 41% of SL and abrupt reduction of tooth size posterior to the fifth dentary tooth (Melo 2001a). Also, in contrast with *A. giton*, the posterior portion of pelvic fin in *A. intermedius* does not surpass the urogenital opening in this species. *Astyanax intermedius* can be distinguished from *Astyanax* sp. aff. *scabripinnis*, by the presence of 5 cusps in most dentary teeth and regular sized adipose fin.

***Astyanax* sp. aff. *scabripinnis* (Jenyns, 1842)**
Figure 2E

Geographic distribution: Unknown.

Diagnosis: This species was represented by a single individual and differs from *A. intermedius* by having 7 cusps in most dentary teeth (vs. usually 5 cusps in *A. intermedius*) and by having a smaller adipose fin. *Astyanax* sp. aff. *scabripinnis* differs from *A. giton* by the following characters: body depth smaller than 41% of SL and abrupt size reduction posterior to the fifth dentary teeth (Melo 2001a)

***Oligosarcus hepsetus* (Cuvier, 1829)**
Figure 2I

Geographic distribution: Coastal rivers from Santa Catarina to Rio de Janeiro state.

Family Erythrinidae

***Hoplias malabaricus* (Bloch, 1794)**
Figure 2D

Geographic distribution: Widespread across South and Central America (Vieira et al. 2015).

Order Siluriformes
Family Trichomycteridae

***Trichomycterus macrophthalmus* Barbosa & Costa, 2012**
Figure 3A

Geographic distribution: Piraí river drainage.

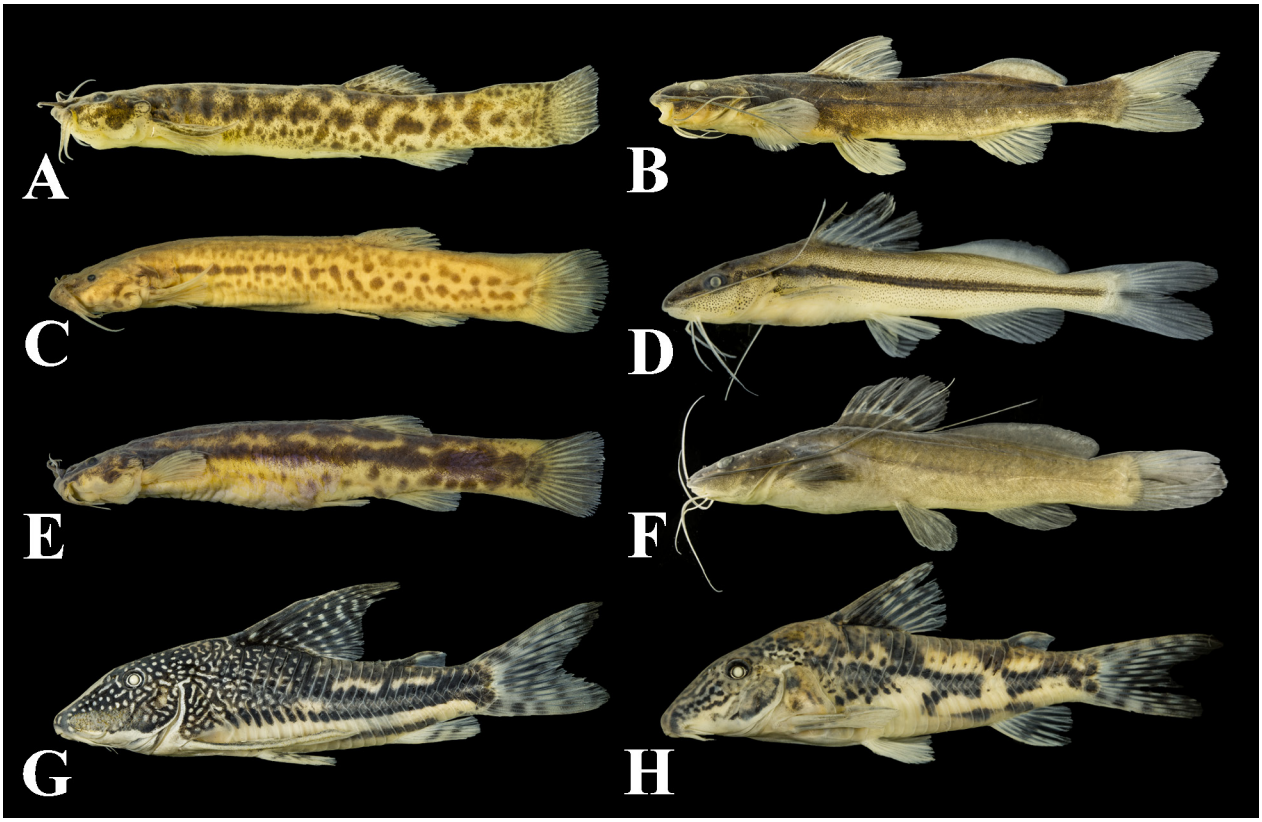

Figure 3. Fish species collected in upper Piraí river drainage. **A.** *Trichomycterus macrophthalmus*, MNRJ 43760, 52.4 mm SL. **B.** *Imparfinis minutus*, MNRJ 43770, 83.4 mm SL. **C.** *Trichomycterus mariamole*, MNRJ 36525, 58.72 mm SL. **D.** *Pimelodella lateristriga*, MNRJ 43888, 39.7 mm SL. **E.** *Trichomycterus nigroauratus*, MNRJ 38003, 48.8 mm SL. **F.** *Rhamdia quelen*, MNRJ 43889, 98.6 mm SL. **G.** *Scleromystax barbatus*, MNRJ 46722, 66.1 mm SL, male. **H.** *Scleromystax barbatus*, MNRJ 46722, 57.62 mm SL, female.

Diagnosis: *Trichomycterus macrophthalmus* is characterized by the colour pattern consisting of transverse dark bars crossing the dorsum, which can be fused with lateral marks in this species (Barbosa and Costa 2012). *Trichomycterus macrophthalmus* is distinguished from *T. mariamole* and *T. nigroauratus* by the presence of 9 pairs of ribs and eye diameter 13.2% to 14.6% the size of head length (HL) (Barbosa and Costa 2012).

***Trichomycterus mariamole* Barbosa & Costa, 2010**
Figure 3C

Geographic distribution: Piraí river drainage and upper reaches of Alambari and Barreiro rivers, Paraíba do Sul river basin.

Diagnosis: *Trichomycterus mariamole* has light yellow background coloration with small circular brown marks on flanks, diameter of the eyes 9% to 11% of HL, opercular region of odontoids reduced and laterally positioned, and 7 pectoral fin rays (Barbosa and Costa 2010). *Trichomycterus mariamole* differs from *T. claudiae*, a species that occurs in the middle portion of the Piraí drainage, by the short ill-defined stripe restricted to the anterior portion of the flank (vs. well defined stripe along the whole flank) and fewer interopercular odontodes (27–34 vs. 41–46).

***Trichomycterus nigroauratus* Barbosa & Costa, 2008**
Figure 3E

Geographic distribution: Upper Piraí and Barreiro river drainages in the Paraíba do Sul river basin.

Diagnosis: *Trichomycterus nigroauratus* differs morphologically from *T. mariamole* and *T. macrophthalmus* by the presence of golden spots on the snout and body, and broad (wider than long) metapterygoid bone (Barbosa and Costa 2008). *Trichomycterus nigroauratus* presents ontogenetic variation of coloration, with juveniles exhibiting a black stripe along the lateral midline, and adults presenting stripes with irregular borders and dark stains that can cover the entire body in a homogeneous pattern (Buckup et al. 2014).

Family Callichthyidae

***Scleromystax barbatus* (Quoy & Gaimard, 1824)**
Figure 3G, H

Geographic distribution: Coastal rivers from Santa Catarina to Rio de Janeiro state.

Family Loricariidae

***Harttia carvalhoi* Miranda Ribeiro, 1939**
Figure 4A

Geographic distribution: Paraíba do Sul river basin.

Diagnosis: The 2 species of *Harttia* that occur in the area of study can be distinguished by the distribution of plates in front of the anus: *Harttia carvalhoi* is distinguished from *H. loricariiformis* by the absence of preanal plates (Langeani et al. 2001).

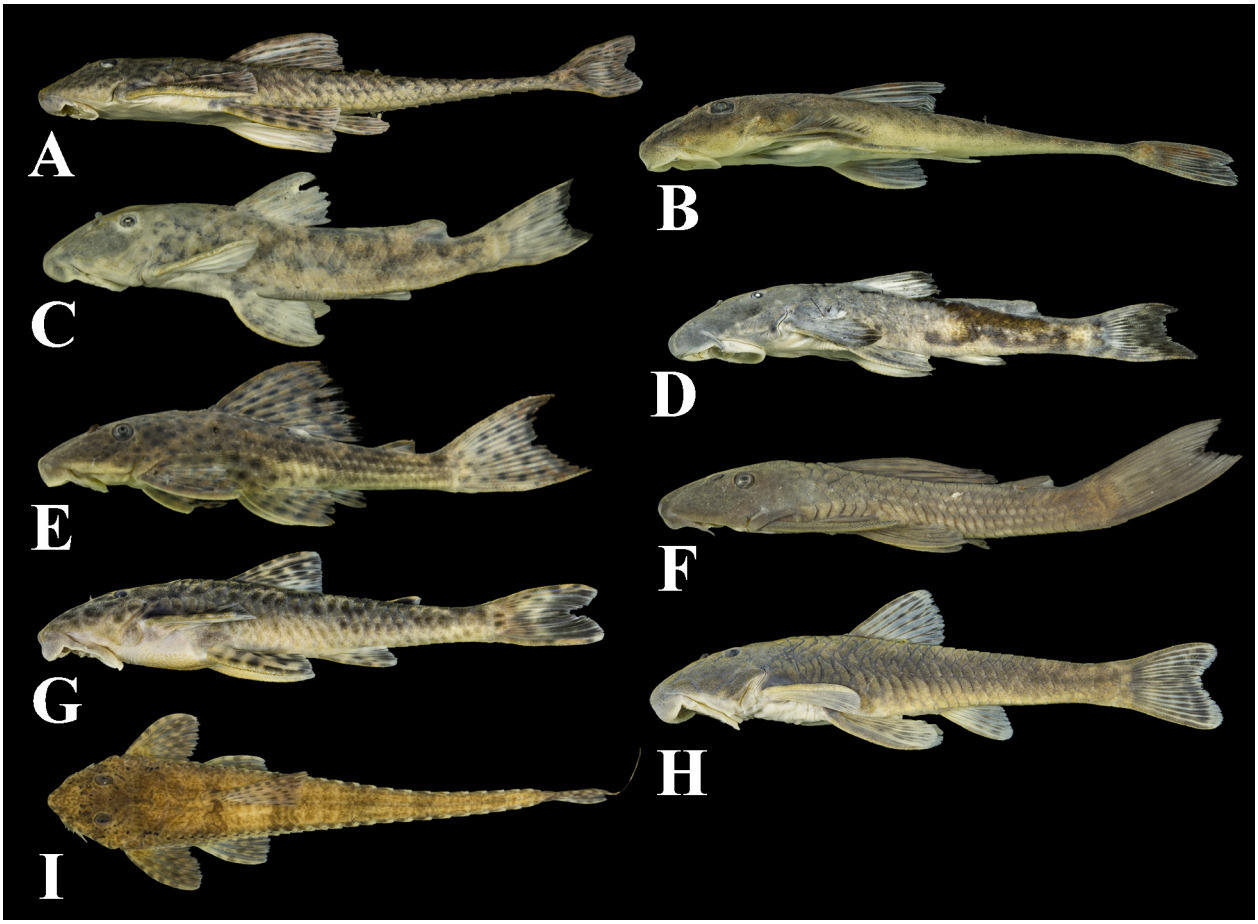

Figure 4. Fish species collected in upper Piraí river drainage. **A.** *Harttia carvalhoi*, MNRJ 43816, 78.1 mm SL. **B.** *Harttia loricariformis*, MNRJ 43773, 42.1 mm SL. **C.** *Hemipsilichthys gobio*, MNRJ 43868, 75.3 mm SL (Adult individual collected in the rio do Braço, 22° 47′ 09″S 44° 10′ 44″W, a tributary of the Piraí river. The exemplar of *H. gobio*, MNRJ 36482, collected in this study is a small juvenile.). **D.** *Hemipsilichthys papillatus*, MNRJ 46657, 53.7 mm SL. **E.** *Hypostomus affinis*, MNRJ 43824, 62.6 mm SL. **F.** *Hypostomus luetkeni*, MNRJ 47007, 112.8 mm SL. **G.** *Neoplecostomus microps*, MNRJ 43808, 87 mm SL. **H.** *Pareiorhina rudolphi*, MNRJ 46835, 65.9 mm SL. **I.** *Rineloricaria* sp. cf. *R. lima*, MNRJ 43826, 76.3 mm SL.

***Harttia loricariformis* Steindachner, 1877a**
Figure 4B

Geographic distribution: Paraíba do Sul river basin and coastal rivers from Rio de Janeiro to Espírito Santo.

Diagnosis: Differently from its congener, *Harttia loricariformis* presents 2 large and trapezoid preanal plates touching the small anterior plates (Langeani et al. 2001).

***Hemipsilichthys gobio* (Lütken, 1874a)**
Figure 4C

Geographic distribution: Paraíba do Sul river basin.

Diagnosis: *Hemipsilichthys gobio* differs from *H. papillatus* by its rectangular or oval-shaped dorsal-fin spinelet, and by the larger orbital diameter (12.0–14.7% HL, Reis et al. 2006).

***Hemipsilichthys papillatus* Pereira et al. 2000**
Figure 4D

Geographic distribution: Paraíba do Sul river basin.

Diagnosis: *Hemipsilichthys papillatus* differs from *H. gobio* by not having plates in the dorsal midline between the base of the dorsal fin and the adipose fin, and a smaller orbital diameter (8.6–11.8% HL, Reis et al. 2006).

***Hypostomus affinis* (Steindachner, 1877a)**
Figure 4E

Geographic distribution: Paraíba do Sul and Doce river basins and coastal rivers of southeastern Brazil.

Diagnosis: Individuals of *Hypostomus affinis* can be distinguished *H. luetkeni* by the presence of 1 main post-supraoccipital plate and 4 lateral ridges on flanks (Mazzoni et al. 1994). The prevailing pigmentation pattern in adults of *H. affinis* comprises numerous black spots, whereas *H. luetkeni* has a more uniform dark pigmentation pattern.

***Hypostomus luetkeni* (Steindachner, 1877b)**
Figure 4F

Geographic distribution: Paraíba do Sul river basin.

Diagnosis: *Hypostomus luetkeni* can be distinguished from *H. affinis* by the presence of 2 or 3 plates in the main post-supraoccipital series and the absence of ridges on the flanks of the body (Mazzoni et al. 1994). Dark spots in the body, if present, are less conspicuous than in *H. affinis*.

***Neoplecostomus microps* (Steindachner, 1877b)**
Figure 4G

Figure 5. Fish species collected in the upper Piraí river drainage. **A.** *Gymnotus pantherinus*, MNRJ 43827, 172.5 mm SL. **B.** *Australoheros* sp., MNRJ 43780, 50.3 mm SL. **C.** *Phalloceros harpagos*, MNRJ 43828, 34.2 mm SL, female. **D.** *Crenicichla lepidota*, MNRJ 43779, 85.9 mm SL. **E.** *Phalloceros harpagos*, MNRJ 43828, 25.3 mm SL, male. **F.** *Geophagus brasiliensis*, MNRJ 43778, 64.2 mm SL. **G.** *Poecilia reticulata*, MNRJ 43763, 36.8 mm SL, female. **H.** *Oreochromis niloticus*, MNRJ 37964, 96.56 mm SL. **I.** *Poecilia reticulata*, MNRJ 43763, 19.2 mm SL, male.

Geographic distribution: Paraíba do Sul river basin and coastal rivers from Rio de Janeiro state.

***Pareiorhina rudolphi* (Miranda Ribeiro, 1911)**
Figure 4H

Geographic distribution: Paraíba do Sul river basin.

***Rineloricaria* sp. cf. *R. lima* (Kner, 1853)**
Figure 4I

Geographic distribution: Unknown.

Diagnosis: In this study we refer this species as *Rineloriaria* sp. cf. *R. lima* due to similarity of the specimens from the Piraí drainage with specimens of this genus collected in the Paraíba do Sul previously identified as *Rineloricaria* cf. *lima* by other authors (e.g. Fichberg 2008). The taxonomic status of *R. lima*, however, is uncertain because the type material is lost, and the type locality is unknown.

Family Heptapteridae

***Imparfinis minutus* (Lütken, 1874b)**
Figure 3B

Geographic distribution: Upper São Francisco, upper Paraná, Paraíba do Sul and Ribeira de Iguape river basins.

***Pimelodella lateristriga* (Lichtenstein, 1823)**
Figure 3D

Geographic distribution: Coastal rivers between Jequitinhonha and Paraíba do Sul river basins.

***Rhamdia quelen* (Quoy & Gaimard, 1824)**
Figure 3F

Geographic distribution: Widespread from Mexico to Argentina.

Order Gymnotiformes
Family Gymnotidae

***Gymnotus pantherinus* (Steindachner, 1908) (Fig. 5A)**

Geographic distribution: Coastal rivers of Southeastern Brazil.

Order Cyprinodontiformes
Family Poeciliidae

***Phalloceros harpagos* Lucinda, 2008**
Figure 5C, E

Geographic distribution: Paraná and Paraguai river basins and coastal drainages from Santa Catarina to Espírito Santo states.

***Poecilia reticulata* Peters, 1859**
Figure 5G, I

Geographic distribution: Introduced species, natural from northern South America.

Order Cichliformes
Family Cichlidae

***Australoheros* sp. Říčan & Kullander, 2006**
Figure 5B

Geographic distribution: Unkown.

***Crenicichla lepidota* Heckel, 1840**
Figure 5D

Geographic distribution: Widely distributed in South America.

***Geophagus brasiliensis* (Quoy & Gaimard, 1824)**
Figure 5F

Geographic distribution: Coastal rivers of northeastern Brazil to Uruguay.

***Oreochromis niloticus* (Linnaeus, 1758)**
Figure 5H

Geographic distribution: Introduced species, originally from Northern and eastern Africa.

Discussion

In this study, the prevalence of Siluriformes and Characiformes in the composition of the fish assemblage follows the observed composition pattern of Atlantic Forest streams (e.g. Sarmento-Soares et al. 2007, Ferreira and Petrere 2009, Camilo et al. 2015) and most Neotropical freshwater systems (Lowe-McConnell 1999, Abilhoa et al. 2011). The ichthyofauna of the upper Piraí is composed mostly by species that are widely distributed in the Paraíba do Sul basin. *Scleromystax barbatus* is a widespread species in coastal rivers; however, this species was collected only once, near the city of Lídice, despite our extensive sampling effort in the Piraí basin. The neotype of *S. barbatus* was collected in a nearby coastal river, and the species is quite abundant in the adjacent coastal plain. The city of Lidice is located less than 10 km from a recreational area in a coastal lowland river. This ichthyofaunal composition indicates that endemic species from Guandu do not live in the study area, probably because the complex system of tunnels, pumps, dams and hydropower turbines, as well as the steep altitudinal gradient across the transposition system serve as an effective barrier for upstream fish migration.

As expected, the species diversity was higher in the lowest stretches of the upper Piraí drainage than in its headwaters. According to the River Continuum Concept (Vannote et al. 1980), the composition and structure of ichthyofauna in freshwater streams is directly related to altitude. Thus, high altitude stretches with comparatively lower temperature, high dissolved oxygen and fast flowing waters tend to have lower species richness than downstream sites with decreasing slope, increasing temperature and high availability of pools.

Among the widespread species in the study area, the high number of individuals of *Phalloceros harpagos* present in our samples is probably correlated with the ability of poecilids to colonize a wide range of habitats and tolerate different levels of environmental quality (Araújo et al. 2009). The second most abundant species in upper Piraí drainage, *Astyanax intermedius*, is an opportunistic strategist, characterized by the capacity of producing rapid population turnover and colonisation (Souza et al. 2015). Regarding taxonomic representation, *Astyanax* and *Trichomycterus* were the most diverse genera in the study area, represented by 3 species each. Oddly, individuals of *Trichomycterus claudiae* (Barbosa and Costa 2010) were not registered in the upper Piraí drainage. This species was expected to occur in the sampled drainage due to the proximity of its type locality.

Two species collected in the upper Piraí drainage are included in the list of Brazilian fauna threatened by extinction (ICMBio 2016): *Brycon opalinus*, present in the lower reaches of Rio das Pedras stream, and *Hemipsilichthys gobio*, collected in the main channel of rio Piraí. *Brycon opalinus*, known as "pirapitinga", is Vulnerable due to commercial exploration and environment degradation, and its restricted distribution to preserved tributaries of the Paraíba do Sul and Doce headwaters (Gomiero and Braga 2007, ICMBio 2016). *Hemipsilichthys gobio* is Endangered due to habitat reduction and fragmentation (ICMBio 2016). The distribution of this species is limited to highly oxygenated cold waters of high-elevation, fast flowing tributaries of the Paraíba do Sul river basin. The presence of these 2 species indicates that preserved stretches in the upper Piraí drainage serve as natural refuge areas for threatened fish fauna.

Two non-native species were recorded in 4 sampling sites along the study area: *Poecilia reticulata* was captured in the lowest stretches of the Passa Quatro stream, and *Oreochromis niloticus* occurred in 2 sites of the main channel of upper Piraí. *Poecilia reticulata* is an exotic poecilid species from Venezuela, widely introduced in aquatic environments of the Americas due to its predation on mosquito larvae (Santos 1958). *Oreochromis niloticus*, known as Nile Tilapia, is an invasive cichlid species, originally from Africa, that is widely cultivated in tanks and net cages in Brazil, and was probably introduced by escapes from pisciculture (Orsi and Agostinho 1999). Regarding environmental conditions, invasive species are usually more successful in negatively affected systems or where native species population are depleted (Leidy et al. 2011). The introduction and population establishment of these invasive species in the mid-lower reach of the Passa Quatro stream and the main channel of upper Piraí is largely associated with areas of intense human occupation and land-use.

Among the 32 species reported in this study, the following 8 were not listed in the first survey of the Piraí headwaters (Buckup et al. 2014): *Hypomasticus mormyrops*, *Hoplias malabaricus*, *Scleromystax barbatus*, *Hemipsilichthys gobio*, *Hypostomus luetkeni*, *Poecilia reticulata*, *Australoheros* sp., and *Crenicichla lepidota*. The absence of *Hypostomus luetkeni, Poecilia reticulata*, *Australoheros* sp., and *C. lepidota* in the sites surveyed by Buckup et al. (2014) has been confirmed in our

current survey, as these species have only been captured outside of the area of that earlier study. The single specimen of *Hemipsilichthys gobio* (MNRJ 36482) was misidentified by Buckup et al. (2014) as *H. papillatus*. In addition to the slight increase of diversity, some species were captured in significant numbers only in the recent survey (e.g. *Brycon opalinus*). The increase in species richness and abundance of the ichthyofauna in the upper Piraí river drainage recorded over our 7-year survey possibly correlates with the consolidation of recent conservation programs implemented in the study area to recover riparian forest (Castello-Branco 2015), although other environmental factors cannot be ruled out. Thus, the record of additional species not previously captured in the area, despite the use of standardized sampling effort, demonstrates the importance of continuous surveys in freshwater systems, in order to increase the knowledge on the distribution and impact of human activity on fish assemblages present in Atlantic Forest remnants.

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Authors' Contributions

PAB conceived and coordinated the project. VB and PAB performed fieldwork and analyzed the data. VB identified the specimens, took the photographs and wrote the manuscript. PAB revised and corrected the manuscript. This study is part of a M.Sc. dissertation study conducted by VB.

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Appendix

Table A1. Catalog numbers of voucher specimens.

Taxon	Catalog number (number of exemplars)
CHARACIFORMES	
Anostomidae	
Hypomasticus mormyrops	MNRJ 46698 (3), MNRJ 47001 (2), MNRJ 47012 (1), MNRJ 47256 (1)
Crenuchidae	
Characidium lauroi	MNRJ 36451 (3), MNRJ 36458 (3), MNRJ 36472 (32), MNRJ 36486 (1), MNRJ 36508 (50), MNRJ 36518 (6), MNRJ 37977 (1), MNRJ 38019 (26), MNRJ 38032 (13), MNRJ 38039 (10), MNRJ 38045 (25), MNRJ 43748 (39), MNRJ 43759 (5), MNRJ 43806 (18), MNRJ 46650 (8), MNRJ 46668 (73), MNRJ 46690 (25), MNRJ 46702 (20), MNRJ 47260 (29)
Characidium vidali	MNRJ 36457 (1), MNRJ 36471 (1), MNRJ 36497 (1), MNRJ 36507 (10), MNRJ 38018 (69), MNRJ 38031 (13), MNRJ 43758 (37), MNRJ 43767 (1), MNRJ 43807 (7), MNRJ 43821 (3), MNRJ 46636 (2), MNRJ 46822 (3), MNRJ 47023 (1), MNRJ 47261 (14)
Bryconidae	
Brycon opalinus	MNRJ 38022 (3), MNRJ 46701 (1), MNRJ 47259 (25)
Characidae	
Astyanax giton	MNRJ 37834 (1), MNRJ 37835 (20), MNRJ 37974 (5), MNRJ 37986 (2), MNRJ 38021 (5), MNRJ 50819 (1), MNRJ 50820 (2)
Astyanax intermedius	MNRJ 36459 (15), MNRJ 36473 (21), MNRJ 36487 (21), MNRJ 36498 (29), MNRJ 36510 (81), MNRJ 36519 (51), MNRJ 36524 (22), MNRJ 37954 (5), MNRJ 37965 (28), MNRJ 37978 (34), MNRJ 38020 (51), MNRJ 38033 (42), MNRJ 38040 (19), MNRJ 38053 (10), MNRJ 38087 (31), MNRJ 43749 (79), MNRJ 43755 (58), MNRJ 43766 (74), MNRJ 43805 (16), MNRJ 43820 (15), MNRJ 46631 (20), MNRJ 46643 (95), MNRJ 46689 (23), MNRJ 46699 (10), MNRJ 46713 (15), MNRJ 46791 (11), MNRJ 46813 (92), MNRJ 47002 (14), MNRJ 47014 (6), MNRJ 47257 (91)
Astyanax sp. aff. *scabripinnis*	MNRJ 36427 (1)
Oligosarcus hepsetus	MNRJ 36460 (2), MNRJ 36474 (2), MNRJ 36488 (1), MNRJ 36499 (5), MNRJ 36509 (3), MNRJ 37966 (2), MNRJ 37979 (1), MNRJ 38023 (3), MNRJ 38034 (16), MNRJ 38052 (2), MNRJ 43768 (6), MNRJ 43812 (6), MNRJ 46644 (1), MNRJ 46700 (5), MNRJ 46714 (13), MNRJ 46792 (21), MNRJ 46814 (1), MNRJ 47003 (15), MNRJ 47015 (9), MNRJ 47258 (2)
Erythrinidae	
Hoplias malabaricus	MNRJ 38051 (1), MNRJ 43830 (1), MNRJ 46802 (1), MNRJ 47013 (1)
SILURIFORMES	
Trichomycteridae	
Trichomycterus macrophthalmus	MNRJ 36467 (1), MNRJ 36478 (4), MNRJ 36494 (16), MNRJ 36504 (12), MNRJ 36513 (4), MNRJ 37957 (5), MNRJ 43750 (22), MNRJ 43760 (27), MNRJ 43772 (13), MNRJ 43813 (2), MNRJ 43832 (1), MNRJ 46640 (8), MNRJ 46795 (1), MNRJ 46825 (1)
Trichomycterus mariamole	MNRJ 36452 (2), MNRJ 36520 (1), MNRJ 36525 (2), MNRJ 38047 (1), MNRJ 38088 (3), MNRJ 47024 (1)
Trichomycterus nigroauratus	MNRJ 36453 (11), MNRJ 36468 (3), MNRJ 36477 (3), MNRJ 36512 (2), MNRJ 37968 (5), MNRJ 38025 (3), MNRJ 38035 (2), MNRJ 38041 (7), MNRJ 38046 (2), MNRJ 38091 (1), MNRJ 43719 (5), MNRJ 43754 (1), MNRJ 43814 (2), MNRJ 43833 (2), MNRJ 46645 (3), MNRJ 46669 (11), MNRJ 46694 (1), MNRJ 46712 (2), MNRJ 46796 (2), MNRJ 46824 (1), MNRJ 46834 (6), MNRJ 47025 (1), MNRJ 47026 (1), MNRJ 47253 (13)
Callichthyidae	
Scleromystax barbatus	MNRJ 46722 (4)
Loricariidae	
Harttia carvalhoi	MNRJ 36461 (3), MNRJ 36480 (9), MNRJ 36501 (3), MNRJ 36515 (2), MNRJ 37969 (5), MNRJ 38026 (15), MNRJ 38036 (3), MNRJ 38057 (1), MNRJ 43816 (2), MNRJ 43823 (4), MNRJ 46641 (2), MNRJ 46826 (1), MNRJ 47022 (2)
Harttia loricariformis	MNRJ 36514 (1), MNRJ 38037 (1), MNRJ 43773 (4), MNRJ 46646 (2), MNRJ 46706 (4), MNRJ 46827 (1), MNRJ 47262 (1)
Hemipsilichthys gobio	MNRJ 36482 (1)
Hemipsilichthys papillatus	MNRJ 36448 (1), MNRJ 46657 (1)
Hypostomus affinis	MNRJ 36502 (1), MNRJ 37958 (1), MNRJ 38062 (1), MNRJ 43781 (1), MNRJ 43824 (3), MNRJ 46632 (1), MNRJ 46710 (1), MNRJ 46723 (4), MNRJ 46803 (1), MNRJ 46820 (1), MNRJ 46821 (1)
Hypostomus luetkeni	MNRJ 47007 (1)

Taxon	Catalog number (number of exemplars)
Neoplecostomus microps	MNRJ 36431 (23), MNRJ 36442 (13), MNRJ 36449 (8), MNRJ 36454 (6), MNRJ 36462 (17), MNRJ 36481 (27), MNRJ 36489 (14), MNRJ 36516 (27), MNRJ 36521 (8), MNRJ 36526 (1), MNRJ 37960 (4), MNRJ 37971 (9), MNRJ 37983 (8), MNRJ 37993 (34), MNRJ 38008 (20), MNRJ 38013 (13), MNRJ 38017 (21), MNRJ 38028 (47), MNRJ 38038 (15), MNRJ 38043 (17), MNRJ 38049 (9), MNRJ 38089 (6), MNRJ 43751 (21), MNRJ 43761 (43), MNRJ 43774 (10), MNRJ 43808 (38), MNRJ 43825 (118), MNRJ 46633 (11), MNRJ 46647 (8), MNRJ 46653 (20), MNRJ 46662 (18), MNRJ 46691 (3), MNRJ 46708 (18), MNRJ 46785 (6), MNRJ 46797 (2), MNRJ 46816 (14), MNRJ 47006 (4), MNRJ 47017 (5), MNRJ 47254 (10), MNRJ 47263 (12)
Pareiorhina rudolphi	MNRJ 36455 (72), MNRJ 36522 (24), MNRJ 38012 (1), MNRJ 38016 (7), MNRJ 38042 (64), MNRJ 38048 (112), MNRJ 46652 (34), MNRJ 46670 (141), MNRJ 46692 (58), MNRJ 46835 (40)
Rineloricaria sp. cf. *R. lima*	MNRJ 36432 (5), MNRJ 36443 (1), MNRJ 36463 (7), MNRJ 36479 (1), MNRJ 36490 (7), MNRJ 36503 (10), MNRJ 37959 (12), MNRJ 37970 (2), MNRJ 37982 (4), MNRJ 37994 (8), MNRJ 38007 (2), MNRJ 38027 (3), MNRJ 38058 (10), MNRJ 43771 (84), MNRJ 43817 (2), MNRJ 43826 (23), MNRJ 46634 (10), MNRJ 46661 (2), MNRJ 46707 (6), MNRJ 46717 (58), MNRJ 46784 (2), MNRJ 46798 (16), MNRJ 46817 (4), MNRJ 47005 (36)
Heptapteridae	
Imparfinis minutus	MNRJ 36464 (2), MNRJ 36476 (5), MNRJ 36491 (1), MNRJ 36511 (1), MNRJ 37956 (1), MNRJ 37967 (2), MNRJ 37980 (2), MNRJ 37990 (1), MNRJ 38024 (3), MNRJ 38056 (2), MNRJ 43770 (5), MNRJ 43822 (3), MNRJ 46637 (2), MNRJ 46703 (5), MNRJ 46721 (1), MNRJ 46788 (1), MNRJ 46793 (6), MNRJ 47004 (3)
Pimelodella lateristriga	MNRJ 36434 (1), MNRJ 36465 (1), MNRJ 36492 (1), MNRJ 38055 (4), MNRJ 43815 (1), MNRJ 43831 (1), MNRJ 46639 (1), MNRJ 46704 (2), MNRJ 46715 (4), MNRJ 46823 (1)
Rhamdia quelen	MNRJ 36433 (1), MNRJ 36466 (7), MNRJ 36475 (3), MNRJ 36493 (1), MNRJ 36500 (1), MNRJ 37955 (1), MNRJ 37981 (4), MNRJ 37991 (1), MNRJ 43769 (2), MNRJ 46638 (2), MNRJ 46660 (4), MNRJ 46705 (2), MNRJ 46716 (2), MNRJ 46789 (1), MNRJ 46794 (5), MNRJ 46815 (1), MNRJ 47016 (3)
GYMNOTIFORMES	
Gymnotidae	
Gymnotus pantherinus	MNRJ 37961 (1), MNRJ 38054 (9), MNRJ 43777 (2), MNRJ 43809 (11), MNRJ 43827 (4), MNRJ 46635 (6), MNRJ 46648 (2), MNRJ 46663 (4), MNRJ 46718 (2), MNRJ 46786 (9), MNRJ 46799 (8), MNRJ 46828 (2), MNRJ 47008 (1), MNRJ 47019 (2)
CYPRINODONTIFORMES	
Poeciliidae	
Phalloceros harpagos	MNRJ 36437 (29), MNRJ 36446 (1), MNRJ 36450 (2), MNRJ 36456 (84), MNRJ 36469 (3), MNRJ 36483 (11), MNRJ 36495 (4), MNRJ 36505 (15), MNRJ 36517 (5), MNRJ 36523 (70), MNRJ 36527 (84), MNRJ 37962 (55), MNRJ 37972 (5), MNRJ 37984 (4), MNRJ 37997 (36), MNRJ 38010 (1), MNRJ 38029 (1), MNRJ 38044 (136), MNRJ 38050 (43), MNRJ 38059 (16), MNRJ 38090 (67), MNRJ 43722 (199), MNRJ 43752 (417), MNRJ 43762 (294), MNRJ 43775 (40), MNRJ 43811 (34), MNRJ 43828 (241), MNRJ 46642 (4), MNRJ 46655 (157), MNRJ 46664 (6), MNRJ 46671 (110), MNRJ 46693 (33), MNRJ 46711 (3), MNRJ 46719 (2), MNRJ 46800 (7), MNRJ 46818 (7), MNRJ 46836 (158), MNRJ 47009 (3), MNRJ 47020 (29), MNRJ 47231 (8), MNRJ 47255 (13)
Poecilia reticulata	MNRJ 43763 (266), MNRJ 43776 (1)
CICHLIFORMES	
Cichlidae	
Australoheros sp.	MNRJ 38060 (2), MNRJ 43780 (1)
Crenicichla lepidota	MNRJ 43779 (5), MNRJ 47010 (6)
Geophagus brasiliensis	MNRJ 36470 (38), MNRJ 36484 (7), MNRJ 36496 (3), MNRJ 36506 (3), MNRJ 37963 (14), MNRJ 37973 (16), MNRJ 37985 (4), MNRJ 37998 (1), MNRJ 38009 (5), MNRJ 38030 (5), MNRJ 38061 (10), MNRJ 43753 (11), MNRJ 43764 (53), MNRJ 43778 (20), MNRJ 43810 (17), MNRJ 43829 (57), MNRJ 46649 (2), MNRJ 46667 (2), MNRJ 46709 (40), MNRJ 46720 (31), MNRJ 46787 (37), MNRJ 46801 (67), MNRJ 46819 (3), MNRJ 47011 (16), MNRJ 47021 (30), MNRJ 47230 (1), MNRJ 47264 (4)
Oreochromis niloticus	MNRJ 36485 (3), MNRJ 37964 (3)